DEVELOPMENT OF A KNOWLEDGE MANAGEMENT SYSTEM TO REDUCE ERRORS IN AVIATION MAINTENANCE

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Abstract: One of the causes of aviation accidents is lack of overview and analysis of the data particularly obtained from its maintenance operation performance. The aircraft maintenance system of an airline is a complex structure with information flow involving various stakeholders ensuring aircraft airworthiness while adhering to several regulatory standards, policies and procedures of Federal Aviation Administration (FAA). Further, the prevalence of HCI design methodologies to perform data management in the aviation industry is very negligible. Little literature exists on information management of the data obtained from various aircraft maintenance processes which have a direct effect on the safety of the aircraft and hence the airline. The current research studies the intricacies of the aircraft maintenance system work flow processes, in order to develop a system that analyzes the aviation maintenance errors. This paper discusses the advantages of using a knowledge management system that shares information and knowledge across various operational hierarchies.

1. INTRODUCTION

Human factors research in aviation maintenance has deemed the human as the central part of the aviation system (Gramopadhye et al., 2000). The emphasis on the human and his role in aviation systems results in the development of error tolerant systems. Such systems will be efficient if they closely monitor and evaluate aircraft maintenance and inspection activities. The increasing number of maintenance and inspection errors in the aviation industry has motivated the need for human factors research. Maintenance error has been found to be a crucial factor in aircraft accidents (Boeing/ ATA, 1995). The significance of the maintenance function was captured by Weick et al. (1999) when they observed that: "Maintenance people come into contact with the largest number of failures, at earlier stages of development, and have an ongoing sense of the vulnerabilities in the technology, sloppiness in the operations, gaps in the procedures, and sequences by which one error triggers another" (Weick et al., 1999). Given the ever increasing complexity of an aircraft, a significant proportion of these errors come at the hands of the maintenance personnel themselves due to greater demands on these individuals. Thus, it is very important to take a closer look at these individuals involved in aviation maintenance, understand the causal factors for these errors and the possible solutions to counter this situation.

On January 8, 2003 Air Midwest (doing business as US Airways Express) flight 5481, crashed shortly after takeoff at Charlotte, North Carolina. The two flight crewmembers and 19 passengers aboard the airplane were killed, one person on the ground received minor injuries, and the airplane was destroyed by impact forces and a post-crash fire. The night before an Air Midwest commuter plane crashed, a mechanic-in-training at an independent repair station improperly adjusted a set of cables that control the pitch of the plane. The National Transportation Safety Board (NTSB, 2003) determined the airplane's loss of pitch control during take-off as the probable cause of this accident. Contributing to the cause of the accident was Air Midwest's lack of oversight of the work being performed at the Huntington, West Virginia, maintenance station and Air Midwest's maintenance procedures and documentation. While any mechanic could make such an error, the fact that it was done by a contractor, instead of a certified, union airline employee, has revived concerns about the airline industry's outsourcing of repair work. It's a trend that started a decade ago, but has accelerated rapidly in the past two years as the major carriers have struggled to survive financially. This has prompted the need to establish better ways to monitor maintenance and identify errors.

The aviation maintenance industry has invested a significant effort in developing methodologies for investigating maintenance errors. Figures emerging from the United Kingdom Civil Aviation Authority (CAA) show a steady rise in the number of maintenance error mandatory occurrence reports over the period 1990 to 2000 (Courteney, 2001). A recent Boeing study of worldwide commercial jet aircraft accidents over that same period shows a significant increase in the rate of accidents where maintenance and inspection were primary factors (ICAO, 2003). The FAA, in its strategic plan for human factors in aviation maintenance cited statistics from the Air Transport Association of America (ATA) showing that the number of passenger miles flown by the largest US airlines increased 187% from 1983 through to 1995. Over that same period, the number of aircraft operated by those airlines increased 70% but the number of aviation maintenance technicians increased only 27%. The FAA concluded that the only way the maintenance program could cope with the increased workload was by increased efficiency at the worker level (McKenna, 2002).

