KNOWLEDGE MANAGEMENT OF PROJECT MANAGEMENT PROCESSES AND THEIR INTERACTIONS

Maya Kaner
Supervisor: Professor Reuven Karni
Faculty of Industrial Engineering and Management
Technion, Haifa 32000, Israel
e-mail: kmaya@tx.technion.ac.il

Abstract

Knowledge management in a project environment provides a challenge to the organization. There is a large gap between organizational understanding of the need for project knowledge management and its application. This is because project knowledge is heterogeneous and consists of different aspects influencing each other; project knowledge is dynamic and gathered according to project progress; and there is no optimal knowledge – two different decision-makers can formulate a problem and a solution in two different ways. This research proposes an architecture for project knowledge management. The framework outlined is based on project management knowledge areas defined by the Project Management Institute and supports generic and domain-oriented knowledge management.

1. Introduction

"Modern organizations are confronted by turbulent operational conditions caused by a network of interrelated factors such as competition in the global marketplace, changing customer expectations and technological innovation. The result is that these organizations are themselves not only complex, but dynamic … complex because they are made up of many interrelated parts … dynamic because they change their functions in order to … innovate or respond to market conditions. [These have led to] resultant changes in the fabric of the organization itself (e.g. its structure, its technology, its skills profile, its manpower level)" (Kueng and Kawalek, 1997).

In seeking to cope with these difficult operational conditions, a paradigm shift in management – the process view of the firm – has swept through the corporate landscape (Davenport, 1998; Hammer and Stanton, 1999). Management focus has shifted to integrating and managing the knowledge-based and process-centered enterprise using tools such as knowledge management, business process modeling and enterprise resource planning (ERP), and knowledge-based project management.

According to the International Data Corporation (Burd, 2000), the drive towards knowledge management awareness is expected to create an $8 billion market by 2003, up from $1.3 billion in 1999. Current research deals mainly with describing knowledge management in project environments and the motivation for incorporating it within the firm (Davenport et al, 1998). It has recognized that knowledge is an organizational asset that needs to be created, captured and reused

for future purposes without strict dependence on human knowledge owners that can leave the organization at any time (Garvin, 1993; Senge, 1993). Our focus on knowledge and knowledge management is based on the following definitions:

> "*Knowledge* is information combined with experience, context, interpretation and reflection. It is the high [essential] value of information that is ready to apply to decisions and actions" (Davenport et al, 1998).
> "*Knowledge management* is the creation, acquisition and transfer of knowledge, and the [concomitant] modification of organizational behaviour to reflect new knowledge and insights" (Garvin, 1993).

Business process reengineering – BPR (Hammer and Stanton, 1999) – has drawn attention to the process-oriented view of the firm, as opposed to the product-oriented view. Encompassing business activity management, business process management focuses not just on such activities, and their incorporation into business processes, but, more importantly, on integration between such processes (Vernadat, 1996). The information systems community has contributed significantly to the adoption of BPR in industry: off-the-shelf information systems such as ERP and CRM (customer relationship management) have resulted from the creation of generic "best practice" business process repositories based on knowledge of such practices in different industries (Van Es and Post, 1996). The academic community and software vendors have launched projects to gather business process knowledge with the intention of creating "handbooks" describing common practices of business processes (Malone et al, 1999).

An initial integration of management processes and knowledge management in the field of project management is presented in the Project Management Body of Knowledge – PMBOK (PMI, 2000). PMBOK is an authoritative sourcebook on project management, which it defines as "the application of knowledge, skills, tools and techniques to project activities in order to meet or exceed stakeholder needs and expectations from a project". Project knowledge is categorized into nine knowledge areas: integration management, scope management, time management, cost management, quality management, human resource management, communications management, risk management and procurement management. These knowledge areas comprise 39 component processes such as: activity duration estimating (time management), risk identification (risk management) and resource planning (cost management). In turn, "each process is described in terms of its inputs, outputs, and tools and techniques" (PMI, 2000). However, PMBOK does not detail decisions to be made, especially regarding comlex questions involving a number of interconnected decisions. It only provides a preliminary sketch of intra- and inter-process procedures that underlie project management integration.

