Strategic Leverage of Engineering Knowledge through Taxonomy Governance

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ABSTRACT

In the heavy engineering industrial sector numerous technical standards, ISO (International Standards Organisation) in particular, exist which invariably contain a glossary of terms providing definition within the context of the standard. However, there is a high level of ambiguity surrounding common terminology and limited consistency across these standards.

Our case study company Silcar Pty Limited (Silcar) has recognised the opportunity to strategically expand its business into the provision of high value services to assist clients with the management of large and complex technical assets in heavy industry and essential service utilities. The strategic development of a knowledge management capability enables Silcar to take-on larger scale, higher value added and more flexible asset performance management propositions across a diverse range of industry, client and geographical situations.

This research paper explores the concepts that support this capability and discusses the approach taken to achieve the vision of consistency on language.

Keywords: Heavy Industry: Work systems: Taxonomy: Governance: Knowledge Management.

INTRODUCTION

In the heavy engineering industrial sector numerous technical standards, ISO (International Standards Organisation) in particular, exist which invariably contain a glossary of terms providing definition within the context of the standard. However, there is a high level of ambiguity surrounding common terminology and limited consistency across these standards.

Our case study company, Silcar is a relatively young organization having been created in the early 1990's to provide outsourced asset management and maintenance services to specific power generation assets. Since that time it has grown and taken on a diverse portfolio of asset management propositions. Its value proposition of delivering asset productivity and reliability is built around (a) access to global knowledge and innovation and (b) multi-client, multi-industry business experience. Silcar has recognised the strategic opportunity to expand its business into the provision of high value services assisting clients to more effectively manage large and complex industrial assets.

Silcar is an Australian based asset management company of some 3,000 people. It provides asset management services to the electrical power, manufacturing mining, and telecommunications industries. Silcar has long term contractual engagements to provide management and maintenance services as an outsourced provider. Its growth strategy is to differentiate itself from its competition through leverage of its significant knowledge and experience in management of technically complex assets. This paper discusses the strategy Silcar has chosen in order to achieve this ambition through the examination of capability maturity frameworks and supporting work practices, knowledge management and the need or taxonomy management to provide terminology governance.

THE KNOWLEDGE MANAGEMENT VALUE PROPOSITION

Silcar has identified its growth path as moving up the value chain which sees a transition from an organisation that responded to requests from clients with transactional delivery of maintenance engineering services to an organisation that provides proactive asset performance management. The new business model requires Silcar to formulate value propositions regarding the management of technically complex assets to the asset stakeholders. This model relies on organisational intellectual capital in addition to individually applied skills.

In the contemporary business context, knowledge is driving innovation and organisations are competing on knowledge intensive products in a knowledge based economy [12]. Given the increasing importance of knowledge in economic activity, there needs to be a focus on managing this knowledge as a business asset [26].

Knowledge can be defined as information combined with experience, context, interpretation and reflection and is a high value form of information that is ready to apply to decisions and actions [23] [9]. Further, recognition of tacit or person based knowledge is also fundamental to a complete discussion of the nature of business knowledge as it is only partially transferable

[21] [26]. This distinction has implications for knowledge work systems which will be considered later.

Before going further with this discussion we need to recognise that there is no commonly recognised definition of knowledge management however, among the many definitions advanced in theory the following working definition encapsulates three important aspects of knowledge: *'Knowledge is a body of information resident within an individual, organised by judgement experience and rules'* [10]. Namely, the definition recognises that knowledge is based on information, secondly, that it requires some human interaction and thirdly it recognizes the need for a conceptual framework to bring knowledge to life. Consequently, this definition is adopted for this research.

Svieby [26] proposed an Intangible Asset Monitor to measure the value of intangible assets (Figure 1). This model emphasizes the linkage and dynamic interaction between human capital, structural capital, and customer (client) capital and places value on items such as employee competence, experience and relationships. He argues this to be necessary to address the inadequacies of current accounting practices that are geared to the measurement of tangible assets, cash, plant, equipment etc. and fail to account for divergence in value between an organisations' book value and its actual market value.

