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Knowledge Enhanced Framework for the Design and Development of e-Workflow Systems

by

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Abstract

For the last two hundred years the neo-classical economy has recognised only two factors of production: Labour and capital. With the advent of the Internet and e-business, the economy is now changing to knowledge and global economy in which information and knowledge are becoming the main factors and the primary wealth-creating assets. Land, labour and capital – the economist's traditional factors of production - do not disappear, but they become secondary. This research work has focussed on the development of a new framework and methodologies to support the process of designing workflow management systems (e-workflow) adapted to the dynamic changes of the new business (e-business) environment in the new economy. Such framework and methodologies will support the automation and the dynamic changes of e-business processes, the integration of heterogeneous application systems, and communications between intra and inter-organisational e-business processes.

An initial literature review has found that traditional workflow metaphors are increasingly inadequate in the new e-business era that is often characterised by an increasing pace of radical, discontinuous and unforeseen change in the business processes and e-business environment. The findings show that current workflow systems are less capable of dealing with the more dynamic situations encountered in ad hoc and collaborative work processes in the new e-business environment. Furthermore, traditional workflow developments fail to characterise the information and knowledge that flows in a workflow design process in such a manner as to promote its reuse. It has also showed that the traditional developments of workflow systems have ignored the human dimension of organisational knowledge creation.

To address the above workflow development limitations, this research work has proposed the integration of a new knowledge perspective to the traditional framework for workflow design and development, which was limited to four perspectives i.e. organisational, behavioural, functional and informational perspectives. This new knowledge perspective has two main roles: monitoring the changes that are happening in the traditional workflow modelling perspectives and reflect the changes on the e-business processes, and enrich the framework with a knowledge repository. The knowledge repository is populated from two sources: the extraction or deduction of knowledge from the data and information flowing between the four perspectives and the memorisation of successful stories, best practices, previous cases which are organised as design patterns. These design patterns will be re-used to continuously evolve and provide flexibility of e-business processes to reflect immediate changes required in the new e-business environment. An evaluation of the proposed framework and methods was carried out through web-based survey and action research case study strategies.

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List of abbreviations

Acronym	*Meaning*
API	Application Programming Interface
AD	UML Activity Diagram
ADL	Activity Description Language
BPR	Business Process Reengineering
BSP	Business Service Provider
B2B	Business-to-Business
B2C	Business-to-Customer
BPMN	Business Process Modelling Notation
BPDM	Business Process Definition Meta-model
BPEL	Business Process Execution Language
BPM	Business Process Management
CBR	Case Based Reasoning
CRM	Customer Relationship Management
CGI	Common Gateway Interface
CSCW	Computer-Supported Collaborative Work
CORBA	Common Object Request Broker Architecture
DBMS	Database Management System
DCC	Digital Content Component
DCOM	Distributed Component Object Model
DEMO	Dynamic Essential Modelling of Organisations
ECA	Event Condition Action
ERP	Enterprise Resource Planning
ERPS	Enterprise Resource Planning System
EAI	Enterprise Application Integration
EDI	Electronic Data Interchange
EPC	Event Driven Process Chain
FAW	Federated-Agent-Workflow
GIS	Geographic Information System
GUI	Graphical User Interface
HTML	Hypertext Mark-up Language
IIM	Implementation Independent Model

IDL	Interface Description Language
IDEF	Integrated DEFinition Method
KEEM	Knowledge-enhanced e-workflow modelling
KM	Knowledge Management
KMS	Knowledge Management System
KBS	Knowledge Based System
LOVEM	Line of Visibility Enterprise Modelling
NCBSP	Network Centric Business Service Provider
OMG	Object Management Group
PERT	Program Evaluation Review Technique
ProM	Process Mining
RMI	Remote Method Invocation
RPC	Remote Procedure Call
SAMPO	Speech-Act-based office Modelling aPprOach
SCM	Supply Chain Management
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
TQM	Total Quality Management
UML	Unified Modelling Language
UTUCS	User-to-User Communication Support
UDDI	Universal Description, Discovery and Integration
UNICAMP	Institute of Computing of the University of Campinas
VAN	Value Added Network
WADP	Workflow application Development Process
WBS	Work Breakdown Structure
WS-BPEL	Web Service Business Process Execution Language
WSDL	Web Services Description Language
WfMC	Workflow Management Coalition
WIL	Workflow Interchange Language
WPDL	Work Process Description Language
WfMS	Workflow Management System
WFS	Workflow System
WOODSS	WOrkflOw-based spatial Decision Support System
WRM	Workflow Reference Model

XML	Extensible Mark-up Language
XPDL	Extensible Process Description Language
YAWL	Yet Another Workflow Language

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Dedication

To my entire family and especially to Ni Emmanuel Ndeta

Part One

Introduction, Background Study and Literature Review

Chapter 1

1.1 Introduction

The importance of process is a key aspect of computing, and the notion of process and role are central in the field of workflow management (Kurt, 2001). A workflow management system "completely defines, manages and executes 'workflows' through the execution of software whose order of execution is driven by a computer representation of the workflow logic" (Hollingsworth, 1995). Workflow systems (WFSs) are an excellent base for process-oriented knowledge retrieval because they are well studied and increasingly common in contemporary e-business organisations, and companies such as FileNet, IBM, Staffware, JetForm, SAP, BAAN, Eastman Software (Van der Aalst, 2003), amongst others, are currently providing software support for WFSs.

Business process modelling is an effective tool for managing organisational change and is known to have brought benefits to many organisations. Organisations and their business processes undergo changes from time to time, and in some cases these changes are dynamic, discontinuous and complex. Organisations change either through anticipation of surprise (proactive) efforts to become more competitive or in response to a need to maintain competitiveness in a changing business environment (Chung et al., 2003). The importance of business process modelling in IT-enabled workflow management and business process management (BPM) strategies is indicated by the recent calls for improving process modelling and process management in contemporary organisations, especially online business-to-business (B2B) and business-to-customer (B2C) E-commerce applications (Madhusudan et al., 2004; Fahey et al., 2001).

Business process modelling techniques have been widely adopted by contemporary businesses and organisations for documenting their operations. In this context, process models describe business activities along with their temporal and logical relationships within business processes of the organisation, either as reflection of the status quo or as a road map for change (Decker et al., 2009). *Business process* *modelling is also a critical tool to enable enterprise application integration as well as standardisation of business processes.*

Workflow systems are designed to support business processes. During the last decade workflow technology (Van der Aalst, 2003) has become readily available. Workflow management systems (WFMSs) such as Staffware, IBM MQSeries, COSA, etc. are suitable for traditional workflow applications as they offer generic modelling and enactment capabilities for structured business processes as opposed to dynamic business processes in the new e-business environment. By making process definitions (schemas), i.e., models describing the life cycle of a typical case (workflow instance) in isolation, one can configure these systems to support dynamic business processes. These process definitions (schemas) need to be executable and are typically graphical. Beside fully-fledged workflow management systems many other software companies have embarked on the bandwagon of the workflow market by providing stand-alone workflow products or implement a workflow component in their existing products.

Consider for example Enterprise Resource Planning (ERP) systems such as SAP, PeopleSoft, Baan and Oracle, Customer Relationship Management (CRM) software, Supply Chain Management (SCM) systems, Business-to-Business (B2B) applications, etc. which embed workflow technology (Van der Aalst et al, 2003). Despite its promises, many issues are encountered during the application of workflow technology in an organisation. One of the issues is that these systems require a workflow design, i.e., a designer has to develop a detailed workflow model accurately describing the routing of work. Modelling a workflow is far from trivial (Van der Aalst, 2003): it requires deep knowledge of the business process at hand and the workflow language that has been deployed.

Furthermore, the new e-business environment has revolutionised traditional business operations, but to date, has not integrated well with organisational knowledge management initiatives. Through the development of e-business and work process focused knowledge, contemporary business organisations can accomplish three critical tasks (1) evaluate what type of work processes they are performing in the e-business environment (know what); (2) understand how they are performing it (know how); determine why some organisations including theirs are likely to undergo change in the near foreseeable future (know why). In this research we pursue a process dimension and reflect upon the value e-business knowledge contributes in enhancing workflow processes. Understanding how e-business impacts these workflow processes, and then leveraging that knowledge to enhanced these processes, is crucial to an organisation's survival and success in deriving competitive advantages in today's global and knowledge economy. In this research, we highlight the central role knowledge management initiatives plays in diagnosing and managing e-business-driven changes in organisational work processes.

Conventional workflow management systems use explicit models and representations of process, i.e., a completely specified workflow design is required that will need to be modified to reflect the changes in organisations. A major limitation of traditional workflow systems is that they can, typically, only support simple, static and predictable processes such as insurance and travel claim processing. The benefits alluded to by process automation or workflow technology are highly desirable and the workflow research community has set the agenda of developing techniques that enable these benefits to be achieved in contemporary e-business organisations characterised by dynamic, complex, uncertain business processes and e-business environments.

The proposed framework aims at providing process support like traditional workflows do, but in such a manner that the system is intelligent enough to deal with new e-business environment that is characterised by rapid, dynamic and discontinuous change. Because of these and other related potential advantages, there is increasing interest in making workflow approaches more flexible and in using knowledge management techniques to allow workflow systems to cope with complex, unpredictable and dynamically changing processes in the new e-business environments characterised by the emerging global and knowledge economy (Dellen et al., 1997, R-Moreno et al., 2007). To tackle some of the above-mentioned problems for this research undertaking, we propose to integrate a new knowledge perspective to the traditional framework for workflow design, in order to increase the flexibility of workflow design and evolution through the reuse of process related knowledge in the form of workflow design patterns from a knowledge repository.

1.2 Problem statements

The work processes and information processing perspectives of the traditional framework for workflow design and evolution has been dominant in information systems practice and research over the past few years. These views originated from the industrial era when business processes and environments was less volatile, the products and services and corresponding core competencies had long multi-year shelf life, and the organisational and industry boundaries were clearly demarcated over the foreseeable future (Malhotra, 2000; 2001). The relatively structured and predictable business processes and competitive business environment rewarded enterprises' focus on optimisation, efficiencies and economies of scale. Such economies of scale were often based on high level of efficiencies of scale in the absence of impending threat of rapid obsolescence of products and service definitions as well as demarcations of existing organisational and industry boundaries that are more representative of the new e-business environment (Mathur & Kenyon, 1997). A work process comprises a set of activities through which information is transferred, converted and generated, many times tacitly, among group members (Nunes et al., 2009).

Workflow management solutions characterised by memorisation of 'best practices' may tend to define the assumptions that are embedded not only in the workflow systems, but also in the organisations strategy, reward systems and resource allocation system. The *embedding* of such assumptions in organisational workflow systems may lead to inflexibility (Hedberg et al., 1996) of the organisation and its business processes to the changing environment.

Institutionalisation of 'best practices' by embedding them in information technology might facilitate efficient handling of routine, linear, and predictable situations during stable or incrementally changing environments. However, when this change is discontinuous, there is a relentless need for continuous renewal of the basic premises underlying the 'best practices' stored in organisational workflow systems. The existing conceptualisation of traditional workflow management systems is devoid of such capabilities that are essential to the continuous learning and unlearning processes mandated by the continual and increasing pace of discontinuous change in e-business environments. A more proactive involvement of human imagination and creativity (March, 1971) is needed to facilitate greater internal diversity of the enterprise that can match the variety and complexity of the new e-business environment.

Paradoxically, it has also been suggested that an enterprise capacity for knowledge creation may even become impaired by excessive reliance on IT-based workflow management (Gill, 1995). It has also been argued that such solutions often specify the "details of machinery" while disregarding how people in organisations actually go about acquiring, sharing and creating new knowledge: "they glorify IT-automation and ignore human psychology" (Davenport, 1994). Based primarily upon a static and 'syntactic' view of workflow management, such solutions consider only a partial perspective of the organisational knowledge creation process.

By considering the meaning of knowledge as "unproblematic, predefined, and pre-packaged" (Boland, 1987), traditional workflow approaches turn to focus on the work processes and information processing view of an organisation's strategy and ignore the human dimension of organisational knowledge creation (Manville & Foote, 1996). Such restricted perspectives of the IT-enabled organisational workflow management, which focuses on IT and which does not use IT to model human intelligent may even, have detrimental influence on the firm's learning and adaptive capabilities (Drucker, 1994; 2000). This technology driven perspective is increasingly problematic given the dynamically changing e-business environments that demand multiple interpretations of information, as well as their ongoing evaluation. The alternative approach of workflow management – based upon the synergy of innovation and creativity of humans and the advanced capabilities of information technologies – delineated in this research, seems to ameliorate the weaknesses inherent in the mechanistic nature of the work processes and information perspective of traditional workflow systems.

Traditional workflow approach is increasingly inadequate in the internet or e-business era that is often characterised by an increasing pace of radical and unforeseen change in the e-business environment (Kalakota & Robinson, 1999, 2001). The new e-workflow (Internet-mediated-workflow) era characterised by rapid, dynamic and discontinuous change requires continual reassessment of organisational work processes and routines to ensure that organisational decision-making processes, as well as underlying assumptions, keep pace with the dynamic changing e-business environments. This issues poses increasing challenge to e-workflow designers as 'best services' of the departed yesterday –turns into 'worst practices' and core competence turns into core rigidities (Malhotra, 2000). The handling of exceptional situations also presents a significant challenge to designers of Workflow Management Systems (WFMSs).

The turbulent e-business environment, characterised by dynamically discontinuous change, requires a re-conceptualisation of the work process and information processing views, as they have been understood in conventional workflow systems practice and research. One such conceptualisation is proposed in this research in the form of a conceptual framework for knowledge enhanced e-workflow systems for business model innovation. A key contribution of this research is to address the critical process of creating new knowledge and renewal of existing knowledge and to suggest a conceptual framework for better representation and design for knowledge enhanced e-workflow systems (Internet-mediated-workflow). It is envisaged that application of the proposed framework and methods will facilitate the development of e-workflow systems that are knowledge-aware and better suited for competitive advantage in the new e-business environment characterised by dynamic, discontinuous and radical pace of change.

1.3 Issues and motivations

This section explains the issues and motivations of this research by firstly, presenting a hypothesis, secondly, explaining some questions and ambiguities with existing workflow management approaches, and finally describes what needs to be done in order to tackle some of these questions and ambiguities

Hypothesis: *The proposed framework, which integrates knowledge management techniques in the form of workflow design patterns and human cognition from a knowledge repository can be used for the modelling, design, evolution and* *development of complex e-workflow systems in the global, digitised and knowledge economy.*

It is this hypothesis that has driven the work undertaken in this research.

Research needs to be done in the premise of workflow management, because of new questions and ambiguities that have emerged in industry and academia. The first ambiguity is the confusion that exists around workflow management. To understand the nature of workflow management and the impact it has on organisations, most researchers subscribe to the claim that elements from organisational science and computer science are necessary.

Conceptual research can help to resolve ambiguities. The practical value of the nature of such research is to prevent delays that are experienced in many first-time workflow projects (Joosten, 1994). Software vendors have been influential in making workflow the hot topic, which it is today. Successes obtained in redesigning business processes using workflow technology have convinced many that the idea of workflow management is around to stay. The field is still dominated by software manufacturers, which explains why we have an abundance of commercially available tools but a lack of theory (Joosten, 1994). As a consequence, many organisations have difficulties to understand the concepts, the impact and the technology of workflow.

Another ambiguity is to integrate achievements in very different related fields of research. Workflow management is a truly multidisciplinary field, in which many researchers from different disciplines find opportunities to achieve their research objectives. For example, the technological integration required in workflow systems offers real-life opportunities to validate new database architectures such as (Miller et al., 1996). Also the business integration, which is aimed for by workflow management, offers opportunities to try out formerly unimaginable organisational structures i.e., Virtual corporations. As a final example, research directed towards understanding the nature of human work is given a new instrument to observe work in distributed and collaborative groups.

Furthermore, workflow management requires existing disciplines to stretch their boundaries of research. For instance, much of the current research in database transactions is inspired by research questions that emerge from workflow tool architectures. Also, research both in electronic data interchange (EDI) and the Internet has taken a new dimension because workflow management systems offer the platform in which these technologies have found a destination. Research in knowledge-based systems (KBS) is promising in the sense that the process knowledge that is stored in a workflow management system can be exploited and re-used to provide assistance to workflow designers, developers, users and executives in a workflow application development process. These examples do not involve new research ideas, but they show how existing boundaries are stretched by the ideas of workflow management.

Methodological research is needed because the analysis and design of workflow processes poses new challenges, unforeseen in existing methods of information systems analysis and design. Organisational research is also needed because workflow management technology is reported to have a great impact on operations, tactics and strategy of the organisation.

More specifically, knowledge is interpreted in terms of potential for action and is distinguished in the following discussion from information in terms of its more immediate link with performance. Knowledge resides in the user and not in the collection of information. It is how the user reacts to the collection of information that matters (Malhotra, 2000). The confusion between knowledge and information has caused managers to sink billions of pounds into IT investments that have often yielded marginal results. There is no direct link between IT expenditures and the firm's organisational performance. This could be attributed to an economic transition from an era of competitive advantage based on information to one based on knowledge creation (Malhotra, 2000).

Another issue that is being addressed is that of workflow conceptual modelling techniques through generic workflow modelling, design specification and reuse. Reuse usually implies software reuse but this research will address reuse at the business knowledge level as oppose to software code reuse. The principles and work of software development for and with reuse will be drawn upon in this research. There is an understanding that application areas (or domains) have much in common, and there is a need to exploit this commonality therefore avoiding arbitrary duplication. Such ambiguities justify the theme of workflow management as a research topic.

A final motivation for researchers to work on this theme is to fulfil some un-kept promises. The idea of the paperless office, discarded one or two decades ago as utterly unrealistic, has gained new credibility because document imaging systems, powerful data communication networks, and workflow technology are all available and affordable. The idea, which was originally launched in the seventies, has been revived with the advent of practical workflow solutions.

1.4 Research aim and objectives

The aim of this research is to develop a new knowledge enhanced framework and methods for the design and development of e-workflow systems adapted to the new e-business environment. To achieve this aim, the following objectives will be undertaken:

- Review the existing frameworks, methods, techniques and approaches, which are being adopted for the development and implementation of workflow management systems.

- Develop a novel knowledge enhanced framework for the development of e-workflow systems adapted to the new e-business environment to overcome shortcomings.

- Develop a knowledge repository and mechanism for storage and retrieval of design of process related knowledge.

- Develop a method within the proposed framework that can be used as a guideline for the development of e-workflow systems adapted to the new e-business environment.

- Use quantitative and qualitative techniques to evaluate the proposed framework and methods.

- Use the results of web-based questionnaire to verify the proposed framework and methods

1.5 Research methods

The research method in this study will be a contemporary comparative multi-method (triangulation) using both quantitative and qualitative research methods. One of the primary aims of this research is to review and compare the current strategies and development approaches adopted by workflow developers, workflow users and workflow researchers in order to evaluate their strengths and weaknesses, and then to define a knowledge enhanced framework for the development of adaptive e-workflow systems that builds on the strengths to address some of the weaknesses.

An extensive search of the literature suggests that the limited amount of workflow research has tended to focus on technical issues, rather than organisational and commercial issues (Georgakopoulos et al., 1995; Stohr and Zhao, 2001). It was therefore decided to undertake a quantitative and qualitative study, targeting workflow developers, users and researchers. The main objective for the choice of multi-method approach in this research was to obtain accurate facts by using different data collection methods in parallel, so as to crosscheck the validity of findings and thus test and verify more rigorously the hypothesis. In addition the following reasons have influenced the choice of multi-method.

Black (1993) suggested that social sciences seem less able to achieve a coherent approach to research than other academic fields. He considers the reason to be that social science research involves many variables, which are impossible to control, and there is a general disagreement about underlying theories and appropriate methods of gathering information, measuring instruments, research tools and approaches. According to (Avgerou, 1989), the study of information systems in general, and workflow engineering in particular, is a new discipline, still searching for its conceptual identity.

In this study the dilemma was if this research project would generate theory or verify theory. Glaser and Strauss (1968) argued that generating theory goes hand in hand with verifying it despite the fact that many see generating theory as secondary. This research work, attempts to verify a number of theories in relation to Workflow Management Systems. Consequently the contribution of the research would be to generate a theoretical knowledge enhanced framework and methods for the design and development e-workflow systems adapted to the new e-business environment characterised by complex, unpredictable and discontinuous e-business processes.

A multi-method approach comprises the use of several data collection techniques used in a parallel sense in an organised manner in order to provide multiple data sets with overlapping information regarding the same phenomenon (Brewer and Hunter, 1989; Sawyer, 2000). A multiple method of data collection is especially useful in organisational studies where a broad level of analysis that spans the whole organisation is needed (Kaplan and Duchon, 1988; Kling and Scacchi, 1982; Sawyer, 2000). Researchers have particularly used the combination of fieldwork and surveys in order to integrate different perspectives (Kaplan and Duchon, 1988; Wynekoop, 1992).

The combination of fieldworks and surveys, as observation and/or interviews with surveys and archival investigation is used in order to draw on the strengths of the combination of data collection methods (Gallivan 1997, Jick, 1979). Brewer and Hunter (1989) consider that multi-method approach is not just an aggregation of styles but also a new method and the most obvious advantages in combining quantitative and qualitative research methods are crosschecking of validity of findings and the access to different levels of reality (Jick, 1979).

A multiple method of data collection is carried out by using a set of data collection methods that surrogate each other's limitation (Siakas, 2002). The importance of multi-method approach is that techniques are used in parallel in order to check the accuracy of each set of results and for comparing data from two or more different methods or techniques in order to provide overlapping information. Usually this involves comparing quantitative and qualitative data in an intertwined way. The multi-method approach is also called triangulation (Gallivan, 1997; Johns and Lee-Ross, 1998). Similarly Ragin (1989) suggested that the linking of intensive and extensive work is a key to a healthy and vibrant comparative social science, because it provides a way to comprehend differences and similarities among many cases in a coherent framework.

Sawyer (2000) also differentiates between intensive and extensive work. Intensive work examines many variables in few cases (qualitative research), while extensive work examines few variables across a large number of cases (quantitative research). Contemporary research, according to Orlikowski and Baroudi (1991) embraces a great variety of research perspectives that operate concurrently. In this research such perspectives involve disciplines concerned with human phenomena such as organisational behaviour and management theories (knowledge management), as well as Information systems in general and workflow management issues in particular, such as methodological approaches to e-workflow application development projects, level of organisational support in e-workflow projects etc.

1.5.1 The research instruments

The research method proposed in this study is the comparative multi-method comprising of quantitative and qualitative investigation. The *quantitative investigation* in this research consists of a survey collecting hard data using web-based questionnaires. The quantitative analysis argumentation appears to be both precise and hard based on numbers and rigorous, statistical relations between the numbers. A qualitative investigation will be performed in parallel with the quantitative investigation in the form of action research case studies in order to address different aspects of the research problem, to confirm the findings from the questionnaire and to test the hypothesis.

Cornford and Smithson (1996) argue that considerable additional insight can be gained by combining quantitative and qualitative approaches. In this study the survey is considered to be a feasible means of providing data with sufficient validity, and the crosschecking by case studies (action research) is considered to ensure a valid result.

A combination of methods will be used to analyse the data. Spreadsheet package and manual techniques will be employed to calculate frequencies and descriptive statistics. These will be displayed using tables and bar charts. The results from the survey and the experience or lessons learned from the action research case study will constitute an invaluable input for both strategic adaptation and workflow design, and also to improve the proposed framework and methods.