Attempts have been made to define a core set of constructs for safety climate (Flin et al., 2000). Although not entirely successful in establishing core dimensions, this research is useful in suggesting constructs that should be considered for inclusion in research on maintenance errors. Taylor and Thomas (2003) used a self-report questionnaire called the Maintenance Resource Management/Technical Operations Questionnaire (MRM/TOQ) to measure what they regarded as two fundamental parameters in aviation maintenance: professionalism and trust. The dimension of professionalism is defined in their questionnaire in terms of reactions to work stressors and personal assertiveness. Trust is defined in terms of relations with co-workers and supervisors. Questions relating to these areas also appear in the questionnaire to be used in the current research. Patankar (2003) constructed a questionnaire called the Organizational Safety Culture Questionnaire which included questions from the MRM/TOQ along with items from questionnaires developed outside the maintenance environment. Following the application of exploratory factor analytic routines to a dataset generated from respondents that included 124 maintenance engineers, Patankar identified four factors as having particular relevance to the safety goals of aviation organizations. They are emphasis on compliance with standard operating procedures, collective commitment to safety, individual sense of responsibility toward safety, and a high level of employee-management trust. In addition to the descriptive accident causation models, classification schemes, and culture surveys, there is a need for empirically validated models/tools that capture data on maintenance work and provide a means of assessing this data. However, such models and schemes often tend to be ad hoc, varying across the industry, with little standardization. In order to contend with this issue, the devised empirical models and tools are required to employ standardized data collection procedures, provide a basis for predicting unsafe conditions and design interventions that will lead to reduction in maintenance errors.

A closer look at the aviation maintenance industry shows that it involves structural hierarchies which results in slow communication of knowledge and information on causes-and-effect of maintenance errors on the aircraft from one hierarchical level to the next. Further, these systems have inherent limitations by virtue of their environment. Consequently, the errors occurring in the systems are a result of human work environment, material fatigue and human error. One way to address this issue would be to continuously monitor the maintenance process and collect information on the efficiency and accuracy of the process. This research hopes to collect the error causes and occurrences using a web based surveillance, airworthiness directive and auditing tool (WebSAT). FedEx is the airline industry partner for this research. This tool will capture and analyze data for surveillance and auditing. However, in addition to adopting surveillance system, there is a need to share information and knowledge across individuals. Knowledge management (KM) has been found to be an important way of rethinking and redesigning organizations (Ernst & Young, 1997; KPMG Consulting, 1998; The Conference Board, 1998). KM initiatives are rare, if they exist, in the aviation industry. This industry although highly regulated, is unfortunately resistant to introduction of new initiatives.

Any industry's viability, like the aviation industry, relies on movement of information seamlessly across the various departments. This movement is hindered by barriers. Two major types of barriers - conceptual and cultural - are inherent in KM initiatives and make it difficult to realize the full value of KM efforts (McCann et al., 2004). Many prevailing values and beliefs within an organization's culture posing as cultural barriers, can be challenged by KM initiatives. There are growing ethical and legal concerns about how organizations capture, share, and transform knowledge into intellectual capital and property. KM initiatives break down barriers and alter the way individuals and groups - both inside and outside an organization interact and share what they know and how they use that knowledge (Davenport et al., 1998; De Long and Fahey, 2000). When intellectual capital is openly circulated, there is a potential threat to the organization. Rewards and incentives systems must, for example, reinforce knowledge creation, sharing, and retention norms (Soliman and Spooner, 2000), and information systems similarly must support open access and sharing (Davenport et al., 1998).

KM largely represents the intersection of four diverse schools of thinking and practice: industrial economic policy (Porter, 1990; Thurow, 1992; US Department of Commerce, 1977); total quality management (Deming, 1982; Juran, 1964; Watson, 1994); organizational learning (Coleman, 1988; Handy, 1989; Hedberg, 1981; Senge, 1990); and enterprise-wide information systems and technologies (Quinn, 1992). The diversity from each of these schools also leads to very different vocabularies, assumptions, models, and solutions that pose a fundamental difficulty in strategically integrating KM initiatives.

The Industrial policy school supports policy initiatives that would increase patent protection in a specific technology industry sector, or lead to government incentives to increase the number of graduates in a scientific field (Thurow, 1992; US Department of Commerce, 1977). Prevalence of Six Sigma and ISO certification (Watson, 1994) shows the integration of Total quality management (TQM) in some form within many organizations. The organizational learning school makes a major contribution by promoting open systems thinking and providing a basis for linking "hard" structural design and "soft" behavioral dimensions of an organization (Hansen et al., 1999; Hedberg, 1981; Nevis et al., 1995). It is important for the organization to make sense of its environment. This can primarily be achieved by interpreting the information and if necessary filtering it before translating it in terms of its impact - all critical dimensions of effective KM. Organization theory and design views the organization as a dynamic integration of people, processes, technologies, structures, and systems designed to achieve an objective (Galbraith, 1995; Miles et al., 1997; Nadler and Tushman, 1997).