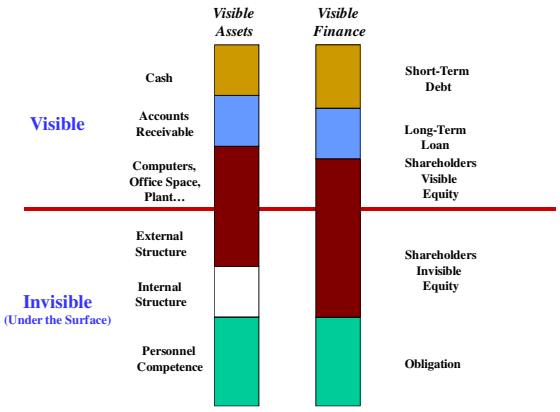

Figure 1- Intangible Asset Monitor (Svieby 1997)

Svieby argues that intangible value resides in individual and organisational experience which is frequently unrecognised and therefore unmanaged. It is this concept of intangible value that is fundamental to Silcar's strategy to leverage its knowledge and experience and position itself as a provider of high value services. Having recognised this intangible value proposition based on its knowledge and experience Silcar further recognises the need not only for management strategies but also the importance of an appropriate governance framework.

BUILDING ORGANISATIONAL CAPABILITY

For Silcar, the strategic development of a knowledge management capability enables it to take-on larger scale, higher value added and more flexible asset performance management propositions across a diverse range of industry, client and geographical situations. Silcar's corporate approach to the management of this diverse asset portfolio is to allow autonomy with limited corporate intervention at an operational level.

As part of its coordinated strategic positioning, Silcar has developed an integrated system of business processes, data repositories and software applications to manage collective knowledge and experience. Significant knowledge and experience is embedded in the historical data collected as a result of managing large and complex industrial and utility facilities over an extended period of time and is also in the operational experience of its engineering staff. However, the utility of this data and information has been limited by the lack of a common structure underlying the storage and naming conventions applied at a point in time and in a specific industrial context. Therefore, one of the dilemmas challenging Silcar's aspirations was how to provide a level of governance consistency across what is necessarily a diverse range of operating contexts.

In a discussion of meta-engineering Callaos [7] argues that commonalties with different kinds of engineering activities are necessary conditions supporting strategic growth. Hawley [16] confirms that "engineering is the process that converts science into technology and then into wealth creating products. For Silcar the establishment of taxonomy to provide consistency of terms and concepts that underpins collaboration across the diverse portfolio of business interests is an important first step. This is a complex task. Consequently, management of this taxonomy is necessary to ensure the value and integrity of the 'knowledge library' and to make this knowledge readily available across the various technical dialects and international contexts of the future business.

Organisational Evolution

An accepted measure of organisational capability is to be found in the commonly accepted Capability Maturity Model (Figure 2) originating from the Carnegie-Mellon Software Engineering Institute [19]. The model is used, particularly in the information technology industry as a means of assessing organisational capability and certification of organisations to deliver quality solutions and identifies five levels of process maturity for an organization which assume an increasing level of capability as organisations mature.

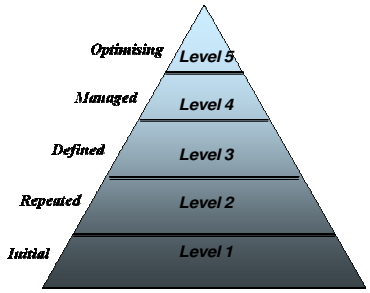

Figure 2 - Capability Maturity Model (Humphrey 1989)

The principles embedded in the capability maturity model are reflected in other organisational certification frameworks including Six Sigma, ISO standards. The fundamental tenet is that clear governance and documented control processes demonstrate clarity of action thereby reducing production variance and producing higher quality outcomes. Further, these principles have been applied as standards to knowledge management capability [2].

Greiner [14] identified an evolution path applicable to organisational growth. He maintained that organisations evolve through five identifiable phases each culminating in a 'crisis' that brings about either corporate disintegration or transition to the next phase of growth. These phases of growth are identified as;

- Creativity;
- Direction;
- Delegation;
- Coordination and
- Collaboration.

