A framework for the improvement of knowledge-intensive business processes

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Abstract

Purpose – This paper aims to present research into the improvement of knowledge-intensive business processes.

Design/methodology/approach – A literature review is conducted that indicates that a gap exists in the area of knowledge-based business process improvement (KBPI). Sir Karl Popper's theory of objective knowledge is used as a conceptual basis for the design of a business process improvement (BPI) framework. Case studies are conducted to evaluate and further evolve the improvement framework in two different organisations.

Findings – Highlights the gap in the literature. Draws attention to the merits of KBPI. Reports on the design of an improvement framework for knowledge-intensive business processes, and on the lessons learned from the conducted case studies.

Research limitations/implications – Practical and time constraints limit the scope of the case studies. General applicability can be inferred, but not tested, due to the small number of case studies.

Practical implications – A new practical way to achieve performance improvement, that utilises structured tools on intangible organisational assets. The framework can be applied by organisations that run knowledge-intensive business processes.

Originality/value – This paper addresses a gap in the area of KBPI. It combines concepts from business process management with a robust theory of knowledge to design a practical improvement framework. The paper also contains interesting argumentation supporting the use of Karl Popper's epistemology in BPI and knowledge management.

Keywords Process management, Knowledge management

Paper type Research paper

The author Peter Dalmaris wishes to thank Professor Ken Dovey, from the University of Technology Sydney, for his valuable contribution and discussions during the writing of this paper.

Business Process Management Journal
Vol. 13 No. 2, 2007
pp. 279-305

1463-7154
DOI 10.1108/14637150710740509

1. Introduction and objective

Processes lie at the heart of everything that organisations do to maintain their existence and grow. Most processes involve knowledge to some degree. Improving organisational efficiency and effectiveness inevitably involves process improvement. In this paper, a framework for knowledge-based business process improvement (KBPI) is presented. This framework is grounded on Karl Popper's theory of knowledge as extended by Niiniluoto's (1999) *Critical Scientific Realism*, and can be applied to the process analysis and improvement of a wide range of business processes. In addition, to this epistemological foundation, the framework consists of an appropriate business process ontology and an improvement methodology. Collectively, the foundation epistemology, the ontology, and the methodology are referred to as the KBPI framework. The objective of this paper is to present the KBPI and its three components.

1.1 Motivation for this research

Over the last 25 years, a variety of business process improvement (BPI) methodologies and frameworks have been proposed and sometimes applied but seldom were actual results integrated into a coherent body of knowledge. BPI gained prominence in the early 1990s through a series of breakthrough books and research papers (Davenport, 1993; Davenport and Short, 1990; Hammer, 1990; Hammer and Champy, 1993) building on Porter's (1985) *Competitive Advantage*. Since, then, improvement methodologies have been designed and introduced in most leading organisations in almost every field of business. During this time, which was socially characterised by a recession (Gregory, 2001) and a rapid change of the geopolitical status quo resulting in a dramatic change of the competitive environment, many methodologies were introduced, while others matured. Those methodologies were designed for delivering competitive advantage through increased efficiency, productivity and agility, which is what the times demanded. Some representative methodologies and techniques of that time include total quality management (TQM) (Whitten *et al.*, 2004, p. 27), activity-based costing (ABC) (O'Guin, 1991) and six sigma (Gordon, 2002). There have also been applications of information technology that resulted in new software-driven paradigms such as the enterprise resource planning (ERP) (Whitten *et al.*, 2004, p. 33) and workflow (Wf) systems (Schultheis and Summer, 1998, p. 338). Povey (1998b) provides a detailed survey of the available BPI methodologies.

Although, those methodologies delivered results that, in some cases, were impressive, their design was often based on various accounting, economic or engineering principles and assumptions. Some of the typical processes on which the above methods are applied are in manufacturing, quality assurance, construction and financial services, to name a few. As a result, their applicability to business processes that cannot be readily described in those contexts is limited. More specifically, it seems that there is no framework or methodology that assumes knowledge as the focal point of BPI, as opposed to the engineering or accounting. Knowledge has been accepted as one of the most important aspects of an organisation's ability to survive, compete, be profitable, and grow (Choo, 1998; Davenport and Prusak, 2000; Koulopoulos and Frappaolo, 1999; Nelson and Winter, 1982). Through knowledge management (KM) enterprise executives hope to leverage their knowledge assets and achieve results that can make a positive contribution to their balance sheet, and also to the lives of each individual employee (E&Y, 2004).

Increasingly, researchers have begun to note the benefits of incorporating knowledge considerations in the efforts to improve the performance of business processes (Seeley, 2002). Some approaches and applications have been proposed (Kim *et al.*, 2003; Papavassiliou *et al.*, 2003; Remus and Schub, 2003). These efforts, however, have not been systematic, nor have they been applied widely enough to make possible the extrapolation of their potential on a wide range of business processes. In addition, the approach typically taken advocates the adoption of process management methods in KM as opposed to the application of a theory of knowledge in the context of business processes.

In the framework presented in this paper, process knowledge is considered the fundamental component of a comprehensive framework for BPI. How this knowledge is managed, be it embedded in the process in the form of its structure (organisational), carried by the process members (subjective) or contained in databases, books, e-mails or other such instruments (objective), is what this framework is mostly concerned with. The objective of process improvement is achieved by improving the way by which the process knowledge is managed.

We propose that this objective can be achieved by using the proposed framework for KBPI, as shown in Figure 1. The figure shows the three main components of the framework (epistemology, process ontology, and improvement methodology), and those tools or techniques relevant to its implementation.

The KBPI is grounded on the epistemology developed by Popper (1972) and extended by Niiniluoto (1999). The fundamental assumptions of this epistemology that are most relevant to the KBPI, will be discussed in the Section 4.1. Based on this epistemology, a knowledge-based business process ontology (KBPO) was developed as the second component of the KBPI. The KBPO is used to systematically describe a business process. The KBPO resulted from work done on three case studies of knowledge-intensive business processes belonging to three seperate international organisations. The KBPO and how it derived from those case studies will be discussed in Section 4.2. Finally, an improvement method (IM) is the third component of the KBPI. The IM can be used to guide a practitioner through the steps of process improvement. The IM will be described in Section 4.3.

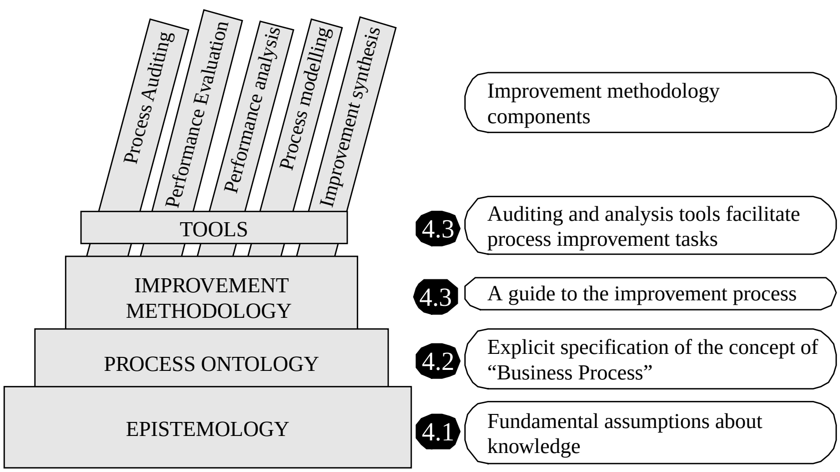

Figure 1.
Process improvement framework components. The numbers correspond to sections in this paper

2. Review of literature

The paper focuses on a specific class of business processes, those that can be described to be of high task complexity and high knowledge intensity. Such processes can be referred to as "knowledge-intensive" (Remus and Schub, 2003). Knowledge-intensive business processes are those with which research in the joint KM – business process management (BPM) and improvement area is mainly concerned.