The research outlined in this paper is intended to contribute to the management of knowledge within and between project management processes.

2. Current knowledge and solutions

The PMBOK (PMI, 2000) is concerned with a (two-level) hierarchical approach to knowledge areas and *project management processes* for organizing the work of the project as opposed to *product-oriented processes* which specify and create the project product (PMI, 2000). Several principles of such knowledge are set out:

- Knowledge areas interact with each other when an event occurs requiring management intervention.
- Processes within knowledge areas are usually executed in sequence.
- Changes in knowledge and practice can be accommodated by adding a new process, subdividing processes or resequencing them.
- Processes may be iterated one or more times during the project life cycle.
- The list of processes provided by the PMBOK is that common to most projects in most application areas; however, not all of these processes need to be executed during a specific project.
- The sequences and interactions described in the PMBOK do not necessarily apply to all projects and are not intended to be complete.
- Thus processes and process interactions need to be customized for specific applications.

Linkages between project management processes are divided into three types:

- Linkages between groups of processes (initiating, planning, controlling, executing, closing)
- Linkages between project phases (e.g. conceptualizing, demonstrating, designing, implementing, operating, supporting)
- Linkages between core processes and facilitating processes (e.g. the linkage between activity duration estimating and cost estimating

Thus the PMBOK provides a generic *framework* for knowledge capture and reuse, but does not detail the intra- and inter-decisionmaking knowledge that would actually accompany a specific project. Thus is a need for a project-specific knowledge management paradigm, building on and argumenting the generic framework, that derives from examples of decisions taken in the past.

Zack (1999) defines five important knowledge management operations: knowledge acquisition (from knowledge sources), knowledge refinement (updating, categorization), knowledge storage, knowledge reuse, and knowledge distribution and representation (to the users). However, even if it were possible to construct a generic *project process model* based upon these operations, it would not be feasible to incorporate only *generic knowledge* in such a model. The nature of decisionmaking in project management requires an example-based paradigm: therefore, we have decided to base our methodology on case-based reasoning – CBR (Kolodner, 1993) and case retrieval networks (Lenz et al, 1996; Lenz et al, 1998). Case based reasoning provides a highly flexible format for storing the variegated knowledge associated with project management knowledge areas, and

the disparate types of decisions taken by different project managers. Case retrieval networks provide a basic graph-theoretic structure (Christofides, 1975) for linking knowledge areas, processes, decisions and decision sequences.

Figure 1 illustrates the three general approaches to handling and presenting knowledge. In the first case, the original knowledge is processed to extract rules; these rules constitute the knowledge seen by the user. The source knowledge is not usually retained (Nilsson, 1982). In the second case, knowledge is processed when required, to create "discovered" knowledge through data mining, the user is presented with a set of relations (Thuraisingham, 1999). Finally, the original knowledge is retained; and selected by a similarity model for presentation to the user through case-based reasoning (Kolodner, 1993; Leake, 1996).

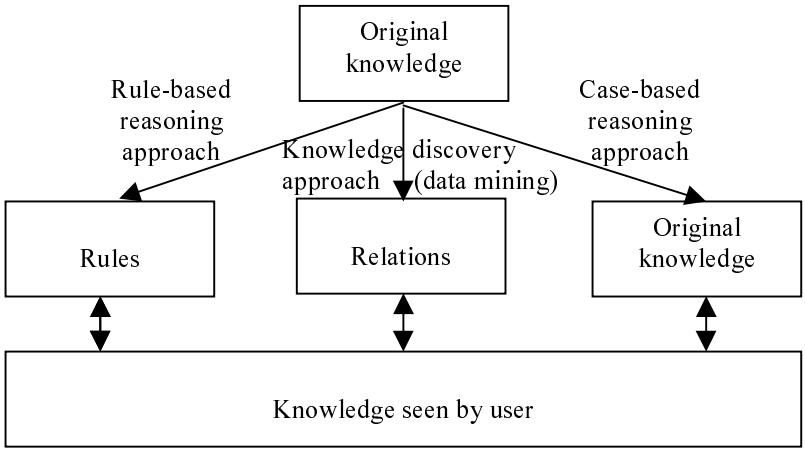

Figure 1: General approaches to handling and presenting knowledge

As mentioned above, project management knowledge derives from wide range of knowledge sources, and is often idiosyncratic. Any preprocessing or processing is likely to eliminate important aspects of decisions taken. We therefore feel that case-based reasoning (example-based knowledge retrieval) is the most appropriate for our domain.