Greiner's view of organisational development is aligned in many ways with the capability maturity model discussed above. In terms of this evolution path Silcar, at the time of writing this paper, appeared to be in the 'crisis of coordination phase' and recognised the need to enhance its corporate capability commencing with the development of a collaborative environment.

Barrett [5] introduced the concept of organisational consciousness and developed a hierarchical model of organisational development drawing from psychology theory. He applies Maslow's hierarchy of human needs in his consideration of organisational growth (Figure 3) and draws the analogy between individuals and organisations with the former being defined by personality and the latter by culture.

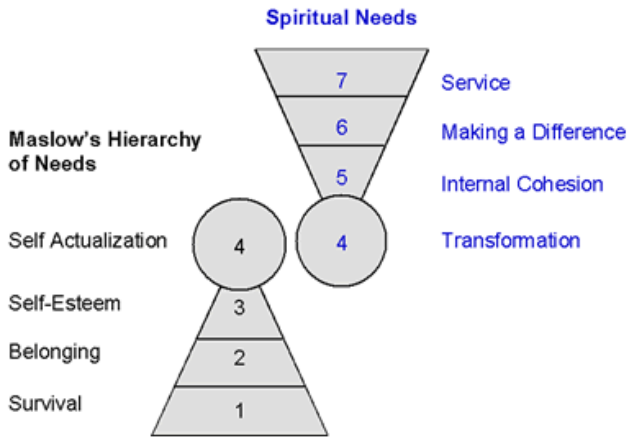

Figure 3 - Hierarchy of Organisational Consciousness

The essential difference between individuals and organisations is that individuals are defined by their personalities whereas groups are defined by their cultures. Barrett's argues that as organisations mature there is a hierarchy of physical, psychological and spiritual factors that need satisfaction in the same way as would be encountered by an individual. Therefore, by knowing this, organisations can consider these evolutionary needs in the development and execution of strategy.

Co-incidentally, but aligned with Barrett's concepts of organisational consciousness Silcar has adopted a philosophy of 'Mindfulness' in its strategic approach to health and safety management with a conceptual view of its evolution path relative to the development of a safety culture through phases of Pathological, Reactive, Calculative, Proactive and Generative phases Hudson [18]. The sentiments of which have recognisable parallels with the Capability Maturity Model and Barrett's hierarchy.

Work Systems

One of the fundamental conceptual assumptions apparent in the various models discussed above is that identification, documentation and implementation of consistent work practices contributes to organisational performance. Porter [22] provides an influential view of organisations as a value chain of processes designed to produce a specific output.

Similarly, Hammer & Champy [15] explore the importance and need for an organisation to understand and document its processes. This theory has underpinned many management initiatives aimed at improving business performance through process improvement.

Building on Hammer & Champy's process theory Hoebeke [17] proposes a theory of 'work systems' which holistically recognise the complexity of internal and external factors involved and the importance of human interventions. Importantly he introduces the concept of *Weltanschauung* in recognition of the differing implicit perspectives that shape the process in its environmental context.

We can see the elementary documentation of process at a simplistic level in the models proposed by Porter and Hammer & Champy. These theories emphasize the interrelatedness of processes including process hierarchies but do not explicitly recognise the contribution of human activity and relationships. Hoebeke adds the dimension of human interaction to process considerations just as Barrett's hierarchy has done at the organisational capability level.

Theorists including Checkland [8], Senge [24] and Senior [25] have further developed systems theory which recognises the importance of 'soft' or human emotional and behavioural factors in work systems. Checkland [8] introduced the concept of soft systems methodology as a recognition of the limitations in the application of logical positivist empirical theory to complex, often fuzzy organisational situations involving human interactions.

There recognisable parallels with the evolution of scientific and academic research methods which have expanded from

empirical methods to the acceptance of action research methods [6]. Senior [25] argues that in an organisational context most phenomena are socially constructed and that action research adapted from social sciences offers the most appropriate research methodology.