BPM is well established as a distinct area of research. This is also true for KM. In the survey of literature it was possible to find only a few peer-reviewed articles, which treated both BPM and KM. The small number of papers suggest that this is an emerging area of research deserving attention.

The review indicates that although the existing KM-BPM methodologies or frameworks demonstrate innovative concepts and applications, often they do not take into account important general business concerns, such as performance, business context, and constraints, nor special ones such as process function goals and purpose, associations between functions, function performance and metrics, functional requirements and constraints, and the role of human agents. In addition, the concepts and tools used make little sense to the average businessperson.

2.1 From traditional approaches to process improvement and management

Many methods for process improvement and management have been proposed over the years. Valirys and Glykas (1999) categorise them into two large groups: management accounting and IS influenced methodologies.

In the first group, representatives include methods such as TQM and ABC, both developed in the 1980s (Harmon, 2003; Whitten *et al.*, 2004, p. 481). More recently, the ISO 9000 family of standards and the SixSigma methodology are used in conjunction with other methods to amplify the quality aspect in process management and improvement (Harmon, 2003, pp. 32, 33). There are also others, such as the Soft Systems Methodology (SSM) (Checkland, 1981; cited in Povey, 1998a) and the Process of Process Improvement methodology (POPI) from IBM (Abbott, 1991; cited in Povey, 1998a).

In the second group, some representatives include workflow management (WfM), case handling (CH), ERP, and customer relationship management (CRM), each designed for the improvement and management of processes using IT as the main enabler (Weske *et al.*, 2004).

These methodologies tend to focus on specific aspects of a process, and then attempt to improve only those aspects. For example, ABC aims to determine the actual cost of each activity in a process and then attempts to redesign the process in order to reduce that cost. SixSigma first establishes a benchmark of quality of a process described as the total number of defects per million executions and then guides the improvement effort until only a specific number of defects are detected. On the other hand, CRM aims to improve a business process by better managing the interactions between the process and its customers, while WfM assists in the automation of business procedures (Wfs) that involve the passing of documents from one Wf member to the other based on predefined rules.

However, important business considerations (performance targets, business context, constraints, etc.), including knowledge and human performance issues, most often are not taken into account. This need to be addressed as these considerations, ultimately, must influence any improvement and management effort of a business process.

2.2 Knowledge-based approaches to BPI and their weaknesses

In the context of knowledge-based approaches to BPI, the lack of a robust theory of knowledge often contributes to hidden logical inconsistencies within frameworks and methodologies. The lack of a suitable theoretical foundation seems to be endemic in this emerging area of research. In most publications, however, a theory of knowledge is hastily adopted or just assumed without thorough examination and criticism.

With the help of examples from the bibliography, we can demonstrate the results of the adoption of a weak theory of knowledge or the adoption of no theory of knowledge at all. Through these examples we will gain a better understanding of progress that has been made in this field.

In a case study involving a large European bank (Eppler *et al.*, 1999) the objective was to improve a knowledge-intensive business process through "new media". The authors report that the process was "reorganised" to make use of an enterprise "knowledge medium" as they call it, which constituted the technological platform through which the process members can communicate. In effect, they improved the way by which knowledge is managed within the process in order to improve the performance of the process itself. The paper suggests that business processes can be analysed from a knowledge perspective, and improved. However, a theory of knowledge was not adopted, leading to epistemological problems. The "types" of knowledge ("in" "about" and "from" the process), the knowledge "mediums" and the concept of the "process knowledge" are loosely defined, making any conclusions useful only as indication of future research directions. Indeed, the authors called for future research towards the design of a methodology that will simplify the integration of such enterprise mediums to knowledge-intensive business processes.

A related approach was adopted in a case modelling a knowledge-intensive business process that belongs to an insurance organisation (Papavassiliou and Mentzas, 2003). Through modelling, the goal was to identify the explicit "knowledge objects" defined as "the means of representing knowledge" such as a web page or a user manual. Knowledge objects are created, stored and/or disseminated by "knowledge assets" (such as a human actor or a network of people), as the authors named them. Based on a meta-model that describes the attributes of and relations between those concepts, a Wf tool was created to demonstrate how this knowledge-based approach can be applied in a knowledge-intensive business process. This way, the tool becomes the control centre of the process and is used to manage and distribute the various knowledge objects. Unlike the study by Eppler *et al.*, Papavassiliou and Mentzas seem to assume a theory of knowledge. Without specifically grounding it, their reference to a broad categorisation of knowledge to "tacit" and "explicit" seems to indicate that they assume a popular epistemology by Nonaka (1991). As it will be argued later in this paper, Nonaka's theory lacks the robustness and granularity necessary to explain knowledge phenomena in the organisation. The Papavasiliou and Mentzas modelling method, being weakly grounded on an already weak epistemology, is particularly simplistic in the way it describes the knowledge aspects of the business process. As a consequence, concepts such as "knowledge assets" "knowledge objects" and "knowledge management tasks" are loosely defined.

In a third example, the analysis of the knowledge that is part of a business process in a manufacturing case study shows that the identification and formalisation of many aspects of this knowledge is possible (Kim *et al.*, 2003), in a way that is analogous to the identification of the "explicit knowledge objects" described by

Papavassiliou and Menztas (2003). A "Knowledge Flow" was defined by Zhuge as a carrier of knowledge that is used to transfer this knowledge from one process member to another following a definite process logic (Zhuge, 2002) and was the focus of the Kim, Hwang and Suh study. The correctness of this term is questionable, as flow is typically used to describe how some material "move(s) steadily and continuously in a current or stream" (*Compact Oxford English Dictionary*). The term "knowledge flow" fails to convey the complex phenomena observed as knowledge progresses through its life cycle. Here, the term "knowledge path" is introduced to better describe this concept. This is the term that will be in use in the remainder of this paper, unless a reference to bibliography is made where the term "knowledge flow" (in quotes) is used.

Similarly to the study by Eppler *et al.* (1999), in the study by Kim *et al.* (2003) a process-based approach is taken for this knowledge path analysis and a relevant framework is proposed. This framework is confined to performing knowledge path analysis and does not go beyond this context.

In the study by Kim *et al,* questions can be raised in respect to the suitability of the framework's theoretical foundations, where the Nonaka and Takeuchi (1995) theory of knowledge conversion is adopted. This leads to logical difficulties in the framework. One example is the transformation of tacit knowledge that resides in the "representation layer" into explicit that resides in the "implementation layer". The transformation occurs in the "knowledge flow" analysis step; however, the mechanism by which this transformation happens is not clear. Furthermore, it is unclear what the role of the "support layer" in the framework is and how this layer influences the "knowledge flow" analysis. Despite those weaknesses, this study leads towards a framework for the knowledge-based improvement of processes because of its recognition of the knowledge paths within those processes. Similar epistemological problems can be found elsewhere in the literature. We argue that these problems, and especially the ones surrounding the concepts of tacit and explicit knowledge, must be attributed to fundamental weaknesses of the underlying theory of knowledge used.

Incorporating concepts such as the ones mentioned above with a robust theoretical foundation and an explicit method for determining value of knowledge embedded in a business process (Smart *et al.*, 2003), can potentially yield a powerful general knowledge-based process improvement methodology.

3. The research methodology

The development of the KBPI was based on a series of case studies. These case studies were used to test and improve an early revision of the KBPI that was developed after the analysis of the existing literature.

Myers notes that the case study is widely used in information systems research (Myers, 1997), and is compatible to different philosophical perspectives, including positivist and interpretive (Darke *et al.*, 1998). In addition, Yin explains that the case study technique is well suited for exploratory question of the "how" or "why" type (Yin, 1994). They are appropriate for environments where the researcher has little or no control, or when the phenomenon under investigation cannot not be isolated from its context. The process of theory building and testing using case studies is also explained in detail by Eisenhardt (1989). As in the case of this research, the phenomenon under investigation is the business process, the case study method provides the best alternative to exposing weak assumptions.