A second characteristic of project management decisions is that they are often made up of a set of individual decisions taken in different knowledge areas. In addition, we wish represent and store these decision sequences – representing complex decisions, as a higher level of project management knowledge. The standard approach to doing this is through the use of graphs (Lenz et al, 1998). Combining the graphic and CBR approaches leads us to suggest the HCRN mechanism described in this paper.

3. Research question

Our research question is: can we develop a *uniform and generic framework or structure* that can handle two types of project management knowledge: intra-process knowledge (individual decisions on a single topic); and inter-process

knowledge (process sequences representing interrelated decisions of a group of topics)?

To illustrate, we present an example of a work breakdown structure (WBS) definition as a part of project planning before its execution and possible updating. This decision making subject involves a chain of processes that influence each other (Figure 2) when a perturbation is made on the WBS. This leads to a sequence of six interrelated decisions, each of which is associated with a different knowledge area.

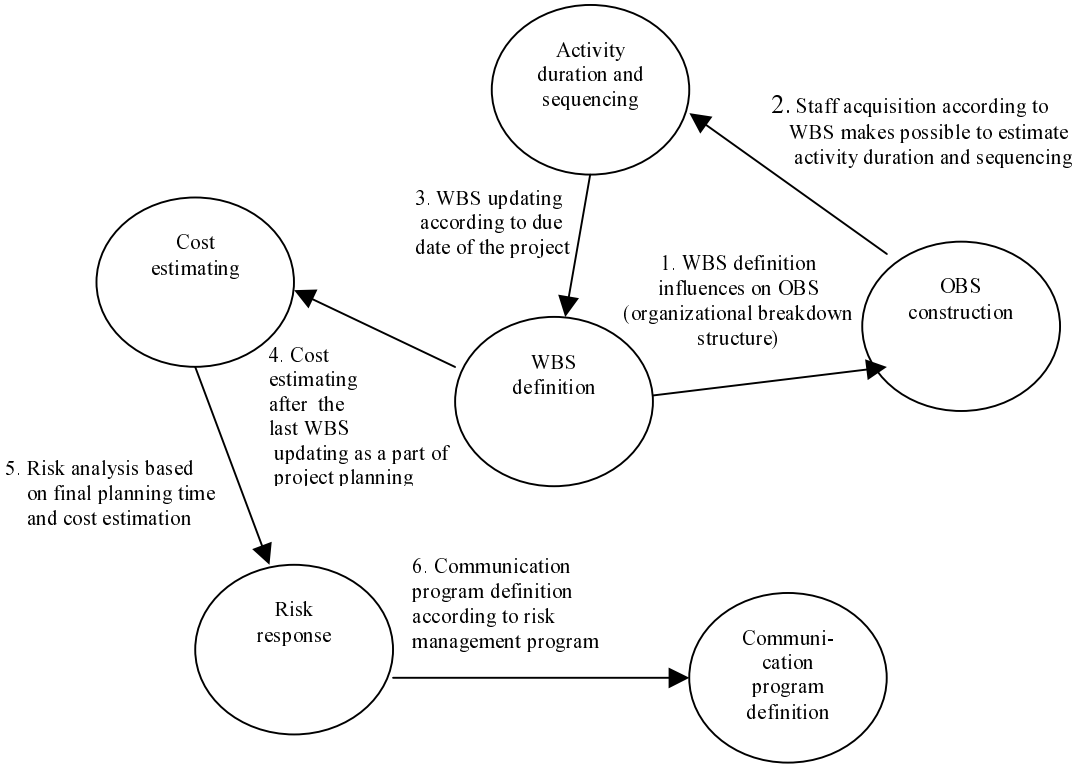

Figure 2: Example of a decision making path linking different individual decisions

This example emphasizes a possible sequence or path of decisions. This path is not necessarely unique. Different project managers may respond in various ways. However, this path provides knowledge of a set of decisions that was carried out in the past to confront a given management problem. Although PMBOK presents a set of generic linkages between project management processes (Figure 3 provides an example), it cannot provide a consistent and complete set of project-specific linkages for a given project. Moreover, as can be especially seen with the core-facilitation linkages, these are suggestive rather than actually defined or described.