1.6 The need for better workflow management

The need for better Workflow management in Intra/inter-organisational applications development can be examined by means of the following questions:

- Why is workflow suitable for the purpose of Intra/inter-organisational application development?
- Why and how does the Internet world-wide-web (WWW) technology complement the WFMS technology?

To begin with, let us consider the first question. An e-workflow application development project usually involves a number of work processes or activities that are executed by different organisations, which are geographically dispersed in terms of time and location. At any time, different organisations that are involved in shared business process (composite business process) may work on their own tasks, which are interrelated to one another. The decision made by one organisation may have significant impacts on those of another organisations involved in the shared business process. To prevent inconsistency and redundant activities, organisations using workflow products must collaborate effectively and efficiently and product activities must be well coordinated. Moreover, workflow technology has been promoted as a model of coordinating and collaboration among different work parties, especially when information systems are extensively used. Van Leeuewn (1977) identifies several possibilities of coordination such as output coordination, process and activity coordination, control coordination, and resource coordination.

As a result, the technology has been implemented in different business domains such as insurance, banking, healthcare and office automation. However, the technology has not yet been fully investigated for its potential as a model for Internet workflow applications. Nevertheless, many attempts have been made in the field of product design and manufacturing (Brockman, 1995). We have now reached a point where existing implementations of workflow systems do not suffice the future needs of tomorrow's turbulent e-business environment. Workflow systems cannot be extended to add new services and functionalities in an appropriate manner and they cannot cope with the high dynamics of the business processes and business environment constituting them. This inflexibility is caused by the following characteristics of existing workflow systems (Jablonski, 1995):

Existing workflow systems are mostly implemented as monolithic applications. Since their components are mutually interrelated, modifying them is difficult to accomplish without producing inconsistencies. Modifications are also cumbersome due to the lack of a comprehensive description (model) of the workflow system. Such a model demonstrates the structure of the system, which would ease modifications. Re-designing a business, i.e. reengineering its *business processes*, is the most significant and vital task in order to move from old-fashion workflow systems to a new generation of e-workflow systems. Such new systems integrate large amount of information services, which are scattered or distributed over a wide area network such as the Internet and support cooperation and collaboration among them. They are able to integrate legacy and new system components, are modifiable, and reflect the high dynamics of today's business processes.

In the context of business process reengineering, new technologies for the execution of business processes are needed to support systems dynamics, customisation, and integration as claimed above. Workflow management promises to provide a suitable infrastructure for the execution of business processes in a distributed environment. However, not all kinds of business processes are suitable for being executed in a WFMS environment. Totally unstructured processes, which can execute in a more or less arbitrary manner, are better suited for specialised groupware systems like Computer Teleconferencing (Ellis et. al., 1991), while WFM aims at the coordination of (semi-) structured processes. Basically, workflows can be characterised as executable images of business processes. Business processes describe and explain how a business is conducted; therefore, more business related terms are used in their definitions. Workflows are executable objects; therefore, exclusively technical terms must be used in their definitions. Such technical terms will not appear in the description of business processes. However, business processes and particularly their process related parts form an appropriate skeleton for the specification of workflows.

The above characterisation of workflow management systems and the fact that WFMS's are considered to provide the execution infrastructure for business processes reveals that workflow management systems do not just deal with single, isolated application systems but aims at the integration of multiple application systems and users which are distributed over autonomous and heterogeneous networks of computers. Due to the comprehensiveness of the WFM approach it seems to be rather risky to implement huge, multi-step, multi-user business processes without having examined them and without having checked their consistency against the actual way of conducting business.

Although it is a vital requirement, existing WFMS's still lacks sophisticated concepts, techniques, methods and tools to realise or implement them. Their simulation capabilities and optimisation tools merely deal with the improvement of workflows but not with the optimisation of the corresponding business processes. Until recently there were no generic tools to support business processes and workflow management. As a result part of the business process were hard-coded in the applications. This means that one application knows about the existence of another application. This is undesirable, because every time the underlying business process is changed, applications need to be modified. Furthermore, similar construct need to be implemented in several applications and it is not possible to monitor and control the entire workflow (Van der Aalst, 1998). Therefore several software vendors and researchers recognised the need for *workflow management systems*.

Let us now turn to the second question: why and how does the Internet world-wide-web technology complement the WFM technology? It has long been established that the Web-based user interfaces were not a novelty but a necessity for WFM systems to be competitive in the open marketplace (e-business environment) or stand the test of time. Undeniably, the web technology has been deployed in developing WFM systems. Miller et al. (1997) referred to a number of web-based or web-enabled WFM systems. Their work on WebWork highlights several advantages of the Web-based WFM such as the ease of development of workflow applications, installation and use. These have also been the main reasons why the author and several other researchers have chosen the Internet technology to complement the development of workflow in the field of service industries. If such workflows are to be coordinated, then Web technology is a natural choice.

1.7 Thesis organisation

This thesis is composed of five parts as follows. In Part One, chapter one is devoted to introduction of the thesis and chapter two introduces workflow and its basic concepts. The chapter also presents the historical evolution of workflow technology, background study relevant to our workflow research, electronic commerce scenarios and workflow automation and a review of some of the existing workflow analysis and process modelling methodologies and techniques. And finally, it presents the research work related to our research. Part Two focuses on the research proposals, chapter three introduces the proposed knowledge enhanced framework for the development of e-workflow systems, chapter four presents the proposed e-workflow knowledge repository and chapter five introduces the proposed e-workflow design and development methods. Part Three is devoted to the evaluation of the proposed knowledge enhanced framework, chapter six introduces the qualitative evaluation of the proposed framework and chapter seven presents the quantitative evaluation of the framework. Part Four is composed of two chapters; chapter seven is devoted to the experiments conducted with the proposed framework and chapter eight is devoted to the conclusion and future work. Part Five is devoted to references and appendices.

Chapter 2

Workflow: Background Study and Literature Review

Since this thesis is about workflow management, this chapter delineates what workflow is and its basic concepts. The chapter also presents the background study relevant to our workflow research, electronic commerce scenarios and workflow automation, and a review of some of the existing workflow analysis and process modelling techniques. Furthermore, the chapter also presents an overview of some research work in the workflow community that is related to the workflow research presented in this thesis. The next chapter presents the proposed knowledge enhanced e-workflow framework.

2.1 Workflow technology: Historical evolution

The workflow concept has evolved from the notion of process in manufacturing and the office. Such processes have existed since industrialisation and are products of a search to increase efficiency by concentrating on the routine aspects of work activities. They typically separate workflow activities into well-defined tasks, roles, rules, and procedures, which regulate most of the work in manufacturing and the office. Initially, processes were carried out entirely by humans who manipulated physical objects. With the introduction of information technology, processes in the work place are partially or totally automated by workflow systems, i.e., computer programs performing tasks and enforcing rules which were previously implemented by humans (Georgakopoulos et al., 1995).

Workflow management systems (WFMSs) are designed to automate entire work processes, rather than isolated tasks. It is believed that two technological evolutions have contributed to the development of workflow management systems. Early work in office procedure systems, such as SCOOP (Zisman, 1977) and OfficeTalk-D (Ellis & Bernal, 1982) are examples. In the beginning of the nineties, these early research prototypes which did not lead to any commercial products, were either directly adopted by industry e.g., (DOMINO → X-Window (Olivetti), OfficeTalk →

FlowPath (Bull) or strongly influenced the development of the current workflow systems (See figure C.1 on page 226 and C.2 on page 227 of Appendix C for history of workflow research). The concept of automating the transmission of documents from worker to worker in an organisation first arose as a necessary addition to imaging systems in early applications such as insurance claim processing (Sviokla & Elam, 1992). Development of image management applications rapidly led to the incorporation of routing and tracking for image documents. Developers and users of such applications quickly realised that the routing capability was an important component of managing their business processes, independent of the data being routed.

The first generation of workflow systems, during the 1980s and early 1990s, was to support the communication between office workers, while concentrating on document routing. The next generation of workflow systems put the business process in focus. By also involving automatic actors or agents, the automation of business processes could be facilitated further (Makey, 1996). Since that time, many commercial WFMSs have been introduced (Ader, 2000) and other technologies such as document managements, call centres, and enterprise resource planning systems (ERP) have also developed workflow capabilities. Like other information technology evolution, the architecture of WFMS has moved from mainframes, to client server architectures, and more recently to the Internet (Ziegler & Barnekow, 1997).

WFMSs deployment within an organisation holds the promise of significant process cycle time reductions, cost reductions, improve accuracy, greater control, and increase worker productivity and satisfaction and, as a result many organisations are now already using or actively evaluating the technology. The large amount of articles devoted to WFMSs in the trade and professional publications is perhaps a good indication of the high degree of interest in this new technology (Information Management & Technology, 1999; Document World, 2000).

Whilst the publications cited above indicates that WFMSs and the technology are likely to play an important role in the operations of the many large organisations in the near future, very little on the evaluation of their commercial potential has been published in the academic literature (Doherty, 1999). An extensive search of electronic bibliographies suggests that the limited amount of research to date has tended to focus on technical issues, rather than managerial, organisational or commercial issues (Chen & Hsu 2001; Georgakopoulos et al., 1995). Furthermore, "The Workflow Handbooks" (Lawrence, 1997, Fischer, 2003, 2004, 2005, 2006, 2007) have provided vital information for this research, despite primarily geared at specialist audience

2.2 Workflow: Definitions and basic concepts

This section presents some basic concepts of workflow. There are many different definitions of workflow from various authors and vendors of workflow management systems. For consistency our research follows the definitions put forth by the respected Workflow Management Coalition (WFMC, 1997). Workflow management is a fast evolving technology that is increasingly being exploited by businesses in a variety of industries (Molden, 2004). The primary characteristics of workflow management are automation of processes involving combinations of human and machine-based activities, particularly those involving interaction with IT tools and applications (Molden, 2004)

The Workflow Management Coalition (WfMC) defines workflow as: "*The automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules*" (Hollingsworth, 2004). Furthermore, they defined Workflow Management Systems (WFMSs) as: " *A system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications" (Hollingsworth, 2004).*

Workflow is therefore the automated process, whilst the workflow management system is the software that manages the automation of an integrated set of processes. A *business process* consists of a sequence of activities. It has distinct inputs and outputs and serves a meaningful purpose within an organisation or between organisations. An *activity* is a distinct process step performed either by a machine or human agent. Any activity may consist of one or more tasks. A set of tasks to be performed by a user (human agent or machine) in a workflow system is called a *worklist.* The worklist is prepared by the WFMS and displayed to the user on his/her screen. The individual tasks on the worklist are also called *work items.* The core terminology (Hollingsworth, 2004) of the WfMC is as shown in Figure 2.1 below.

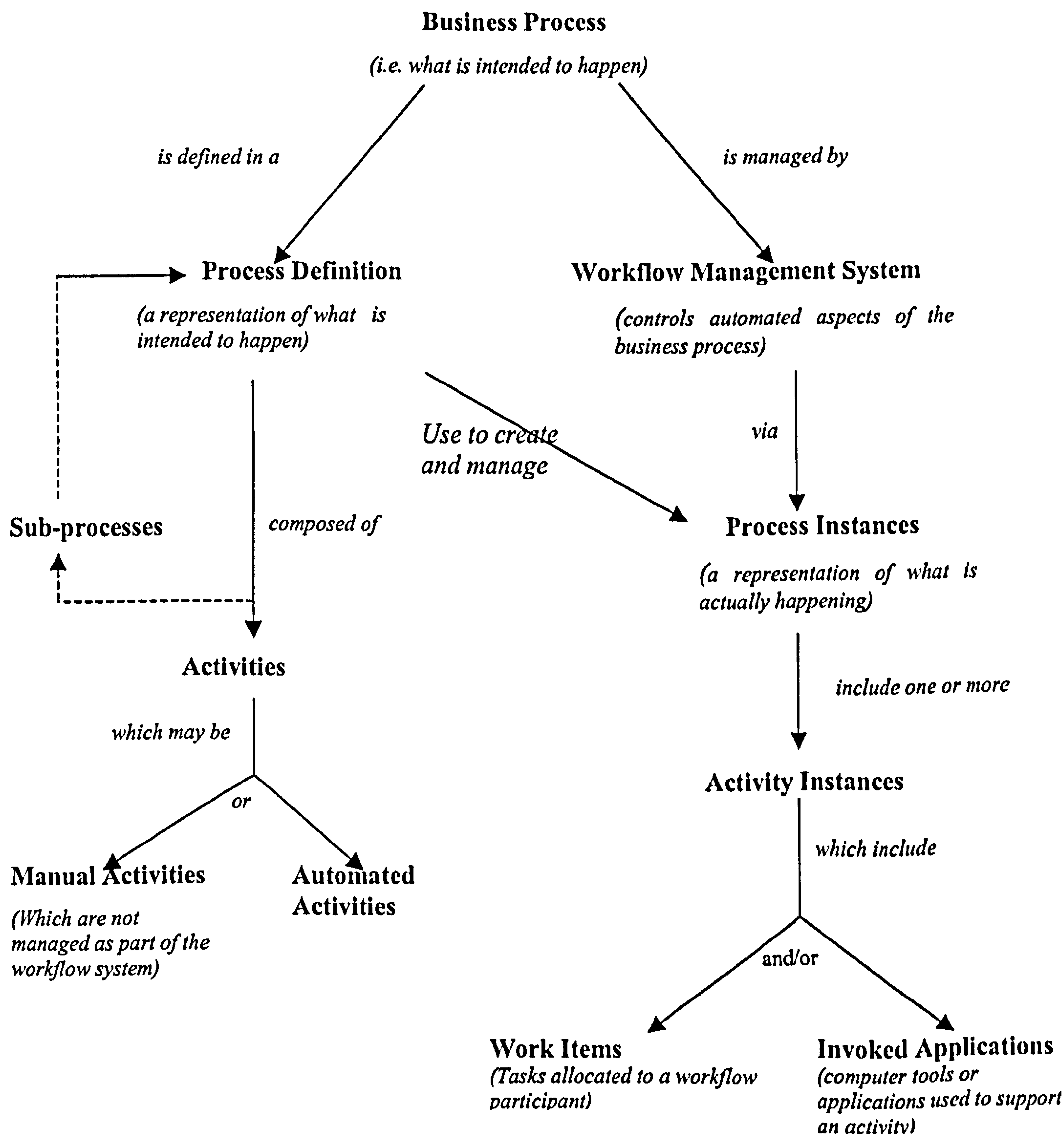

Figure 2. 1: WfMC Core terminology

Project management software shares many concerns with workflow systems (WFMC, 1997). A complex workflow structure as shown on figure 2.1 above is broken down into manageable tasks and assign to resources in a similar way to work breakdown structure (WBS) used in project management. The fundamental difference between the two is that project management software is not "live": it does not provide online software support for either the tasks which are required to complete the processes, or the flow of control between tasks in a process. Project management systems are concerned with models of processes rather than with direct run-time support for the process itself (WFMC, 1997).

One of the benefits of a workflow management system is its capability to separate the workflow logic from the logic of the applications that are used to automate or help workflow participants in performing specialised tasks. This allows application programs to act as independent computational units and greatly simplifies the task of enterprise integration. In particular, workflow management deals with modelling and controlling the execution of application processes in complex organisational and technical environments. Therefore, a workflow application is an information systems application whose process structure is modelled explicitly using a workflow modelling methodology and whose execution is under the control of a workflow management system. A workflow management application may use external applications such as spreadsheets, word processors, imaging systems, Power Points, databases and legacy mainframe applications that are invoked by the workflow management systems during workflow executions.

Workflow management systems (WFMSs) are qualitatively different from the traditional information systems in that they typically focus on the process, not the data that supports the process and, consequently, they have the potential to change greatly the way in which people work and interrelate with another. The trade press often makes a distinction between three types of workflow software (McCready, 1992): *production, administrative and ad hoc workflows.* These types of workflows are often expressed along the following dimensions (Georgakopoulos et al., 1995): Repetitiveness and predictability of workflows tasks, and also how the workflow is initiated and controlled, e.g., from human-controlled to automated workflow.

2.3 Function-oriented and process-oriented organisations

Most organisations have traditionally been organised by functional divisions, i.e., companies have been separated into departments such as manufacturing, marketing, sales, account, production, purchasing, engineering and human resources or personnel. This practice continues: human, physical, and financial resources are often managed by function, and most coordination is intra-functional rather than inter-functional, see figure 2.2 below.

However, the traditional functional organisation has been seen to have a number of problems. One effect of this is that employees belonging to one functional unit start thinking in a narrow manner concerning only their own functions. They no longer have the company as a whole in mind and therefore build organisational barriers between them and other functional units. This leads to a lack of communication between the various functional units and employees, slower working patterns and more intensive administration (WFMC, 1997).

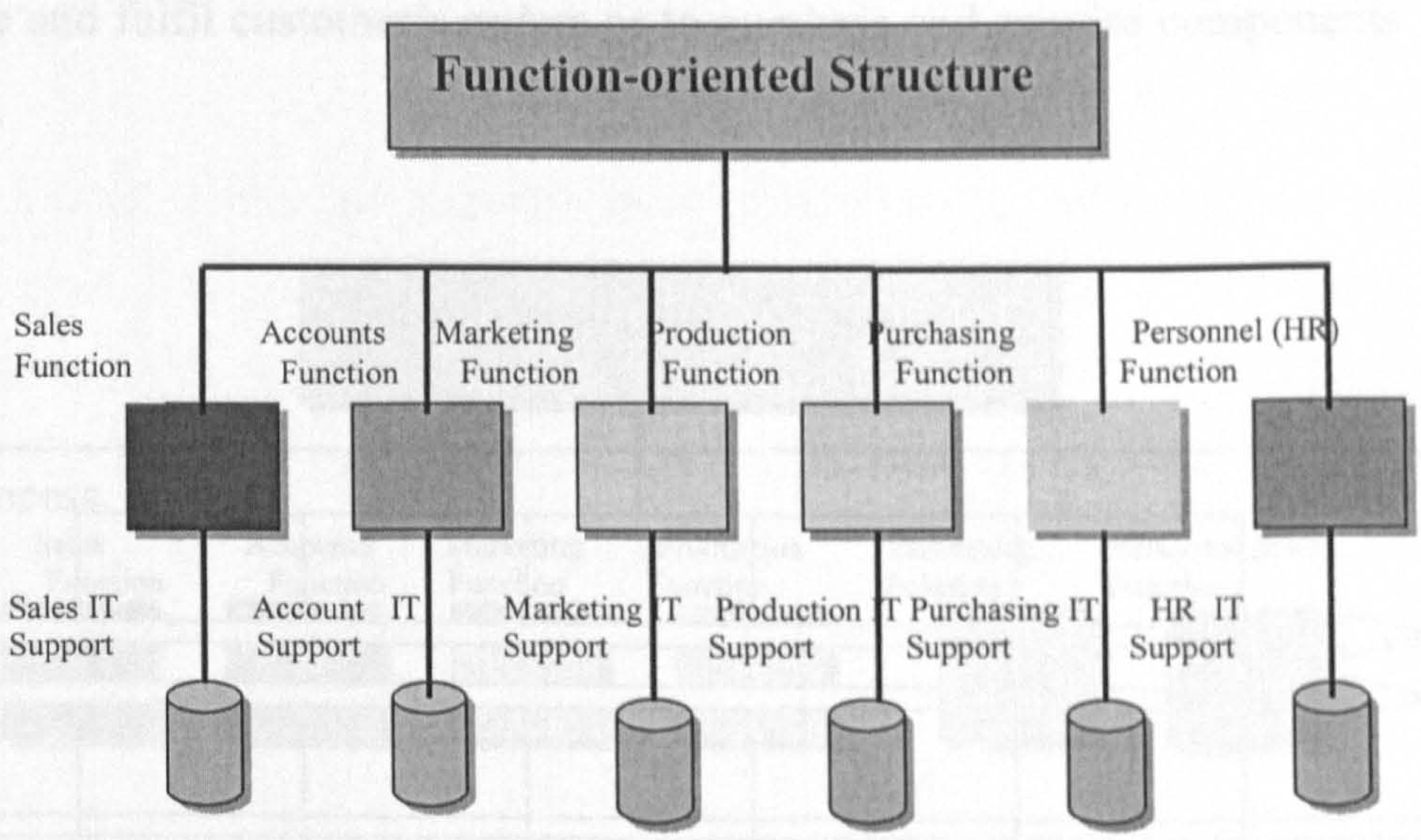

Figure 2. 2: The traditional function-oriented organisation with business functions and IT support

(Adapted from Johannesson & Perjons, 2001)

In particular, it requires a huge administrative effort to deal with issues crossing functional boundaries, and considerable resources are allocated to tasks that do not create value to the organisation. Furthermore, in most traditional organisations the applications have been built around the different departments or functions, i.e. marketing function has built up its own IT system with specially designed marketing applications, while production function has another IT system, containing other kinds of applications, and so on. The end result has been an association or relationship between the functions and the applications, where every function in the organisation is supported by its own applications, which do not communicate well across the functions in the organisations see figure 2.2 above. However, many organisations are discovering that they must also manage their business processes – such as purchase order, new product development and inter-organisational supply chain management – that span their separate functional units and that integrate their activities with those of other organisations or business partners (Basu & Blanning, 2000).

To overcome the weaknesses of the traditional functional organisations, contemporary e-business organisations have turned to focus on their business processes see figure 2.3 below. In order to get work done, every organisation creates and aligns specific sequences of tasks to achieve particular purposes. For example, a substantial number of related tasks must be executed in a specific sequence in order to receive and fulfil customer's orders or to purchase and acquire components from suppliers.

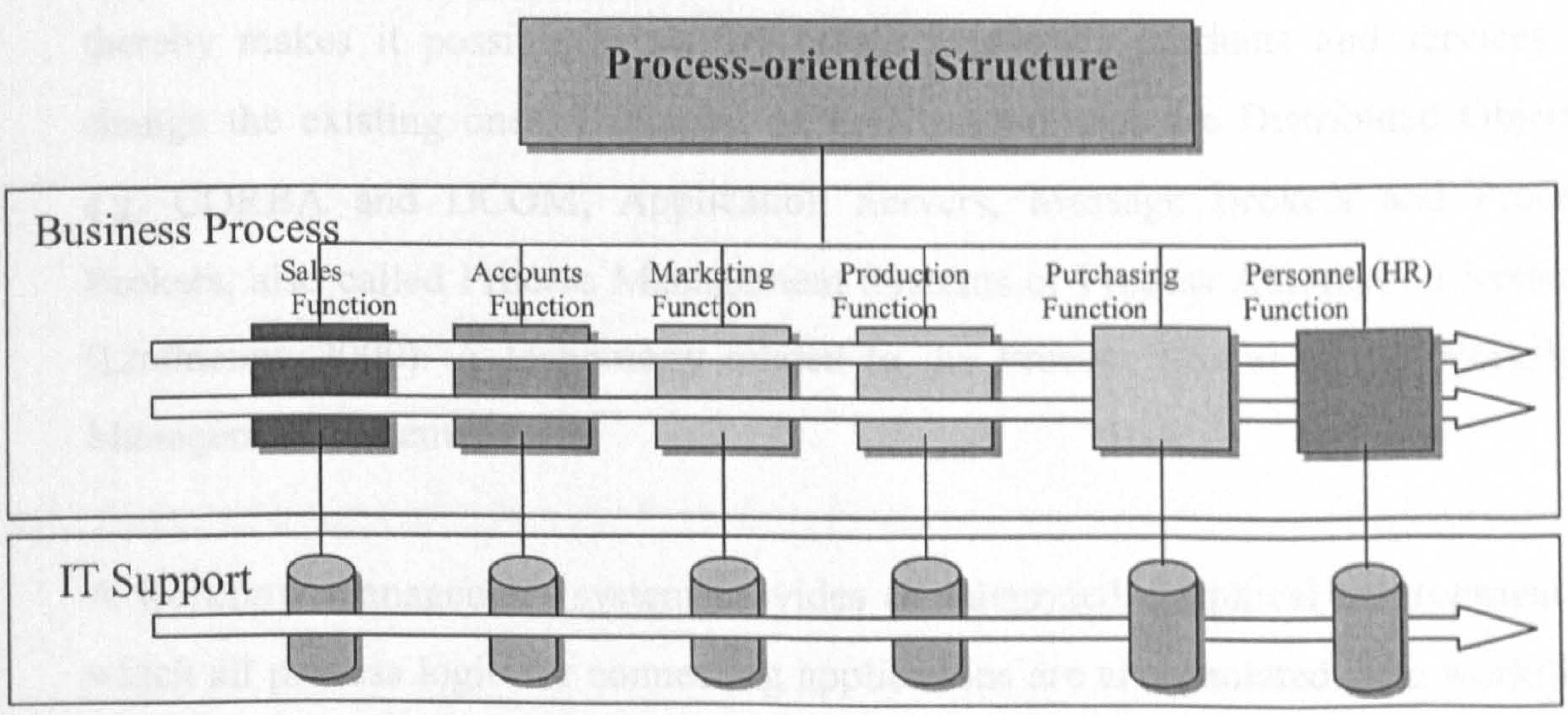

Figure 2. 3: The process-oriented organisation, which requires an integration of the IT systems (adapted from Johannesson & Perjons, 2001)

When a number of tasks cumulate to constitute the execution of some substantial organisational (or business) requirement, they are commonly referred to as a business or organisational process (Hammer, 1996). In this spirit (Davenport & Prusak, 1998) asserts that "processes are the structures by which an organisation does what is necessary to produce value for its customers." These processes span the functional boundaries of an organisation and sometimes even reach the boundaries of other organisations (Wirtz et al., 2001). An emphasis on business processes places the customer in the centre, and when customers request for new products and services, the organisation can meet this requirements by adapting its business process accordingly. In order to handle frequent adaptations, the enterprise needs flexible and integrated applications.