3.1 Summary of case study design

The use of case study as the testing technique for the research problem and tentative solutions requires planning and coordination. The testing plan determined that three case studies were needed within a period of one year. Table I summarises the objectives of each case.

Cases 1-3 tested of the research problem ("is the right question being asked?") and the tentative solution ("is this answer acceptable?"). In addition, to that, case 1 was also concerned with testing and improving the case study design, which is discussed in this section. In essence, case 1 was a pilot case.

Each case study was conducted on a knowledge-intensive business process. The processes chosen belonged to organisations active in different market segments. The studied processes were radically different in each case. Figure 2: case study procedure is a depiction of the steps followed at each case study.

In the data collection meetings (step 1), the researcher holds individual conversations with process members to try to gain a detailed understanding of the process. After completing of the meetings, the researcher analyses and records the collected process data using the improvement tools developed as part of the process (step 2). Those tools are presented in the second part of this paper.

The next step is further data collection, using emailed questionnaires (step 3). An individualised questionnaire is sent to each process member with the aim to clarify on parts of the earlier discussions, or to request the responder elaborate on other parts.

Once all of the questionnaires have been received, a new cycle of modelling and data analysis is completed, during which the contents of the improvement tools are updated (step 4). Before committing to the next and final step, a final round of face-to-face meetings with the process members is held to review and validate the researcher's understanding of the processes, and the validity of the recorded data (step 5).

The final step involves the authoring of two reports (step 6). The first report contains the result of the process audit, and critically examines it. The purpose of the examination is to find problems with the way that knowledge is being managed within the process, if such problems exist. The second report is a suggestion on how knowledge related problems could be corrected.

Case	Objectives
1	Test the research problem Test the tentative solution Test the case study design
2	Test the reformulated research problem Test the reformulated tentative solution
3	Test the reformulated research problem Test the reformulated tentative solution

Table I.
Case study objectives

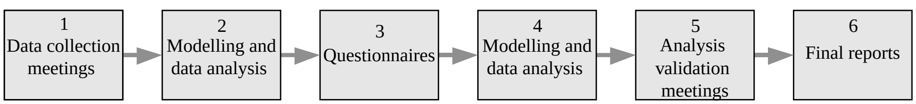

Figure 2.
Case study procedure

Each of the three case studies yielded a wealth of data that can be used towards improving the components of the research, which are the problem, the tentative solution, and the application, as shown in Figure 3.

The next section details how the improvement of those components occurs, a function shown by the "Error reduction" line in Figure 3.

3.2 Error reduction

Error reduction is a mechanism through which existing theories are improved. Each statement we make consists of a theory. Formulations of problems (problem statements) and solutions are theories that help us make sense of and act upon our environment. Error reduction is critical towards the design of a better theory.

Following Popper (1972) and Niiniluoto (1999), each attempt falsify a theory provides an opportunity for improvement. Falsification can be achieved by using deductive logic, as it happens in the field of mathematics, or through experiment. In most cases, including this research, both ways of falsification are applied. Here, logic was used to produce the original problem statement and original tentative solution. The use of experiment was in the form of case studies.

An error in a theory is discovered when what is perceived through our senses does not agree with the theory – what we expect. This result to the falsification of the original theory, and many indicate the location and nature of the inconsistency between the theory and the actual fact. This information is used by the researcher to correct the error indicated by the test, to produce a new and presumably better theory.

In this research, errors were located in both the problem statement and the tentative solution. For problem statement, error deduction was a simpler task than it was for the tentative solution, as it amounted to re-phrasing in order to remove ambiguity and make the statement more relevant and interesting. As expected, the process of rephrasing the problem statement so as to better reflect the topic of the research continued until this thesis was written.

On the other hand, the process of reducing error in tentative solutions is more challenging. The kinds of solutions detailed in Section 4 and onwards of this paper, consist of a comprehensive framework incorporating practical and theoretical components. As the framework consists of three components (Figure 1), the errors that were detected during each of the three case study cycles were classified in three corresponding classes:

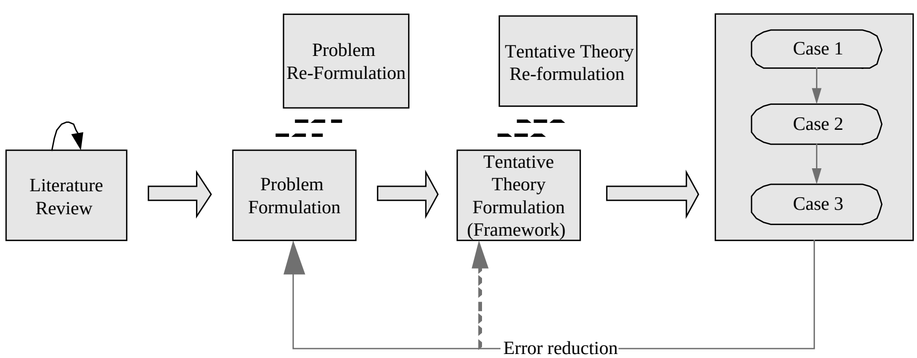

Figure 3.
Method for the improvement of the problem and solution formulations

(1) *Errors of theoretical foundation.* These are errors relating to epistemology, and its ability to provide suitable definitions to the fundamental questions related to this research, such as "what is knowledge".
(2) *Errors of process representation.* These are errors relating to the representation of a business process as an instance of a business process ontology.
(3) *Errors of improvement methodology.* These are errors relating to the application of the improvement framework on a business process.

This simple error classification improved the quality of the error reduction process. Errors were discovered more easily, and their elimination was streamlined as the necessary resources (literature, advisory input) had already been determined. In other words, the infrastructure for dealing with errors in each error class had been created and improved so that quick error reduction cycles could be achieved. In addition, to faster error reduction cycles, the solutions given to the various errors maintained the consistency of the framework.

Following are some examples of errors that were detected and corrected, representative of the three different types:

(1) Problems in defining the concept of knowledge and the forms by which knowledge can be found in a business process belong to the first class of errors. It was determined that the solutions (answers to the basic problem of epistemology) available in the literature were not adequate, as the definitions or explanations were too ambiguous to be practically useful. Solutions to those errors were subsequently found in Karl Popper's works and were adopted into the framework. Those solutions became fundamental to the rest of the framework, as both the business process ontology and the improvement methodology were based on them.
(2) Problems in accurately representing a knowledge-intensive business process belong to the second class of errors. For example, initially it was not obvious how to represent the various systems (such as e-mail, word processors, and file servers) that are related to a business process in a process model. A number of possible solutions was examined, such as combining special worksheets with graphical business process modelling notation that proved to be tedious to work with and unable to express the richness of the case study processes. Newer possible solutions were tested, and modelling based on an ontology editor was determined to be the best candidate. Clearly, in this case a process of educated trial and error took place.
(3) Problems relating to applying of the framework to a business process belong to the third class or errors. For example, the techniques and methods used to collect data during the process audit evolved through the series of case studies so that the audit result is comprehensive and accurate, while minimising the cost of time of the process members involved in the audit. Similarly, the task of processing the results of the process audit and generating the reports also went through a process of trial and error.

During this research, a considerable amount of time was spent on reducing errors in the KBPI methodology. Performing the error reduction "consciously" following a repeatable pattern of detection, correction, and testing helped to accelerate the research.

4. A framework for knowledge-based business process improvement

Following from the above conclusions, the author designed a framework for the KBPI. This framework specifically targets only business processes that are knowledge-intensive. It consists of the following three parts; each one will be discussed in this section:

(1) A foundational theory of knowledge.

(2) An ontology for dissecting, describing and discussing business processes.

(3) A method for the evaluating and improving of business process performance.

4.1 Foundation: theory of knowledge and business processes

A fundamental problem for many KM practitioners and researchers is that the discipline lacks a clear and consistent understanding of what constitutes “knowledge”. This problem exists because basic assumptions about knowledge and its nature have been adopted implicitly by these communities of practice from a small number of assumed authorities and have generally not been expressed explicitly by the practitioners using them.