We thus require a generic methodology to describe project and situation-specific linkages; to allow them to be constructed and fathomed as the project progresses; and to retain heterogeneous knowledge about different project management topics and decisions for utilization by future projects.

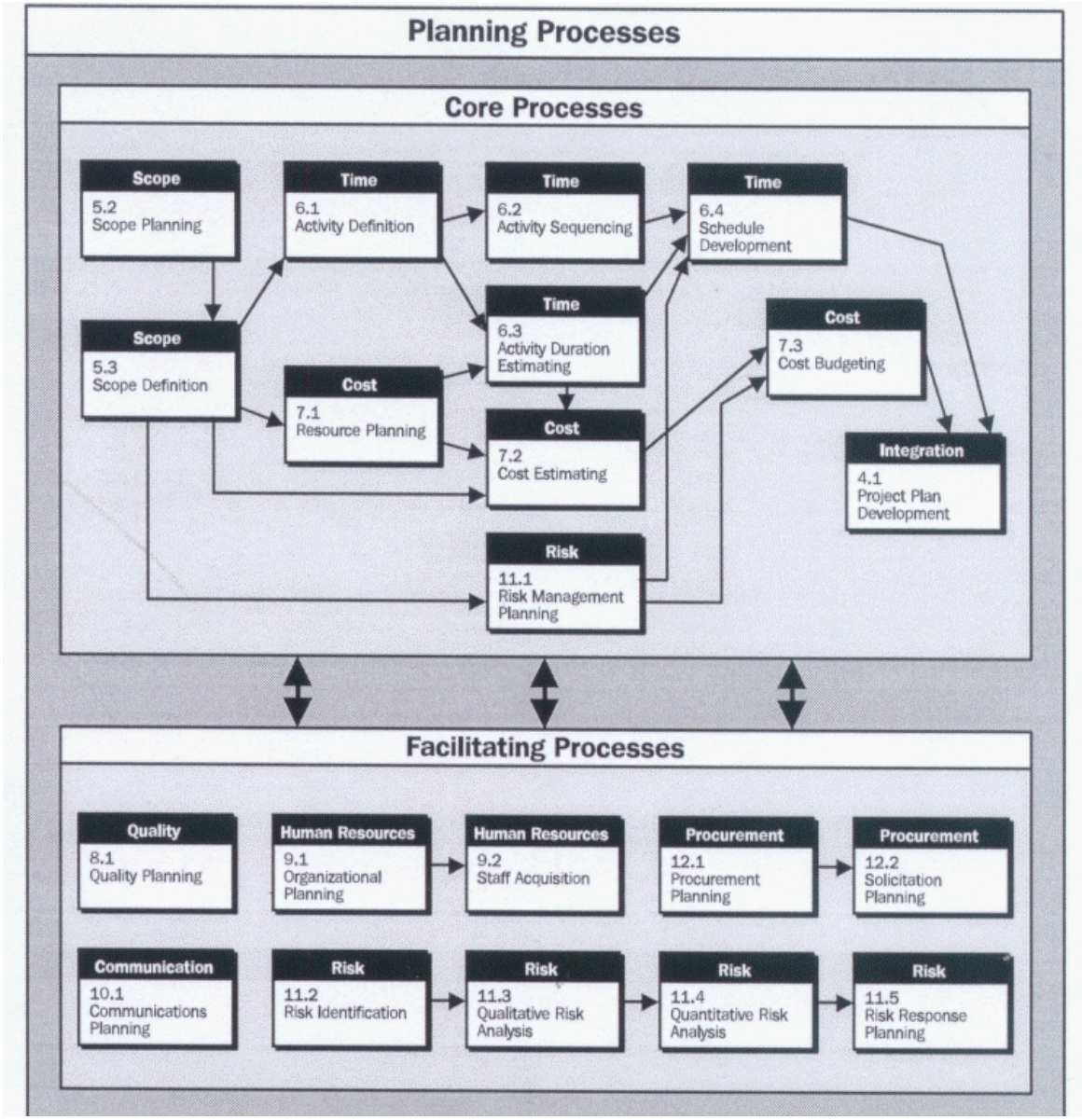

Figure 3: Relationships among the planning processes (PMI, 2000)

In summary, our research is aimed at the following aspects of knowledge management for project management:

- Our domain covers project management processes.
- We wish to facilitate knowledge management associated with (repetitive) decision-making within project management processes.
- We have to deal with two dynamic aspects of knowledge management: how to represent decision-making knowledge within processes, and how to represent sequences between various processes (and knowledge areas).
- We are therefore concerned with capture and storage of new knowledge related to a decision being made within the framework of a process; capture and storage of new knowledge related to the sequence of processes invoked when making a set of related decisions; and retrieval

and reuse of stored decision and process sequence knowledge related to the decision-making activity

4. Proposed approach

In order to be able to manage project knowledge at the *decision level*, we add another layer to the PMBOK hierarchy: knowledge area ← process ← issue. An issue corresponds to a decision to be made, as part of the execution of project management process. For example: selecting a candidate for a specific task is an issue within staff acqusition process (human resource management). In addition, we set this hierarchy on top of a case retrieval network to create a heterogeneous case base, which we term an *hierarchical case retrieval network* (HCRN). The graphical representation is defined by nodes and edges, and operations on the nodes and edges (Figure 4).

(a) Nodes - knowledge levels

We recognize five levels of knowledge:

1. An *information entity* is an atomic knowledge item in the domain. It represents the lowest granularity of knowledge representation for cases, queries and issues. It usually corresponds to a particular attribute-value pair (Lenz et al, 1998).
2. A *case* consists of a unique case descriptor and a set of related information entities. It encompasses a *specific* (decision-making) situation and a specific solution (decision) to that situation – i.e. the information entities describe problem, solution and outcome attributes.