Senge's [24] concept of the learning organisation has essential characteristics including nurturing the growth of new capabilities, transformational learning for survival, leadership by communities of servant leaders, learning through performance and practice, and the inseparability of process and content. Any work system must incorporate this learning aspect as a characteristic of high capability performance.

Synergistic developments in organisational psychology have introduced emotional intelligence theory at an individual emotional level into management science leadership discussions which form parallel trains of thought with the concepts of organisational consciousness inherent in Barrett's hierarchy [13] [4].

Jacques [20] provides a model of effective hierarchical organisations with an emphasis on accountably and competencies. Importantly, Jacques identifies organisations as 'systems for getting work done'. This he terms the Management Accountability Hierarchy consisting of layers of activity defined in terms of task complexity relative to information complexity and timeframe to do the job. It is this management accountability framework that provides structure for organisational activity with people provided with accountabilities commensurate with ability and an inherent hierarchy of authority.

From these base principles Jacques develops Stratified Systems Theory which structures an organisation into eight strata based on task complexity. The argument is that each stratum has an increasing level of complexity with accountability for managing and leading the activities of subordinate strata. At the higher levels there is the need for inherent capability to construct and oversee complex systems and is requisite for strategic leadership.

Similarly, Hoebeke [17] describes a work system as a 'purposeful definition of the real world in which people spend effort in more or less coherent activities.' He argues that work systems involve human activity and relationships between people within an environment for a specific purpose. In Hoebeke's model the transformation of inputs to outputs occurs through layered domains and a process hierarchy defined by the involvement of actors contributing human activity to make the activity successful. These domains are:

- Level 1, Added Value;
- Level 2, Innovation;
- Level 3, Value Systems; and
- Level 4, Spiritual.

Importantly these domains have recursive relationships within the model and are based on holistic interaction with internal and external environment. Porter's value chain model can be considered as the level 1, Added Value of Hoebeke's work systems and at the transactional level of work activity. Examples of processes at this level include accounts payable, maintenance procedures and the knowledge management process which will be discussed later.

Aligned with Jacques stratified systems theory Hoebeke describes the work system domains in terms of a process hierarchy. This process hierarchy includes recognition of human relations and transformation activities. Each level within the process hierarchy is defined in terms of the relative timeframe and outcomes that will be achieved and are seen in terms of a recursive relationship within the work system hierarchy.

Alignment between Hoebeke's work systems and Jacques Stratified Systems Theory lies in the consideration of relative timeframe for task completion as a defining variable as presented in table 1. However, a fundamental divergence is evident over the issue of an implied management hierarchy within the system structure inherent in Stratified Systems Theory.

Hoebeke Domain	Jacques Strata	Time Horizon
Recursion level 1 Added Value	Strata 1 - 3	1 day – 2 years
Recursion level 2 Innovation	Strata 3 - 5	1 – 10 years
Recursion level 3 Value System	Strata 5 - 7	5 – 50 years
Recursion level 4 Spiritual	Strata 7 - 8	20+ years

Table 1- Hoebeke / Jacques Time Horizon Comparison

We have previously noted that the dimension of human interaction has been introduced into the consideration of organisational capability and work processes. We see with Jacques and Hoebeke the introduction of the time dimension as a variable in organisational work systems. Although there is not an explicit consideration measured in time horizon there is observable alignment between Barrett's view of spiritual needs and organisational consciousness and the higher levels of the spiritual and higher stratum proposed by Hoebeke and Jacques respectively.

KNOWLEDGE WORK SYSTEM

The discussion so far has established the importance of Work Systems in building organisational capability. Silcar's strategy is to leverage its knowledge and experience and therefore the knowledge management work system is a fundamental requirement. Hoebeke's [17] descriptions of work systems as having a tiered domain structure also recognised that knowledge occurred across the various domains of a work system and

therefore needs to be understood at multiple levels. Therefore we must define knowledge management as a work system at a number of levels.

Earlier, recursive relationships within the work systems framework were discussed. This has implications for knowledge management as knowledge necessarily flows in, out and across recursive level boundaries both internal and external to the organisation. Hoebeke [17] recognises strategic information processes that contribute to management creating, conveying and developing meaning.