Popper’s (1972) approach to knowledge provides a comprehensive and useful alternative to popular “post-critical” approaches. Niiniluoto (1999) extensively validated Popper’s epistemology as a tool for understanding phenomena in the real world in a detailed comparison with a wide range of competing epistemologies including various flavours of constructivism followed by many knowledge managers. Popper’s approach to knowledge is adopted for the development of the KBPI. Niiniluoto’s work may be consulted for a deeper analysis and justification of the “critical rationalist” approach adopted here.

One of the cornerstones of this epistemology is that knowledge can be independent of a “knower”. Much like Copernicus (following earlier observations by Aristarchus of Samos, 3rd century BC) proposed the heliocentric system as opposed to the dominant geocentric system (that can also be interpreted as “human centric”), Popper argued that our brain is just one of the places where knowledge can be found. Whereas Polanyi (1958, 1983), who developed the epistemology most often cited in KM literature, made the human brain the only place were knowledge can be found (personal knowledge), Popper created an epistemology where knowledge can be found in many places, including the human brain (objective knowledge). For Popper (1972, pp. 73, 74), knowledge can exist outside the human brain in an objective sense. In other words, objective knowledge can be autonomous and independent of a knower (Popper, 1972, p. 118). And because of its independence from the knower, objective (or explicit) knowledge can be subjected to criticism, a critical difference from tacit knowledge which cannot be criticised (Popper, 1972, p. 66). The quality of the knowledge does not relate to its host or container, but to the degree by which it has been tested and verified (criticised for potential errors byt the community of practice).

Popper’s concept of knowledge is rooted in a fallibilist tradition, which states that we can never know the truth, in the sense that there is “nothing like absolute certainty in the whole field of our knowledge” (Popper, 1972, p. 77). Assuming a fallibilist philosophy, knowledge does not refer to “beliefs” (justified or not) but to claims about the world that can be tested. This definition implies that satisfying a test is not sufficient to prove that a claim is true (certain) – the test only proves the adequacy of the claim in the test.

Popper's epistemology also specifies the *locus* of knowledge. Knowledge can be found in three different ontological worlds. World 1 is the physical world and all that is in it. World 2 is the world of our conscious experiences. And world 3 is the world of the logical contents of things like books and computer memories (Popper, 1972, p. 74).

World 1 represents reality. As living entities evolve brains and consciousness, world 2 knowledge also evolves. The entity creates internal representations of the word, including predispositions and beliefs. As sufficiently evolved brains, such as those of humans, create language able to codify knowledge (their claims about the world) in persistent forms, world 3 knowledge is finally created.

World 1 is important as it relates to the physical reality in which the organisation functions. Buildings, machinery, offices, and products are all examples of world 1 objects. But, worlds 2 and 3 are especially important for KM and BPM. World 3 is where objective knowledge is to be found, a term that describes persistent objects of knowledge such as the logical contents of books and computer memories or other products of human behaviour (Popper, 1972, p. 115). Niiniluoto (1999, p. 23) misreads Popper when he defines world 3 as "the products of human social action". In our understanding, world 3 encompasses persistent products of linguistic expression and human action. Although such products will ordinarily be socially available, in many cases they are produced and used by individuals.

For KM, world 3 today is the main field of application as it is clear that our technological tools of language processing (from writing on papyrus sheets to the actions and capabilities of computer networks, which are all world 1 objects) can indeed contain and transport knowledge. Popper specifically distinguished between knowledge itself (the logical content) representing world 3, and the physical container for knowledge, such as the book or computer that exists in world 1. World 2, on the other hand, is where consciousness, beliefs and predispositions are situated. The knowledge in world 2 is subjective, in that it is personal to a knowing agent, cannot be criticised, and cannot be easily shared with another knowing agent (Firestone and McElroy, 2003, p. 13). World 2 knowledge is very similar to what Polanyi named personal knowledge, and from this respect world 2 encompasses Polanyi's concept. Knowledge is created and used in world 2. KM must influence and augment our world 2 knowledge and efficiently utilise world 3 knowledge in order to generate new and better world 3 knowledge.

As a foundation, Popper's epistemology provides the necessary conceptual tools needed for the development of the KBPI. In particular, three points are most important:

(1) Objective knowledge exists outside brains and can be stored in knowledge containers. Therefore, technology can be used for the, storage and transport of world 3 knowledge. Knowledge that can exist independently and autonomously in objective forms is of great value to KM and BPM.

(2) KBPI emphasises objective knowledge as opposed to subjective. This is because objective knowledge is testable, whereas subjective knowledge is not. Nevertheless, subjective knowledge is still recognised as important.

(3) For our purposes, world 3 knowledge is expressed linguistically. Language is necessary for transferring of codified knowledge from one knower to another, and must be used with care to ensure objectivity and clarity.

Having understood Popper's epistemological assumptions, it was possible to design an ontological schema that can be used to describe knowledge-intensive business processes. This ontology is presented next.

4.2 A knowledge-based business process ontology

Gruber (Corazzon, 2005) defines ontology as "an explicit specification of a conceptualisation". In the context of computing science a formal ontology aims to provide an explicit, exhaustive, and rigorous conceptual schema or model of a given domain's concepts, relationships, rules, and resources. Typically, an ontology is depicted as a network or lattice structure of entities, their relations, and related rules. Semi-formal ontologies can often provide a consensual view of concepts and relations in a domain (Denny, 2002, 2004; Gruber, 2004). Ontologies are also being increasingly used to design and improve IT and related projects (Welty *et al.*, 1998). A variety of ontologies that describe business processes from a variety of viewpoints exist. Examples include the "Open source business process ontology" (Jenz & Partner, 2004), and the APQC (2004) and Malone *et al.* (2003).

An ontology that describes a business process is particularly useful for developing of a framework such as the one presented here. An ontology-based description of a business process helps to develop a formal conceptual model that is useful both to the framework design and, later, to its application. Formality contributes towards reducing certain misunderstandings that can lead to application errors.

Figure 4 shows the top-level components of the KBPO. It allows for a detailed description of a knowledge-intensive business process and is used for the construction of the process analysis and evaluation tools that will be presented in the methodology section.

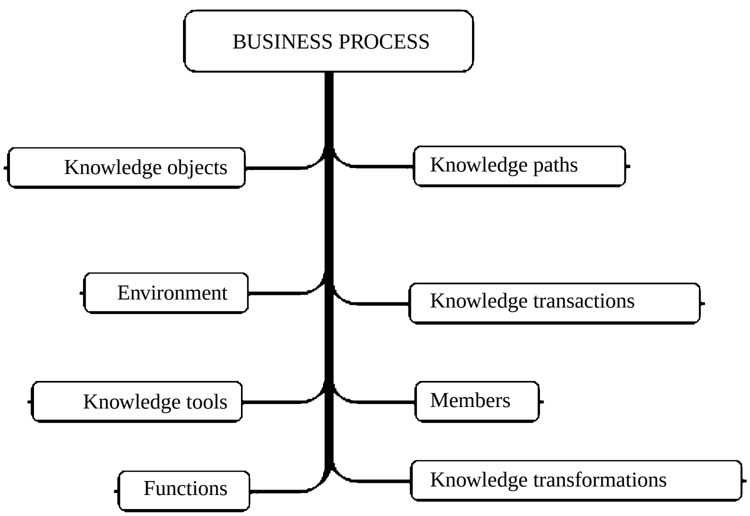

Figure 4.
The top-level business process ontology

The KBPO describes a business process based on a number of ontological classes. Examples of those classes are the knowledge transformation class and the member class. Each class describes a component of the business process, and defines various associations with other classes. For example, an instance of the knowledge tool class may be associated with one or more instances of the knowledge container class and none or more instances of the member class. In real life, this can be translated to something like:

> The Document Management system (an instance of the knowledge tool class) that contains one hundred documents (each one an instance of the knowledge container class) and is accessed by three process members (each one an instance of the member class).