3. An *issue* consists of a unique issue descriptor and a set of related cases. An issue encompasses a specific decision area within a project management process. The cases relate to various decisions taken within the domain of the issue.
4. A *process* consists of a unique process descriptor and a set of related issues. In accordance with the scope of the PMBOK, there are 39 processes associated with project management.
5. A *knowledge area* consists of a unique knowledge area descriptor and a set of related processes. In accordance with the scope of the PMBOK, there are nine knowledge areas associated with project management.

(b) Edges – structural knowledge links

We recognize five types of structural knowledge links:

1. The *similarity* between two values of the same information entity is described by a similarity function $\sigma (V_j, V_k)$. This is the basis on which the similarity of cases is determined (Lenz et al, 1998).
2. The *relevance* of an information entity to a case is described by a relevance function ρ (E, C). This is the basis for defining the case composition for each specific case type (Lenz et al, 1998).
3. The *pertinence* of a case to an issue is described by a pertinence function φ (C, I). This is the basis for denoting those cases that could be retrieved when a specific issue is to be dealt with.

4. The *mapping* of an issue within a process is described by a mapping μ (I, P). This is the basis for denoting one or more issues that could be invoked when a specific process is accessed.
5. The *inclusion* of a project management process within a knowledge area is described by an inclusion function κ (P, K). This is the basis for denoting a process that could be invoked when a specific knowledge area is accessed.

(c) Edges – knowledge path links

A (non-structural) *path* of a decision event between two nodes (issues/cases/entities) is described by a path function π . This is the basis for denoting those nodes to be handled when a specific decision event is triggered. We note that a graph representation and the associated adjacency matrices (extended to deal with loops in the path) make it possible to capture the decision-making paths of experienced project managers and reuse them for future organizational purposes.