As a response to this needs, a new breed of middleware technology has emerge, Enterprise Application Integration (EAI), which strives at integrating individual applications into a seamless whole, enabling business processes and data to speak to one another across applications, (see Figure 2.3). EAI makes it possible to connect Enterprise Software Packages to legacy systems and create extended supply chains involving applications of customers, business partners and suppliers, through the Internet World Wide Web (Johannesson & Perjons, 2001).

EAI also makes it possible to adopt new applications in a flexible manner and thereby makes it possible to swiftly create innovative products and services or change the existing ones. Examples of EAI technologies are Distributed Objects, e.g. CORBA and DCOM, Application Servers, Message Brokers and Process Brokers, also called Process Management Systems or Process Automation Systems (Linthicum, 2000). A technology related to the Process Broker is the Workflow Management system.

A workflow management system provides an integrated, graphical environment in which all process logic for connecting applications are encapsulated. The workflow management system enables workflow users to visualise, design, analyse, simulate and execute business processes for application integration. Processes must be adapted to meet specific circumstances, such as legal requirements or negative response to new products (Nunes et al., 2009). The specific collection of tasks, resources and information elements involved in each such circumstance comprises a workflow.

Several persons will be associated with the management of a process and their workflows (Hammer & Champy, 1993; Hammer, 1996). Senior executives need to understand what information objects (documents) are required and produced by a business process and what resources are needed. Process managers need to understand how the tasks in each workflow interact with each other through the information objects they use and produce. Information technology managers need to understand how information objects, tasks, and resources interact, so that effective operational and decision support systems can be designed.

This suggests a need for modelling processes in a way that facilitates identification and analysis of their component workflows (Basu & Blanning, 2000). To deploy workflow management technology for application integration in e-business environments involves a complex design activity. Therefore, it requires adequate methodological support by introducing a number of strategies and principles for the design, validation, adaptations and presentation of various process models aligning the applications of an organisation to its business processes.

2.4 Workflow standards

The Workflow Reference Model (WRM) describes the architecture for automating workflow in business processes as depicted in Figure 2.4 below. This model was first proposed by the Workflow Management Coalition (WfMC), which started in 1993 as a voluntary organisation whose main objectives are to promote workflow technology through the establishment of standards for software technology, interoperability and connectivity between workflow products. Although the intent of the model was to set a standard for interoperability of disparate workflow systems, the model also represents the vision of a new Information technology application development environment.

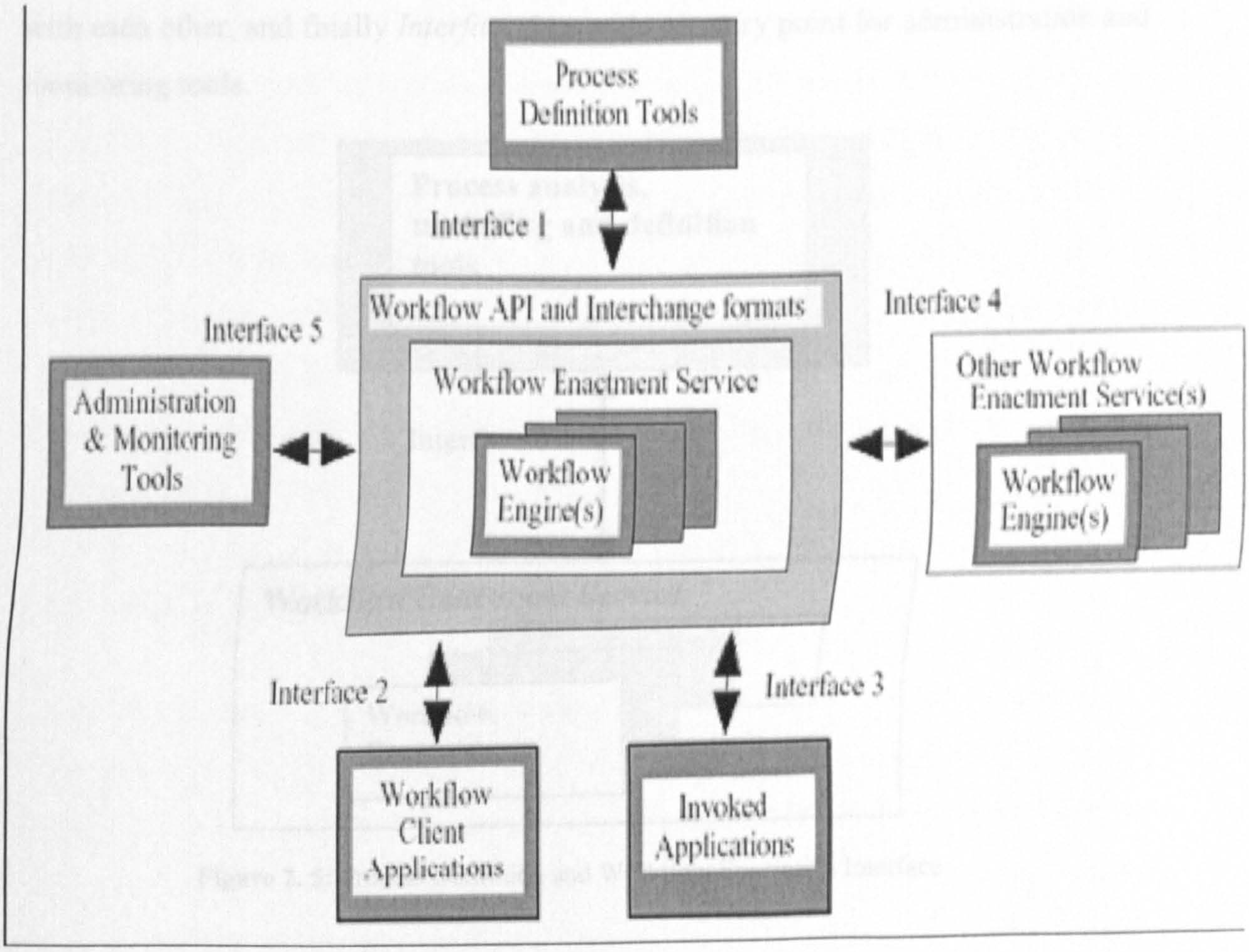

Figure 2. 4: Workflow Reference Model - Components & Interfaces
(Source: Hollingsworth, 2004)

The workflow engine shown at the centre of the figure, contains the logic necessary to spin new business process instances in response to triggering events, execute routing logic, determine the human or software agents to perform each of the process activities, route documents to the selected agent, generate and maintain a menu or "work list" of tasks to be performed by each human agent, maintain security, and log all activities. As shown in Figure 2.4, the WfMS engine provides five standard Workflow Application Program Interfaces (WAPI's) by means of which it interacts with the external world. The specific details of these interfaces are described in (Hollinsworth, 1994).

However, in summary, *Interface 1* defines a common format for the interchange of static process specifications; *Interface 2* enables workflow participants to control process execution and manipulate work items; *Interface 3* provides access to the workflow applications; *Interface 4* enables different workflow servers to interact with each other, and finally *Interface 5* provide an entry point for administration and monitoring tools.

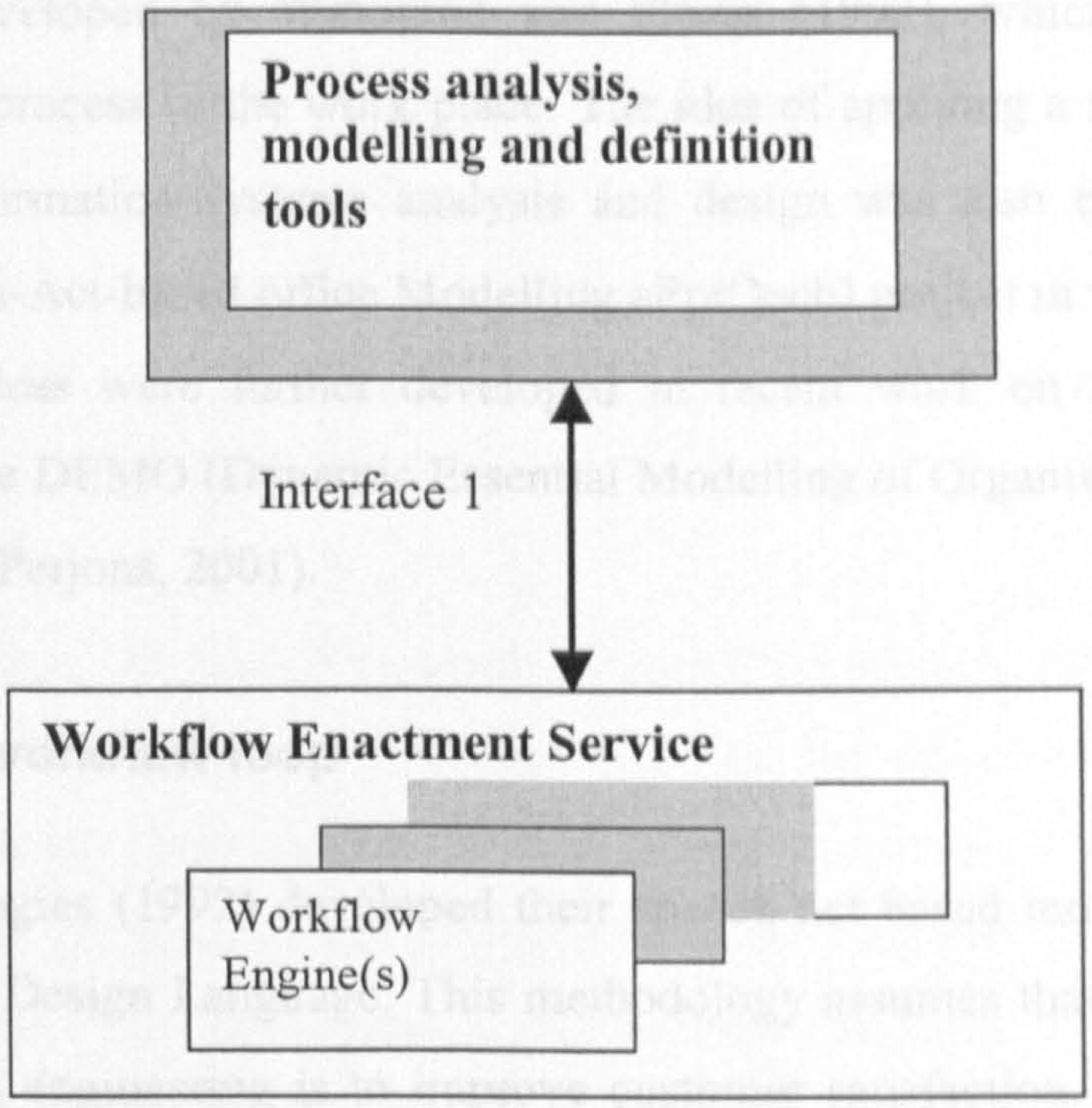

Figure 2. 5: Process Definition and Workflow Enactment Interface

For the purpose of this research we are focussing on *Interface 1*, namely process definition tools and the workflow enactment service as shown in Figure 2.5 above. The interface between the process analysis, modelling and definition tools and the runtime workflow management software, is commonly, termed the process definition import/export interface.

2.5 Methodology and language for workflow specifications

A number of languages and methodologies for workflow process specification and design have been proposed. A distinction can be drawn between communication-oriented and activity-oriented methodologies.

2.5.1 Communication-based methodologies

A communication oriented language, focuses on communicative processes describing the interaction between people and systems in terms of sending and receiving messages, which provides an opportunity to support the communication by means of information technology (Winograd, 2006). Communication oriented languages have been heavily influenced by speech act theory (Searle, 1969). One of the first systems based on communication and speech act oriented approach was the Coordinator, developed by Winograd and Flores (1992), which supported the communication process in the work place. The idea of applying a speech-act-based approach to information systems analysis and design was also employed by the SAMPO (Speech-Act-based office Modelling aPprOach) project in the middle of the 1980s. These ideas were further developed in recent work on Business Action Theory and in the DEMO (Dynamic Essential Modelling of Organisations) approach (Johannesson & Perjons, 2001).

2.5.2 Action workflow loop

Action Technologies (1992) developed their speech act based modelling approach within Business Design Language. This methodology assumes that the objective of business process engineering is to improve customer satisfaction. It reduces every action in a workflow to four phases based on communication between a customer and a performer as shown on Figure 2.6.

1. ***Proposal*** - a customer request (or the performer offers) completion of a particular action according to some stated conditions of satisfaction.
2. ***Negotiation*** - the customer and the performer comes to a mutual agreement on the conditions of satisfaction, including the times by which further steps will be taken.

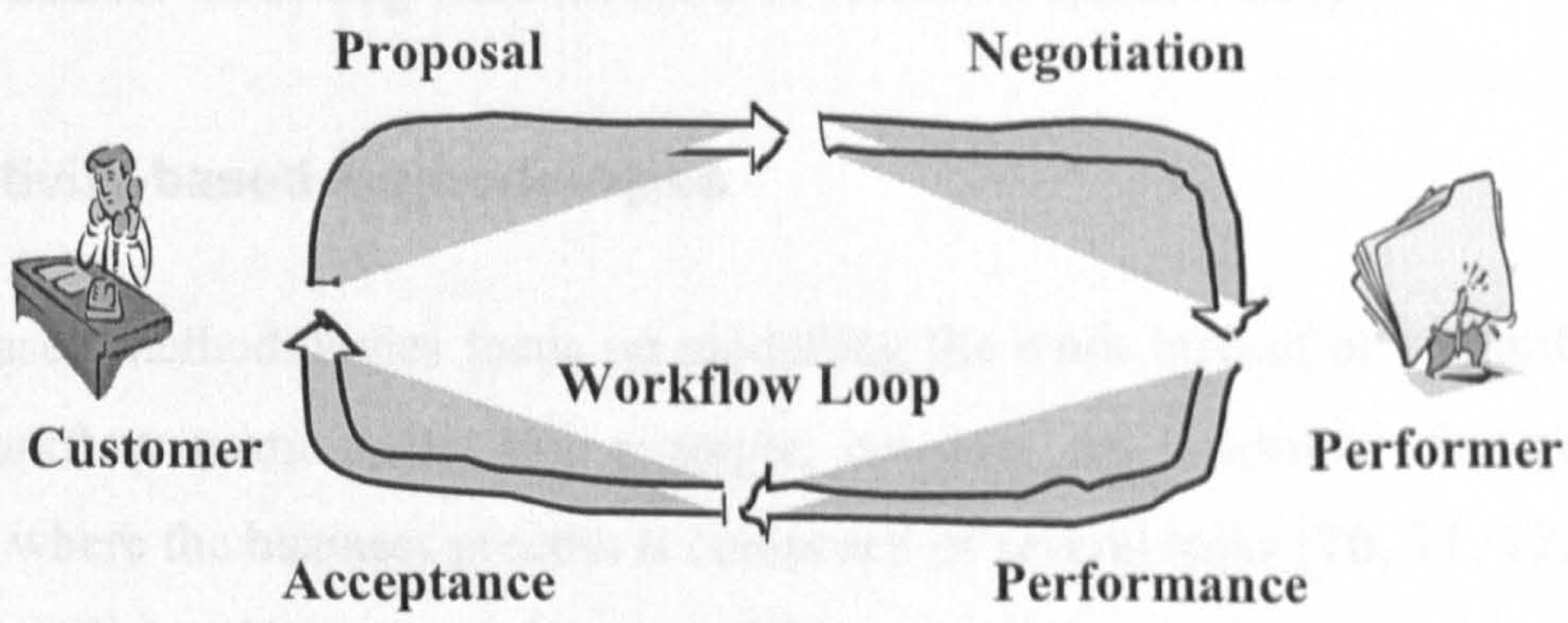

Figure 2. 6: A Basic Action Workflow Loop

3. ***Performance*** - the performer declares that the action is completed according to the terms established.

4. ***Acceptance*** - the customer reports satisfaction (or dissatisfaction) with the action.

Each *workflow loop* between a customer and a performer can be connected with other workflow loops to complete a business process. The performer in one workflow loop can be the customer in another workflow loop. The resulting business process reveals a social network in which a group of people, filling various roles, fulfils a business process.

Workflow specifications using this methodology do not indicate which activities can occur in parallel or if there are conditional or alternative actions. Since this methodology assumes that the objective of business process re-engineering is to improve customer satisfaction, the emphasis is on the customer. However there are business processes where the emphasis may be superficial, e.g., if the objective are to minimise applications development cost or reduce waste of material in a process. Therefore, this methodology is not suitable for modelling business processes with objectives other than customer satisfaction (Georgakopoulos et al., 1995). The key difference between other traditional workflow approaches and the Action Workflow Loop is the shift from task or information flow oriented action coordination to request and commitment oriented action coordination. That is, business processes are modelled as networks where different Action Workflow Loops are connected by links at different phases of the loops. See (Madina-Mora et al., 1992) for more details of business modelling with networks of Action Workflow Loops.

2.5.3 Activity-based methodologies

Activity-based methodologies focus on modelling the work instead of commitment among workflow participants. For example, consider the workflow depicted in Figure 2.7 where the business process is composed of several tasks (T0, T1, T2, T3). The arrows indicate the sequential nature of this process map.

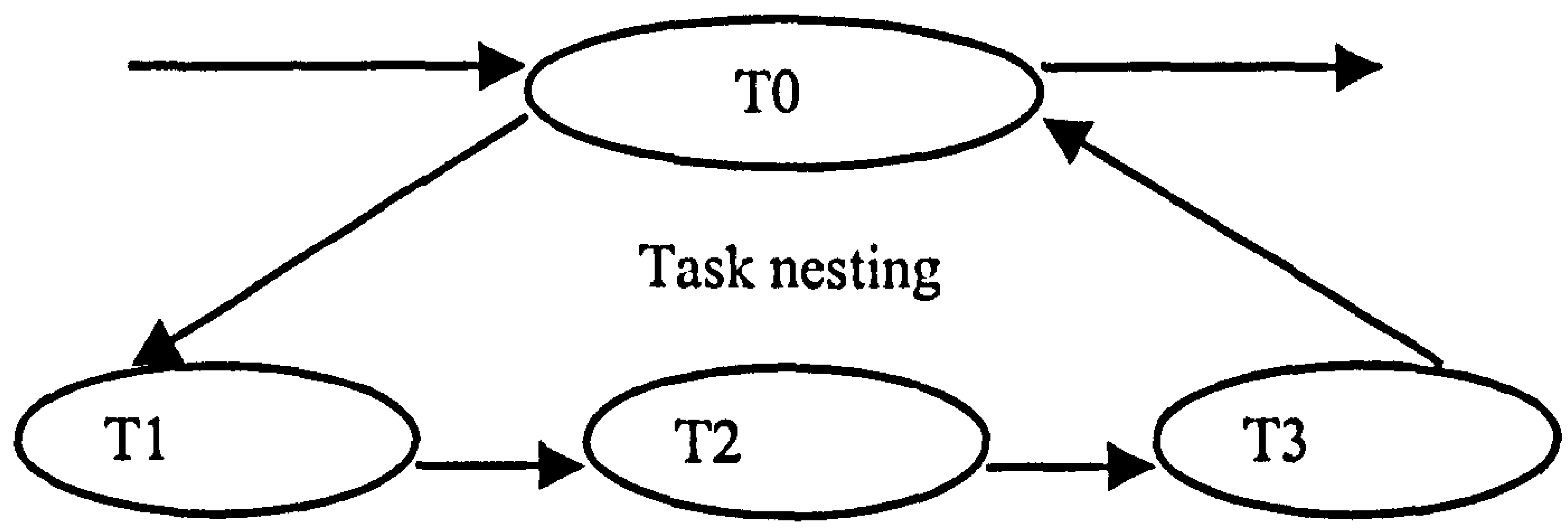

Figure 2. 7: Activity-based workflow

Note that a task in one workflow may be a sub-task in another workflow, and that tasks may nest arbitrarily deeply. Unlike communication-based process modelling languages, activity-based process modelling languages do not capture business process objectives such as customer satisfaction. Many commercial WFMS provide activity-based workflow models. For example, in the workflow model supported by InConcert (McCarthy & Sarin, 1993), workflows (referred to as jobs) consist of tasks. Each task may comprise several sub-tasks. Each task has dependencies on other tasks at the same level and has an assigned role, which can either be a human or computer program (software agents) that performs the task.

GTE's RAPID methodology (Eckerson, 1994) is also activity-based. RAPID provides two workflow models: a high level model for performing conceptual business process analysis and a lower-level model describing the corresponding information process. In the high-level workflow models, workflows (referred as process maps) contain tasks (referred to as steps) necessary to perform a particular business process. These steps can be partially or totally ordered as necessary to indicate alternatives or parallel execution of business steps or policies. The communication-based and activity-based workflow models can be combined when business process re-engineering objectives are compatible with both models (e.g., satisfy the customer by minimising workflow tasks and human roles).

2.6 Workflow specification

There is no universally accepted basis for workflow specification languages, each workflow application imposes its own language based on the domain of application which can be based on directed acyclic graphs, rules, finite state machines, Petri-nets or any other formalism. In general, it is common practice to program workflows visually as a directed graph where the nodes represent activities and the arcs represent control and data flows between activities.

The development of methods came as a result of intensive and extensive search for solutions to eradicate some of these problems e.g., product cost reduction and quality enhancement (Lawrence, 1997). Most of the methods concentrated on technical aspects, neglecting the enterprise structure and culture consequently ignoring the users needs. The latest promise comes in the form of Object-Oriented methods, which are believed by many to be a panacea to all the problems of information technology (Coad & Yourden, 1996).

