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Contribution of Computing Services to Benchmarking Asset Management Knowledge Management

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Abstract. Asset management has broadened from a focus on maintenance management to whole of life cycle asset management requiring a suite of new competencies from asset procurement to management and disposal. Well developed skills and competencies as well as practical experience are a prerequisite to maintain capability, to manage demand as well to plan and set priorities and ensure on-going asset sustainability. This paper has as its focus to establish critical understandings of data, information and knowledge for asset management along with the way in which benchmarking these attributes through computer-aided design may aid a strategic approach to asset management. The paper provides suggestions to improve sharing, integration and creation of asset-related knowledge through the application of codification and personalization approaches.

1 Introduction

The research question examines how benchmarking elements of knowledge management such as asset data, integrated asset information systems and relational approaches for managing, difficult to codify tacit knowledge offer a strategic approach to the asset management life-cycle. We argue a strategic standpoint for asset management establishes a framework for knowledge management that includes tactical and operational aspects that can be brought into a comprehensive integrated approach delivered through computer-aided design. Precisely, computing services and knowledge management systems enabled the required data collection along the asset management life-cycle in order to process the right information. Prior research on asset management frameworks have identified the various operational, tactical and organisational elements that need to be considered, however, these models have not addressed how to operationalise the various aspects of knowledge management. The research establishes a coherent framework for benchmarking as a possible approach to start to develop integrated asset management from a strategic standpoint. Strategic asset management is achieved through the systematic management of all decision-making processes taken throughout the life of a physical asset. It is seen to support decision making related to the acquisition, maintenance, and disposal of assets, and allows the generation of comprehensive and long term asset management plans (Jolicoeur & Barrett, 2005). Based on our strategic asset management approach, we present a way to develop a benchmarking model that incorporates computer-aided design to understand, map and manage data, information and knowledge of whole-of-life cycle asset management activities.

In this paper we present two equally important approaches to effective knowledge management for strategic asset management: codification and personalisation. Codification involves the application of data and information management systems, suited to capture, store and transfer explicit knowledge that is easily codified and categorised (Arif et al, 2009).

These systems now cover a range of Asset Management areas such as asset registration; process scheduling and control; materials, maintenance, risk, reliability, and safety management; and condition monitoring (Mathew et al, 2008). Personalization approaches are typically used to integrate and share tacit knowledge, which requires multifaceted and interpersonal approaches (Goh, 2002). Some examples of personalization approaches include face-to-face interactions, team meetings and on-the-job training. Existing technological solutions are designed to promote interpersonal interaction and collaborative practices and have capability for more embedded, tacit knowledge sharing and integration (Murphy & Salomone, 2013). These applications, including Web 2.0 solutions, comprise social networking, blogs, virtual communities of practice, and wikis to form a network effect built from users' contributions, in which users are the co-developers of the content (O'Reilly, 2007). The following definitions of codification and personalization differentiate the explicit and implicit knowledge management approaches. *Codification* — a knowledge management approach that involves the application of data and information systems to codify, categorize and transfer asset explicit knowledge, information and data (Murphy & Salomone, 2013). *Personalization* — a knowledge management approach used to share and integrate tacit knowledge, create new knowledge, and assist in asset management decision-making. It involves personal interaction or use of collaborative technological solutions.

2 Data, Information and Knowledge

Knowledge is a multifaceted concept with multilayered meanings (Nonaka, 1994) and it represents a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information (Davenport & Prusak, 1998). Knowledge originates in the minds of knowledge holders and can be transferred into documents, organizational routines, processes, practices, and norms. It is necessary to distinguish knowledge from data and information. In asset management these terms are sometimes used interchangeably; however, their scope differ significantly.

Data are a set of discrete, objective facts about events. There is no meaning in data. Data provides no judgement or interpretation or basis of action. Information is a message, usually in the form of a document or an audible or visible communication. It has a sender and a receiver, and moves around organisations through hard and soft networks. Unlike data, information has a meaning. Data becomes information when its creator adds meaning, for example by contextualising, condensing, or categorizing it. Once the information is used and becomes actionable, it is transformed into knowledge (Davenport & Prusak, 1998).

In asset management, we suggest all three — data, information and knowledge — are necessary. At several stages of the asset life-cycle, information is required on the condition of the assets. Knowing what to measure, how to measure it, and what to do with the information becomes highly important. Often information must be maintained for many years in order to identify long-term trends. There is a range of asset information systems available that allow the capture of and access to data related to asset performance, asset location, monitoring of asset condition, as well as to record work activities related to an asset, and forecast asset demand.