4.2.1 Knowledge objects. A knowledge object is a world 3 construct. As such, it is independent from the person who has created it, and that can be identified as being separate and complete in its own right(in that it makes sense "as is") from other related world 3 constructs. A knowledge object represents a claim that is a solution to a problem, or a claim that can be used in a solution (which can be interpreted as "information"), or data that can be utilised by a solution. Those constructs can be objectified and, therefore, can be considered as knowledge objects.

For example, the actual content of a chapter of a textbook (what the chapter "talks" about) is a knowledge object, because it is independent from the author (as language was used) and it is separate from other chapters in the book. It may also be complete, in the sense that a reader can read that chapter alone and understand it. The same knowledge object can be represented as a series of overhead slides suitable for presentation or recorded in audio format as an audio book. In all cases, the knowledge object is the same, but is represented differently depending on the medium that is used.

4.2.2 Knowledge tool. A knowledge tool is defined as the technological artefact that can be used to perform actions on knowledge objects. For example, a knowledge tool can be used to record, copy, delete, transform, transport and distribute knowledge objects. Often, especially in IT environments, knowledge tools offer various processing capabilities, on top of the traditional record/disseminate features. The knowledge tool only performs the action and nothing more. In the case of recording, for example, a knowledge container is required in order for the knowledge object to be captured. However, the knowledge tool is what gives a person the ability to record a knowledge object on a knowledge container. Similarly, in the case of knowledge object transportation, a knowledge tool requires the use of a knowledge container that will contain the knowledge object, and provides the necessary infrastructure for the transportation of the knowledge container and it contained knowledge object.

For example, in order for me to record my world 2 knowledge object in a MS Word file, I must make use of an appropriate word processing application. This application is the knowledge tool that I am using to perform this recording. The same knowledge tool allows me to perform various actions on the content of the MS Word file, such as spelling check, or correct syntactical errors.

4.2.3 Function. A function is defined as the smallest sub process that a given business process team decides to illustrate on their process diagrams (Harmon, 2003, p. 457). In other words, a function is a smallest practical denomination of work to which a business process can be analysed. A business process can be decomposed to a small or large number of functions. Usually, a function consists of a single step, in its simplest form, or it may be more complex.

Apart from this traditional definition, in the KBPO a function is also loaded with the idea that some action in relation to a knowledge object takes place within it. It is not uncommon to find functions without any particular (identifiable) action that relates to a knowledge object, especially in processes that are not knowledge-intensive. However, when such an action does exist, it must be documented.

For example, a simple function is one that can be named "Invoice processing". This function involves a knowledge object called "invoice" which can be represented on paper or on a computer screen. The function prescribes that the necessary action for the payment of an invoice must be taken (such as the writing of a cheque), and the results of that action be documented on the invoice, in one of its forms (on-screen or paper).

4.2.4 Member. A member represents a, most often, human performer of one or more functions. It is possible for a member to not be responsible for a particular function, but to have some other non-executive role, such as a process owner or a domain expert, from whom other members can seek advice.

Members are the users of knowledge tools and perform all non-automated actions that relate to knowledge objects.

Members are critically important because they are the only component of a business process that can initiate and implement changes. In other words, it is only because of the members, their mistakes, and their ability to address theses mistakes sufficiently that makes process improvement possible through learning.

4.2.5 Knowledge path. A knowledge path is defined as the sequence of functions through which a knowledge object travels. A knowledge path is concerned with the knowledge object, the functions through which it passes, and the sequence of functions. By identifying and tracing knowledge paths, the life cycle of a knowledge object can be analysed, including the various knowledge tools and containers used, the members involved, and the communications that take place. It follows that analysing knowledge paths is very important for the process improvement effort.

An example of a knowledge path is the sequence of functions through which a loan application has to travel until it is either accepted or rejected. In the same knowledge path we can identify one or more bank officers who process the application, the knowledge tools that they use to perform their functions (for example, a credit history tool). It is also interesting to note in this example how the same knowledge object may start its life in a paper knowledge container (a typical bank form), and then continue contained in an electronic form as a Wf knowledge object.

4.2.6 Knowledge transaction. A knowledge transaction is defined as the transportation of a knowledge object between two or more process members. To identify a knowledge transaction, a business process is scanned for evidence of communication, and then the focus is on identifying the attributes of this communication. A knowledge transaction is different to a knowledge path because in a knowledge transaction only a knowledge object is being transferred, not the control of the process. Instead, in a knowledge path, the control of the process is being passed from one function to next.

Knowledge transactions must be easy to identify (discreet), must have a beginning and end (definable), must end within a reasonable time frame (finite), and must relate to identifiable knowledge object(s).

For example, in a hypothetical process of "equipment installation" in a shop, the contractor responsible for installing the equipment may send confirmations for completion as each step of the installation is completed. Those confirmations, although simple status updates, signify knowledge transactions.

4.2.7 Knowledge transformation. A knowledge transformation is defined as a change that is made to a knowledge object. A knowledge transformation is associated with a knowledge tool. Transformations may include merging, splitting, modifying or changing formats of the knowledge object. A member may use a knowledge tool in order to perform a transformation of a knowledge object that resides on a knowledge container. The knowledge transformation class provides details on how knowledge objects are transformed (changed) locally, that is, at the function level.

An example of a knowledge transformation is the amendment of a sales record with updates of the latest sales. After the event of the update, the sales record is changed to contain the latest available information.

4.2.8 Environment. Finally, the environment plays an important role in the context of a business process as it can influence its structure and performance. Anything that exists outside the business process, but influences it, makes up the environment of the process. For example, management policies and business targets are both parts of the environment.

4.2.9 Conclusion. In practical terms, the KBPI ontology guides the researcher through the process of creating an instance of a business process, as will be seen in the following section. This means that the researcher collects data related to all classes in the ontology in order to create class instances (for example, for knowledge paths, knowledge transactions, functions, and members) that will capture a comprehensive snapshot of the business process from a knowledge perspective. The method for doing so is the third component of the KBPI and will be shown in the following section.

4.3 Knowledge-intensive business process improvement methodology

The improvement methodology proposed here is designed to guide the KM practitioner through the improvement process. It is firmly based on the KBPO, and is composed of three parts: audit, analysis, and design. The method in detail is shown in Figure 5. There is nothing innovative or radically different in this methodology. Its value lies in that it exploits the KBPO to derive recommendations for improvement of a business process.

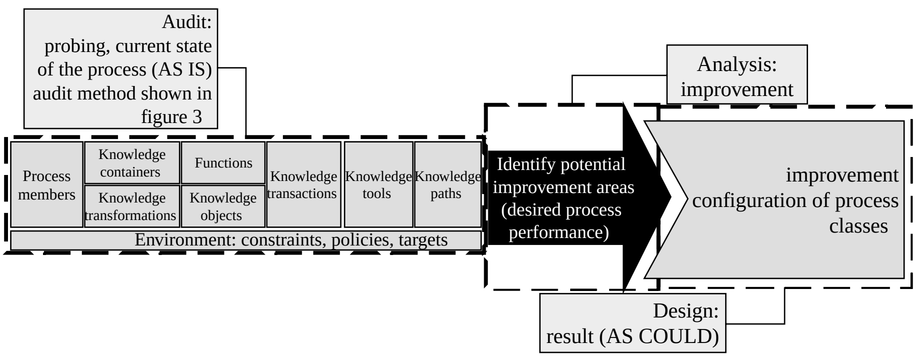

Figure 5.
The improvement method

4.3.1 Process audit. The process audit stage is concerned with the collection of data for the creation of an accurate representation of the process under investigation. This is done by collecting the data required by the process ontology based on which an instance of that ontology can be created. In Figure 5, each one of the boxes at the left side of the diagram that is enclosed in the Audit dashed box corresponds to one of the top-level branches of the ontology. Guided by the ontology, the researcher uses a combination of interviews and questionnaires to collect the data.