Figure 2.8 below depicts some of the existing process and data modelling techniques, which can be used to support the conceptualisation of business transactions for workflow specifications. One of the critical issues towards the development and implementation of workflow management systems, as can be seen in traditional information system development is its conceptual model.

To be in line with the well-established conceptual modelling principles, the specification of workflow process models representation or (surface-structure) should be separated from the implementation level (physical structure).

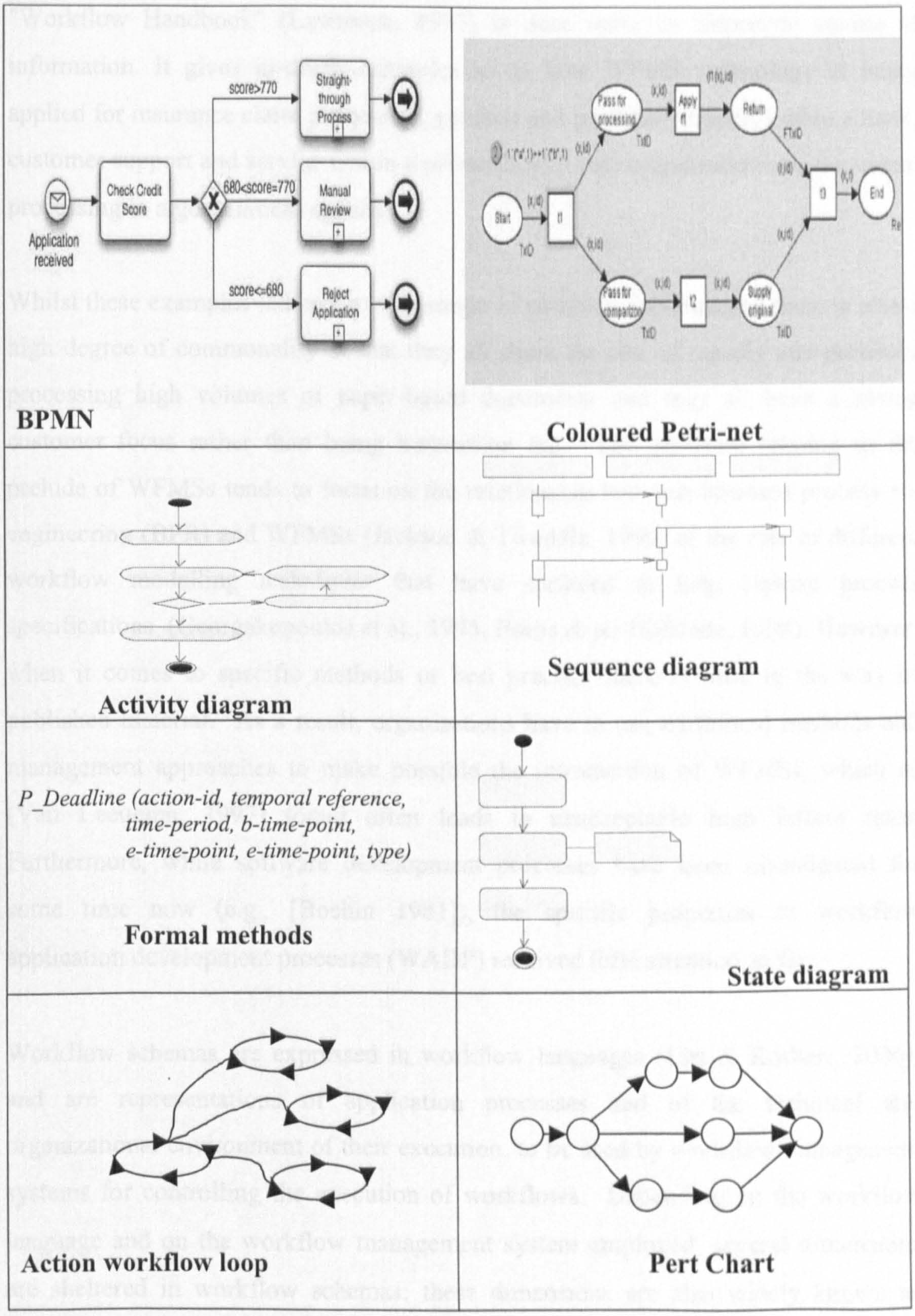

Figure 2. 8: Possible Workflow Specification Modelling Techniques

The areas for applying WFMS technology are broad, with applications being used in most sectors of the economy, in particular the banks, finance, insurance and governmental departments (Van der Aalst, 1999). For specific applications, the

"Workflow Handbook" (Lawrence, 1997) is once more an important source of information. It gives in-depth examples as to how WFMS technology is being applied for insurance claim processing, product and customer support within a bank, customer support and service within a private health care organisation and document processing in a government agency.

Whilst these examples indicate a wide range of potential applications, there is also a high degree of commonality in that they all share the aim of rapidly and precisely processing high volumes of paper-based documents and they all have a strong customer focus rather than being transaction led. The literature relating to the prelude of WFMSs tends to focus on the relationship between business process re-engineering (BPR) and WFMSs (Jackson & Twaddle, 1999) or the role of different workflow modelling techniques that have surfaced to help capture process specifications (Georgakopoulos et al., 1995, Baros & ter Hofstede, 1998). However, when it comes to specific methods or best practice there is little in the way of published material. As a result, organisations have to use traditional methods and management approaches to make possible the introduction of WFMSs, which as (Van Leeuemn, 1997) found often leads to unacceptable high failure rates. Furthermore, while software development processes have been investigated for some time now (e.g., [Boehm 1981]), the specific properties of workflow application development processes (WADP) received little attention so far.

Workflow schemas are expressed in workflow languages (List & Korherr, 2006), and are representations of application processes and of the technical and organizational environment of their execution, to be used by workflow management systems for controlling the execution of workflows. Depending on the workflow language and on the workflow management system employed, several dimensions are sheltered in workflow schemas; these dimensions are also widely known as workflow perspectives (kwan & Balasubramanian, 1998; Wirtz et al., 2001; List & Korherr, 2006). The next step is to assemble the complex relationships between the model elements into four views or perspectives to facilitate understanding and analysis. We categories the elements of the workflow models collected in Table 2.1 below according to these perspectives and then checked the elements and perspectives that are represented in each method. While the set of perspectives depends on the specific requirements of the application domain, the following perspectives are present in almost all types of workflow applications:

	WBS	PERT	BPDM	BPMN	Petri-net	Flow-chart	Action Workflow	EPC	IDEF3	AD
Functional			√	√	√	√		√		√
task	√	√	√	√	√	√	√	√	√	√
Task decomposition	√		√	√	√		√	√	√	√
input			√	√	√	√				√
output			√	√	√	√				√
Organisational	√		√	√						√
agent (program or human)						√				
resource						√			√	
role			√	√			√	√	√	√
actor			√	√						√
responsibility			√	√			√	√		√
group			√	√						√
department	√		√							√
Informational				√					√	
Information entity				√	√	√			√	√
Behavioural		√	√		√	√	√	√	√	√
sequence		√	√		√	√	√	√	√	√
parallel		√			√			√	√	
constraint		√	√						√	√
choice					√				√	
repeat until					√	√		√		
cond. loop			√		√	√		√	√	√
state									√	
specific date		√								
duration		√								

Table 2. 1: Perspectives addressed by different workflow modelling methods and techniques (Adapted from List & Korherr, 2006; Oliver et al., 2007)

The functional perspective describes what has to be done within a workflow. The operational perspective determines how it is done, i.e., which methods, techniques and tools are used to perform a given workflow. The behavioural perspective defines the behaviour of the workflow, i.e., it specifies when and under which conditions a workflow is executed. The informational perspective specifies the data objects, which are being manipulated during workflow executions and the flow of data between workflow activities. The organizational perspective describes how the workflow is embedded in the context of the organization, both in terms of personnel and information infrastructure. This perspective is often covered by roles, which specify properties of personnel and software systems. When a workflow is performed, a technique called role resolution is used to assign persons or software systems to workflow activities. Once a workflow schema is defined, a workflow instance can be instantiated, which represents a business process, e.g., the processing of an order or insurance claim.

We denote by workflow application an information system in which work is coordinated by a workflow management system. Typically, numerous persons with different backgrounds and experiences collaborate in a workflow application. In order to develop adequate workflow applications, these persons, their skills and expertises also have to be taken into account (Berztiss, 2000).

Workflow applications are developed in complex processes in which numerous persons with different backgrounds participate. While workflow application development processes differ from one project to the next, the general procedure can be described as follows (Weske et al., 2001): The first phase deals with gathering information, relevant for the application process. Empirical studies based on interview techniques and analyses of available documentation are used. The activities in this phase are centred on the application domain, and technical issues are often not considered. The next phase involves business process modelling, in which the information gathered is used to specify business process models. The main purpose of business process modelling is to provide a general and easy-to-read notation, which enables information system experts and domain experts to validate and optimize business process models.

The result of this phase is specified in a business process model, which is used as a basis for the next phase, the workflow-modelling phase. Its aim is to enhance the business process model with information needed for the controlled execution of workflows by a workflow management system, involving adding technical information and purging application specific information, which is irrelevant for workflow management. Finally the workflow application is deployed in the target environment, and the operational phase starts (List & Korher, 2006; Oliver et al., 2007).

2.7 E-business scenarios and workflow automation

Distributed Component Object Model (DCOM) from Microsoft, Common Object Request Broker Architecture (CORBA) from Object Management Group (OMG), along with distributed Java are distributed object technologies. They provide interface description languages and services that allow distributed objects within distributive systems like workflow systems and Internet application to be defined, located and invoked.

Whilst workflow management has been successful in the context of a single organisation (intra-organisational), a new trend or breed is inter-organisational workflows, i.e., workflows crossing organisational boundaries. Inter-organisational workflows are very important in the context of e-business, since modelling and efficiently enacting processes involving multiple organisations is a vital aspect in transactions involving multiple organisations. E-business embodies the most pervasive, dynamic, discontinuous, non-linear and complex form of change. It leaves no aspect of managing organisations untouched, it challenges long accepted business models and work processes, and organisation leaders and workflow designers have little to draw on from their past experience to manage its effects. In particular, its ability to transform business processes is no longer in dispute (Fahey et al., 2001).

The new technological platforms at the core of e-business open up many possibilities not just to reconsider the re-engineering of existing processes but also to design, develop, and deploy fundamentally new ways of conceiving and executing business and work processes. Business executives and workflow designers in every organisation as a consequence are confronted with a new challenge: How should they endeavour to capture, analyse, and project the transformational impact of e-business on their organisation's core business and work processes? In this research we lay forward the thesis that knowledge management provides one useful vehicle for doing so, by demonstrating how knowledge management can and should contribute to leading and managing e-business-driven change in business or workflow processes.

Handling processes is fundamental to contemporary e-business organisations. Designed well, it increases productivity, improves quality, and enhances customer service and operational control. Combining the information communication capabilities of the Internet, with the business process automation and integration capabilities of workflow engines will pave the way for developing efficient e-business enterprises etc. Due to the need for capturing and supporting group collaboration processes within and across departmental and organisational boundaries, the term workflow has emerged in the research community. Behind most world-wide-web applications, there are work processes e.g. purchase order, bank loans and insurance claims. Workflow on the Internet provides the opportunity to co-ordinate those processes and enables continuity between a client requiring service, and the production of those services.

In spite of its popularity, visibility, and impact, e-business still remains a poorly understood phenomenon. E-business is defined as the ability of a firm to electronically connect, in multiple ways, many organisations, both internally and externally, for many different purposes. It allows an organisation to execute electronic transactions with any individual entity along the value chain – suppliers, logistics providers, wholesalers, distributors, service providers, and end customers (Fahey et al., 2001). E-business can also be defined as the computerised facilitation of business processes. E-business raises a number of critical business issues, each of which in turn generates distinct knowledge issues and challenges specific to the e-business transformation of business and workflow processes as follows:

Firstly, e-business is transforming the solutions available to customers in almost every industry, that is, the breadth of solutions and how the solutions are obtained and experienced. Consumers can now buy books, food, clothing and other goods over the Internet in ways that allow distinct forms of customisation and delivery schedules that dramatically lower the costs of search, increase speed of delivery, and as a consequence reduce prices of goods. These new solutions open up possibilities for customer value creation and delivery that were simply unimaginable in the past.

Secondly, in part due to the competitive context changes just noted, the nature and context of strategy, and by implication, the dynamics of marketplace rivalry, are undergoing profound change. No longer can most firms rely on making modest, incremental changes to long established strategy success formulas. In fact, organisations are adjusting their strategies according to the new notion of "the customer" where customer intimacy, customer relationship management, 1-to-1 marketing, and the concept of the customer as opposed to the product as the new asset of the organisation and real carrier of value dominates (Fahey et al., 2001). In short, e-business offers the platform for new forms of marketplace strategy models.

Thirdly, e-business requires firms to refocus and reconfigure almost every type of tangible and intangible asset. It places heavy priority on developing and leveraging intangible assets, including many different types of new skills, new forms of integrated and intensive relationships with external partners, new sets of perceptions held by customers, channels, and suppliers, and, of course, significant new knowledge. Consider the following example. Many new start-up, e-business-based organisations such as Expedia.com, Travelocity, E*TRADE, and Amazon.com create integrated networks of relationships with channels, end customers, suppliers, providers, and even rivals that would not be possible in the absence of the ever increasing electronic interconnectivity.

These relationships provide the e-business-driven organisation the ability to access and leverage the assets of external partners. By connecting the buyers and the sellers of travel-related products, Expedia.com can now access and leverage the assets of its supplier firms in the airline, hotel and car rental industries. Also the creators and purveyors of the new customer value propositions represent new types of rivals. Traditional booksellers are confronted by Amazon.com; Merrill Lynch faces E*TRADE. These new entities recast the profile of rivals in many industries and, partly as a consequence, reshape the contours and boundaries of most traditional competitive spaces or industries. E-business requires workflow support (Kumar & Zhao, 2002). Workflow technology plays a key role as an enabler in E-Commerce applications, such as suppler chain management and customer relation's management. Actually, e-business has been around for many years in the form of Electronic Data Interchange (EDI). However, e-business that is build around Electronic Data interchange is limited to business-to-business (B2B) commerce and is based on structured document formats (called transaction sets), which are transmitted over value-added networks (VAN). E-business has opened up new possibilities of business-to-customer (B2C) commerce by obviating the need for value added networks (Kumar & Zhao, 2002). In the first step, the Internet serves as a router for communications between trading partners, but more importantly, in a broader sense it can lead to the creation of new types of value chains between business partners. E-business activities point to the importance of workflow automation and knowledge management initiatives as further exemplified in this thesis.

SOA (Service Oriented Architecture) has received more and more interest for its convenience to support B2B and/or EAI applications. Web service composition technology is used to bring various services together in a meaningful structure to meet the requirements of the business process. SOA can be realized by Web services technologies [UDDI (Universal Description, Discovery and Integration), WSDL (Web Services Description Language), SOAP (Simple Object Access Protocol), etc.] as a set of flexible and interoperable standards for distributed systems (Kuk et al., 2008).

2.7.1 Workflow in mail-order processing

Consider that a customer places an order over the Internet for four books with Amazon.com. Amazon in turn places four different orders (one for each book) with the respective publishers, who send their books separately to a shipper. The shipper coordinates the receipt of four different shipments from the publishers and makes one package to be shipped to the customer. In this simple example, there are at least seven parties coordinating amongst themselves to complete the purchase order. Even during the order-processing phase, there are several complications that can arise:

- The customer may cancel or change the order.
- A publisher may not have a book in stock.
- A publisher may delay shipment.

These are called *exceptions* and numerous other such abnormal situations can arise (R-Moreno et al., 2007). In all these scenarios, there is a need for additional coordination and, possibly negotiation.

2.7.2 Workflow in the mortgage Lending sector

Technology has already made a significant impact in the mortgage-lending sector. The provision of web-based workflow systems has and will largely automate the mortgage application process and many consumers are already familiar with their mortgage brokers using these tools to search and compare mortgage products from different providers. Today, approximately 60% of new mortgage products are being sold through the broker and intermediary channels. By providing intermediary access to their workflow solutions lenders can generate substantial loyalty from their sales channel, decrease operational cost and improve productivity at the same time. These automated solutions to a large extent reduce the administrative burdens for all stakeholders; they ensure compliance and speed up the overall mortgage process for the client. To successfully migrate to the e-business market, web-based workflow system must have the flexibility to handle the business processes involved in underwriting existing mortgage products and also to accommodate future changes in the mortgage business environment.

Workflow systems allow disparate systems from all stakeholders involved in the mortgage process to be seamlessly and directly connected. Each mortgage case can be tracked and analysed no matter at what stage it is. From the application form to the underwriting process, workflow allows lenders, intermediaries and third parties to eliminate re-keying and benefit from full electronic communication. It is obvious that the use of workflow technology will significantly enhance the competitive edge of a lender's operation, improve the speed and cost of underwriting and help create a loyal network of intermediaries. Those lenders, who have been able to implement e-workflow, are already extending their systems to automate non-compliance mortgage products to secure their share of new business in the e-business environment characterised by the emerging global and knowledge economy. But for those who are not embracing the path to automation, their time is beginning to run out.

E-business is dramatically reshaping every traditional business and work process: from developing new products and managing customer relationships to acquiring human resources and procuring raw materials and components. By enabling major new tasks to be added to individual processes, e-business broadens their scope, content, and value-generating capability. For example, customer relationship management has been essentially reinvented through e-business's ability to access large bodies of data, massage and mine such data in radical new ways, and customize the outputs of such analysis to customer segments, and in many cases, to individual customers. And, by integrating traditionally largely separate processes, e-business in effect creates what might well be described as new business processes.

2.8 Knowledge management

For the last two hundred years the neo-classical economy has recognised only two factor of production: Labour and capital. With the advent of the Internet and e-business, the economy is now changing to knowledge and global economy in which information and knowledge are becoming the main factors and the primary wealth-creating assets. Knowledge has become the resource, rather than a resource. Knowledge has sidelined capital and labour to become the sole factor of production (Drucker, 1993): the central wealth-creating activities will be neither the allocation of capital to productive uses nor labour. Value is now created by productivity and innovation, both application of knowledge to work. The productivity of knowledge is going to be the determining factor in the competitive position of a company, an industry, an entire country. No country, industry, or company has any "natural" advantage or disadvantage. The only advantage it can possess is the ability to exploit universally available knowledge (Takeuchi, 1998).

The function of knowledge management (KM) is to allow an organisation to leverage the information resources it has and to support purposeful activity with positive definable outcomes (Checkland & Scholes, 1990). Knowledge and consequently its management are currently being publicized as the basis of future economic competitiveness (Watson, 2001), for example: In the information age knowledge, rather than physical assets or resources is the key to competitiveness. What is novel about attitudes to knowledge today is the recognition of the need to harness, manage and use it like any other asset, this raises issues not only of appropriate processes and systems, but also how to account for knowledge in the balance sheet (Moran, 1999).

Entrepreneurs are no longer seen as the owners of capital, but rather as individuals who express their tacit knowledge by "knowing how to do things" (Casson, 1997). In order to enact the capability to respond to events more quickly and appropriately, knowledge workers must have greater insight primarily into critical operational work processes. Providing relevant feedback to decision makers at near real time (or right time) can improve the quality of their decisions and as a consequence help improve operations (Morris et al., 2009). One of the foremost challenges facing the KM community is how to capture and compose the organisational knowledge repository. Capturing tacit knowledge scattered amongst the organisation's members and continually feeding this knowledge repository may yield major competitive advantages in an environment where competition, collaboration and communication have surpassed geographical boundaries (Nunes et al., 2009). The knowledge management initiative is spreading throughout the organisation, from sales, marketing, accounts, production or product development, purchasing and personnel (HR).

With knowledge now being viewed as a significant asset, there is a thrusting imperative to create, share and manage organisational knowledge within and between contemporary organisations. Boisot (1998), refers to the "paradox of value" when considering the nature of knowledge, in particular its intangibility and inappropriateness as an asset and also the difficulties of assessing and protecting its value (Priest, 1994). For fifty years there has been a settled business equilibrium or stability, dominated by established firms, that is now prone to radical reforms. In a world of e-business characterised by global and knowledge economy, workflow executives can no longer afford to be complacent about knowledge. More organisations fall prey to their own inertia than those, which learn to change and adapt (Lomax, 2002). Knowledge management is a vital aspect of organisational learning and adaptation and has been portrayed by many as a growing area of research during the past few years (Drucker, 1994, 2000; Malhotra, 2001; Dellen et al., 1997; Davenport & Prusak, 1998; Davenport et al., 1997; Nunes et al., 2009).

Knowledge management is defined as an approach to improving organisational outcomes and organisational learning by introducing a range of specific processes and practices for identifying and capturing knowledge, know-how, expertise and other intellectual capital, and for making such knowledge assets available for transfer and reuse across the organisation (Wikipedia-KnowledgeManagement, 2006).

The increasing application and impact of knowledge management is established through, the transformation of society, knowledge work, knowledge workers, intelligent organisations as well as intelligent products and services. Basically, knowledge embodies organisational processes that seek synergistic combination of data and information processing capacity of information technologies, and the creative and innovative capacity of human beings. Knowledge management issues also addresses the critical issues of organisational adaptation, survival, and competence within the increasingly complex, dynamic and discontinues changes inherent in the new e-business environmental characterised by emerging global and knowledge economy (Griman et al., 2002). Based on the above arguments, it seems logical to account for the human attention, innovation, and creativity needed for the renewal, of archive knowledge, the creation of new knowledge, and innovative applications of knowledge in new products and services that yield market share.

Growing interest in knowledge management initiatives stems from the observation that in the global and knowledge era, organisational knowledge is a strategic cooperate asset that needs to be captured, retained, updated, disseminated and applied to future organisational problems (Drucker 1994, 2000; Stewart 1997). Recent advances in information technology such as Lotus Notes, Internet/Intranet have offered the means to organise various scattered segments of information into organisational 'knowledge repositories.' Consulting firms are promoting the idea of building "knowledge databases", which are attempts to pull scattered information throughout virtual organisations together and convert it into organisational memory in the form of a database.

For example: Andersen Consulting set up Knowledge Xchange; Booz Allen & Hamilton developed knowledge On-line; Ernst & Young created their Centre for

Business Knowledge, KPMG Peat Marwick established A Knowledge Manage; and Price Waterhouse has Knowledge View (Takeuchi & Nonaka, 1998). Organisational memories are inspired by the aspirations to safeguard and share the knowledge, values and experiences that reside in an organisation using workflow technology. As such, most workflow systems focus on capturing the existing knowledge, storing it, and making it accessible, rather than explicitly supporting the creation of new knowledge that is necessary to assist e-workflow users and designers in executing their day-to-day work processes.

WFMS is especially suitable for realising organisational memory because it enables the automation of a business process across teams, functional departments, and partners in order to reduce product or services cycle times, and also to decrease costs. Workflow systems also have the capabilities to integrate people, the organisational structures, and the information sources such as database management systems, image processing systems, document management systems, email systems and desktop applications (Stohr and Zhao, 1997). By enhancing workflow systems with knowledge management concepts the exchange of information and knowledge within e-business organisations can be made much easier and efficient. The idea is that this could be done by integrating certain knowledge management techniques with a workflow system that would support knowledge collection, storing, sharing and creation within a knowledge organisation, which depends on their knowledge.