These systems provide access to different types of information captured in documents, drawings, photographs of the asset, asset attributes (e.g. make, model, serial number, age, capacity) subjective information about the asset (e.g. asset performance, condition, serviceability assessments) and so on (The Institute of Asset Management, 2011). The ultimate purpose for collecting data and information is to make decisions. Making meaning out of data and information and translating it into knowledge that combines experience, values, information in context, and insight, forms a basis for decision-making (The Institute of Asset Management, 2011).

3 Asset Data Management

Asset Data Management concerns the capture, management and utilisation (data acquisition, data analysis and information use) of asset data. The resulting translated data is essential to improve asset reliability, safety, availability, utilisation and an increased return on investment. Asset data is underpinned by the two aspects of its type and of its desired outcome. There are four key types of data that organisations often acquire (Table 1).

Table 1. Asset management data types

<table>
<tr>
<td>CONFIGURATION DATA</td>
<td>Typically originates from Original Equipment Manufacturer (OEM)-related asset data
Informed by periodic enhancements and upgrades
Hazard assessments requiring configuration changes
Used to provide benchmark comparisons with condition data</td>
<td rowspan="3">Each data type can potentially relate to a number of generic outcomes including:

Regulatory compliance: In many instances the consequences of physical asset failure dictate a level of regulatory compliance for most engineering assets.

Time-based Asset Management: Refers to institutionalised, reactive or planned maintenance where data collected is only used to maintain the current condition of the asset.

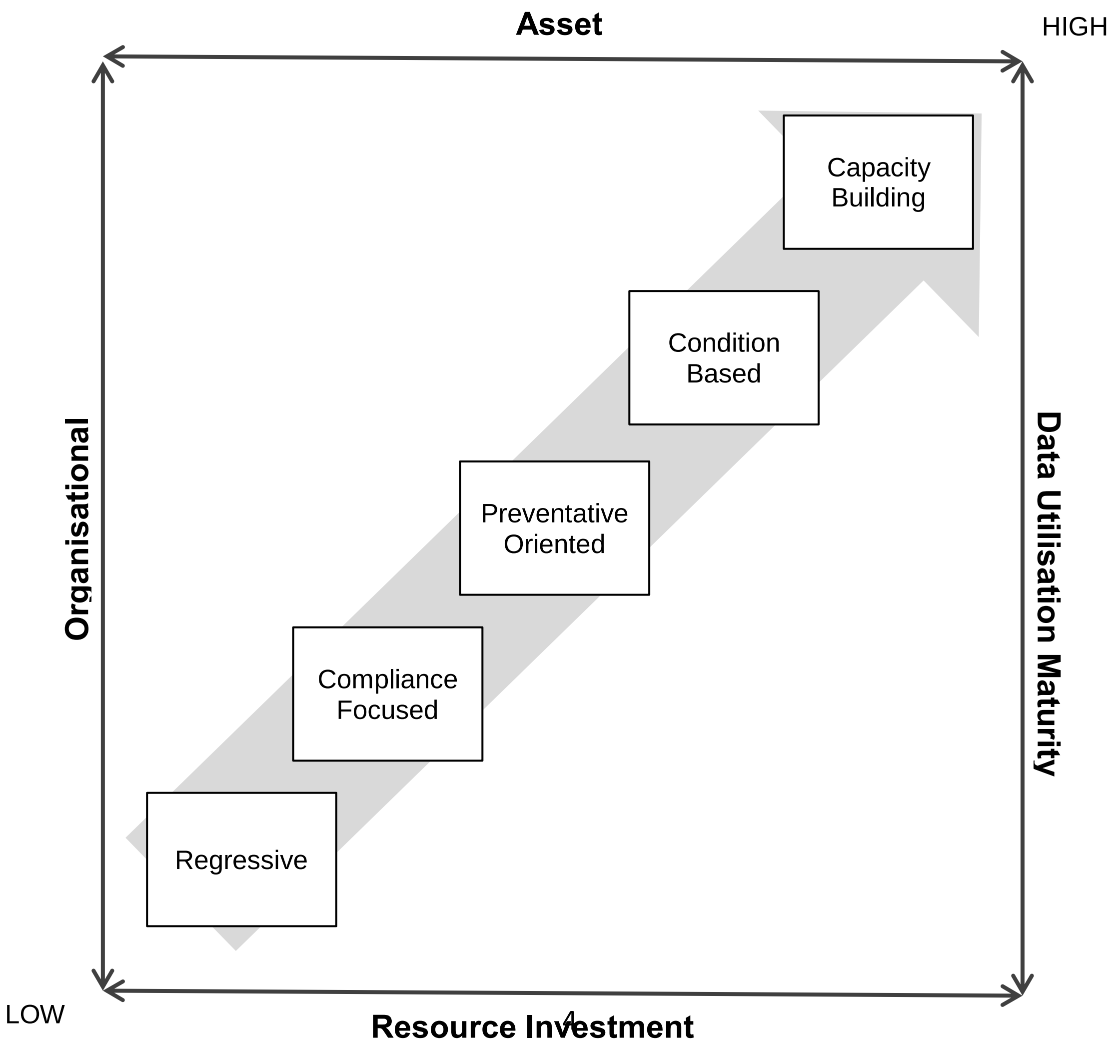
Condition-based Asset Management: This Asset Management outcome largely relates to maintenance regimes such as Condition Based Maintenance (CBM) that rely on sophisticated predictive modelling to determine maintenance schedules.