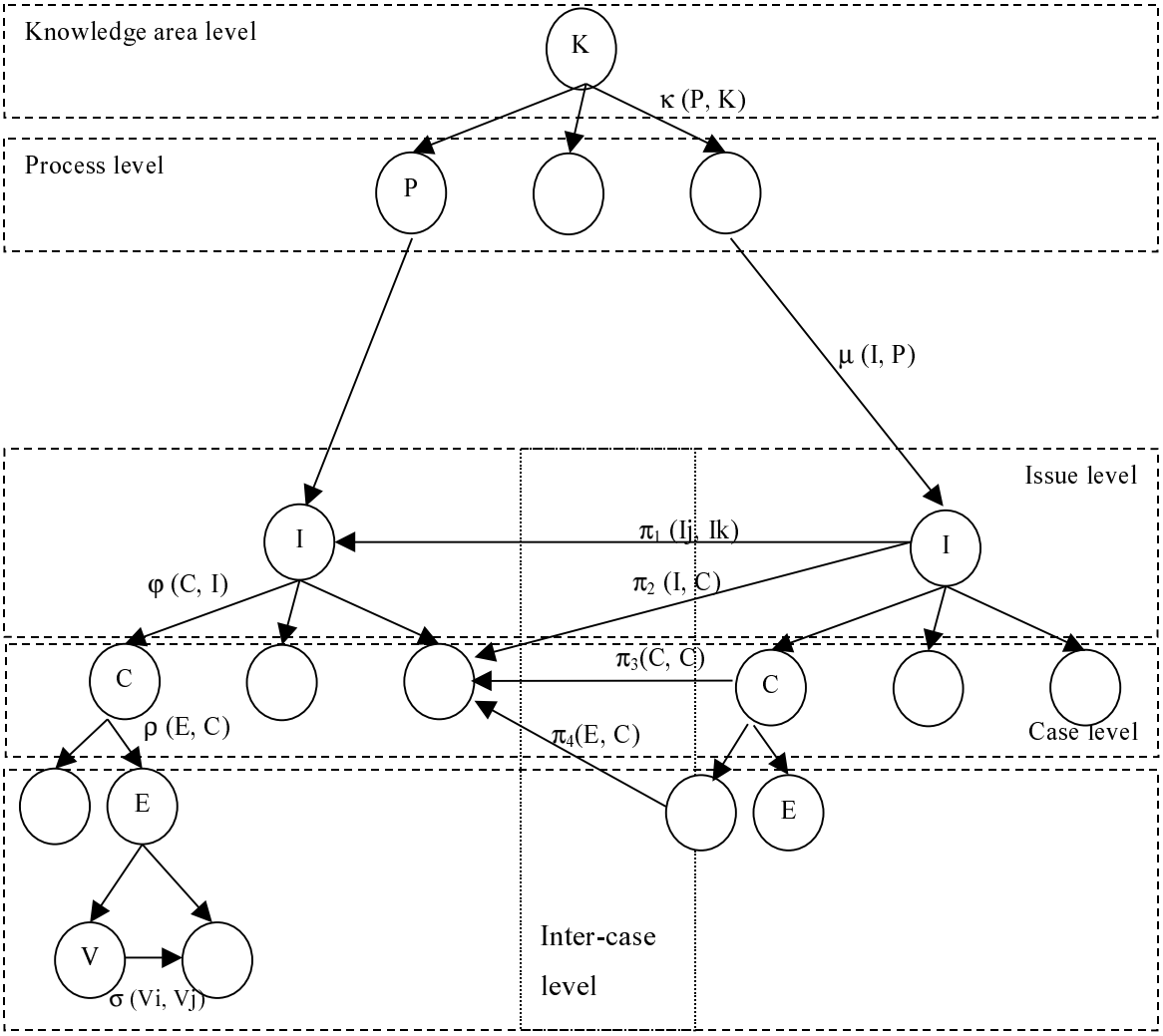

Figure 4: Graph-theoretic architecture (HCRN)

(d) Operations

We recognize six knowledge operations, covering acquisition, reuse and learning:

1. *Knowledge acquisition* (structural: intra-issue) – when a new decision is made regarding a specific issue, a new case is created. A new issue may be required as well. The component information entities are inputs to and outputs of the decision, and any lessons learnt (outcome).
2. *Knowledge acquisition* (path: inter-issue) – when a comprehensive decision is made, the decision-maker moves through knowledge areas, processes, issues and cases. Thus a new path is created.
3. *Knowledge reuse* (structural: intra-issue) – when a decision is to be made regarding a specific issue, relevant cases are retrieved.
4. *Knowledge reuse* (path: inter-issue) – when a comprehensive decision is to be made, relevant paths are retrieved.
5. *Knowledge learning* (structural: intra-issue) – when a decision is to be made regarding a specific issue, several relevant cases are retrieved and a CBR technique is applied to select the best case(s).
6. *Knowledge learning* (path: inter-issue) – when a comprehensive decision is to be made, several relevant paths are retrieved and a path-based reasoning (PBR) technique (to be developed) is applied to select the best path(s).

5. Research methodology

The research methodology comprises four steps:

1. Model development – development of the HCRN graph-theoretic model for knowledge management of project management processes and their interactions
2. Prototype development – development of an HCRN prototype (issues, cases, paths)
3. Scenario development – development of a comprehensive project scenario
4. Model validation – demonstration that the model contributes to project success

Validation of a knowledge management model is complex, as it is necessary to show that (a) the knowledge contributes to the better decisions based on past experience; and (b) that knowledge organized according to the proposed approach makes a higher contribution than unorganized knowledge.

(a) Validation technique

We intend to validate the model by simulating project management situations with a group of subjects. These will be drawn from students attending a project management course. This provides a fairly homogeneous population of "inexperienced" or "new" workers that have joined an organization and need to learn to use organizational knowledge based upon past experience.

(b) Influencing factors

We propose studying the two following influencing factors:

1. Intra-process knowledge received by the subject (individual decisions) (X1)

- X1 = 0: the knowledge is disorganized and relevant or irrelevant (not in case form)
- X1 = 1: the knowledge is disorganized and relevant (not in case form)
- X1 = 2: the knowledge is organized and relevant or irrelevant (in case form)
- X1 = 3: the knowledge is organized and relevant (in case form + CBR)

2. Inter-process knowledge received by the subject (concatenated decisions) (X2)
   - X2 = 0: no inter-process paths are given
   - X2 = 1: an inter-process paths are given

Each replication would require 4 x 2 = 8 combinations.

(c) Affected variables

The affected variables relate to project success factors (time, cost, quality and scope) and the subject's degree of satisfaction in dealing with the decision event.

(d) Experiment description

Students will be required to respond to a series of decision events according to a given project scenario and a combination of X1 and X2.

(e) Expected results

We expect that both components (cases and paths) of the suggested methodology will contribute, separately and together, to project management success.

6. Contributions

The suggested methodology provides a model for project processes knowledge management. It contributes both a knowledge management and project management paradigm.

1. Knowledge management contributions
   - Extension of case retrieval networks to hierarchical case retrieval networks
   - Extension of the homogeneous (single type) case base to a heterogeneous (multiple type) case base
   - Incorporation of path-based reasoning
2. Project management contributions
   - Extension of the PMBOK hierarchy to include issues and cases
   - Extension of the PMBOK inter-process sequences to include dynamic construction of such sequences
   - Incorporation of issue-based cases for representation, capturing and reuse of project knowledge
   - Creation of a basis for project knowledge learning

7. Summary

The proposed methodology deals with project management processes knowledge of two types: intra- and inter- issue. The outlined level of knowledge management is the detailed level, which enables induction of a generic conclusion from

previous experience; as opposed to the PMBOK level of knowledge management which allows deduction (such as the recommendation to use a questionnaire for risk analysis) of a specific process activity from the generic level of knowledge management. The combination of these two directions, bottom-up (from the detailed to the generic level) and top-down (from the generic to the detailed level) provides project managers with a powerful knowledge management tool: generic project management knowledge and example-based experience.

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