Appropriate data capture tools facilitate data collection. These tools help streamline of the data capture process and in organising the data to simplify the following analysis stage. In the three case studies conducted as part of this research, the data capture was facilitated by the use of Protégé an ontology editor, and Visio, a visualisation application.

Protégé was used implement the ontology as a hierarchy of classes. It was also used to capture of instances of the ontology classes that describe the studied business processes. In Figure 6, the Protégé window is configured to display the ontology classes on the left side, and the details of the function class on the right side. The bottom area of the function class window contains the attributes of the class, named "Slots" in Protégé. These attributes can be of various types, including instances of other classes, as is the case for the knowledge tools and members classes.

In Figure 7, Protégé displays instances of classes. In this example, the central pane of the Protégé window ("Instance Browser") shows function instances that are members of the process instance. The right pane ("Instance Editor") shows the attributes of the currently selected function. Some of those attributes, such as "Name" are simple and text-based.

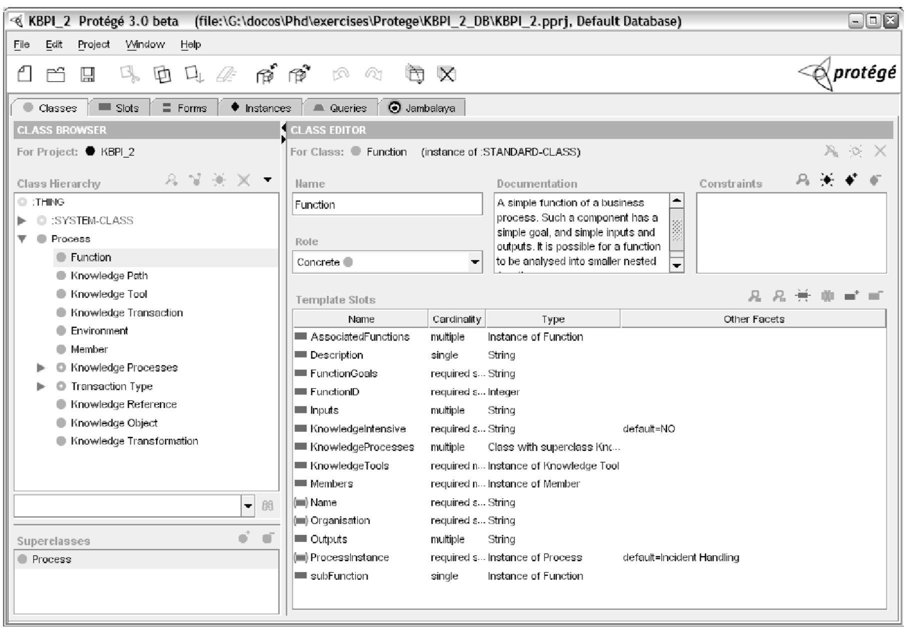

Figure 6.
Protégé displaying details of the function class

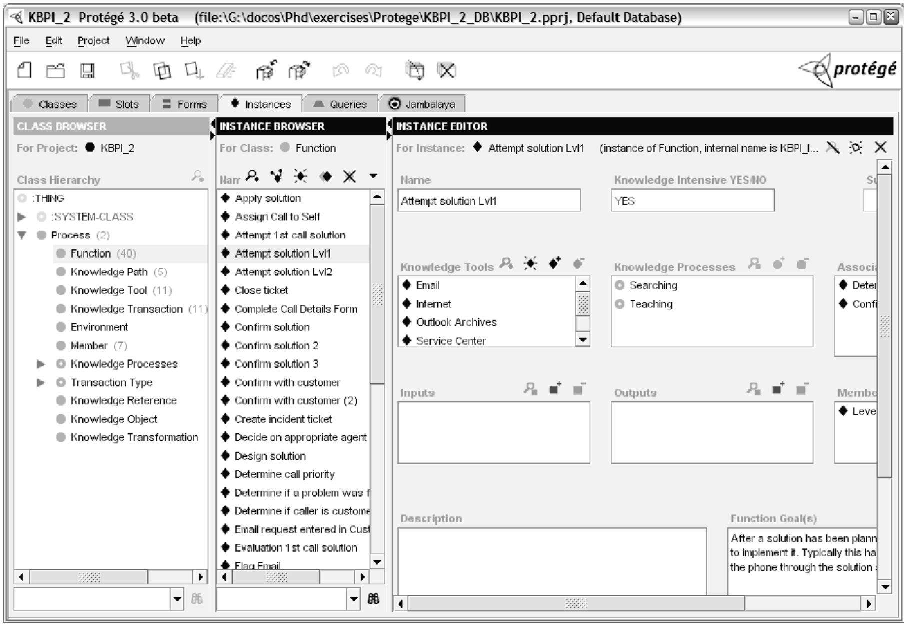

Figure 7.
Protégé displaying instances of the Function class

A diagrammatic representation of the business process is also an important part of the knowledge-based analysis. Using Visio, the BPMN notation (BPMI.org, 2004) was extended so that knowledge paths, knowledge tools, and knowledge transactions could be depicted. In Figure 8, a portion of the original BPMN process model is shown. Details of instances of the ontology classes can be seen attached to particular functions or group of functions in the model. This extension of the BPMN standard notation allows both the researcher and the process members involved in the study to rapidly

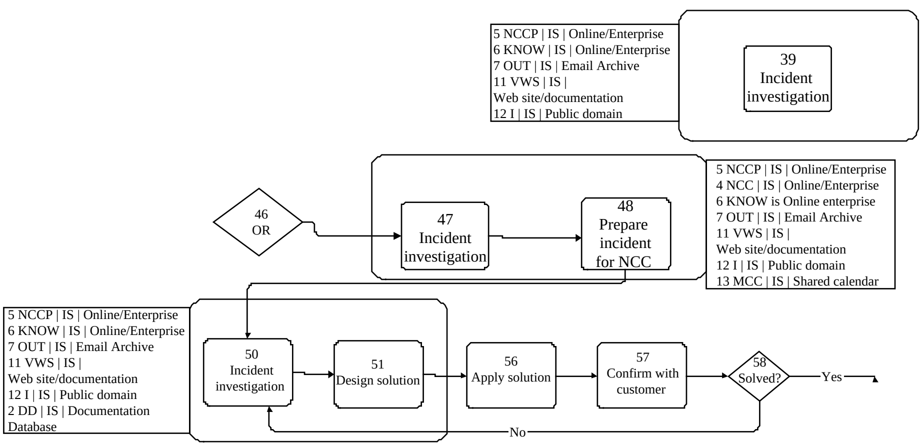

Figure 8.
Part of the process model, highlighting instances of knowledge paths and knowledge tools

visualise the interrelations of many of the business process classes, in addition to their representation in Protégé.

The purpose of the data capture tools is to formalise and organise what is known about a business process. The data that is contained within those tools is used at the analysis step, during which areas for potential improvement are discovered.

4.3.2 Process analysis. Potential improvement areas in two levels are evaluated: at the process level, and at the function level (Figure 9).

At the function level, the objective is to detect potential areas of improvement in instances of the classes of function, member, knowledge object, knowledge transformation, and knowledge tool.

At the process level, the objective is to detect potential areas of improvement in instances of the classes of knowledge paths, knowledge tools, and knowledge transactions.

The instances of the classes of knowledge Tools are examined in both the function and the process levels because they are involved in both levels.

4.3.2.1 Function level analysis procedure. At the function level, the objective is to detect knowledge-intensive functions that are not performing as desired. The following procedure is followed in order to detect areas of improvement that may affect positively the performance of a knowledge-intensive function (Table II).