Capability</td>
</tr>
<tr>
<td>CONDITION DATA</td>
<td>Used to confirm compliance with regulatory requirements
Used to ascertain asset health
May identify the need for reactive (unplanned) maintenance
Can be used for the trending of asset health</td>
</tr>
<tr>
<td>EVENT AND INCIDENT DATA</td>
<td>Used to identify appropriate actions to reinstate the asset back to its ideal state/operational state (component focus)
Used to identify appropriate long-term strategies to prevent future asset failures of this type (system focus)
Used to inform predictive asset health systems
Used to improve future design enhancements</td>
</tr>
</table>

PROCESS DATA	▪ Used to accurately determine Asset Management requirements ▪ Used for scheduling, workforce planning and material management ▪ Used to revise work instruction and safety hazard documentation ▪ Used to drive business process improvements ▪ Used to capture tacit knowledge	**development:** Refers to the use of data to improve the design, development and manufacture of future physical assets or ancillary processes (maintenance routines, safety procedures).

The degree to which equilibrium can be achieved in terms of desired data management outcomes, asset performance and optimum levels of investment can be seen in the Data Management Maturity Model (Figure 1).

Figure 1: Data Management Maturity Model. Source: “Murphy G D, Chang A (2009): A capability maturity model for data acquisition and utilisation. In: Proceedings of the International Conference of Maintenance Societies, 1-4 June 2009, Sydney”



4 Information Management

Asset Management information systems can be defined as "a combination of processes, data, software, and hardware, applied to provide the essential outputs for effective Asset Management, such as, reduced risk and optimum infrastructure investment". According to INGENIUM, an Asset Management information system may provide connectivity to other corporate information systems or databases and support a subset of engineering Asset Management processes/functions, as identified by the International Infrastructure Management Manual (INGENIUM, 2006):

- Asset Register Management
- Asset Hierarchy Management
- Asset Accounting
- Asset Life-cycle Costing
- Environmental Monitoring
- Social Monitoring
- Contract Management
- Resource Management
- Inventory Control
- Condition Monitoring
- Performance Monitoring
- Predictive Modelling
- Risk Management
- Optimised Decision-making

Different types of asset data and information can be often found in different information systems and databases, geographical data can be found in corporate repositories, whereas maintenance data and reports are often stored in separate technical databases. Some authors calls for a need to integrate IT systems and decision-making tools to execute the task of asset management (Schneider et al, 2006). It is acknowledged that isolated, independent systems when integrated into the Asset Management system are likely to provide continuous data on the physical and financial asset conditions (Amadi-Echendu et al, 2007). Examples of such systems as identified by Cato and Mobley (2002) and Baskarada (2009) are provided in Table 2.

Table 2. Integrated information technology systems

SYSTEM	USE
Computer Aided Design (CAD) systems	CAD systems are mainly used in the design stage of the asset life-cycle.
Supervisory Control And Data Acquisition (SCADA) systems	SCADA systems are typically used to perform data collection and control at the supervisory level. They are placed on top of a real-time control system to control a process that is external to the SCADA system.
Geographic Information	GIS may provide for better management and

Systems (GIS)	visualisation of special asset information. It involves a software system, which provides a means of spatially viewing, searching, manipulating, and analysing an electronic database.
Computerised Maintenance Management Systems (CMMS)	A CMMS provides functionality that is normally grouped into subsystems or modules (along with relevant databases and/or files for the storage, manipulation, and retrieval of information), which may include asset records maintenance, asset bills of materials maintenance, inventory control, work order management, preventive maintenance plan development and scheduling, human resources management, purchasing and receiving, invoice matching and accounts payable, reporting, and so on.