Most multinational or contemporary corporations are highly knowledge-intensive companies, particularly since their aim is to compete on quality rather than on price. This aspect requires that organisational, methods and workflow applications domain knowledge is well managed and applied. One way of ensuring the optimum use of knowledge is to encode this knowledge in knowledge based systems (KBSs), or on an intranet/Internet site that supports e-workflow users, researchers and product developers (Everest, 1998). Projects have been held by some organisations to understand and acquire knowledge within their organisational settings. The knowledge captured during those projects where distributed in knowledge bases, knowledge repository and Intranet/internet sites to business partners and innovation centres globally.

2.9 Related research work

In the previous sections the research environment was introduced. This section will give an overview of some research work in the workflow environment that is related to our research. Following the limitations of the traditional Workflow Management Systems (WFMS), there have been numerous attempts to tackle some of the problems. However, most of the attempts do not provide clear phases and activities within each phase on how to analyse, design and implement e-workflow systems in the new e-business environment characterised by the emerging global and knowledge economy.

In (Agostini et al., 1993), an attempt to couple WooRks and User to User Communication Support (UTUCS) is presented. WooRKs is a workflow management system and UTUCS is a communication support system. The realised environment supports a natural and immediate switch from the WFMS into the communication support system within a common framework in order to accompany the user while his/her attention switches from the routine (WFMS) to the solution (UTUCS) of the occurred breakdown. Generally, the WFMS (WooRKs) where a performer executes his/her routinised tasks is separated from the system supporting his/her conversations with other actors, and therefore when a breakdown occurs, s/he has to leave the first system (WFMS) and enter into the second (UTUCS).

Basically, WFMS (WooRKs) support routine work, while the communication support system (UTUCS) supports exception handling. Although this work present steps for modelling workflow, its main focus is on business process reengineering. The method jumps into design using Activity Description Language (ADL) and a prototypical implementation without an implementation independent analysis. This will make it difficult to maintain, adapt and evolve the workflow application. The proposed framework is suitable for client-server environment and not for Internet environment.

In (Maiden & Sutcliffe, 1993), analogy as an alternative approach to specification reuse is proposed, and the need for analyst involvement during specification reuse is discussed. Analogy is defined as follows: *Analogous reasoning transfers a complete* *network of knowledge rather than unrelated facts* (Gentner, 1983). The authors also highlight the fact that, existing knowledge-based approaches to software development tends to apply isolated facts about a domain or method heuristics to a new application. However specification reuse involves the transfer of a network of domain knowledge representing a whole solution.

In the article, Gentner uses several example of analogy (e.g. an analogy between a hydrogen atom and our solar system) to demonstrate that analogy is not based on syntactic similarities between problems, but is crucially determined from a deeper knowledge structures. Research into the critical determinants of software engineering analogies suggests that such analogies are determined by similarities with the problem domain underlying the reusable specification rather than with the reusable specification itself, so specification reuse must be justified by similarities between knowledge about the problem domain rather than between solution knowledge.

Furthermore, the article states that analogy only maps domain knowledge which causally supports the system's goals and which belongs to an abstraction shared by both the reusable and the target domains. A prototype version of the problem identifier and analogy engine components has been developed. The problem identifier elicits a description of a new problem then the analogy engine matches this description to a restricted search space on 10 abstract domains hierarchically structured to represent four fundamental types of abstract domain (object containment, object monitoring, object allocation and space monitoring). This hierarchy is supported by approximately 30 heuristics, which identify critical differences between abstractions. The approach focus on specification reuse in the context of traditional information systems analysis and design which is data-centric rather than workflow analysis and design which is process-centric.

In (Dellen et al., 1997), they integrate knowledge-based techniques with a workflow management approach in order to address flexibility problems in workflow applications. Using explicit process and product models as a basis for a workflow interpreter provides them with the facility to alternate planning and execution steps, resulting in an increased flexibility of project coordination and enactment. To gain the full advantages of this flexibility, change processes have to be supported by the workflow systems. These require an improved traceability of decisions and have to be based on dependency management and change notification mechanism.

To summarise, they gave an overview of their approach by developing: (1) Explicit process and product models (2) A workflow engine which interprets the process model (3) Generate dependencies between information based on the process model (4) Allow them to refine and extend the process model on the fly (5) Allow them to change planning decision. This approach is applicable in civil and software engineering. The approach focuses more on implementation issues and says very little about the phases and steps involve in developing a workflow application. It doesn't look at all the other perspectives of workflow modelling e.g., informational and organisational perspective.

In (Van der Aalst, 1999), a process-oriented architecture for modelling inter-organisational workflow for Internet e-commerce is presented. It also presents the classifications of some conceptual communication architectures that could be used to model inter-organisational workflows. The article uses Petri-net formalism to model behavioural/dynamic aspects of inter-organisational workflows and the concept of soundness to verify the workflow model. It also stresses the support for business processes rather than the technology required to exchange information – which is often referred to by other researchers. The work failed to show how to model the other perspectives, which are essential during workflow specification and modelling i.e., organisational and information perspectives. There is no clear procedure on how to handle exceptions in communication scenarios or architectures for modelling workflows.

The TBPM (Jarvis et al., 2000) project is based on a work carried out in the Enterprise project and centres around an intelligent workflow engine that includes an interactive process planner. The planner uses Artificial Intelligent (AI) planning techniques to assist in task planning, while empowering and at the same time permitting the user to participate in planning decisions. An agent-based architecture is incorporated with the approach to support the execution and co-ordination of the planned process amongst multiple stakeholders and distributes processes across computer networks. The workflow user is able to plan a workflow task by assembling fragments and then to refine it, generating a hierarchical model or the workflow process to be performed. To increase the flexibility of the system, the user is able to edit the process model before and during its enactment, in order to specialise it. This approach focuses more on the functional perspective and implementation issues of workflow application development.

In (Manolescu, 2001), his PhD research thesis started from the observation that current workflow systems do not provide the workflow functionality required in object-oriented applications, so developers are forced to built custom workflow solutions. Furthermore, the thesis claimed that traditional workflow architectures are based on the requirements and assumptions that do not hold in the context of contemporary object-oriented software development. This mismatch makes current workflow systems unsuitable for developers who need workflow within their applications. The thesis has described work leading to and including the development of micro-workflow, a novel workflow architecture that resolves this mismatch. Micro-workflow solves workflow problems through techniques specific to object systems and compositional software reuse. It aims at software developers and provides the type of workflow functionality they need in object-oriented applications. The components at the core of the architecture provide basic workflow functionality. Other components implement advanced workflow features. Software developers can select the features they need and add the corresponding components to the core through composition.

As an example, the thesis presents the design of an object-oriented framework, which provides a reusable micro-workflow architecture and enables developers to customise it through framework-specific reuse techniques. The thesis also showed how to build the core framework and other components. In addition, it shows how through composition, developers can extend micro-workflow to support other components such as history, persistence, monitoring, manual intervention, work-lists and federated workflow. The approach was evaluated with three case studies that implement processes with different requirements. The approach focuses on implementation issues in the form of code reuse as apposed to knowledge reuse at the design level that is presented in this thesis.

In Cardoso & Sheth (2002), the author's main idea is to encapsulate an organisation's functionality within an appropriate interface and advertise it as Web services. It is also stated that while in some cases Web services may be utilised in an isolated form, it is normal to expect Web services to be integrated as part of workflow processes. The design of workflow processes that model e-service applications differs from the design of traditional workflows, in terms of the number of tasks (Web services) available to the design process, in their heterogeneity, and in their autonomy. The paper also tries to solve two problems namely, to discover Web services based on functional and operational requirements. Furthermore, to facilitate the interoperability of heterogeneous Web services.

The author's use of ontologies for the explication or clarification of knowledge is a possible approach to overcome the problem of integrating heterogeneous tasks and web services. To assist designers with solution for these problems an algorithm to simultaneously discover Web services and resolve heterogeneity amongst their interfaces and the workflow host was devised. The approach focuses on the functional and information perspective of e-workflow modelling and fails to mention anything about the organisational, social and behavioural perspectives, which are essential if a complete picture of e-workflow modelling is to be exemplified. The approach also fails to provide clear phases and activities within each phase on how to analyse, design and implement what it calls e-workflow.

In (Zhuge et al., 2002), the paper cited the fact that traditional workflow approaches are too rigid to adapt to the changes of domain business and are not useful in rapid development of virtual organisations. Once the domain business has changed, the system has to be re-designed. The paper proposes a simulation-based development framework for establishing virtual organisations. The framework consists of a federation-agent-workflow (FAW) model, a set of rules for establishing the mapping from the domain organisation into the virtual organisation, a set of management services, and a macro development process.

Basic elements of the model are agents, which can perform active domain behaviour, and they are organised as autonomous federations. Agents within the same federation perform relevant tasks according to an overall workflow. Domain organisation is simulated by the multi-level agents whose behaviour are driven by a nested-workflow mechanism. The framework unifies the traditional domain organisation and information system model into a virtual organisation model, and allows users to develop intuitive virtual organisations from the viewpoint of the domain. The virtual level is separated from the implementation level that consists of a runtime-support mechanism and a behaviour repository. The approach focuses on implementation issues in the form of a simulation framework. There are no clear procedure and step on how to model some of the workflow perspectives i.e., functional and information perspectives.

In (Chung et al., 2003), it is stated that, while existing workflow management systems are widely used for the streamlined management of 'administrative' business processes, current systems are unable to cope with the more dynamic situations encountered in ad hoc and collaborative processes. Furthermore, the author's also stated that a major limitation of traditional workflow systems is that they can, typically, only supports simple, predictable, but not the dynamically changing and complex processes that are present in many organisations. The researchers/academics stressed the fact that there is increasing interest in making workflow systems more adaptive and in using knowledge-based techniques to provide more flexible process management support than is possible using current workflow systems.

To summarise, their adaptive workflow approach investigates the use of ontology – a term borrowed from philosophy, refers to the science of describing the kinds of entities in the world and how they are related (Smith et al., 2004), intelligent agents and knowledge based planning techniques in the form of a *plan library* to provide support for adaptive workflow or flexible workflow management, especially in the area of new product development within the chemical industries. This approach is particularly important in a highly technical field such as chemical engineering. The approach focuses on the modelling of the functional perspective in the form of process plan and not on the behavioural and organisational perspectives. It also fails to mention clear steps and procedures on how to manage the insertion and deletion of plans in the plan library. No clear classification or categorisation of project plans is provided.

In (Kaster et al., 2005), the paper discusses a software tool under development at the Institute of Computing of the University of Campinas (UNICAMP), Brazil. The goal of this tool is to help decision makers in the environmental domain to collaboratively exchange their experience, and profit from learning about the past solutions to similar problems. The tool, named WOODSS (WorkflOw-based spatial Decision Support System), works in conjunction with a Geographic Information System (GIS). This approach combines work on database systems, artificial intelligence and workflows. Artificial intelligence research is used in the context of case based reasoning (CBR), whose retrieval techniques are added to the retrieval mechanisms of WOODSS, offering context sensitive similarity analysis.

Case-based reasoning is a model of reasoning, which consists in solving new problems by customising/adapting solutions that were used to solve old problems (Madhusudan et al., 2004). CBR research is tightly connected with artificial intelligence, within the domain of knowledge management (Watson, 2001). The principle of CBR is based on a cognitive model (Schank, 1982). This model states that human memory is dynamic because it is continuously changing according to the new experiences one is exposed to. These individual experiences, or *cases* in the CBR terminology, encompass lessons learned in a specific context, which can be used to face new situations. Thus, knowledge in CBR is embedded into particular cases, and in their interrelationships.

In (Medeiros et al., 2005), the paper presented the ongoing research on the WOODSS scientific workflow framework. Originally conceived for supporting scientific work in environmental planning it is now being extended to support distributed web-based applications for other scientific domains. The core of this work is based on creating repositories containing workflow specifications at several abstraction levels. These specifications are encapsulated in digital content components (DCCs), which provide a standard search and composition interface based on metadata and semantic annotations linked to domain ontologies. Scientists can query repositories to reuse and compose workflow elements at design and execution stages. This allows, for instance, comparing various versions of workflows that solve a problem.

The main contributions are (1) discussion of issues concerning a data model that induces a methodology for workflow design; (2) presentation of the DCC reuse model, which integrates the two different levels of workflow production – specification and execution. The framework support several requirements of scientific workflows, such as on-the-fly intervention and modification. The data model and WS-BPEL export facilities have been implemented (Pastorello, 2005), and DCCs manual composition has been implemented for map management in environmental applications. Ongoing work concerns porting the graphical interface to the web, creating DCCs for bioinformatics applications.

According to Haddad (2006), software organisations have to invest huge sums of money to start successful reuse methodology and it's a barrier for them. In his opinion, the core of reuse is source code. According to an estimate mentioned by the author, "domain specific components represent up to 65% of the application size. One approach to effective reuse practices focuses on domain specific components". He proposed an integrated approach for component-based development to support domain specific components. An integrated approach is a collection of reusable components in a development environment.

The author also discusses the concept of interface to describe a wrapper interface mechanism. The wrapper interface mechanism will be used to manage and control the interface between or among the integrated collection of reusable components. The objective of his research is to develop benchmarks for software organizations so that they begin reuse practices by emphasizing mainly on programming effort and not on management and operational perspectives. The main focus of the author's research is on the development of domain specific reusable components but not on the construction of reusable components of different domains of concern. This problem can be handled through software engineering for adaptive and self-managing systems. The approach focuses on implementation issues through the reuse of source code rather than design specifications

In (Van der Aalst et al., 2007), their solution to the aforementioned problems is based on workflow mining. The goal of workflow mining is to reverse the process and collect data at runtime to support workflow design and analysis. Workflow mining results in an "a posteriori" process model that can be compared with the "a priori" model. Clearly, workflow-mining techniques can be used to create a feedback loop to adapt the workflow model to changing circumstances and detect imperfections of the design. The paper assumed that it is possible to record events such that (i) each event refers to a task (i.e., a well-defined step in the workflow), (ii) each event refers to a case (i.e., a workflow instance), and (iii) events are totally ordered. The term process mining is referred to a method for distilling a structured process description from a set of real workflow execution log.

They also introduce a common XML-based format for storing and exchanging workflow logs. The final goal of the approach presented in this article is to find explicit representations for a broad range of process models, i.e., they want to be able to generate a concrete Petri-net rather than a set of dependency relations between events from the workflow logs. Van Der Aalst (Van der Aalst et al., 2007) added the word Concrete to Petri-net to mean a workflow model is generated from workflow logs (data) instead of designing it from scratch.

The approach also integrates the ProM framework. The ProM framework has been developed as a completely plug-able environment and can be extended by simply adding plug-ins, i.e., there is no need to know or recompile the source code. The approach focuses more on the functional, organisational, behavioural and case perspectives and on implementation or operational issues in the form of reverse engineering. There is no clear procedure and steps on how to develop a workflow application. It is also not clear how the informational perspective of workflow modelling is dealt with in this approach.

2.10 Chapter summary

In this chapter we have introduced workflow and its basic concepts. The chapter has also presented the background study relevant to our workflow research, electronic commerce scenarios and workflow automation and a review of some of the existing workflow analysis and process modelling methodologies and techniques. Finally, the chapter has also presented an overview of some research work in the workflow environment that is related to the workflow research presented in this thesis. The next chapter presents the proposed knowledge enhanced framework for the development of adaptive e-workflow systems – a conceptual approach for the development of Internet workflow systems.

Part Two

Proposed Knowledge Enhanced e-workflow Framework, e-workflow Knowledge Repository and e-Workflow Design and Development Methods

Chapter 3: The Proposed Knowledge Enhanced e-Workflow Framework

This chapter presents the proposed knowledge enhanced framework for the development of adaptive e-workflow systems adapted to the new e-business environment characterised by rapid, dynamic, agile and disconcerting change. The framework consists of five perspectives for knowledge-enhanced e-workflow modelling i.e., functional, organisational, behavioural, informational and knowledge.

3.1 Traditional framework for workflow design and analysis

This research argues that knowledge holds the key to generating continuous innovation. An old concept dating back to 400BC (Takeuchi, 1998) has emerged in the West as the newest management ideas. It would be pitiful, however, if it ended up being just a buzzword or if "knowledge management" degenerated into little more than a fad, as many management concepts have done in the past. For example, reengineering started out as a perfectly sensible management concept (Hammer & Champy, 1990). But the hype, which subsequently developed, meant that the human issue was too quickly ignored in favour of technological issues. It would be tragic if history repeats itself with knowledge management.

Traditional framework for workflow modelling focuses on the work process and information processing perspective of an organisation workflow strategy and are increasingly inadequate in the new e-business era that is characterised by increasing complexities, unpredictable and discontinuous change. Figure 3.1 below depicts the traditional framework for workflow design and analysis. The relationships between data (informational perspective), the data processing requirements (functional perspective), organisational and behavioural perspectives as delineated below are the key perspectives used during workflow requirements analysis, design and evolution.

Workflow modelling and design is well understood for traditional intra-organisational workflow applications, which span only one organisation and are characterised by structured and predictable business processes and business environment. However, for e-workflow design and evolution within e-business environments characterised by global and knowledge economy, in which some organisation cooperates with other organisations, for example by outsourcing parts of its own internal process to these other organisations, additional modelling concepts are needed for specifying the processes and knowledge flow between companies.

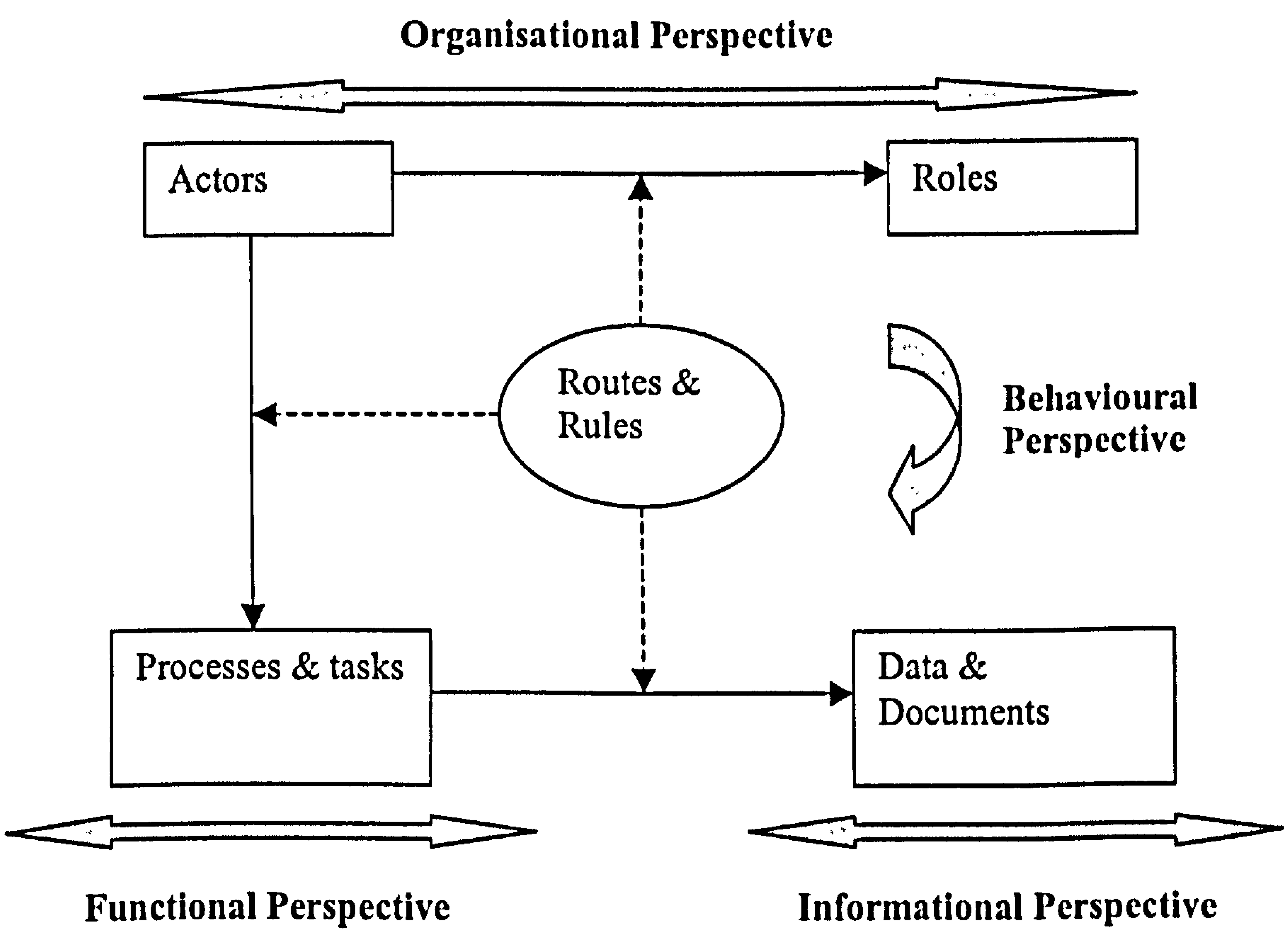

Figure 3. 1: Traditional Framework for workflow design and analysis

3.2 Proposed knowledge enhanced framework for e-workflow design and analysis

Made to order manufacturing, a strategy successfully implemented by Dell, depends crucially on a short cycle time from customer order to delivery. This type of time-based competition is now pervasive in manufacturing as well as service industries where the responsiveness and cycle time, i.e., the time from placement of customer's order to its fulfilment, is a key determinant of success. Responding to customer request in the new e-business environment characterised by emerging global and knowledge economy requires a new set of management concepts (Rummel et al., 2005; Hammer and Champy, 1993; Pande et al., 2000) such as in total quality management (TQM) and business process reengineering (BPR). Although some scepticism regarding TQM and BPR has set in, simply because the nature of the aforementioned concepts were often misunderstood by management, it has left some benefits. One is the identification of an organisation as a set of processes as opposed to functional divisions. The other is an emphasis on knowledge management (Berztiss, 2000; Davenport, 1997; Georgakopoulos et al., 1995; Malhotra, 2005).

The impact of e-business on business and work processes now becomes clear. It provides the electronic means to enable connections amongst and between processes to take place in fundamentally new ways and at such speed that it opens up the ability to reconfigure each core work process, to create new sub-work processes within each core workflow process, and to enable new modes of integration across the business and workflow processes. Indeed, it seems fair and logical to put forward the argument that e-business requires business executives to think about core business and workflow processes in fundamentally new ways. The guiding premises or theory underlying this thesis is that knowledge management facilitates and guides such thinking by serving as a means to designing, adapting, managing, and learning from these new forms of e-business-driven transformation of traditional business environment and work processes, which were suitable for static and predictable business processes and environments.

To provide workflow support for new e-business environments characterised by complex, unpredictable and dynamic business processes, we need to analyse it from the organisational and behavioural perspectives, and integrate them with the functional and informational perspectives as well as the new knowledge perspectives. There are many model elements involved in describing a workflow process and the relationships between these models are complex.

By organising these model elements into perspectives that reflect the interests of different groups of stakeholders that are involved in a business process, i.e., customers, suppliers, partners and e-workflow designers etc., the framework will provide help in designing, adapting, understanding and communication both for the e-workflow designers and stakeholders during workflow design and evolution in the e-business environment characterised by complex, dynamic and disconcerting processes. With recent advances in information technologies such as the Internet, organisations have to overcome, at different levels, several challenges. To assist organisations, their business processes have to be well defined in order to meet flexibility, adaptability, scalability and knowledge management requirements (Georgakopoulos et al., 1995). These processes are critical to the survival and growth of e-business organisations characterised by dynamic, global and knowledge economy (Davenport, 1993).

