Published as: Onions, P.E.W. (2008), "Projects in the Knowledge Economy", 9th European Conference on Knowledge Management (ECKM 2008), Southampton Solent University, Southampton, UK, 4-5 September

Projects in the Knowledge Economy

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Abstract
New ways of working have to be explored to ensure learning and knowledge become prime foci in the Knowledge Economy. One approach would be to re-engineer conventional processes to centre on knowledge rather than on tangible deliverables and their production activities. This paper demonstrates that strategy, by proposing radical new theories of projects and project management.

Project management has been successfully applied in wide range of industries where deliverables are tangible and planning and control are predictable, such as construction and aviation. These are environments where the outcomes and tasks to achieve them are known or can be accurately described. Knowledge Economy projects on the other hand are characterised by knowledge intensive or novel activities, unique or unknown solutions, complex and dynamic environments, and skilled and creative staff.

Projects in the Knowledge Economy have been difficult to plan and control. Empirical evidence suggests a higher than normal project failure rate in information technology, creative industries and research. Lack of success may be attributed to the inherent complexity and 'unknowability' of these projects' work breakdown structures, particularly during initial planning phases. Conventional project management approaches have attempted to mitigate this situation through techniques such as iterative methodologies, experience based estimation and project reviews. By accounts these too have met with limited success.

Lack of an explicit theory of project management hampers efforts to devise new approaches. Establishing theory for knowledge-based projects and knowledge based project management was consequently a primary objective of this research. This theory uses algebraic models to redefine projects as finite sets of interrelated knowledge configurations, and project management as a process of systematically and optimally arranging and coordinating these knowledge configurations to achieve specific objectives.

It is intended that these theories address the demands imposed by the Knowledge Economy on projects, whilst retaining those project characteristics that are important to practitioners. These theories will also underpin a knowledge based project management methodology that may be used to inform and describe relevant practice.

Keywords: knowledge, projects, project management, Knowledge Economy

1. Introduction

The Knowledge Economy is a broad and somewhat vague term with numerous definitions that focus on information, knowledge and related assets. Irrespective of theoretical definitions, the Knowledge Economy is very real to most workers today and this reality pragmatically defines the concept. Production of information and knowledge may have overtaken conventional industry in some areas (Lopes and do Rosário Martins, 2006), and resultant changes in the workplace are diverse with transformation in the areas of finance, information/knowledge and technology (Peters, 2004).

The paradigm shift has not been accompanied by changes to working practice in all areas. Project management practitioners are educated in and subsequently apply methods designed to solve Industrial Economy problems. Outcomes for Knowledge Economy projects are mixed however. Project failure in knowledge intensive environments is frequently described as high (Goulielmos, 2003), and a series of reports published between 1995 and 2001 found that between 40% and 83.8% of all information systems projects are described as failures (IT Cortex, 2006).

Empirical evidence from practice shows significant uncertainty is a key reason for high IT project failure rates. Novelty of technology, environment, requirements and solutions hinders the project manager and even by experienced technical team members in forecasting what has to be done, how long it will take and how much it will cost. Risks consequently cannot always be reliably identified, and the output may differ substantially from its original conceptualisation.

Remedies have emerged, but without the anticipated improvements. Iterative methodologies such as the spiral model (Boehm, 1988) divide a large problem into a series of versions of the final solution and repeat the waterfall model a number of times throughout the duration of the project. This is intended to mitigate risks such as delivery diverging from requirements and changes in scope. Other methodologies, such as Critical Chain (Goldratt, 1997) and the Theory of Constraints (Goldratt, 2002; Dettmer, 1998) estimate tasks differently and include a buffer in the project plan to absorb task overruns. Practitioners have long used estimation techniques like COCOMO and function point analysis, as well as project review and collaboration techniques like COLA (Thomas and Thomas, 2008; Burke et al., 2005).

It may be that Industrial Economy planning and control techniques are inherently unsuited to projects in the Knowledge Economy. To find a solution this research has adopted a strategy of reengineering management processes to pay less attention to tangible deliverables and activities, and more to knowledge and knowledge processes. Knowledge becomes the unit of measure in a process, not work, and in so doing it is intended that benefits will accrue to environments characterised by:

- Scope and outcomes that are initially unknown and even unknowable.
- Inability to identify or describe tasks in sufficient detail.
- Complexity and dynamism.
- Solutions that are unknown or novel.
- Activities that are creative, novel or knowledge intensive.
- Skilled and creative staff.