4.1 Asset Register

Asset Registers house information relating to various aspects of an asset portfolio, allowing it to be cross-referenced and retrieved as needed. Assets that have service potential and/or the capacity to provide economic benefits through their use in service delivery should be recorded in an Asset Register. Asset Registers come in many forms and can be electronic (e.g. computer) or paper-based (e.g. card file). Data can relate to one or more categories including:

- service delivery functions
- physical properties
- technical data
- financial information (e.g. asset valuation and expenditure)
- property title details
- key operational data
- maintenance data
- performance records.

It is contended that Asset Registers should be integrated into the organisation's management information system. While organisations have different needs a consistent approach can be adopted. A four-staged process for the development of Asset Registers identified by the NSW Treasury (2004) is outlined in Table 3.

Table 3. Steps for the development of asset register

STEP	ACTIVITIES
Conduct a needs analysis	▪ Identify information needs ▪ Identify system needs ▪ Prioritise needs
Plan the system	▪ Review the system development options ▪ Review data collection requirements ▪ Choose options
Plan the asset register	▪ Choose the register model

	▪ Establish assets hierarchy ▪ Establish information hierarchy
Implement the register	▪ Prepare action plan ▪ Establish data management procedures ▪ Prepare business case ▪ Implement plan

a. Asset Register Maintenance

Asset Registers should be updated on an ongoing basis. Asset changes are generally either caused or identified by operational activities. The point of time of change or discovery is the best time to identify this information and update the Asset Register. Based on the Asset Register and on the results of the Demand Management process, a Gap Analysis can show discrepancies between the agency's existing and required asset availability and reliability (capacity and performance), utilisation and functionality, safety and sustainability, and value for money.

b. Thesaurus

A records classification tool (thesaurus) can assist asset managers to maintain the integrity of information on assets. The thesaurus links an agency's business activities to the records it creates. According to the National Archives of Australia, classifying business activities can allow agencies to:

- link records relating to the same activity or purpose
- be consistent in titling records
- develop a systematic framework for the creation, management (including
- storage and security protection) and disposal of records
- enhance records retrieval
- describe Australian Government online resources and services.

The Australian Government's Interactive Functions Thesaurus (AGIFT) is an example of a records classification tool, describing the business functions carried out across Australian federal, state and local governments. AGIFT contains 25 high-level functions and each function has second- and third-level terms, non-preferred terms and related terms. The range of activities covered by each preferred term and any relevant cross-references are provided by way of a scope note. A well designed and detailed agency-based functional thesaurus, congruent with the AGIFT, ensures information is available across space and time. For further information see http://www.naa.gov.au.

5 Relational Knowledge Management

Existing solutions to managing knowledge for asset management focus primarily on codification approaches that apply databases and information systems to capture asset information. We suggest that these systems provide quality and timely data for decision-makers, contributing primarily to management of explicit knowledge, but overlook the importance of tacit knowledge. The lack of personalisation approaches for managing tacit knowledge means that knowledge management for asset management is only fragmentary. Although technology-driven asset information repositories play a central role in the capture of asset data and information such as incident data and data on asset condition and monitoring, it is the relational capital promoted by personalisation approaches that have a strong potential to share and integrate tacit knowledge, underpinning the capacity to develop new ways of thinking and creative responses necessary to improve asset management decision-making.

Personalisation approaches involve the use of collaborative technological solutions or providing environment for personal interaction to facilitate sharing, integration and creation of knowledge. Accordingly, personalisation can now be achieved through the use of sophisticated technological solutions like Web 2.0 that provide alternatives to more static knowledge repositories. These technologies can be used for collaboration (Alavi et al, 2006) and solving cognitive problems (Kimmerle et al, 2010). They can improve visibility and quality of knowledge (Wiewiora & Murphy, 2013), and have a capacity to share and integrate knowledge across a diverse range of experts, enabling large-scale creation of distributed communities of practice, and providing a single point to raise opinions and ideas used to improve decision-making (Chui et al, 2009). Having the ability to generate concepts and thoughts these technologies are able to innovate and expand asset-related knowledge. One example of Web 2.0 applications is a wiki. Wikis enable users to edit the content of entries, allowing them to freely create and organically grow web page content around a specific knowledge domain — a process sometimes referred to as dynamic authoring. Users can track the longitudinal changes to a document creating a high degree of accountability and transparency (Murphy, 2010). With wikis, text can be revised with little effort; users are free to change, add or even delete content. Most wikis have a revision-control feature that saves a history file allowing users to track all the revisions made. Users who want to improve a wiki text have to connect new content to what already exists. This procedure helps to reorganise and reconceptualise content and may lead to improved problem solving and knowledge building in an organisation (Kimmerle et al, 2010).