4.3.2.2 Process level analysis procedure. See Table III.

4.3.3 Solution design. The result of the analysis is a recommendation. The recommendation suggests changes to the configuration and composition of the process classes. As the KBPI is concerned with the management and configuration of process knowledge, we expect that the major opportunities for change and improvement will be in the classes of knowledge tools, knowledge paths, knowledge containers and knowledge transactions. Structural changes may be required as well. By structural changes it is meant those changes that affect the organisation and sequence of process functions and process members.

The output of the design step is recorded by creating a new version of the process instance that was captured in the Protégé ontology and in the process model. In effect, this new version of the process indicates the new configuration of

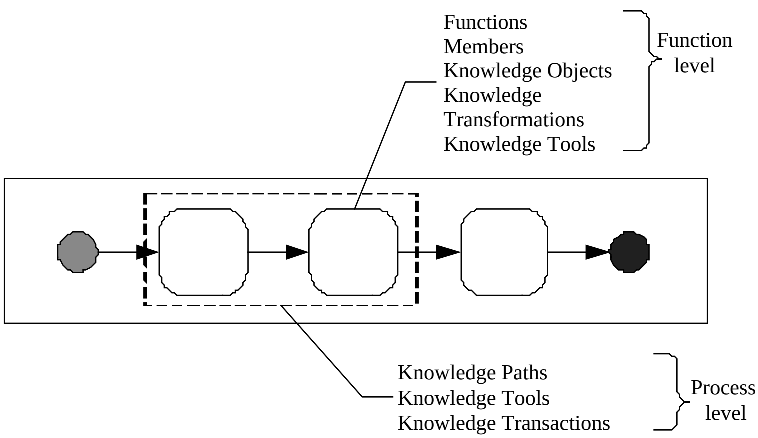

Figure 9.
Evaluation and improvement levels

Table II. Function level analysis procedure

Action	Comments
1. Determine all functions that are knowledge-intensive	Functions that are not knowledge-intensive will not benefit from this analysis, and therefore must be excluded A knowledge-intensive function is one that involves decision making, requires considerable context knowledge (e.g. the number of years of experience in the field), and its inputs and outputs are complex and dynamic. Also, the output may be of high impact (i.e. an important decision) to the process as a whole. Detecting knowledge-intensive functions that are not performing at the desired level is possible by measuring function-specific metrics or by evaluating reports from the process members responsible for executing those functions
2. For all knowledge-intensive functions, designate one or more descriptors of performance	This unit may be qualitative or quantitative. For example, "time to completion" is a quantitative unit of performance; "quality of document" is a qualitative unit of performance
3. Define the current performance value for each of the functions	The current performance of a function becomes its baseline, and used to compare it with its future performance
4. Define the desired performance value for each of the functions	The future performance becomes the objective of the improvement effort
5. For each process member involved in a function, define the critical knowledge success factors	The critical knowledge success factors represent the required skills required for the successful execution of the tasks contained in the function
6. For each function, define the involved knowledge objects	Self-explanatory
7. For each function, define all knowledge transformations that take place	Self-explanatory
8. For each function, determine the knowledge tools that are used	Self-explanatory
9. For each of points 5-8, evaluate their corresponding current status and correlate their impact on the performance of the function	This step requires that an audit of the current status of process members, knowledge objects, knowledge transformations, and knowledge tools is done. The objective is to determine the status of the classes that influence the performance of a function
10. For those points where the current status is not aligned to the desired performance defined in point 4, provide: An analysis of the likely causes of the non-alignment A possible solution that may enable the alignment	The audit in step 9 may reveal classes whose status does not contribute towards the desired function performance. For example, a process member may not satisfy the critical knowledge success factors, or a knowledge object may be inadequate For these cases, the reasons for this non-alignment must be first established. Understanding the reasons will provide a background on which a solution that will enable alignment may be designed. For example, if it was determined that a process member does not satisfy the critical knowledge success factors, a solution that involves training can be designed which will specifically address those critical knowledge success factors that are not being met

Table III.
Process level analysis procedure

Action	Comments
1. Determine all knowledge paths present in the process	The analysis begins by defining of all knowledge paths contained in the process. It is the performance of the knowledge paths that is targeted for improvement at the process level
2. For each knowledge path, define a single unit of performance (qualitative or quantitative)	A unit of performance is a qualitative or quantitative measure of performance. For example, "time required to determine premium" is a quantitative unit, while "customer satisfaction" is a qualitative unit
3. Define the current value of the unit of performance for each knowledge path	A baseline of performance is established by giving a value to the unit of performance decided in step 2
4. Define the desired value of the unit of performance for each knowledge path	The target value of the unit of performance is defined here. The purpose of this analysis is to modify the classes indicated in steps 5 and 6 so that this performance is achieved for the knowledge paths
5. For each knowledge path, determine the knowledge tools that are being used	Self-explanatory
6. For each knowledge path, determine the knowledge transactions that take place	The knowledge transactions are especially important because they consist of the internal communication between the process actors. Poor communication is generally translated to poor process performance
7. For each points 5 and 6, evaluate their current status	This step requires an audit of the existing knowledge paths and transactions. The details of their status will be needed for step 8
8. For each points 5 and 6, evaluate how their current status can change so that the desired performance defined in step 4 can be achieved	Through logical analysis, examine how knowledge tools and knowledge transactions can be changed so that the performance of the knowledge path can be changed so that it matches the desired performance indicated in step 4

the process ontology instances. Besides, the data required by the process ontology, the tools are extended to include performance evaluation fields for each ontology instance. These fields allow the analyst to provide an evaluation of the likely outcome of the proposed changes to justify those changes. The performance evaluation can be done using a variety of techniques, such as simulation and logical analysis or scenario playing. Simulation is especially useful when supported by an ontology (Fishwick and Miller, 2004).

Following the design step, implementation may take place. In the implementation step, not shown in Figure 5, the recommended changes are introduced into the business process. Through observation over time, the performance of functions, knowledge flows and knowledge paths can be measured using metrics that are specifically designed for each component. The results of those measurements can be used towards a new cycle of knowledge-based process improvement, thus establishing a continuous improvement cycle.

The experiences and lessons learned from the application of the KBPI in a series of three case studies will be presented next.

5. Case studies

Three case studies have been conducted as part of the research into the KBPI framework. A set of objectives guided the three case studies; these objectives are shown in Table IV.

The business processes examined are critical for their respective organisations. In case A, the process is that of the new store opening for a large retail organisation in the Asia-Pacific region. In case B, the process is that of help desk incident handling for an international IT services corporation. In case C, the process is that of the R&D funding approval for an Australian engineering and project management contractor.

In case A, the business process is facilitated by the use of mostly traditional business process tools, such as telephone, fax, and printed documentation. E-mail is also used for person-to-person and person-to-group communication, including the distribution of documents and instructions. The use of IT is minimal.

In case B, and in a lesser degree in C, the business process is facilitated by the use of extensive enterprise-wide information systems. Traditional knowledge tools such as telephone, fax, and printed documents are also used. However, they are secondary to the IT infrastructure.

5.1 Audit design

For the purposes of the knowledge audit, the data collection was done using a combination of meetings with the process members and questionnaires. Figure 10 shows the audit design.

The first round of meetings between the researcher and each process member yields the bulk of the process audit data. The data is entered in the data capture tools. Based on that data, questionnaires that are particular to each process member are prepared and sent to them. The replies help to clarify uncertainties, and in extending the original audit data where necessary. A final round of meetings is conducted, where the data, as recorded in the data capture tools, are presented to the process members (again, individually), thus giving them a last chance to detect and correct errors.

The analysis procedures presented in the section "process analysis" may identify potential areas for improvement. These areas are reported together with the detailed presentation of the current status of the process in a report called "AS IS". The AS IS report provides a thorough knowledge-based examination of the business process and records the identified potential improvement areas.