2. Defining projects and knowledge

According to the Project Management Institute (PMI, 2004), "*A project is a temporary endeavour undertaken to create a unique product, service or result*". Kerzner (2001, p2) defines a project as a series of activities and tasks with a specific objective to be completed within certain specifications, between start and end dates, possibly within funding limits, consumes resources and cutting across functional lines. Turner (2006) regards a project as a temporary organisation, which the owner creates to create value, consuming resources to do non-routine, risky work to deliver an output, and which will be operated to achieve a beneficial outcome.

What is knowledge? Discounting the myriad definitions (mainly to avoid the lack of consensus in the discipline), knowledge for theoretical purposes may simply be regarded as what people know. This theory will acknowledge it has tacit and explicit characteristics (Polanyi, 1966); where tacit knowledge remains in the mind of the knower and can seldom be written down, and explicit knowledge is knowledge that has been written down. Another relevant interpretation is that of Styhre (2003) who regards knowledge as an object, as a process, or both. In discussing knowledge as an integral element of project activities, this theory will make no distinction between the type and nature of knowledge. Knowledge in this paper may refer to an entity or 'piece' of knowledge, the process of knowing or applying knowledge, knowledge embedded in a product or output, or the configuration of knowledge.

There is some evidence of the importance of knowledge to project management. Turner (2006) notes that information is important in the management of projects, but does not define it. His usage however treats information and knowledge synonymously, which is consistent with literature (Müller-Merbach, 2004) and supported by arguments that explicit and tacit knowledge can be difficult to differentiate (Jasimuddin et al., 2005). Completion and success also appear strongly dependent on the knowledge used in project execution. Kerzner (2001, p161-216) observes that selection of skilled individuals is critical to project success, and Burke et al. (2005) find a positive correlation between knowledge retention and project performance.

3. A knowledge based theory of projects

One solution to project problems in the Knowledge Economy may be to manage the knowledge needed, applied and generated during the course of the project. No relevant and appropriate theory appears to exist in this area, so an abstract and generalised understanding should be sought in order to provide a communicable and stable foundation for future work and to avoid concerns about specificity that have been levelled at other theory (Sauer and Reich, 2007). Furthermore this theory should be prescriptive (normative, or how projects ‘ought-to-be), rather than descriptive (explaining the ‘as-is’ of projects) (Sauer and Reich, 2007).

A project P may be described as a finite collection (or set) of planned and unplanned activities A with specific objectives, and constrained by limits usually measured in terms of time, cost and quality:

$$P = \{A\} \qquad 1.$$

This is not meant to imply that projects are merely a collection of activities. Project activities are interconnected by working towards the same project objective, and have an optimum sequence described by the critical path. Any group of interconnected activities form a ‘configuration’, an arrangement that includes the activities, their dependencies and relationships with time.

It is possible to consider each of these project activities from a knowledge perspective. An example from an actual project illustrates:

> A software developer needs to know how many users the customer anticipates the system will need to accommodate. This requirement is a ‘piece’ of knowledge, or *knowledge object/entity*. The customer knowing this, combined with the knowledge the software developer already has of the software being written, constitutes a *knowledge configuration*. The software developer acts on that knowledge over a definite period of time and produces a piece of code.
>
> On completion there is a different knowledge configuration. There is knowledge embedded in a deliverable (the software code), revised knowledge the developer has of the solution (he knows how it was done, rather than thinks how it should be done - as he did at the start of the activity), and the project manager knows that the deliverable has been produced. This change in configuration occurs over a finite period of time, and, if comprehensively defined, may even be treated as a closed system.

From this example it may be seen that knowledge is required to commence an activity. Knowledge evolves during each activity and, assuming that nothing is forgotten or lost such as through team members leaving, there is a nett gain in project-relevant knowledge. Gain may be by the project team, individuals and even in the deliverable if knowledge is embedded in the product. At the end of an activity, and provided the activity is signed off or the project completed, no further knowledge is involved in or required by that activity.