Another approach to personalisation relates to creating an environment for personal interaction. Research indicates that people prefer to turn to other people rather than documents for information (Mintzberg, 1973; Newell et al, 2008). This can be achieved through building social networks and creating space and time for informal meetings, coffee breaks and workshops. Organisations can endorse the development of social networks by promoting frequent interaction, openness, informality and collaboration, this in turn improves trusting relationships and leads to a greater willingness to share knowledge. Furthermore, building a collaborative environment has a potential to increase cross-functional sharing of asset-related knowledge, including insights about asset pitfalls or failures, without a risk of knowledge hoarding. Incorporating an integrated relational approach into existing data and information management systems will facilitate access to both tacit and explicit knowledge and assist in leveraging existing social and organisational relationships, thus will fully utilise organisational capabilities including skills, expertise and knowledge leading to effective knowledge management outcomes.

5.1 Barriers to Knowledge Management

Effective management of asset knowledge can benefit all asset management stakeholders; however, there are barriers that exist in relation to knowledge management that prevent effective sharing and integration of knowledge, and in result leading to knowledge loss and poor decision making outcomes. Table 4 lists a range of barriers to knowledge management (James, 2005; Wiewiora et al. 2009) and Table 5 proposes a number of counter strategies available to negate their effect (James, 2005).

Table 4. Barriers to knowledge management

BARRIERS TO KNOWLEDGE MANAGEMENT
▪ Knowledge management is not prioritised or rewarded thus there is no compelling reason why knowledge should be managed
▪ The existence of a culture of hoarding where sharing of “bad news” is not encouraged
▪ Functional and geographical separation between asset teams
▪ Lack of time for knowledge sharing activities (the focus is on activates directly related to the management of asset)
▪ Natural conservatism
▪ Red tape and bureaucracy
▪ Lack of standardised systems and taxonomies
▪ Uncertainty and job insecurity
▪ Highly competitive internal organisational climate where knowledge is considered as a source of power
▪ Reward systems that encourage individual performance
▪ Mechanisms stimulating socialization and communication between asset management teams are missing

5.2 Knowledge Management Action Plan

The use of both codification and personalisation approaches to knowledge management have the potential to bring desired outcomes for improved asset management decision-making. We argue that relying solely on one approach may not be sufficient. Technological, computer-based approaches may provide superior access to explicit knowledge, but overlook the importance of tacit knowledge acquisition, sharing and application.

Table 5. How to achieve improved knowledge management practices

STRATEGIES TO IMPROVE KNOWLEDGE MANAGEMENT	PRACTICAL IMPLICATIONS
▪ Establishing a climate of continuous learning ▪ An open culture and getting rid of red tape	▪ Building open, knowledge-oriented asset management culture that promotes continuous learning often requires a cultural change. ▪ To do so your organisation needs to be aware of and evaluate its dominant culture characteristics. This will uncover knowledge sharing patterns specific for a given culture type. ▪ Application of Denison and Spreitzer, Denison[1] or Cameron and Quinn[2] Frameworks may be useful in determining the dominant culture. Based on that, an action plan can be undertaken to introduce values promoting open, knowledge-oriented asset management culture. (For further details please refer to the next Section titled Organisational Management, Subsection: Asset Management Culture)
▪ Communication, participation and	▪ A supportive and participative leadership style will promote knowledge sharing and creation endeavours.

[1] Denison, D. R., & Spreitzer, G. M. (1991). Organizational culture and organizational development: A competing values approach. Research in organizational change and development, 5(1), 1-21.