The AS IS report is circulated to all process members, who provide feedback. The feedback received is then integrated to the AS IS report, and a new document named AS COULD report is produced. The AS COULD report contains specific change

1	To help towards the formulation of the KBPI ontology
2	To help towards the design of a method suitable for the "process audit step"
3	To help towards the design of a method suitable for the "analysis step"
4	To help towards the design of a method suitable for the "design step"
5	To apply the KBPI

Table IV. Case study objectives

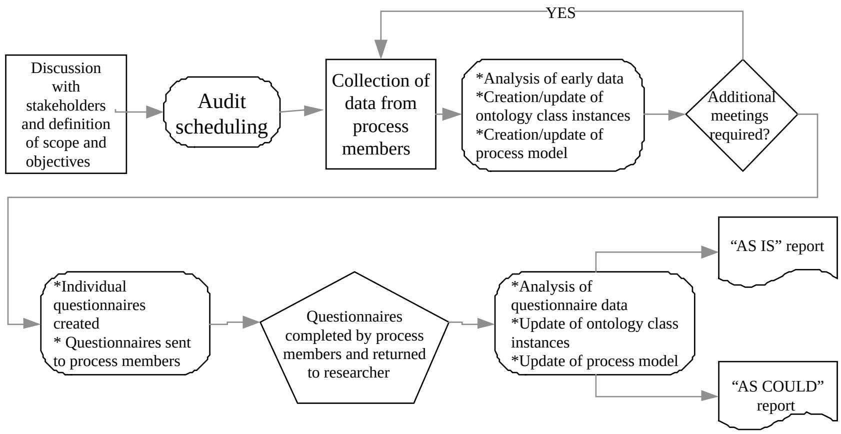

Figure 10.
The process audit design

suggestions to knowledge tools, knowledge paths, knowledge containers and knowledge transactions.

5.2 Results of case studies and discussion

The process members that participated in the studies responded positively to the idea of process improvement through KM, and noted that the proposed KBPI framework gives them a way achieving such improvement.

The early formulation of the KBPI contained problems that were exposed as it was applied on the three cases. These problems were technical and ontological in nature.

The technical problems involved the instruments that were used at the time to capture and then analyse the case study data. The use of a multitude of worksheets in the first case proved to be unsustainable because of difficulties in keeping the data set current during the progress of the meetings and questionnaires, and because the segmentation of the data in many files made their analysis cumbersome. The MS Visio application was very useful for creating the process models, especially when used in the meetings with the process members. The notation was intuitive as noted by the process members. Often, they would use a pencil and make changes directly onto the model. This was an excellent way to improve the accuracy of my communication with the process members, while reducing the meeting times.

In the second case study, the testing of the corresponding revision of the KBPI revealed that the new data capturing and analysis tool based on Protégé was far better than the early worksheet-based version. The use of Protégé benefited the case study in two ways:

(1) First, it enabled much faster editing of the process data, while the editor ensured that data was entered correctly and in accordance to the KBPO schema.

(2) Second, it revealed problems with the author's (at the time) understanding of how an ontology should be designed, and with the KBPO. These problems where easy to detect using a good ontology editor (in this case, Protégé developed by Stanford Medical Informatics at Stanford University), but would be hard to do so without it.

Using the worksheet-based tool along side the ontology-based tool showed that the differences in usability (ability to update process data, ease of use, ability to analyse process data, ability to create reports and export data, etc.) and quality (the ability of the tool to enforce the ontology schema and prevent erroneous data entry) were significant.

Protégé provided all the basic features that enhance usability and quality, but also offered features that promoted various forms of ontology and instance visualisations that can be exploited by the KBPI. These features come in the form of freely available plug-ins to the base software. On top of this, further visualisation components can be developed, as well as other components, such as for storage or for connection with BPM middleware. The use of a full-featured and advanced ontology editor such as Protégé has extended the ways by which the KBPI can be used.

Finally, the graphical process modelling tool, in this case study Microsoft Visio was used, was very useful. The graphical model, using BPML (BPMI.org, 2001) standard notation extended with custom symbols to visualy display the basic KBPO classes, has the ability to instantly present the structure of a knowledge-intensive business process. The case study participants were able to quickly acknowledge the sequences of the various functions, the instances of communication between the process members, and the way that the knowledge tools are allocated and used inside the process functions.

In the third case study, there were no significant problems in the use of the ontology editor and the graphical process modeller (Visio). To the contrary, opportunities for further enhancement were noted given that the Protégé is based on an open plug-in architecture, which allows components to be added. This feature allows the integration of automation for various features that are now completed manually, such as creating and updating the graphical process model, and compiling of the AS IS and AS COULD reports. Especially, for the later, a significant part of those documents could be automatically generated, thus speeding up the analysis and design phases of the KBPI.

Protégé also allowed the experimentation with a variety of third party visualisation products. Through these products, the ontology and its instances can be visualised. These visualisations may be useful for the analysis phase; however this is a topic for future research.

5.3 Changes to the process ontology

The KBPO also required significant changes. In its early revision, the KBPO contained the four basic classes: knowledge object, knowledge container, knowledge flow transaction, and knowledge instrument. However, these were poorly defined, and it was not clear how these classes (and their instances) are combined to compose the process system.

An important realisation was that there was confusion between various class elements. For example, the original knowledge instruments (later renamed knowledge tools to clarify its role) contained an element called "Carrier Medium". In the class knowledge flow transactions (later removed from the KBPO), there was an equivalent element called simply "Carrier". These two elements, members of two classes, were defined to be equivalent, however, they were used differently. In the case of the first class, it was used to classify the knowledge instrument into analogue or digital (computer based), while in the second class it was used to describe the actual mechanism or system used to transport a knowledge object (for example, e-mail or telephone). Many similar confusions were detected and eliminated at this stage.

Changes were made in the original classes of the process ontology. The idea of the knowledge flow, defined as the transportation of a knowledge object between two functions of a process was eliminated because it was difficult to definitely mark them on the graphical process model. Further, it was difficult to the define transactions between knowledge flows. This was an example of poor class naming and description. Eventually, after the completion of the second case study, this class was replaced by a new one named knowledge transaction, which simply describes the exchange of knowledge objects between process members.

Other similar issues were detected and corrected as a result of the first case study. In comparison, the second and third case studies resulted to fewer such problems.

In the second and third case studies the KBPO was revised to include a number of abstract classes in support of the normal classes, and to modify some of the attributes of the normal classes.

Specifically, the following abstract classes were added:

- knowledge object taxonomy;
- media;
- containers;
- medium types; and
- appropriate attributes (Protégé "slots") were introduced in the normal classes to incorporate the new abstract classes in them.

The abstract classes take advantage of regularities that were detected in the three processes that were studied. For example, all three processes made extensive use of E-mail and MS Word and therefore these were entered in the abstract classes Media and Containers (they appear in both because they can be used to either record a knowledge object, or to transport it).

6. Conclusion

In this paper, a framework for the improvement of knowledge-intensive business processes (KBPI) was presented. The framework is composed of three parts: a foundational theory of knowledge based on Karl Popper's epistemology, an ontology for the representation of a business process, and a method for process audit, evaluation and improvement.

The framework focuses on the application of KM as the means for the improvement of a business process. The knowledge that is embedded in a business process is defined by the original concepts of the knowledge path, knowledge transaction, knowledge tool, function, knowledge transformation, knowledge object, member, knowledge container, and the environment. All of those concepts are included in the business process ontology.

The framework was applied to three business processes in three separate case studies to assess its ability to detect potential improvement areas and to guide the development of recommendations for improvement in those areas.

Using or creating classic metrics of performance for functions, knowledge paths, and knowledge transactions seems to be the most difficult part of the process audit and analysis, mainly because the KBPI is concerned with concepts that cannot be readily described in quantitative terms. Therefore, the use of critical knowledge success factors for functions, and qualitative units of performance for functions and knowledge paths is an idea that was coined but was not investigated thoroughly; this is the topic of further research.

As the KBPI can help organisations improve the performance of their processes by improving the way that knowledge is managed within a process. The KBPI does not exclude the use of other improvement methodologies, and can be aided by the likes of SixSigma and TQM, and should be seen as a continuous process.

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