The term *configuration* has been referred to and may axiomatically defined as follows:

Definition 1: *A knowledge configuration is the temporal arrangement of knowledge associated with a project, activity or entity, or any combination of those..*

The knowledge component of any activity A may therefore be described as the finite set of all knowledge K_A used, gained, created and lost during the duration of that activity whether or not that knowledge can be articulated or made explicit; and expressed as follows:

$$K_A = \{K_1, K_2, \ldots K_n\} \qquad 2.$$

If the activity A is regarded solely from a knowledge perspective, it becomes A_k:

$$A_k = \{K_1, K_2, \ldots K_n\} \qquad 3.$$

Likewise if project P is regarded from a knowledge perspective, project P_k may be regarded as a finite set of knowledge K_n involved in all project activities A_n:

$$P_k = \{K_{A1}, K_{A2}, \ldots K_{An}\} \qquad 4.$$

Considering the configuration of activities, a knowledge-centric definition may be proposed:

Definition 2: *A knowledge-based project is a finite and unique set of interrelated and interdependent knowledge and knowledge configurations that change over a finite period of time in order to achieve specific objectives within certain constraints.*

3.1. Quantification for estimating, planning and control

Project managers will no doubt see complications. As a pragmatic construct, projects require quantification to facilitate planning and control. A set-based theory may be useful in identifying boundaries, elements or requirements, but it does little to assist quantification. And tacit knowledge is unfortunately notoriously difficult to quantify in its own right. To circumvent this problem, indirect quantification of the knowledge component should be considered in ways that are tangible and relevant to projects and project management – particularly the dimensions of time, cost and quality.

Experience suggests it is possible to estimate and measure the cost or time required or taken to acquire, create, apply, transfer or reuse knowledge. If each piece of knowledge can be quantified in these ways, it follows from equations 2 and 3 above that the cumulative value of any activity A_x in a particular unit (such as time or cost) may be computed by the summing individual values of members of the set of knowledge required to undertake and complete that activity (in the same units):

$$A_x = \sum K_{Ax} \qquad 5.$$

Consequently the value or cost of a knowledge-based project P_k is the sum of all knowledge and knowledge activities in any particular unit:

$$P_k = \sum K \qquad 6.$$

3.2. The impact of time

By nature and by definition, projects and activities are time dependent. As this characteristic would be inherited by the knowledge-based approach, it should be possible (and beneficial) to model the effect of time on the theory.

The knowledge configuration at the start of an activity is different to the configuration at the end. At the start of each activity A_x, what is known about that activity and how to complete it is notionally at its lowest (K_{start}). On completion of that activity, what is known about that activity is notionally at its greatest (K_{end}). Each activity may therefore be seen as a nett change in knowledge over the course of that activity:

$$A_x = K_{end} - K_{start} \qquad 7.$$

If the complexity of knowledge loss is ignored, a knowledge-based project P_k may then be conceived of as a nett change in knowledge:

$$P_k = \sum K_{end} - \sum K_{start} \qquad 8.$$

Since project activities are time dependent, any knowledge-based activity A_x may also be described as a change in knowledge ΔK_x over activity duration t_x:

$$A_x = \frac{\Delta K_x}{t_x} \qquad 9.$$

From equation 6 above, a knowledge-based project P_k may be regarded from a knowledge perspective as the change in knowledge ΔK that occurs over the duration *t* of that project:

$$P_k = \frac{\Delta K}{t} \qquad 10.$$

Assuming that knowledge can be measured in terms of time, cost or other quantifiable interval or ratio measure, a project can be quantified accordingly:

Definition 3: *A knowledge-based project may be quantified though the measuring of effort and cost required to making changes to knowledge and knowledge configurations over the finite duration of the project.*

4. An introduction to project management

Project management is an approach used to manage project activities and resources an optimal manner. Originally employed successfully in high-profile military, aerospace and construction environments, project management has subsequently been widely adopted in technology, business and the public sector.