The proposed framework for e-workflow design, analysis and evolution as shown on figure 3.2 below consists of five related views or perspectives. Within each perspective of the proposed framework knowledge exist in the form of memorisation of successful stories, best practices, experiments, previous cases which are organised as workflow design patterns in the knowledge repository that describe frequently occurring solutions to business problems in an implementation-independent manner, and is based on the work of (Kwan & Balasubramanian, 1997; Wirtz et al., 2001; Stohr & Zhao, 2001; Malhotra, 2005; Nonaka & Takeuchi, 1995).

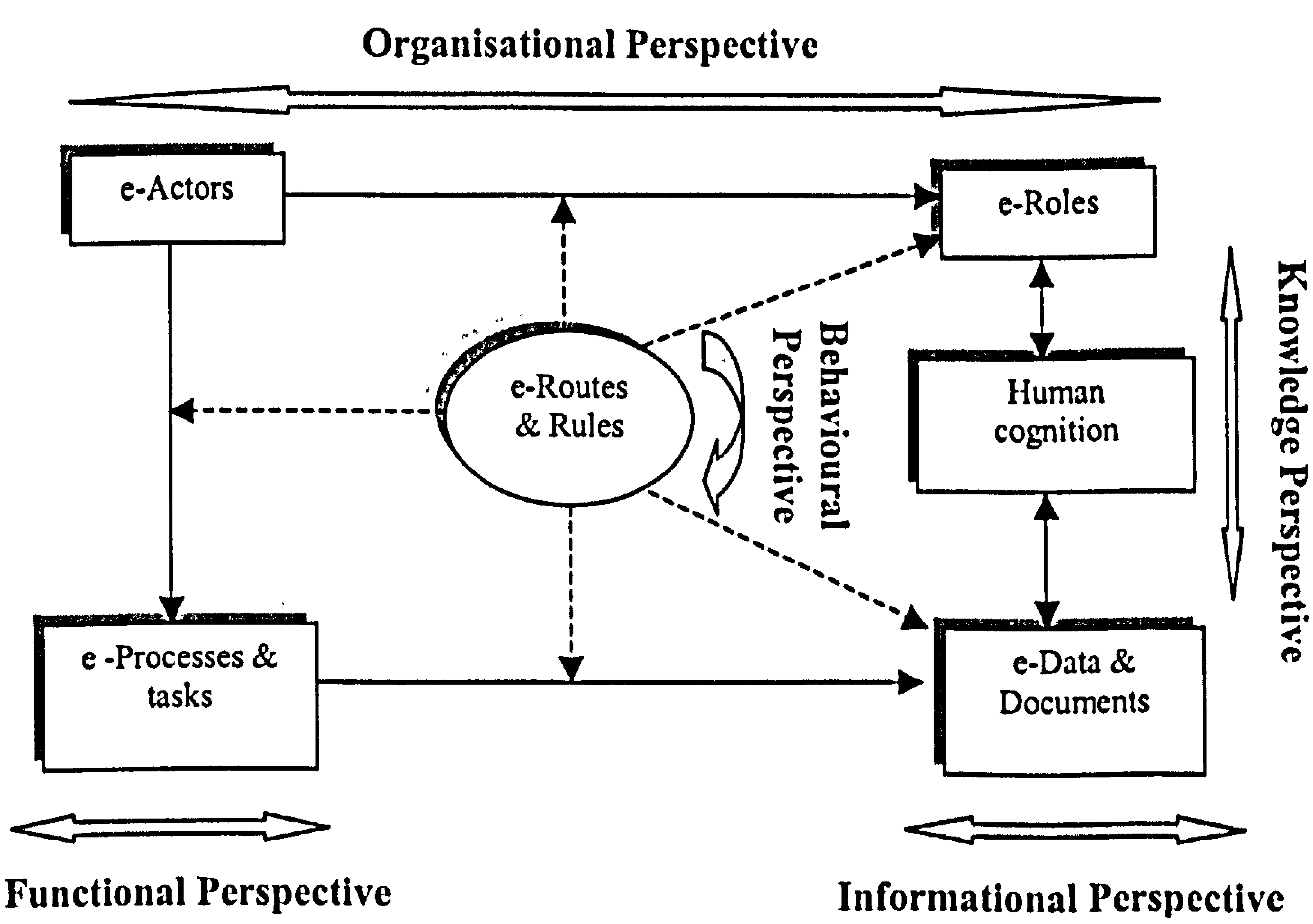

Figure 3. 2: Proposed knowledge enhanced framework for e-workflow design and analysis

By doing an implementation-independent analysis, the workflow specifications will not be constrained by the limitations of existing technology, and will be more reusable when applications need to be updated. Figure 3.2 above illustrates the interrelationships between these perspectives or concepts. At build-time the e-workflow designer must define each of the above perspectives and ensure that the resulting systems is internally and externally consistent and knowledge-aware.

3.3 Perspectives for knowledge enhanced e-workflow modelling

Organisations and their business processes must be able to adapt to changes in the business environments and to specific exceptions such as passing job to the wrong person or negative response to new product release. Processes and their associated workflows can be modelled in several ways using various methods, languages and tools. Four perspectives commonly used in the traditional framework for workflow design and evolution are as follows: *functional, organisational, informational, behavioural perspectives* (Wirtz et al., 2001, Kwan & Balasubramanian, 1997).

Traditionally these perspectives have been implemented separately and they turn to focus on the work processes and informational elements of workflow analysis. A significant contribution of our proposed framework is that it extends the traditional framework for workflow design and evolution by adding a new knowledge perspective and integrates the *functional, organisational, behavioural; informational* and *knowledge* perspectives into a single framework for knowledge enhanced e-workflow modelling, design and evolution. Each perspective in the conceptual framework harbours patterns. The next section introduces the aforementioned perspectives as follows:

3.3.1 Knowledge perspective

This research attempts to extend traditional framework for workflow modelling by adding a new knowledge perspective in order to address flexibility problems during workflow design and evolution in the new e-business environment. The research also presents a knowledge repository, which serves as a storage point for memorisation of successful stories, best practices, previous cases, experiences and experiments organised in the form of workflow design patterns templates. With regards to the usefulness of a knowledge repository, there should be guidelines on how to use the knowledge repository in an efficient manner, i.e., how to access it in a way that facilitates decision making by the e-workflow system that depends on it.

Also, a knowledge repository should be domain-independent and prearranged in such a way that adequately addresses knowledge acquisition and integration of new with existing knowledge. This is why knowledge management systems must not be confused with Expert Systems. Expert systems are based on methods and techniques for constructing human-machine systems with specialised problem-solving expertise (Simon & Schuster, 1988). The pursuit of this area of artificial intelligence research has emphasised the knowledge that underlies human expertise and has simultaneously decreased the apparent significance of domain-independent problem solving theory that are increasingly relevant for emerging e-business environments characterised by global and knowledge economy (Malhotra, 2005). An expert system assists or replaces an expert to solve problems whereas knowledge management or knowledge engineering as delineated in this research is a discipline whereby knowledge is integrated into computer systems to solve complex problems normally requiring a high level of human involvement, expertise and experience (Simon & Schuster, 1988).

In contrast, given the dynamic subjective nature of human construction of meaning and the diversity of personal constructions, different meanings could be construed from the assemblage of data at the same time by different individuals. Moreover, the data archived in expert systems and artificial intelligent systems is rational, static and without context, and such systems cannot account for the renewal of existing knowledge and creations of new knowledge (Malhotra, 2001) in the new economy

Knowledge management systems also support social capital by establishing structural links between people, regardless of time and geographical barriers, thereby improving the capacity to combine and exchange intellectual capital.

e-Workflow systems provide a unique facility for managing organisational knowledge because of their novel features. In our proposed framework for knowledge-enhanced e-workflow modelling, design and evolution (see figure 3.2), the *knowledge perspective* contains relevant information and knowledge about the various e-workflow modelling perspectives in the form of workflow design patterns in a knowledge repository and human cognition (knowledge from personal experience or view). Also, the new knowledge perspective within the proposed framework is active while the other four perspectives (organisational, functional, informational and behavioural) are passive.

The knowledge repository is populated from two sources: the extraction or deduction of knowledge from the data and information flowing between the four perspectives and the memorisation of successful stories, best practices, previous cases, experiences which are organised and stored in the knowledge repository as workflow design patterns templates. These design patterns will be reused to continuously evolve and provide flexibility of e-business processes to reflect immediate changes required in the new business environment. Patterns provide a good degree of flexibility and promote reusability of design knowledge and experiences (Casati et al., 1999).

It is being increasingly realised that differences in views or solutions to a problem may have a very powerful role in the innovation needed for new e-workflow product and service definitions. Characterised by some management thinkers as "creative abrasion," this view encourages the promotion of individual autonomy experimentation and learning (Malhotra, 2000). Furthermore, it emphasises the questioning of all given assumptions regardless of their legitimacy – for their ongoing and continual assessment. Instead of emphasising best practices archive in organisational workflow systems, our approach encourages the continuous pursuit of better practices that are aligned with the rapid and dynamically changing e-business environment characterised by the emerging global and knowledge economy.

Nonaka & Takeuchi (1995) have suggested that knowledge is created through four different modes: (1) *socialisation* which involves conversion from tacit knowledge to tacit knowledge, (2) *externalisation* which involves conversion from tacit knowledge to explicit knowledge (3) *combination* which involves conversion from explicit knowledge to explicit knowledge, and (4) *internalisation* which involves conversion from explicit knowledge to tacit knowledge. The e-workflow framework proposed in this thesis attempts to capture explicit as well as tacit process-related knowledge in order to assist knowledge workflow designers during the design and evolution of e-workflow applications in the new e-business environment.

3.3.2 Functional perspective

The functional perspective decomposes process functionality into a task hierarchy that can be allocated to e-actors (human or software agents) on the Internet. A number of KBSs have been developed to support the task of diagnosis of processing lines (analysing the business process in order to detect faults). On-line KBS uses sensors to take measurements in the processing line, and can therefore alarm the e-workflow user and suggest causes and solutions as soon as an exceptional situation is detected. In a more complex process, the workflow designers or users might not know all the steps in the process, or the variation of a work process to follow in an exception case or workflow design problem (Kurt, 2001). These functions are not flexible in the context of traditional workflow development. They are difficult to adapt when there is a change in the business process or business environment. This is largely due to the fact that the workflow designers or users are not provided with sufficient process related knowledge that is necessary to facilitate workflow process adaptation and evolution if there is a change in the business environment.

Within the proposed knowledge enhanced e-workflow system, if work is passed to a workflow participant who is not knowledgeable enough to accomplish the e-task within the work process, or if there is an exception in the work process, then the workflow system should be able to link the workflow participant manually or possibly automatically to a knowledge repository which captures users requirements or relevant information and knowledge about the workflow design problem or exceptional situation at hand. This is being accomplished by the knowledge repository that underlines the knowledge perspective and which contains context-specific information and knowledge about the workflow design problem or exception and how to perform the task at hand in order to take the right decisions. In fact, typical sequence of activities can be identified and packaged into knowledge to be reused in one or more workflow application domains. Most conventional workflow systems failed to provide appropriate functionalities and support for this type of problem situations. This is due to the fact that they are based on predictive models rather than anticipation of surprises.

3.3.3 Informational perspective

The informational perspective however, describes the information objects that are consumed and produced. This perspective also describes the business e-data, e-documents, and electronic forms that are transported between e-actor and the files and databases that store persistent application information on the Internet. The *knowledge repository,* which underlines the knowledge perspective also contains detail information and knowledge about the e-document, e-data and electronic forms used within the e-workflow application. The use of information technology to support organisational memory and subsequently enhance knowledge management has been examined in several studies.

The majority of conventional workflow systems have been designed to enable knowledge management activities that target the capture of data and information as opposed to harvesting knowledge itself (Rinkus et al., 2005). Thus traditional workflow development frameworks and approaches focuses on information processing (or transaction led) rather than the knowledge creation and innovation which is vital for survival and growth in the new world of e-business characterised by the emerging global and knowledge economy.

For example, a company analyses customer orders to extract patterns (information) revealing popular combinations of product features. It then advertises and promotes these already popular combinations to morph the made-to-order order-delivery process into one that approximates a more efficient made-to-plan approach with marginal customisations at the last minute. As such, customers modifying advertised special configurations do so at prices that reflect the higher process costs related to features they wish to modify. This is known as "From Data to Customer Insight" which means the behaviour of a customer is deduced from the analysis of data and this behaviour is used to adapt the organisation marketing strategy to fit the customer behaviour.

3.3.4 Organisational perspective

This perspective specifies the e-roles and e-actors that are involved in e-workflow execution. Again the knowledge repository contains knowledge about the e-actors and e-roles, relating to detail knowledge about the e-actors in terms of workload, experience, expertise, and background. The organisational perspective describes how the organisation configures its resources to perform business processes. There are two interrelated parts: (1) the resource inventory which consists of collections of actors, tools and information objects, the relationships between them, and the rules that govern the deployment of these resources and (2) the organisational structure which defines the organisational hierarchy, the "roles", the security and access authorisations, the document approval levels, the teams and work groups that need to be recognised, and the list of agents (individual people and software applications). We define these elements below.

A *resource* is an entity or object that is involve in the execution of a task. We distinguish three types of resources. An *actor* is a resource that can perform a task. An actor may be a human or a computer. A *tool* is a resource that is employed by an actor in performing a task. Examples are a payroll system or a spreadsheet program. Resources may be consumable or reusable. They may be used only in one task at a time or in multiple tasks. Each task is associated with a role that is *responsible* for the task and one that actually *performs* it. A role is a placeholder for an actor. Furthermore, a role is a collection of tasks and responsibilities that can be assigned to agent at run-time. The notion of a role is important for two reasons. First, it provides flexibility since the WFMS is insulated against the comings and goings of individual people in the organisation. Second, it facilitates dynamic balancing of workloads since users can be switched between roles as bottlenecks occur in the workflow process (Stohr & Zhao, 2001).

A process may contain roles from external organisations, e.g., customer or supplier. Organisational units also have inter-organisational relationships such as customer-supplier, alliance partner relationships. Roles, organisational units and their relationships establish the organisational structure that assigns actors to tasks. In the traditional workflow framework and development approaches, external roles are not well defined as the system fails to provide process related knowledge and knowledge flow for all the parties involved. If there is a breakdown during the execution of a workflow process, it is sometimes difficult to know who is responsible for the breakdown since the system fails to provide efficient flow of process related knowledge between the stakeholders involved in the execution of the workflow process.

The traditional workflow systems have failed to provide support for knowledge workers in order to assist them in performing their everyday tasks. This often causes delays in the work process when an exception occurs due to the fact that the workflow participant is not empowered with context-specific knowledge about the task within the work process (Nunes et al., 2009). This also causes delays for workflow designers during workflow design and evolution in the new e-business environment characterised by complex, dynamic and disconcerting business and workflow processes.

3.3.5 Behavioural perspective

This perspective specifies when and under which conditions a workflow is executed. Start conditions or transition conditions are typical language constructs to specify the behavioural perspective. e-routes define the way information and knowledge are channelled through the different steps of the process on the Internet. e-rules are the result of the blend of business policies and practices. They describe the way information packets and knowledge will be routed on the Internet. These can be specified using process logic in Petri-nets (Reisig, 1998; Van der Aalst et al., 2007), state-charts (Hazel, 1987), or other process models (Kumar & Zhao, 2002).

Event/Condition/Action (ECA) rules have also been widely employed in workflow management systems as an activity scheduler (Kappel et, al., 1995). These rules represent the knowledge that the organisation has in terms of handling situations flexibly. They are relatively difficult to get because they tend to reside in the manager's head. A simulation tool may help create or make explicit this knowledge about dynamic process execution.

While the traditional business logic was based on a high level of structure and control, the dynamics of the new e-business environment demand a different approach to organisational and workflow design. The new framework proposed in this research is characterised by its less emphasise on structure and bureaucratic control as described by (Malhotra, 2002). It is based on only a few rules, some specific information, and plenty of freedom, which can lead to innovation and creativity. We have introduced the proposed framework for knowledge-enhanced e-workflows modelling, design and evolution for e-business environments or virtual enterprises. The five views or perspectives, their characteristics and representations are summarised in Table 3.1 below.

Perspective	Questions	Workflow elements	Modelling tools
Functional	What, Why	e-Processes, e-tasks and activities	Functional decomposition (with variants), prototypical tasks, process patterns
Behavioural	When, How	e-Routes and rules	Flowcharts, state charts, Petri-nets, sequence diagram, activity diagram, control flow patterns
Organisational	Who, with what	e-Actors, e-roles, resources and resource management rules	Organisational charts, object hierarchies, workflow resource patterns, work breakdown structure
Informational	On what	e-Data and e-documents	Class diagrams, XML E-R diagrams, data patterns
Knowledge	On what	Workflow process, business process and e-business environments	Design patterns, cognition (knowledge from personal experience or view), knowledge repositories, workshops, and communities of interest, best practices, mentoring, training and development, social network analysis, self-learning. (Socialisation, externalisation, combination and internalisation) (Nonaka & Takeuchi, 1995)

Table 3. 1: Perspectives and characteristics for knowledge enhanced e-workflow modelling

3.4 Human factors within the proposed framework

Traditional workflow management technologies based upon the work processes and information-processing perspectives of a business strategy are limited in their capabilities for creation of new knowledge or renewal of existing knowledge (Nunes et al., 2009; Fahey et al., 2001). No doubt, such mechanistic approach provides the optimisation-driven efficiency-seeking behaviour (transaction led) needed for high performance and success in a business environment characterised by a predictable and incremental pace of change (Malhotra, 2000). However, given a radical and "discontinuously changing" e-business environment as described by (Malhotra, 2000), these automation centric technologies are less capable of sensing changes that they have not been pre-programmed to sense and in view of that unable to modify the logic underlying their behaviour.

The idea applies to an outdated business model and workflow strategy. Information systems in the old industrial model mirror the notion that businesses will change incrementally in an inherently stable market and executives can foresee changes by examining the past. The new business model of the Knowledge Age, however, is marked by fundamental none incremental change. Businesses cannot plan long term; instead, they must shift to a more flexible "anticipation-of-surprise" model. Thus, it is impossible to build a system that can predict the future in this new economy (Malhotra, 2002).

Until workflow systems embedded in computerised automation become capable of anticipating change and changing their basic assumptions (heuristics) accordingly, we would rely upon humans for performing the increasing relevant function of self-adaptation and knowledge creation (Malhotra, 2000). On the other hand, the vision of workflow systems that can autonomously revise their past history based upon their anticipation of future change is yet far from reality (Wolpert, 1996).

Given the constraints inherent in the existing mechanistic (programmed) nature of traditional workflow technology, the human factor assumes greater significance for maintaining the programmed heuristics (programmed routines based upon previous assumptions). Therefore, the human function of ensuring the reality check by means of repetitive questioning, interpretation and modification of the assumptions underlying the workflow system – assumes an increasingly important role in the era marked by radical and discontinuous change.

Although the growing recognition of the importance of tacit knowledge as a critical resource is welcome news in contemporary organisations since it holds the key to productivity and continuous innovation, the focus in traditional workflow development has been only on (1) explicit knowledge, (2) measuring and managing existing knowledge, and (3) the selected few carrying knowledge management initiatives.

This bias reinforces the view of the organisation simply as a machine for work process and information processing (Takeuchi & Nonaka, 1998). What e-business companies need to do is to change their existing view of knowledge by explicitly encouraging experimentation and rethinking of their organisation's e-workflow solution generating processes and pay more attention to (1) tacit knowledge, (2) creating new knowledge, and (3) sharing it within the organisation. Only then can the organisation be viewed as a living organism capable of creating continuous innovation in a self-organised manner (Takeuchi, 1998).

3.5 Chapter summary

This chapter has introduced the proposed knowledge enhanced framework for the development of e-workflow systems in the digitised, global and knowledge economy characterised by complex, dynamic and unpredictable business processes and environment. The proposed knowledge enhanced framework consists of five perspectives for e-workflow modelling. The next chapter presents the knowledge memory and mechanism for storage and retrieval of design knowledge in the form of workflow design pattern from the knowledge repository within the proposed framework

Chapter 4

The Proposed e-Workflow Knowledge Repository

This chapter presents the e-workflow knowledge repository, the architecture of the e-workflow design patterns environment to support the proposed framework, and the mechanisms for storage and retrieval of workflow design patterns from the knowledge repository.

4.1 e-Workflow design pattern knowledge repository

The main goal of the knowledge workflow design pattern repository is to serve as a source of sound solutions, proven by experience from previous cases, for problems occurring during workflow design, modelling and evolution (Perronne et al., 2006). A knowledge workflow design pattern repository is one of the possible ways to assist knowledge workflow designers and users in building their workflow models efficiently, while avoiding re-inventing already existing solutions of problems, which are common in the domain context, thus enhanced the competitive edge of the organisation.

The knowledge repository is populated from two sources: the extraction or deduction of knowledge from the data and information flowing between the four perspectives and the memorisation of successful stories, best practices, experiences, previous cases which are organised as design patterns. These design patterns will be reused to continuously evolve and provide flexibility of e-business processes to reflect immediate changes required in the new e-business environment.

The knowledge workflow design pattern repository is based on the memorisation of successful stories, best practices, past experience and previous cases organised in the form of workflow design patterns; they express sound solutions for problems frequently recurring in a workflow domain in the form of business process workflow design pattern templates. When a knowledge workflow designer or user is faced with a workflow design problem, he/she can look up for a solution which is similar to the problem domain at hand from the knowledge workflow design pattern repository and reuse it in the target domain, thus spending less time and effort on solving the problem and ensuring the soundness of the solution. For instance, many workflow processes are faced with the need for managing such situations as changes in the business environments, the cancellation of an order or of a service request, or the violation of data or temporal constraints.

Business process workflow design pattern templates define these behaviours in abstract template forms, and the templates may be reused, customised or specialised for different workflow application domains, thereby increasing the speed, flexibility and quality of workflow design and evolution and consequently reduce the development effort, time and cost. The importance of recognising the right workflow design pattern templates from the knowledge repository will help to improve productivity as well as reduce the expert skill requirements of the workflow designers during the design and evolution of e-workflow applications in the new economy (Xiao & Zheng, 2007).

The availability and applicability of such workflow design patterns is one of the key aspects of the e-business process and domain knowledge and experience that must be provided by a flexible and adaptable knowledge enhanced e-workflow system if it has to provide effective support for workflow design and evolution in the new e-business environment characterised by complex, dynamic and unpredictable business processes and environment. During the design and evolution of a workflow application, the knowledge workflow designer must be able to identify suitable combination of design pattern templates and processes for achieving the e-workflow design tasks, select the ones most appropriate to the current problem situation, and, if necessary, reuse, adapt/customise them for that problem situation.

To support this, our proposed knowledge enhanced framework approach for e-workflow modelling, design and evolution incorporates a *knowledge workflow design pattern repository*, which maintains a history of process structure, relating each structure to the types of tasks for which it is a suitable method. Each workflow design pattern specifies a set of tasks, together with the ordering constraints and object flows between them. Thus, a workflow design pattern represents one possible means of achieving a given type of task by breaking it down into a particular structure of sub-tasks. Each workflow design pattern specifies a single level of structural decomposition. However, the decomposition is into a further set of tasks, for each of which further workflow design patterns may exist in the knowledge repository. These workflow design patterns may in turn be selected to specialise/instantiate the sub-tasks, and so a multi-level hierarchical process structure may be generated by composition of many workflow design pattern templates.