[2] Cameron, K. S., & Quinn, R. E. (2005). *Diagnosing and changing organizational culture: Based on the competing values framework* (Revised ed.). San Francisco, USA: Jossey-Bass Inc Pub.

consultation	▪ Support from leaders can endorse feelings of belongingness, enhance the collaborative climate and help staff recognise they are not competing amongst themselves, but are part of a team who, by sharing knowledge, will build its knowledge capabilities and gain a competitive position in the market. ▪ Promoting active leadership engagement could potentially improve knowledge management endeavours by encouraging the use of collaborative tools for knowledge sharing and ensuring transparency of asset management norms and practices.
▪ Trust-building and team enabling activities	▪ In order to enhance conditions for trust building, managers may consider: ○ reviewing organisational norms and practices that encourage or discourage the high frequency of interaction and collaboration ○ supporting and recognising knowledge sharing and creation initiatives ○ endorsing and maintaining a friendly and non-competitive atmosphere at work ○ creating an atmosphere for learning not blaming ○ ensuring the visibility of other people's skills and competencies; this will bring the awareness of 'who knows what' ○ ensuring confidence in the measures evaluating people skills and expertise.
▪ High quality, capable staff ▪ Senior management commitment ▪ Induction programs ▪ Education	▪ Where possible, facilitate face-to-face interactions by designing open plan offices or creating designated areas where staff can meet and exchange valuable tips and experience ▪ Designing comprehensive induction programs and mentoring and training sessions will facilitate access to asset management-related knowledge
▪ Supporting technology	▪ Introduce an easily accessible, intelligible and user-friendly technological solution to capture asset data, information, and allow collective sharing and creation of knowledge ▪ Whenever possible and applicable, incorporate an asset register and asset data management databases into the system to ensure greater useability, one point of reference and transparency of data ▪ Develop a clear action plan for capturing, documenting and reusing asset data ▪ Catalogue asset data and information according to themes ▪ Enhance the system by supporting technologies, such as hyperlinks, tags, bookmarks and RSS to allow for improved discoverability ▪ Introduce ownership — a coordinator accountable for quality control, content maintenance, implementation, structuring links to the content and adding value ▪ Use the system as a tool for decision-making and knowledge creation, encourage users to co-develop the content, but assign a coordinator to provide control to ensure the quality of the entry ▪ Ensure user-friendly use and interface ▪ Encourage use of the tool and creating understanding about its value and applicability through building appropriate culture and leadership support

Whereas relying only on relational approaches mean that opportunities can be lost because no one is accounted to capture these elements, revisit and follow up on them (Cooper, 2003). Table 5 provides a range of practical implications for asset managers and for agencies that aim to improve knowledge management endeavours taking into account both approaches: relational and technological (Wiewiora & Murphy, 2013).

Findings from recent studies reveal that knowledge stored in databases or PDF documents is hard to retrieve and employees are often reluctant to search through overloaded spreadsheets that contain a large amount of historical data which is hard to deal with (Wiewiora & Murphy, 2013). For knowledge to be utilised and shared there needs to be a platform to ensure greater quality and transparency of knowledge. Figure 2 provides a platform for developing a dynamic computer-based knowledge management for improved knowledge sharing, integration and use (Wiewiora & Murphy, 2013).

UPDATED AND DYNAMIC TOOL FOR IMPROVED KNOWLEDGE SHARING AND USE

CONTENT AND MAINTENANCE OF ENTRIES

Require ownership and quality control	Require moderate ownership, control and maintenance	Free entries
Explicit knowledge	Tacit and explicit knowledge	Tacit knowledge
▪ Static information ▪ Links to processes ▪ Templates	▪ Lessons learned ▪ Valuable links ▪ Technical information	▪ Space for collaborati on and knowledg e sharing

DESIGN

- User friendly (search capability with indexing for a more intuitive way of finding knowledge)
- Intelligible (clear, easy to use and understand)
- Comprehensive (includes all types of knowledge and end-to-end processes)

ENVIRONMENT

ORGANISATIONAL CULTURE

Cultural norms and practices supporting the use of online knowledge storage tool

LEADERSHIP ENGAGEMENT

Active support and engagement from top management to use online knowledge storage tool

OWNERSHIP

A person responsible for updating and maintaining entries (e.g. Project Management Office personnel)

Figure 2: Steps to achieve updated and dynamic knowledge storage and sharing platform. Source: Wiewiora, A., Murphy, G.: Unpacking 'lessons learned': investigating failures and considering alternative solutions. Journal of Knowledge Management & Practice (2013)

5 Conclusions

Asset data and information includes particular repository material about asset characteristics, categories of assets and asset valuations and evaluative data. The current organisational environment can be considered 'knowledge rich' and, in this context, the effective management of information and information systems is a critical and complex responsibility. A contribution of this research is the differentiation between codification and personalization of asset data, information and knowledge. While ICT systems can assist in delivering highly efficient information management for firms, professional information managers also have a vital role and add enormous organizational value in carefully considering employee information and knowledge needs, employee means of accessing and utilising data and importantly considering how the integrity of the system can be reserved.

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