This discipline appears to be more pragmatic than theoretical, with academics noting a lack of clear and precise theory. Koskela and Howell (2002) begin their analysis of project management theory by stating that there is no explicit theory of project management, and feel that a general theory to underpin the discipline could be found in theories of management, planning, control and projects. Turner (2006) feels that there is 'embryonic' theory contained in literature, particularly in his books. Sauer and Reich (2007) are of similar opinion, but do note that explicit theory is lacking.

Reasons for this situation appear to be deep seated. Koskela and Ballard (2006) feel there is no clear consensus as to whether project management should be based on theories of economics or production. Alleman (2004) notes a lack of theory and consequent practice issues in the field of software engineering, and suggests that solutions could be found in other domains with similar behavioural patterns. Levner (1991) for example built a project management theory on an application of programming theory; a branch of mathematics that finds optimised control solutions to multi-step problems.

The lack of theory is problematic in any search for alternative solutions. Emerging theory needs consistent understanding to build on and to compare and contrast against. Emerging methodologies require the clarity and guidance that theory provides. Practice requires theory for consistency and professionalism to develop.

A clear concise model would resolve some concerns, but should be sufficiently abstract and general to encompass the entire discipline. Project management arranges elements such as resources, time, risks and activities in such a way as to achieve a result. Normative project management theory therefore cannot be based on a single dimension such as cost, time or quality. An approach based on configuration and control would therefore appear to be the most universal.

One definition that appears to somewhat meet this criteria for generality is the British Standards' (1996) BS6079: "*Project management is the planning, monitoring and control of all aspects of a project and the motivation of all those involved in it to achieve the project objectives on time and to a specified cost, quality and performance.*"

5. A theory of knowledge based project management

Project management may be defined in terms of knowledge in the same way that projects are defined above. Assuming the purpose of knowledge based project management processes is to manage knowledge, the BS6079 definition may be restated as a hypothetical and normative definition of project management that emphasises the stance that project management is essentially a problem of control, coordination and configuration:

Definition 4: *Knowledge-based project management is the systematic and optimal arrangement and coordination of knowledge and knowledge configurations over a period of time to achieve specific objectives within certain constraints.*"

Analysis of this definition's variables and the relationships between them may have theoretical and practical implications that may lead to validation. The variables of time and knowledge and their relationships will be explored here in terms of the learning curve, risk, nature of work, the project lifecycle and project management techniques.

5.1. The learning curve

Project knowledge and project knowledge configurations change and evolve over time. Assuming that this knowledge is cumulative over time, the situation may be represented as an increase of project knowledge over the duration of the project. Figure 1 illustrates this, with K_x being cumulative knowledge and t_x cumulative time. At t=0 the project is in conceptualisation, requirements and solution are unknown and the team is not yet assembled so K=0.

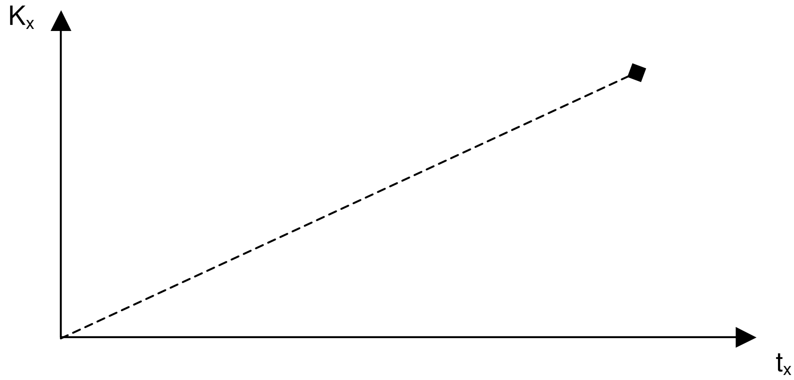

Figure 1. Knowledge versus time curve

The linear plot in Figure 1 is simplistic and ignores two issues. Firstly, projects may lose staff and people forget, thereby reducing the cumulative project knowledge. Such events would plot as a negative slope at a point in time on the curve. Secondly, and more importantly, knowledge-based project theory stipulates there is a relationship between knowledge configurations over time. As solutions are found to one problem, or as knowledge of the environment or eventual solution evolves, this knowledge becomes an input into or element of subsequent knowledge configurations. Retained knowledge is applied to other problems.