Theory and results of Social Network Analysis associated with knowledge management endeavours have confirmed that knowledge flows through an organisation through a series of networked social and semantic relationships [27]. Importantly, in most cases these flows do not follow the communication channels implied by the formal organisational structure of the organisation and are largely tacit in nature. Consequently, the knowledge management work systems must be based on holistic interaction with the internal and external environment and be able to reflect the needs of employees at operating within various domains.

The link between the organisational work systems, which can be defined relative to recursion domains, and the knowledge work system, which exists across and independent of these domains is created through a taxonomy structure. Taxonomy provides a consistent reference point and translator of explicit and tacit knowledge. In a diverse organisational environment this necessarily creates the need to define standard terms and manage a complex semantic network of synonyms and homonyms which inevitably occur across a diverse operating environment. Figure 4 attempts to present this complex scenario showing the taxonomy as the filter and reference point between the organisational work systems and knowledge work system based on social and semantic relationships.

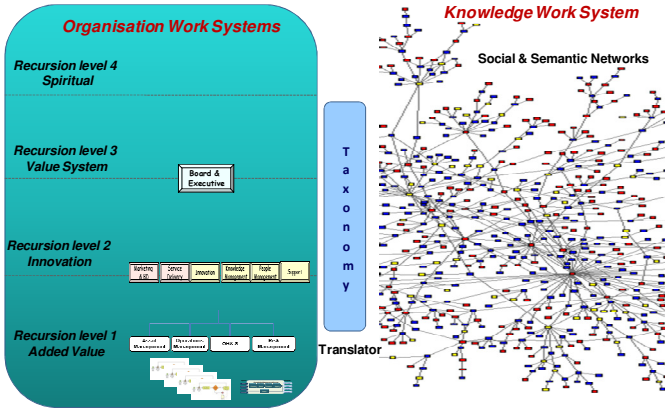

Figure 4 - Knowledge Work System

Knowledge Management Process

It is important to recognise that the knowledge management process lies at the value adding level of a work system and can be seen as the mechanical process supporting the overall knowledge work system.

The knowledge management processes have been derived through adaptation of Porter's value chain model [22]. The literature indicates a general set of processes constituting knowledge management and although there are differences in terminology, the following process life cycle can be observed. [11].

- **Creation of Knowledge** which is concerned with the way in which an organisation acquires or generates knowledge;
- **Storage of Knowledge** process includes knowledge codification and storage of both tacit and explicit information;
- **Access to Knowledge** concerned with understanding where knowledge is needed, how and under what conditions it is accessed; and
- **Application of Knowledge** is application of knowledge as input to business activity.

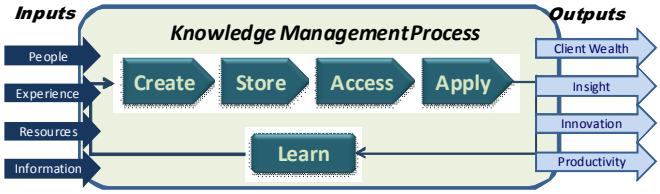

Figure 5- Knowledge Management Process - Value-Adding Domain)

In addition to the knowledge management process described above, a feedback (learning) loop, where lessons learned are continuously incorporated back into the process completes the life cycle view of knowledge management. Hoebeke [17] defines control information processes as related to a corrective action feedback loop and audit information processes that inform continuous improvement and innovation. Argyris and Schön [3] also introduce the concept of 'double loop' learning consisting of continual review and iteration as a fundamental concept underlying organizational learning and self improvement. Again there are conceptual parallels to be found relative to various continuous improvement methodologies found in the engineering industry based on operations management theory including Six Sigma, Total Quality Management and Kaisen.

We must note that the learning loop must be present across all domains of Hoebeke's work system hierarchy and not exclusively tied to any one domain. Hoebeke discusses audit information processes that lead to a questioning of the process although this discussion is limited to within the innovation domain.