It is known that effective KM is impossible without effective information systems and technologies (IS/IT). The IS/IT enable information acquisition, retention, and sharing. Company intranets and knowledge sharing portals are increasingly common. IS/IT produces a conceptual barrier, however, when information is fundamentally confused with knowledge, IS/IT captures or "codifies" information (Hansen et al., 1999). However, it is important to make the distinction that information is not knowledge. Further, timely information is primarily the factor that translates it to knowledge. Meaningful knowledge creation and application, requires information to be accessible and relevant to a moment and situation. Mountains of information captured by very expensive, often inflexible IS/IT initiatives too frequently make it difficult to identify and measure what really drives organization performance. Major investments in information systems will, however, never pay their way until IS/IT accepts a subordinate, enabling role in KM. IS/IT is a means, not an end in itself, and must be effectively integrated with people-based KM initiatives (Hansen et al., 1999). This paper explores WebSAT's ability to harness IS/IT for information sharing to reduce the errors and to implement KM initiatives.

2. METHOD

The airlines maintenance environment, involves several vendors. There is a need to monitor these vendors to provide continuous quality and air safety. Aircraft surveillance is the day-to-day oversight and evaluation of the work contracted to an airframe substantial maintenance vendor to determine the level of compliance with airline's Maintenance Program and Maintenance Manual with respect to the airline's and FAA requirements. For example, the airline has a surveillance representative, stationed at the vendor location who schedules surveillance of an incoming aircraft. The specific task to be performed on an aircraft at a vendor location is available on a work card. The representative performs surveillance on different work cards according to a surveillance schedule. The data obtained from a surveillance visit at the maintenance facility is grouped into categories. These categories are called process measures. They measure maintenance processes and eliminate existing inconsistencies. The process measures were identified based on various surveillance tasks and the C.A.S.E. (Coordinating Agency for Supplier Evaluation) guidelines that have to be adhered to by the substantial maintenance vendor and the airline.

The figure 1 depicts the hierarchy of data flow across the different levels in a maintenance environment. The figure 1. below shows the following:

1. Senior manager refers to the higher manager who reviews all the maintenance activities;
2. Manager refers to the individual who reviews and reports on all the maintenance activities to the senior manager;
3. Airline representative refers to the individual who performs day-to-day surveillance at the vendor location;
4. Vendor refers to the independent maintenance operator who performs maintenance operations on the aircraft.

As shown in Figure 1, the information flow is bidirectional. However, there is a growing need to understand the value of such a system. The senior manager is interested in reviewing all the maintenance activities. The senior manager is always kept informed about the overall performance of the various vendors by the manager. The manager, in turn, communicates the quality goals that the airline representative has to achieve for continuous airworthiness of the airline itself. The airline representative is consciously aware of the aircraft safety and the federal aviation regulations (FAR) that are associated with a maintenance activity. By continuous oversight, the information from this representative is passed to the maintenance personnel working on an aircraft. The information passed by the representative to the vendor personnel is primarily errors such as inadequate lubrication, lack of training certification etc., noticed by him while observing the maintenance work. Thus, there is a transfer of information across the various levels for maintenance. However, what is not noted is the repetition in this information sharing. One direct consequence of this is that there is no direct measure on how effective the vendor is performing unless a methodology is implemented where the information transfer between the two individuals is documented and stored for future reference. The information at the appropriate time helps in translation into knowledge (Hansen et al., 1999). Further, repetitive delivery of information means there is little or no knowledge translation.