Kerzner (2001, p951-974) describes this effect of experience as ‘economies of scale’, where costs of production decrease as experience (knowledge) increases. He refers to the resulting effect as a ‘learning curve’ and implies a logarithmic relationship between cost of production and experience. Therefore it is more likely that the cumulative knowledge-time curve would plot in Figure 2 below:

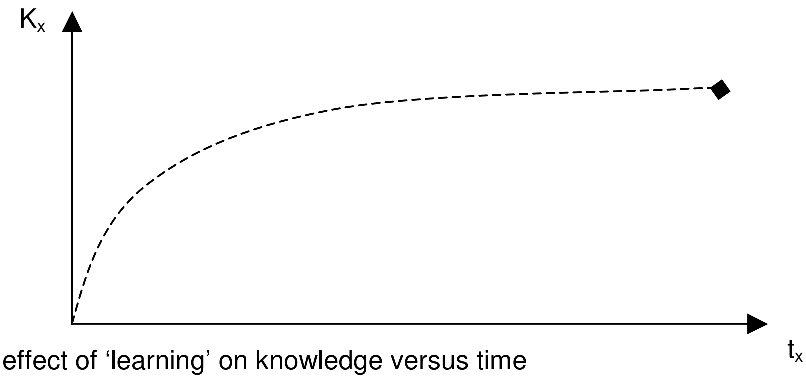

Figure 2. The effect of ‘learning’ on knowledge versus time

Project and environment specific factors would render mathematically precise expression of this curve as speculative. Generalising data from a number of projects however may be more useful line of research, and lead to identification of ‘*learning profiles*’ typical to particular types of projects, domains or industries.

5.2. Project risk

Project risk according to Kerzner (2001) refers to probability and consequences of not achieving a defined goal. The PMI define it as “*An uncertain event or condition that, if it occurs, has a positive or negative effect on a projects objectives*” A situation where the factors are completely unknown is described as *uncertainty*, and where there are calculable probabilities there is *risk* (Anderson, 2003). Risk and uncertainty may therefore be regarded as or directly associated with knowledge-deficient situations.

If risk and uncertainty are regarded as ‘what is not known’ about the outcomes or how to achieve them, then risk (r_x) at any point in time (t_x) in the project may be represented by the gradient of the tangent to the curve plotting project knowledge against time (figure 3 below).

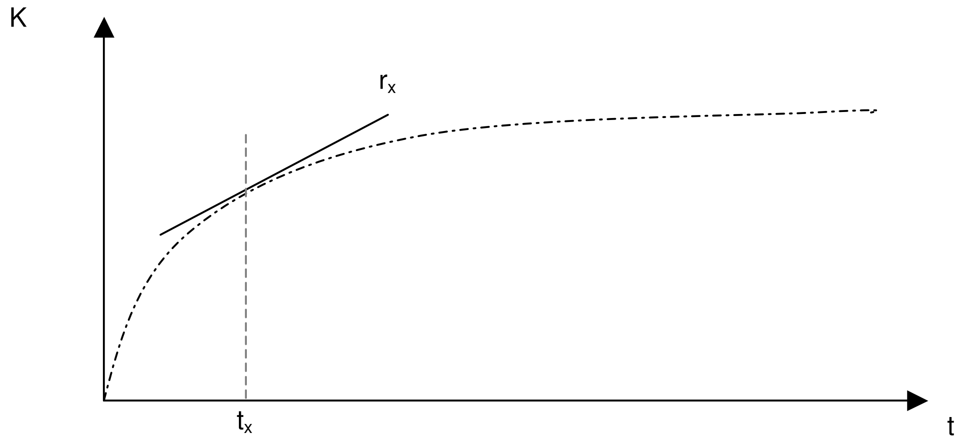

Figure 3. Knowledge versus time graph

At the beginning of the project (t_0) the 'risk gradient' is steepest (r_{max}) and, notionally, on completion of the project (t_c) the gradient of the tangent to the knowledge-time curve is flat and hence risk to the project (r_{min}) is zero. This is curve could be termed a *risk profile* and depicted as in figure 4 below.