4.2 E-workflow design patterns

Object-orientation and component software engineering suggest well-proven design patterns (Gamma et al., 1995) in order to implement solutions for typical recurring design problems. Patterns are a way for the designer to specify the workflow schema (process definition) by reusing previous experience and knowledge of the best designers. Workflow management systems are generally used to support, control and monitor business processes. Explicit models of different perspectives, i.e. process, organisational, behavioural and informational, etc, typically drive them. In order to build a workable model with the help of a workflow system efficiently, all the requirements of the e-workflow systems from functional, informational, behavioural, organisational and knowledge perspectives, must be well understood and applied.

Several steps have already been made in the direction of formalising patterns in the workflow domain and substantial effort in the form of workflow patterns (van der Aalst et al., 2003), Workflow data patterns (Russel et al., 2004), and workflow resource patterns (Russel et al., 2004), are currently under investigation. These pattern languages address the process, data, and resources perspectives in isolation. Note however that in a real-world e-workflow system, process, data, and resources perspectives interplay, thus considering every perspective in isolation is not sufficient. No attempts have been made to formalise the patterns combining several perspectives (Mulyar & van der Aalst, 2005). Workflow designers and users, working in the same problem domain, experience similar difficulties while solving the same kind of problems. Since problems to be solved are multi dimensional and are often not unique to a particular domain i.e. they recur in many systems; e-workflow designers and users often invest their time and effort on solving a problem and often reinvent the wheel (reinvent already existing solutions) due to lack of methods and domain knowledge. Patterns are viewed as a description of a problem, of a solution, and of the context in which this solution works.

We introduce design patterns as generalised description to problems and solutions that can frequently occur in e-workflow design, modelling and evolution in the new economy. Patterns encapsulate typical rules or set of rules that capture the knowledge about the occurrence of a problem situation and the actions that can be performed to deal with it. Patterns consist of *predefined parts*, *parameterised parts*, and *optional parts*. Parameterisation and optionality are introduced to support pattern re-usability and adaptation in workflow design for aspects related to workflow design and evolution (Casati et al., 1999).

The proposed framework presented in this research borrows concepts and solution from both design and rule patterns to support flexibility issues during workflow modelling, design and evolution in the new e-business environment. Traditional approaches to workflow modelling mainly deal with the use of rules in specific contexts serving as a mechanism for workflow enactment and evolution (Casati et al., 1999). The proposed framework focuses on providing abstraction mechanisms to represent in an implementation-independent manner the knowledge and experience associated with workflow design and evolution. The goal is the reuse of "good" old workflow design patterns for new workflow modelling tasks. This requires an "Experience and knowledge Management Factory" like the workflow design pattern repository with efficient retrieval and adaptation techniques in order to avoid reinventing the wheel. It is a basis for long-term process improvements resulting in increased competitive advantage for the new e-business enterprises.

The proposed framework also involves human cognition (knowledge from personal experience or view) and problem solving. People have the tendency to use existing methods and solutions to solve new problems in the global and knowledge economy. Unfortunately, the role of human cognition is often neglected in traditional workflow development approaches, which hinder creativity and innovation (Zhuge et al., 2002). A cognitive-based e-workflow process model can unify the workflow process and the developers' cognitive process. The proposed workflow framework provides a knowledge perspective, which allows incorporation of human cognitive skill and experience (knowledge repository) to support designers and developers in their task of designing flexible e-workflow systems or application.

Finally, the proposed framework for e-workflow design, evolution and development needs less design work than the traditional approaches do, another is that the proposed framework can adapt more easily to changes of the business domain. Thus compared to traditional framework methods for workflow design and evolution our proposed framework provides a proactive and consistent development process, so it meets the needs of virtual organisations for rapid, low cost and flexible development. The framework also takes into consideration the four perspectives of the traditional framework for workflow design including the new knowledge perspective during the design, modelling and evolution of e-workflow applications in the new economy (Ndeta & Marir, 2005).

4.3 Architecture of the e-workflow design pattern environment

In this section we specify the architecture and functionalities of the e-workflow design environment, and then we present the sample usage of the environment. The architecture is specified in figure 4.1 below. The definition of a workflow schema is performed through the schema interface by reusing some of the available business process workflow design patterns templates in the knowledge workflow design pattern repository.

Note that workflow schema and workflow process are used interchangeably in this research. From within the workflow schema interface, the knowledge designer or user can interactively search the knowledge repository for suitable generic workflow design patterns templates.

Retrieved patterns are instantiated/customised/specialisation for the workflow schema at hand, through the schema interface, which can also be used to define new patterns from scratch if the available ones in the pattern repository do not fit the workflow requirements.

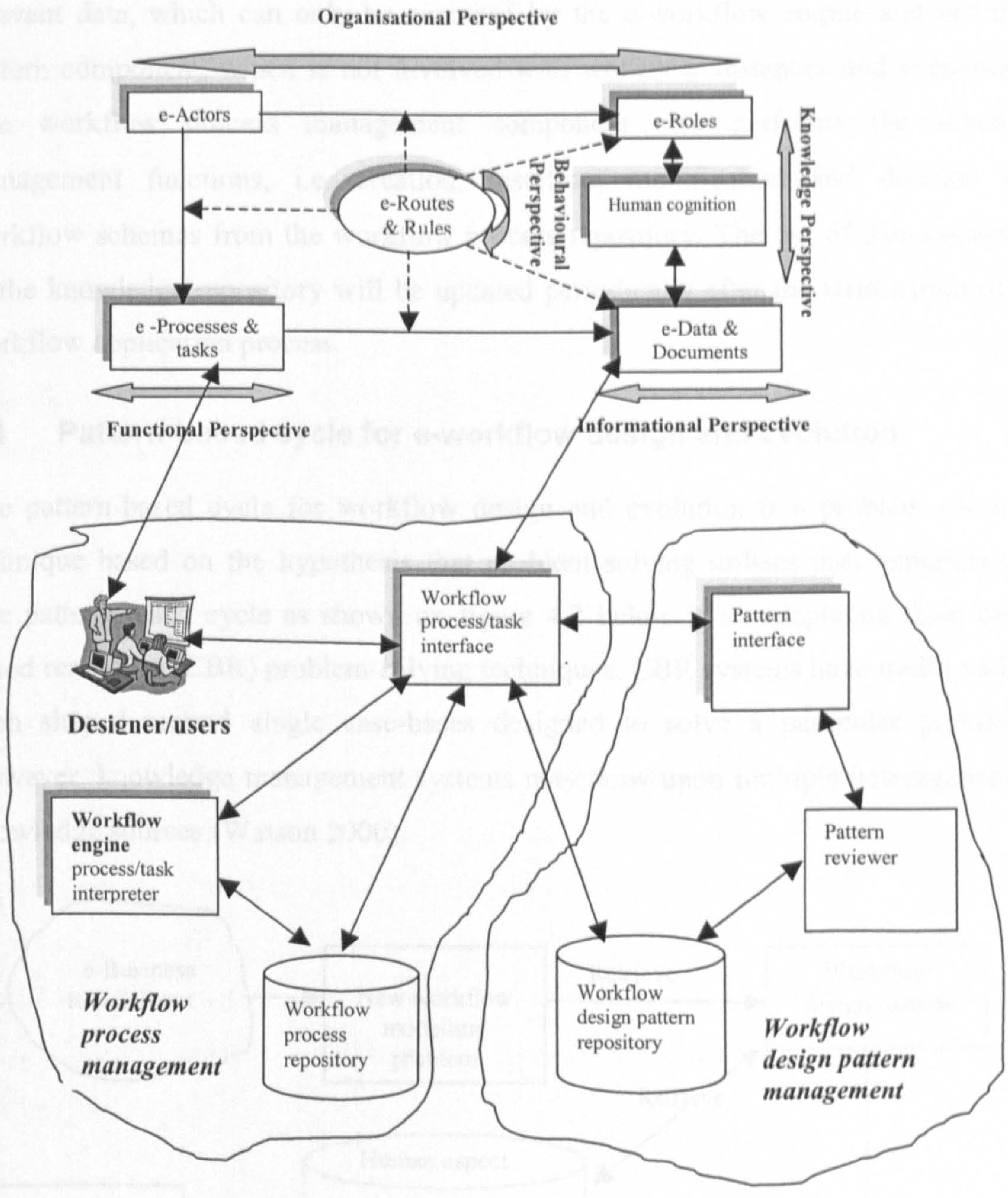

Figure 4. 1: Architecture of the e-workflow design pattern environment

Patterns defined for a workflow schema must be reviewed through the reviewer component before storing them in the repository. The workflow design pattern management component performs the pattern repository management functions, i.e. creation, insertion, modification and deletion of workflow design patterns from the pattern repository through the pattern interface. The workflow schemas are defined through the schema interface. The schema interface accesses the schema repository in order to insert, modify, and delete workflows. The defined workflow schemas are then accessed and interpreted by the e-workflow engine during workflow execution.

E-workflow execution may involve the modification of system and workflow relevant data, which can only be accessed by the e-workflow engine and not the pattern component, which is not involved with workflow instances and execution. The workflow process management component also performs the schema management functions, i.e. creation, insertion, modification and deletion of workflow schemas from the workflow process repository. The out of date contents in the knowledge repository will be updated periodically after the termination of a workflow application process.

4.4 Pattern-based cycle for e-workflow design and evolution

The pattern-based cycle for workflow design and evolution is a problem solving technique based on the hypothesis that problem solving utilises past experiences. The pattern-based cycle as shown on figure 4.2 below is an adaptation from case based reasoning (CBR) problem-solving techniques. CBR systems have traditionally been shaped around single case-bases designed to solve a particular problem. However, knowledge management systems may draw upon multiple heterogeneous knowledge sources (Watson 2000).

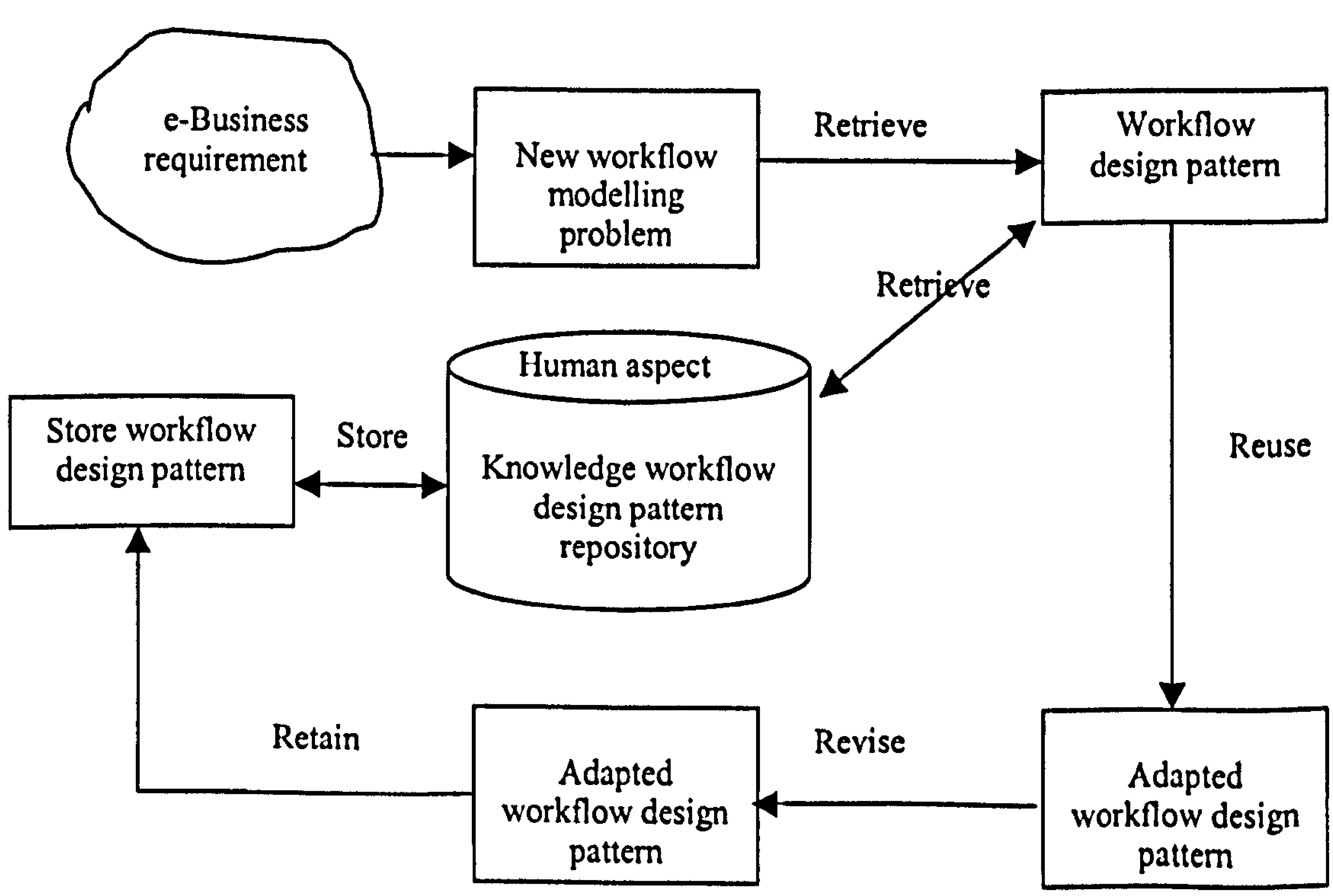

Figure 4. 2: Pattern-based cycle for e-workflow design and evolution

The pattern-based cycle for e-workflow design and evolution proposes a solution where knowledge could be drawn from multiple distributed heterogeneous sources and temporarily held in a virtual knowledge repository. This would still require a knowledge workflow designer to design the structure of the workflow design patterns. Knowledge can be retrieve from best practices, past experiences, previous cases, documentations, feedbacks as well as specifically authored workflow design patterns.

The adoption and reuse of workflow design patterns to support activities such as workflow design and evolution is feasible because of the recurrence of similar business tasks, data and tasks dependencies in different business context, and recurrence of common types of business problems and constraints across a variety of business processes and domains. The workflow design and evolution process begins when new business requirements are provided and used to initiate a search of the knowledge repository as depicted in figure 4.2 above.

Appropriate workflow design pattern templates from the knowledge repository maybe retrieved using text based query mechanisms. The retrieval step ensures that available process knowledge, which may be useful to model the new business requirement, is identified upfront during the e-workflow design phase. Retrieved patterns are analysed (manually, possibly automated) to decide if any of the retrieved process knowledge, particularly workflow design pattern templates, is appropriate for further modification or a new solution needs to be generated from scratch.

In the reuse step, a retrieved workflow design pattern possibly from multiple alternatives may be modified. Appropriate domain knowledge may be added or deleted and constraints may be re-configured during the design of the various workflow-modelling perspectives (functional, organisational, informational and behavioural). This refined model is then subject to validation and verification based on domain dependent rules and formal approaches. Successful validation of the workflow model may trigger deployment and execution on the workflow engine. Also this newly developed solution is stored in the knowledge repository as workflow design pattern template during the retain step of the cycle which can be reuse in the future to solve new workflow problems in different business settings or contexts.

4.5 e-Workflow design pattern input format

We developed an input format for pattern creation so that a pattern's contents would be structured and predictable. We surveyed pattern libraries on the web to devise a base set, and after some trial and error, settled on the following fields (See appendix B). The fields required to define a pattern are the Name, Problem, Sample usage, and Solution fields. Other fields that aren't filled out don't show up on the pattern detail page. They are considered to be optional fields.

4.6 e-Workflow design pattern repository indexing and retrieval scheme

In order for the mechanism and data structure of workflow design patterns retrieval to be applicable to retrieving context-sensitive workflow design patterns and sub workflow design patterns from the knowledge repository during the reuse step, the indexing scheme for patterns and sub patterns must be at an appropriate level of generality of the global and local context (CTX) and to reflect the hierarchical structure of the workflow design pattern templates. In (Dey, 1999), context is defined as "any information that can be used to characterise the situation of entities that are considered relevant to the interaction between a user and an application, including the user and the application themselves.

For this purpose, two main interconnected indexing schemes are provided in the knowledge workflow design pattern repository; workflow design pattern indexing scheme and the sub-workflow design pattern indexing schemes as shown on Figure 4.3 below. Each of the indexing schemes is composed of two types of indexes with different functionalities. *Classification indexes* represent the global and local context (CTX) features of workflow design patterns and their sub-workflow design patterns that represent the acquired knowledge and experience in the workflow domain. These indices are considered as difference-based indexing scheme by their main function of differentiating a workflow design pattern from another similar workflow design pattern.

However, these indexes are mainly used to classify and direct the retrieval to context-sensitive workflow design patterns and sub-workflow design patterns. This reflects the importance given to the context knowledge (knowledge related to the workflow design problem at hand) which domain experts retrieve and adapt patterns and also adds an advantage to the proposed framework approach by reducing the scope of the retrieval search space of classes of similar workflow design patterns rather than the whole knowledge workflow design pattern repository.

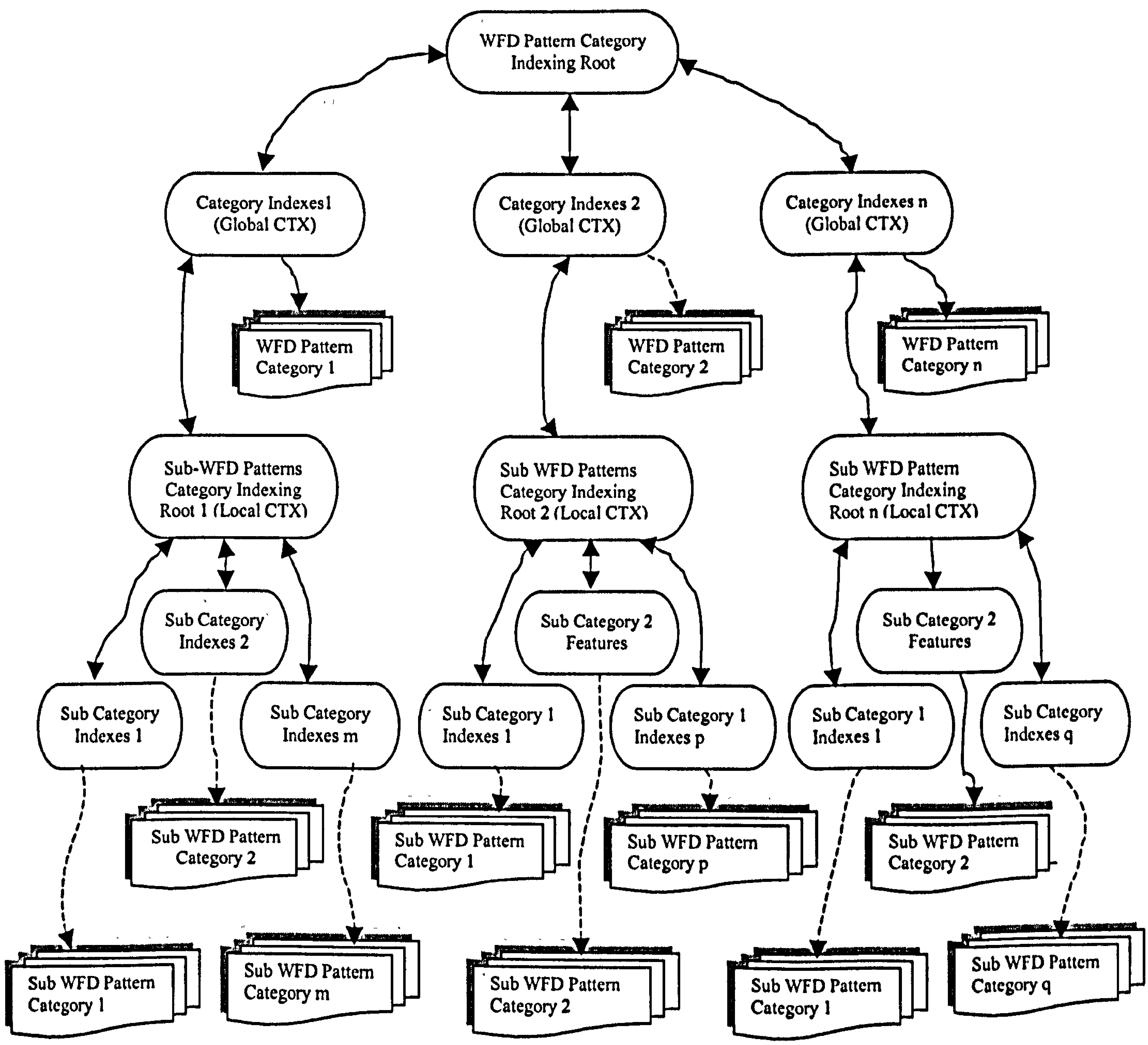

Figure 4. 3: Workflow design pattern indexing scheme in the knowledge repository
(Adapted from Marir & Watson, 1995)

Retrieval indexes represent a strategy for accessing the workflow design pattern repository and search for suitable workflow design patterns. Two search strategies are provided namely, *keyword-based* and *classification-based* search. The first is based on a pre-defined glossary of terms loaded during the specification of patterns to characterise the pattern within the knowledge repository. Keywords can refer either to pattern elements (e.g., names of events, actions) or can be more generic, domain-related words (Casati et al., 1999).

The second strategy allows for the retrieval of patterns based on two criteria: Typology of the patterns with respect to event types (e.g., temporal, external, data); and abstraction level of patterns in the repository. The knowledge workflow design pattern repository is extensible by defining new workflow design patterns from scratch or by adapting the existing ones. For this reason, the pattern environment provides maintenance functionalities to maintain the repository. Administration or management of the knowledge workflow design pattern repository mainly involves the creation, modification and deletion of patterns. Nonetheless, it also takes into consideration the management of the categories and sub categories used to classify and retrieve patterns.

4.7 Selecting, designing and building the knowledge repository

It was determined that the knowledge repository should

- Be scalable
- Be customisable
- Be easy to use
- Encourage collaboration
- Allow categorisation

As the knowledge workflow design pattern repository grows, finding a solution to a given problem in the repository would become increasingly difficult. To this end, some categories for classifying patterns were developed. These categories did not spring forth from the forehead; they emerged after studying sample content and by listing the content we anticipated. Several of the vocabularies that were initially suggested had to be scrapped. In particular, it was found to be counter-productive to classify patterns by their product type or language.

4.8 e-Workflow design pattern repository administration

The development and population of the workflow design pattern repository is an important task in the development of the proposed framework approach. The pattern-based repository in the proposed framework approach needs to be populated with an initial population of workflow design patterns for it to support the life cycle within the framework and the development of Expedia.com workflow model. To populate the repository, workflow design patterns templates have been synthesised from existing best practices handbooks from various functional domains, interpretations of manual process execution and process analyses from knowledge designers.

In the initial development of the proposed knowledge enhanced framework for the development of adaptive e-workflow systems, we have populated the pattern-based repository with design patterns collected from real world case studies in areas such as business process reengineering, business process modelling and workflow modelling and design. In addition, we have also acquired workflow design patterns wrapped together with some existing workflow products and also from the research literature review.

Presently the categories of workflow design patterns are organised as template files in the directory hierarchy defined by the indexing and retrieval scheme (see figure 4.3, page 79). The hierarchy based workflow and sub-workflow design pattern structure provide multiple indices into the pattern-based repository and enable structured management of patterns. Analysing the existing workflow design patterns in the knowledge repository help to facilitate the development of the hierarchies.

For example, the search for a pattern template in other to include a new workflow task into Expedia.com workflow schema described by the keywords "*hotel pick-up service*" may retrieve 'pick-up service' related tasks across numerous functional areas in the knowledge repository. An entry or a search for the 'hotel pick-up service' task in the task hierarchy supports retrieval of appropriate design templates from different functional areas in the knowledge repository. Nevertheless, for each type of 'pick-up service task', task parameters, inputs, outputs, pre-conditions and post-conditions in each context may be different.