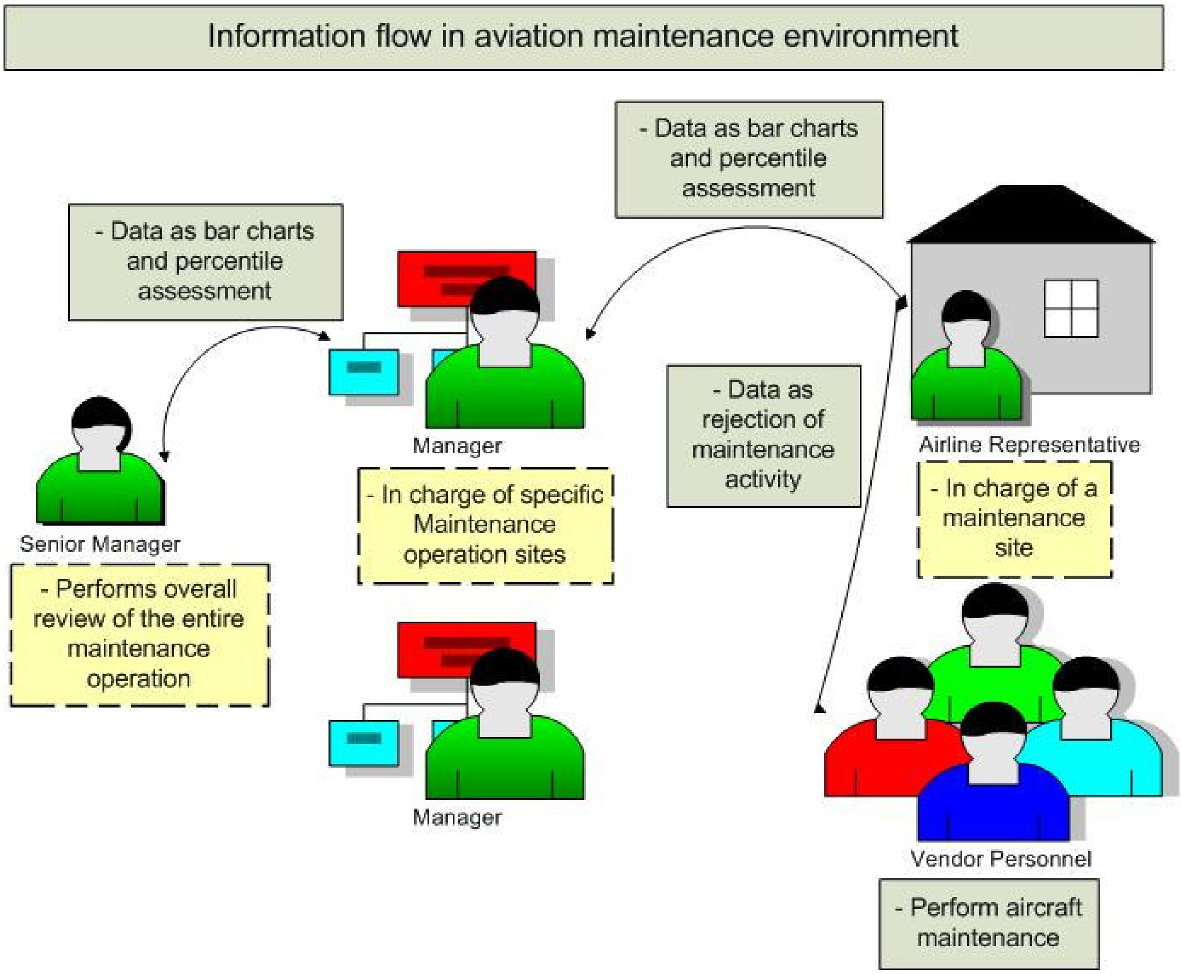

Figure 1. Information flow in aviation maintenance environment

3. DISCUSSION

The research team currently has the ability to measure the repetitive nature of information delivery. The team has developed process measures which allow the airline representative to categorize the surveillance they perform on the vendor's maintenance activities. This means that increase in process measure findings or rejection of a surveillance activity/work card by the surveillance representative, compared to a previous maintenance event, would mean repetition in information indicating lack of knowledge transfer. It must be noted that there is information transfer between the manager and the airline representative. The information here is the percentile completion of the aircraft maintenance and the accuracy of performance (aircraft errors performed by the maintenance/vendor personnel.) Further, the rejection of a work card is often qualitatively described by the representative. This data in an open ended form are invaluable as not only do they provide insight on the cause of the error but in doing so they also provide an opportunity to categorize them. These categories provide more information on the impact these errors have on the aircraft and have therefore been called as aircraft level impacts (ALI). The ALI allows the manager and the representative to communicate the cause of the error clearly between each other.

WebSAT has the ability to store this maintenance data in terms of process measures and ALI. These measures allow the airline to interpret and assess the transfer of knowledge. Despite the perception that knowledge is a competitive asset to be actively managed, some very basic steps need to be taken to introduce KM initiatives with WebSAT. Creating a learning organization and involving the managers and higher executives to manage its knowledge in this effort is paramount. Seeking corporate assistance during WebSAT implementation would allow KM strategies to collect and define very specific knowledge and anticipate future trends and errors. Further, this will also facilitate flow mapping information flow for investigation of knowledge transfer and decay. Finally, it is very important that the right information is getting to the right people when it is needed, and how well it helps integrate the organization's people with its other stakeholders through shared knowledge systems (Quinn *et al.*, 1997; Winslow and Bramer, 1994). To motivate the vendor maintenance fleet and improve vendor performance, the airline should also develop strategies such as referral, rewards and other incentive schemes. Concerns about vendor performance, airline industry safety, and competition in the budding knowledge age are valid. It is therefore, essential for us to appreciate what it means to strategically manage knowledge for sustained competitive advantage.

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