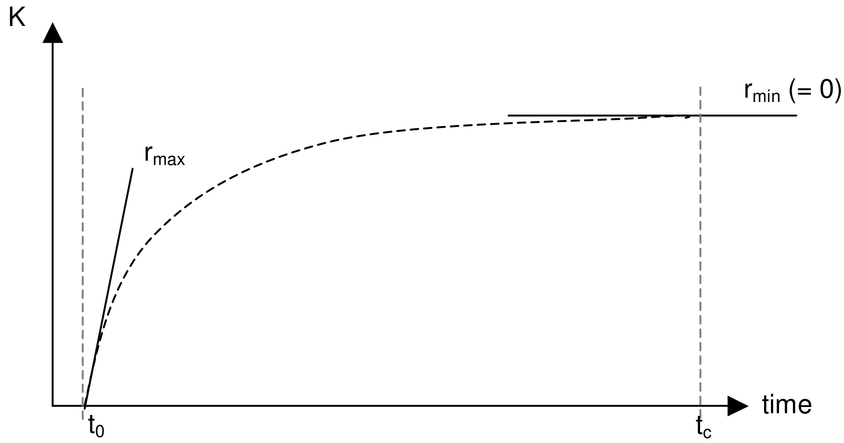

Figure 4. Project risk profile

This plot would verify empirical and anecdotal evidence (such as Kerzner, 2001) that suggests a project is less likely to overrun when more time is spent on project definition early in the project lifecycle. This tendency may be explained through considering the rate of change in the slope of the risk profile curve combined with the cumulative network effects of knowledge discussed previously. The area above the curve that is bounded by the limit imposed by total project knowledge is greater when knowledge is acquired late (area A_2) that when acquired early (area A_1 figure 5 below).

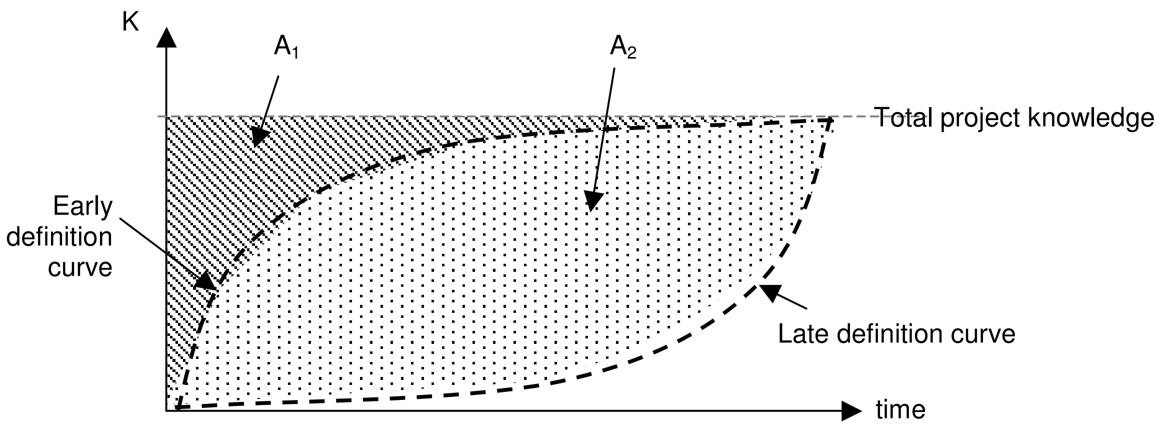

Figure 5. Risk profile for early and late project definition

5.3. The nature of work and delivery

Work may be broadly described as batch, process or project. The knowledge-based theory of project management may be used to explain the difference between a project and work executed in a process or as a batch.