THE STRATEGIC NEED FOR TAXONOMY AS GOVERNANCE

We have introduced the concept of taxonomy as the translating link between organisational work systems and the knowledge work system. The purpose of taxonomy is to reduce the uncertainties and ambiguities encountered in the differing natural languages of different work environments [20]. Taxonomy is a collection of vocabulary terms organised into a hierarchical structure [1]. Each term has only one definition in order to reduce the ambiguity of multiple meanings of the same term. I.e. each term has one and only one meaning, thereby providing clarity.

For Silcar, there is the need to maintain multiple taxonomies across its diverse business portfolio however, it must dynamically manage the complex range of synonyms, homonyms professional, technical and colloquial terms that are used at site level. Because of its international setting this necessarily includes terminology in languages other than English.

Jacques [20] discusses the common situation evident in modern organisations that lack this clarity or meaning of commonly used terms. He claims that this situation makes it 'impossible to think, or to test propositions, or to talk to one another without any hope of understanding', citing human resource management terms including: manager, supervisor, duty, and performance. This ambiguity inhibits the management science that forms the foundations upon which modern organisations are run.

In the engineering environment with its necessary emphasis on safety and risk, any uncertainty amplifies this risk. The clear definition of commonly used terms and the creation of a consistent, known and precise taxonomy is a critical strategic risk mitigation strategy and necessary precursor for functional alignment.

In an engineering industrial sector numerous technical standards, ISO (International Standards Organisation) in particular, exist which invariably contain a glossary of terms providing definition within the context of the standard. However, there is a high level of ambiguity surrounding common terminology and limited consistency across these standards.

Accordingly, Silcar has elected to define its own taxonomy applicable to the diversity of its operations that will leverage, as far as practicable, terminology definitions from existing standards. Given Silcar's operating environment across different industry and organisational legacies, there are multiple 'technical dialects' in colloquial usage. Therefore the construction of taxonomy is a complex task. In fact, the solution is to compile a number of taxonomies and to manage the identification and management of homonyms, synonyms and semantic relationships between them within a master controlled vocabulary. To achieve this, requisite information management and librarian skills supported by a taxonomy management technology have been developed.

The utility of the taxonomy and governance structures over the taxonomy delivers a high confidence that all information about a subject of interest is to hand allowing access to best practice and complete asset management knowledge.

To illustrate that taxonomy and clarity of meaning is an important governance issue consider the following common engineering terms: Gantry, Crane and Hoist. These terms are often used interchangeable (synonyms) depending on industry, site or professional context. As assets and items of equipment of major industrial plants each will be subject to a management strategy for preventative or routine maintenance and operational procedure. However, as these terms are synonyms it is important to precisely define and agree the nomenclature for the equipment item in terms of function and purpose in order to apply optimal operational procedures and maintenance strategy. This then helps in identifying the strategy which will minimise losses in reliability, operational life and costs over an extended period of time.

In an operating environment consisting of diverse operating and professional environments and a specific need to incorporate multiple language sets the management of taxonomy is a complex undertaking. Consequently a taxonomy management technology has been selected and forms an integral component of the business and technical architecture. This tool provides the governance required to ensure a consistent set of terms are used within clearly defined parameters.

CONCLUSION

Silcar has recognized the need for planned strategic growth leveraging intellectual assets rather than growth by acquisition or volume expansion. The creation of the capability to be able to fulfil this strategic vision relies heavily on the development of an operating culture where knowledge is identified as the key asset. The characteristics defined at the higher levels of the various capability measurement models discussed, provide guidance as to how to develop the requisite capability. The ongoing definition of work systems is important to this future as is wide access to knowledge and experience. Implementation of these structures requires establishment of the necessary processes and governance structures and requires the development and acquisition of leadership capability and people to manage the knowledge based organisation at a higher level.

The operating vision and governance architecture described in this paper represent the strategic approach to the developing of asset performance management capability based on its collective knowledge and experience. This architecture provides effective control over the language used to create policy and procedure and is also the focal point for the search and retrieval of the knowledge and experience that is embedded in its asset performance management systems, document management systems and engineering community. At the heart of this strategy is taxonomy which provides the link between work

systems within and across defined domains of activity and the knowledge asset itself.

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