The solution begins with a premise that all work involves applying three types of knowledge:

- Knowledge of what must be done – requirements and solution (scope)
- Knowledge of tools and technology to be applied (skills)
- Knowledge about team members, project schedule and the workplace (environment)

This may be described as:

$$K_{work} = K_{scope} + K_{skills} + K_{environment} \qquad 11.$$

Using this equation, the differences between the types of work may be expressed as follows:

- *Processes* are repetitive, producing the same item over again. Scope, skills and environment remain constant between one work completion and another. Therefore the overall difference in knowledge between one job and another (ΔK_{work}) is zero.
- *Batches* involve the production of similar items in perhaps different environments ($\Delta K_{environment} < > 0$). Skills and scope would remain the same across completions ($\Delta K_{skills} = 0$ and $\Delta K_{scope} = 0$). For batches the overall knowledge would differ from one job to another ($\Delta K_{work} < > 0$).
- *Projects* are unique, so skills, scope and the environment all change between one project and another ($\Delta K_{skills} < > 0$; $\Delta K_{scope} < > 0$; $\Delta K_{environment} < > 0$; so $\Delta K_{work} < > 0$).

5.4. Project lifecycle

Theory proposed is intended to be normative, but project management has evolved as a practical solution to a type of problem. Any theory would be careless if it did not at least consider the many techniques used by the profession or pay attention to its implementation. Project lifecycles and project management activities should both be investigated to determine the suitability of knowledge-based theories to current practice.

Many projects follow a lifecycle that can be generalised into five main phases; conceptualisation, design, development, implementation and closeout (Kerzner, 2001; PMI, 2004). This lifecycle has been empirically proven to be functional, efficient and natural. Any normative project management theory should therefore predict such a lifecycle, accommodate it, or lead to a suitable alternative.

The relationship between knowledge, work and delivery has been discussed in literature in the fields of sense-making (Choo, 1996), work (Bohn, 1994), learning organisations (Senge, 1990), the knowledge lifecycle (Nickols, 2000; Davenport and Prusak, 1998), decision-making (Frishammar, 2003; Hendry, 2000; March and Simon, 1958), the control cycle (Shewhart, 1939) and looped learning models (Senge, 1990). Processes that knowledge undergoes are likewise described, with models for knowledge lifecycles, processes and knowledge transfer (Nonaka and Takeuchi, 1995). This literature leads to the assumption that:

- Knowledge and people are inseparable.
- Knowledge is a prerequisite for work and decisions.
- People must know both what must be done and how it must be done.
- There may be inherent phases in knowledge processes and transfers.

It can be deduced from the knowledge-based project theory that:

- Work can be described in terms of knowledge.
- There is direct and evident coupling between particular knowledge and specific work.
- The arrangement of knowledge at a point in time can be described as a configuration.
- Knowledge can usually be quantified, at least indirectly in terms of cost and time to acquire, create, apply or transfer it.

A project lifecycle and phases may therefore be predicted on the assumption that the overall knowledge configurations of a project will evolve and change: from a focus on knowing what to do (*conceptualise*), to knowing how to do it (*design*), to acquiring that knowledge and applying it (*development*). Acceptance and transfer of the project (*implementation*) is also predicted through projects being open systems as a result of having to achieve specific objectives within externally imposed constraints.

5.5. Project management techniques and activities

Project managers apply a range of activities and techniques in managing a project throughout its lifecycle. These include scoping of work, estimation, work breakdown and organisation breakdown structures, scheduling, delegation, communication and coordination of activities, monitoring and close out. These activities are not explicitly provided for in the knowledge based project management theory. They are however predictable due to the need to optimally configure knowledge so as to achieve project objectives with the best possible consumption of resources.

6. Conclusion

This paper presents a novel theory that describes a project in terms of its knowledge, together with new definitions that describe the management and measurement of these types of projects. This represents a departure from the conventional understanding of projects and project management. Inspection of the definition derived for project management shows this theory to be commensurate with current understanding in five areas.

Intended for specific environments, this theory assumes projects involve a high proportion of knowledge and may be managed and quantified solely in terms of knowledge. Such theory could have several benefits. Project management theory is sparse, and this may contribute to the general body of knowledge and add knowledge specific models that appear to be lacking. Practical benefits are also intended. In focusing on knowledge, it is suggested that this theory will be more relevant and that the high failure rates of projects in the Knowledge Economy may be improved.

This theory is intentionally abstract, to illustrate and facilitate communication of concepts. Subsequent research by the author has been focused on developing a practical methodology and deepening understanding of the implications on management, teams and working practice. Future commercial application is planned, so as to test theoretical arguments and identify real world effectiveness.

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