The indexing scheme supports the development of efficient domain-specific query mechanisms. As the number of patterns in the knowledge repository grows, efficient indexing scheme is imperative. Presently, during pattern retrieval, the indexing scheme is mainly employed for guiding search (text-based retrieval) for a pattern across multiple domains and also for effective filtering when there are large numbers of design patterns involved. We envisage to expand the indexing scheme to include other indexing strategies as required in the future. The development of the existing knowledge repository has focused on representational issues to support pattern retrieval, reuse, customisation, adaptation and composition of Expedia workflow models.

4.9 Chapter summary

This chapter has introduced the proposed e-workflow knowledge repository, the architecture of the e-workflow design patterns environment to support the proposed framework, and mechanisms for storage and retrieval of workflow design patterns from the knowledge repository. The next chapter present the e-workflow design and development methods.

Chapter 5

Proposed e-Workflow Design and Development Methods

This chapter presents the macro e-workflow method and life cycle within the proposed framework for the development of complex e-workflow systems adapted to the new e-business environment. The chapter also presents an overview of the proposed framework and related components.

5.1 e-Workflow application development process

The application development process of a workflow management system encompasses everything from business process modelling up to the synchronisation (Georgakopouos et al., 1995) of activities of information systems and human agents that carry out the processes. (Van der Aalst et al., 2003) describes one of the traditional life cycles as shown on figure 5.1 for the development of a workflow application. This traditional workflow life cycle consists of four phases: (1) *workflow design,* (2) *workflow configuration,* (3) *workflow enactment,* and (4) *workflow diagnosis.*

The traditional workflow life is based on the structured waterfall model. The waterfall model works on the principle that the output from an earlier stage is used as input for the next stage (Sallis et al., 1995, Pressman, 1997). Thus there is a flow or 'waterfall'. The traditional approach fails to incorporate the concept of inheritance as opposed to the proposed knowledge-enhanced e-workflow application development approach. Inheritance has an important influence on future reusability of the workflow design models and robustness in the face of change (Allen & Frost, 1998).

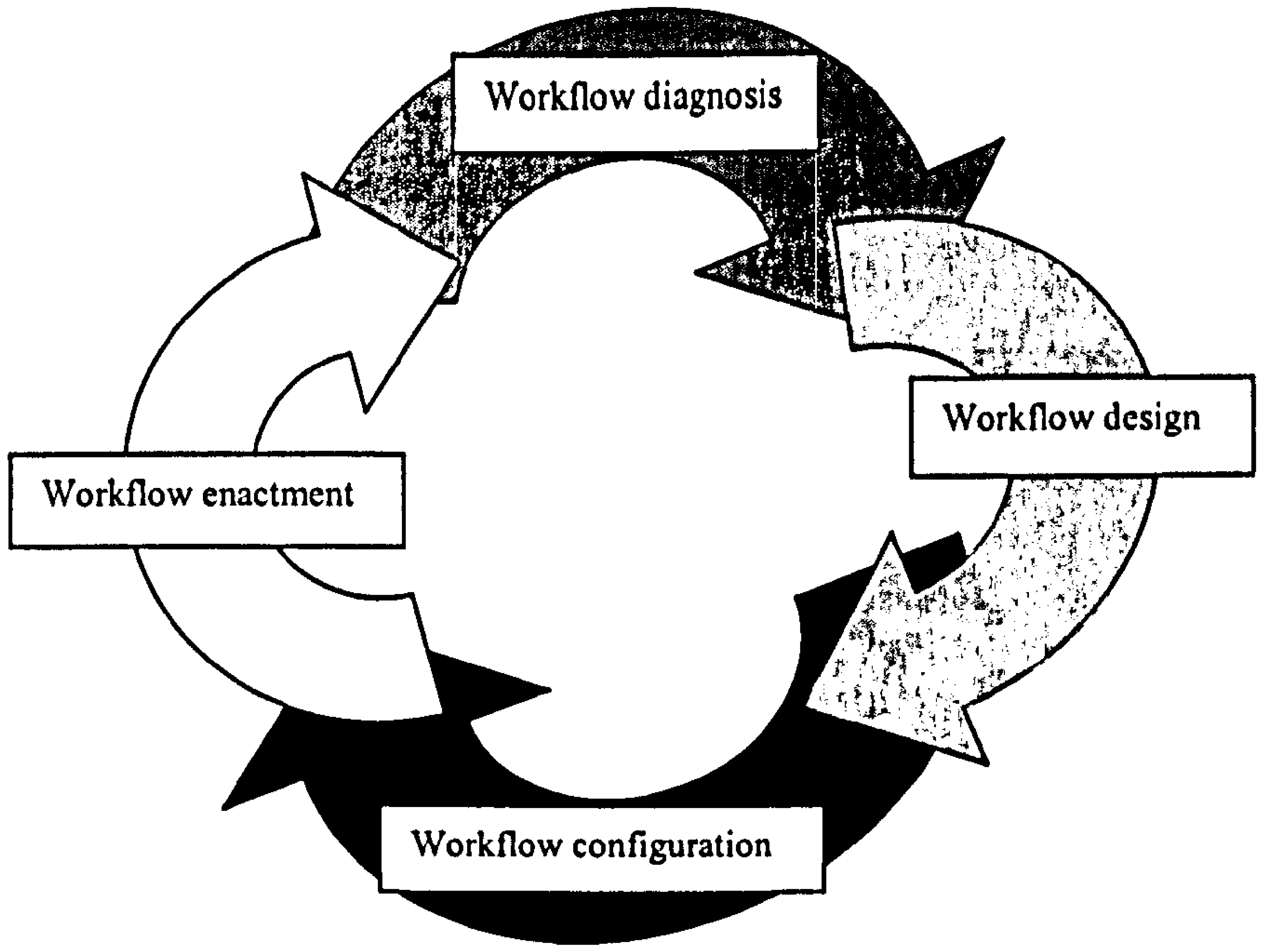

Figure 5. 1: Life cycle of Traditional workflow application development approach.
(Source: van der Aalst et al., 2003)

In *the traditional approach* for workflow applications development, the design phase is used for constructing a workflow model. This is typically done by a business consultant and is driven by ideas of management on improving the business processes at hand. If the design is finished, the workflow system (or any other system that is "process-aware") is configured as specified in the design phase. In the configuration phase one has to deal with limitations and particularities of the workflow management system being used (van der Aalst et al., 2002).

In the enactment phase, cases (i.e., workflow instances) are handled by the workflow system as specified in the design phase and realised in the configuration phase. Based on a running workflow, it is possible to collect diagnosis information, which is analysed in the diagnosis phase. The diagnosis phase can again provide input for the design phase thus completing the workflow life cycle.

In conventional workflow systems development approaches, the specification and design for the whole process, which is to be supported, are completed before execution commences, and the model produced is used many times for different examples of the same process. In most contemporary e-business environments there are many business processes for which this approach is not feasible. Some processes may be too complex or unpredictable to completely specify in advance, others have to be performed in dynamic environments, which frequently lead to changes to the original workflow specifications and designs being required (Chung et al., 2003). The traditional life cycle approach as shown on figure 5.1 ignores the problem domain-modelling phase, which deals with the business and process model. Domain or conceptual organisation consists of an analysis of the business and process models that the workflow application is design to support.

Traditional workflow approaches are too rigid to adapt to changes in the business domain (Zhuge et al., 2002). Once the business domain has changed, the system has to be re-designed. It is often difficult for the customer to state all requirements explicitly. The traditional approach requires this and has difficulties in accommodating the natural uncertainty that exist at the beginning of many e-workflow projects. Traditional approaches are suitable for repetitive, predictable and structured processes i.e., administrative processes like expense claim processing etc.

To summarise, traditional workflow approaches are not flexible enough to support contemporary e-business organisations, except in a very limited way, since the information and knowledge that flows in a well design workflow process is not often categorised and treated in such a way as to advance and promote its reusability (Nunes, 2009). A more flexible approach than current workflow approaches is particularly needed in e-business organisations where many of the tasks cannot be specified prior to execution, and where the duration of co-operation is typically very long (Dellen et al., 1997). In a sense e-workflow projects are the most challenging case of virtual organisations that may consist of very dynamic business processes, characterised by the emerging global and knowledge economy.

Distributed e-workflow projects are also interesting because of the apparent need to reduce cost and increase the speed of products and services development by enabling knowledge workflow designers and users in different organisations to work directly in a peer-to-peer relationship rather than being separated by several layers of management. This would allow the e-business organisation to develop and sell its products and services quicker and cheaper than its competitors.

Figure 5.2 below depicts the life cycle within the proposed framework for the development of adaptive knowledge enhanced e-workflows for e-business organisations in the new economy, and it's an adaptation from (Zhuge et al., 2002; Pressman, 1997; Jablonski, 1995; Kalakota & Winston, 1996; Jackson & Twaddle, 1999; Booch et al., 1996; van der Aalst, 2003). The life cycle evolves around three phases: (1) problem domain modelling phase, (2) the e-workflow design phase and (3) the e-workflow support or implementation phase as shown below.

The framework approach allows the three phases of the life cycle to be interleaved, and is also incremental and iterative. Traditional workflow development approach captures and focuses on explicit knowledge. Our proposed framework approach attempts to capture and focus on explicit and tacit knowledge management. The new knowledge perspective in the proposed approach is active while the other four perspectives are passive. This is because the knowledge perspective is constantly monitoring the method and domain changes and reflecting these changes on the workflow process. The proposed framework approach also tries to characterise work process related knowledge in such a way as to promote its reuse.

The life cycle within the proposed framework approach for the development of e-workflow systems shown in Figure 5.2 below, tackles some of the limitations of the life cycle of the traditional workflow design approach shown in Figure 5.1 above such as inheritance and reuse of previous experiences.

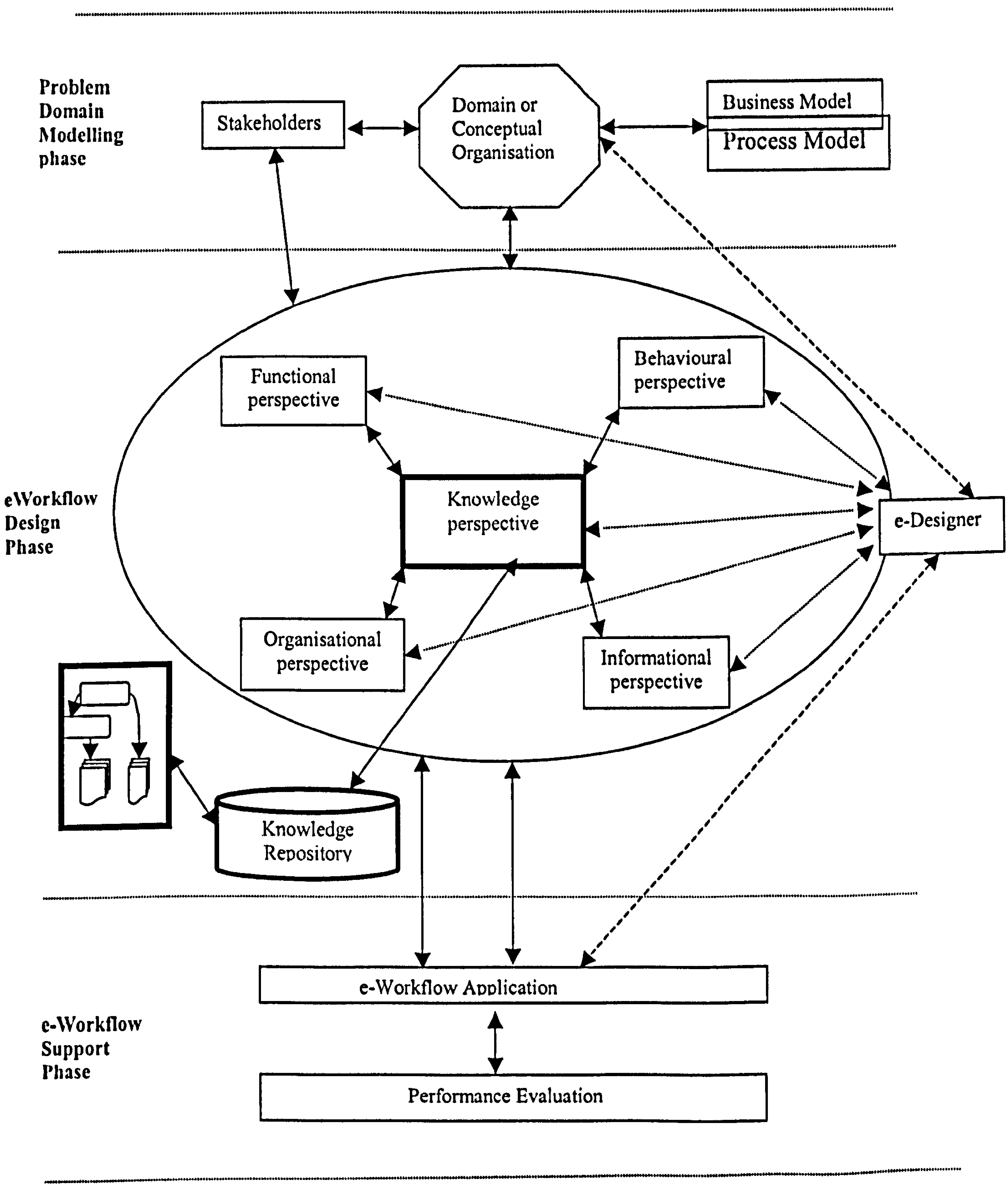

Figure 5. 2: Life cycle for the proposed e-workflow application development

5.2 Phases of the e-workflow application development process

5.2.1 Phase 1: Problem domain modelling phase

The *problem domain-modelling phase* involves the definition of the domain or conceptual model as a multi-divisional hierarchy organisation. This represents the modelling of the business model and process model of the organisation and process improvements or adaptations should be taken into consideration at this stage. The purpose of a business model is to describe the fundamental business aspects of the knowledge enhanced e-workflow system to be built. A business model describes which actors are involved, what the actors offer each other, and what activities they perform within the system. The central concept in an e-business model is that of knowledge and value, and the model describes how knowledge and value is exchanged between actors (Perry, 1954; Porter, 1998).

The business model can be distinguished from the process model, which aims at describing the operational and procedural aspects of a process and specifies the control flow of the activities involved in the development process of a knowledge-enhanced e-workflow application. A business model usually specifies the declarative aspects of e-workflow systems. A process model specifies the actors involved in operations, which activities they perform as well as sequencing of these activities. Thus a business model defines the '*what*' in an e-workflow system, while a process model defines the '*how*' (Perry, 1954). The e-workflow design phase below is concerned with the process model. This phase actually starts the e-workflow project.

5.2.2 Phase 2: e-workflow design phase

This phase focuses on the process model, which leads to the definition of the workflow schemas. The knowledge repository should be used here. During the design and development of an e-workflow application, the knowledge designer should be able to use the pattern-based design cycle for workflow design and evolution (see Figure 4.2) to browse through the knowledge workflow design patterns repository for suitable patterns.

Retrieved patterns should be reused or customised for the workflow schema or problem at hand. If there is no workflow design pattern in the repository that can be reused to meet the workflow requirement, then the proposed framework and methods (see Figure 3.2) for knowledge enhanced e-workflow modelling through workflow process definition interface should be used to define the workflow schemas for the new workflow application from scratch. This phase should also take into consideration that the virtual organisation is related to our framework for e-workflow modelling and is a direct simulation of the domain organisation. This phase constitute the following steps and activities:

Step1: Definition of the functional perspective of the framework (see Figure 3.2).
Step2: Definition of the organisational perspective of the framework(see Figure 3.2).
Step3: Definition of the behavioural perspective of the framework (see Figure 3.2).
Step4: Definition of the e-workflow data model (Information perspective) of the framework. Identify the e-service meta-data structure for establishing the communication relationship between the various business entities. This could be a table or data object defining the business entity and the e-services that they provide (see Figure 3.2).
Step 5: Knowledge perspective: In the proposed framework, the knowledge perspective has two main roles: monitoring the changes that are happening in the different perspectives and reflect these changes on the e-business processes, and enrich the framework with a knowledge repository (see Figure 3.2).

5.2.3 Phase 3: e-workflow support phase

The e-workflow support or implementation Phase supports the execution of the e-workflow design phase. *Workflow implementation and automation*: requires methodologies/technologies for bringing together agents (information systems and human performers) to implement, schedule, execute, and control the workflow tasks as expressed by the workflow specification. Design and implement the specific web services of the e-workflow virtual organisation, and then add them to the run-time e-workflow virtual support mechanism. This phase is consistent with the operational perspective of the e-workflow virtual organisations.

5.3 Overview of the framework and related components

Figure 5.3 below depicts an overview of the proposed framework and its related components (see Figure 3.2 page 59, Figure 4.1 page 75 and Figure 5.2 page 87).

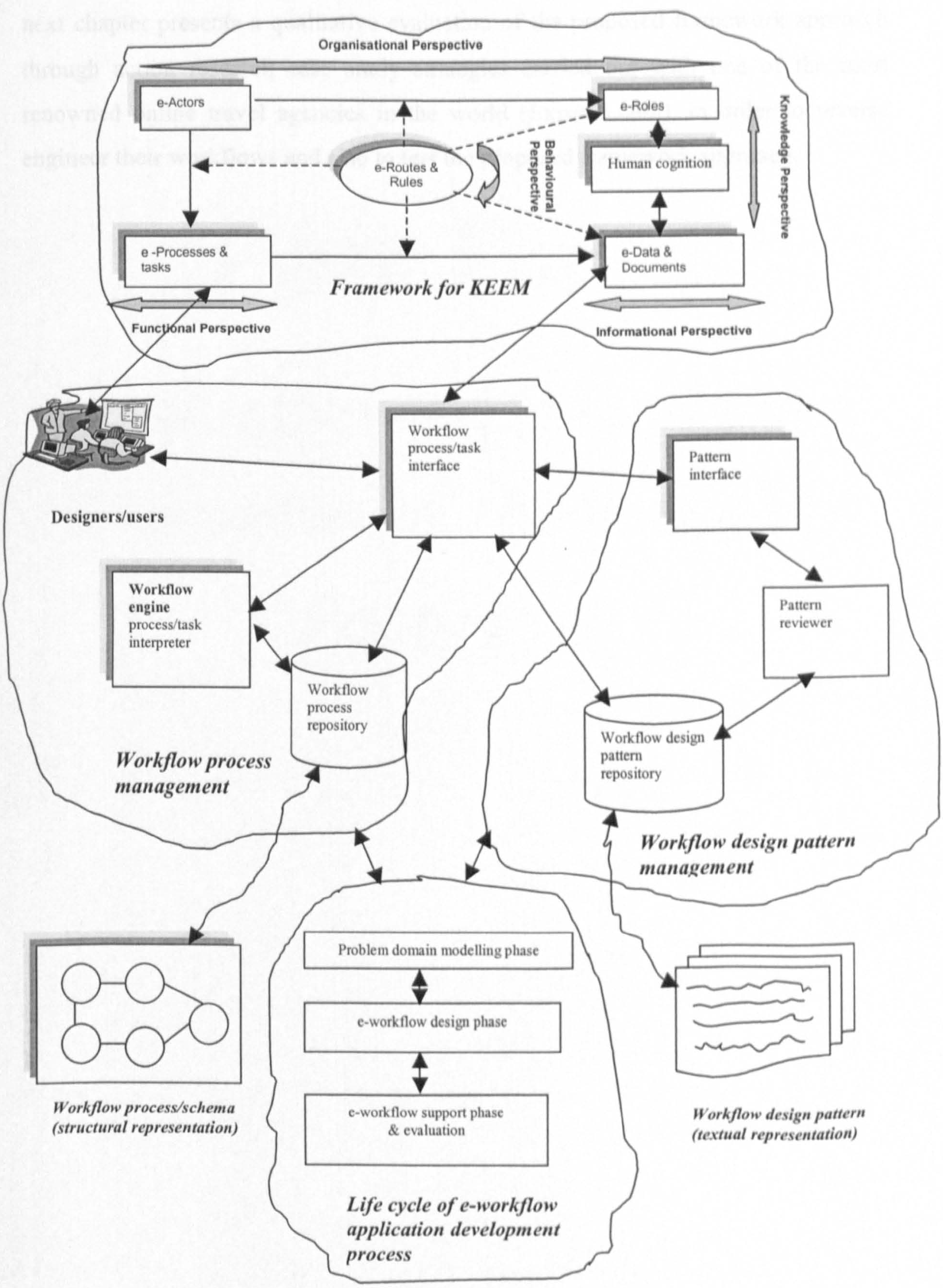

Figure 5. 3: An Overview of the proposed framework and its components

5.4 Chapter summary

This chapter has introduced the proposed e-workflow design and development methods and an overview of the proposed framework and related components. The next chapter presents a qualitative evaluation of the proposed framework approach through action research case study strategies carried out with one of the most renowned online travel agencies in the world (Expedia.com), in order to reverse engineer their workflows and also to test the proposed framework approach.

Part Three

Qualitative and Quantitative Evaluation of The Proposed Framework

Chapter 6

Qualitative Evaluation of the Proposed Framework

This chapter presents a qualitative evaluation of the proposed framework approach through action research case study strategy. We employ the proposed framework, which consists of pattern retrieval, pattern reuse, pattern adaptation and pattern review tasks, to support workflow model reuse during Expedia.com workflow design. In the application the Implementation-Independent Model (IIM) is created using the Unified Modelling Language (UML). The framework for knowledge enhanced e-workflow modelling and design will be applied within our proposed approach, for the creation of an IIM based on Expedia.com workflow schemas (definitions). For this purpose we will use an illustrative example of the UK's largest online travel agent by reverse engineering Expedia's workflow model in order to depict some possibilities, some benefits and some limits of the proposed approach. One of the main lessons learned in this experiment is the importance of the level of abstraction of the e-workflow meta-models used.

6.1 Action research

The framework will be evaluated qualitatively by case studies that will be carried out using the action research method drawn from social science. Action research is an approach to applied social research in which the action researcher and customer collaborate in the development of a diagnosis of a problem and its solution. In most of its forms action research is participative and qualitative and emphasis tends to be upon the need to understand a total system (Guba and Lincoln, 1989; Dick, 1999). Our research therefore attempts to understand how system analysis and design is interpreted through objective idealism. We believe that to understand this process it can be thought of in terms of action research in situation enrichment for the proposed workflow approach as a whole and the models of 'the parts' of the approach. The problem context under consideration here is the analysis and design prior to the implementation of workflow management systems projects. The particular topic within that area is the development of a suitable methodological approach enabling the analysis and logical design to be done cost-effectively within the very heavy constraints imposed by the unavoidable shortage of expert systems analysis of workflow management systems.

According to (Avison et al., 1999), a particular strength of qualitative research methods is their value in explaining what goes on in organisations, and action research can address complex real-life problems and immediate concerns. In addition, qualitative methods permit the evaluator to study selected issues in depth and detail (Kauppinen et al., 2004). Furthermore, (Potts, 1993) suggest an 'industry-as-laboratory' research approach where researchers identify problems through close involvement with industrial projects, and create and evaluate solutions in an almost invisible research activity. Consequently, these prompt researchers to emphasise what people actually do or can do in practice, rather than what is possible in principle (Kauppinen et al., 2004). Foreman and Johnson (1999), suggested that 'case studies' can be based on real events in real organisations. Case studies were "originally" devised for use in medicine and law, and have long been used in business and management studies as a way of encouraging the development of analytical skills as well as enhancing practical knowledge (Oriogun, 2006).

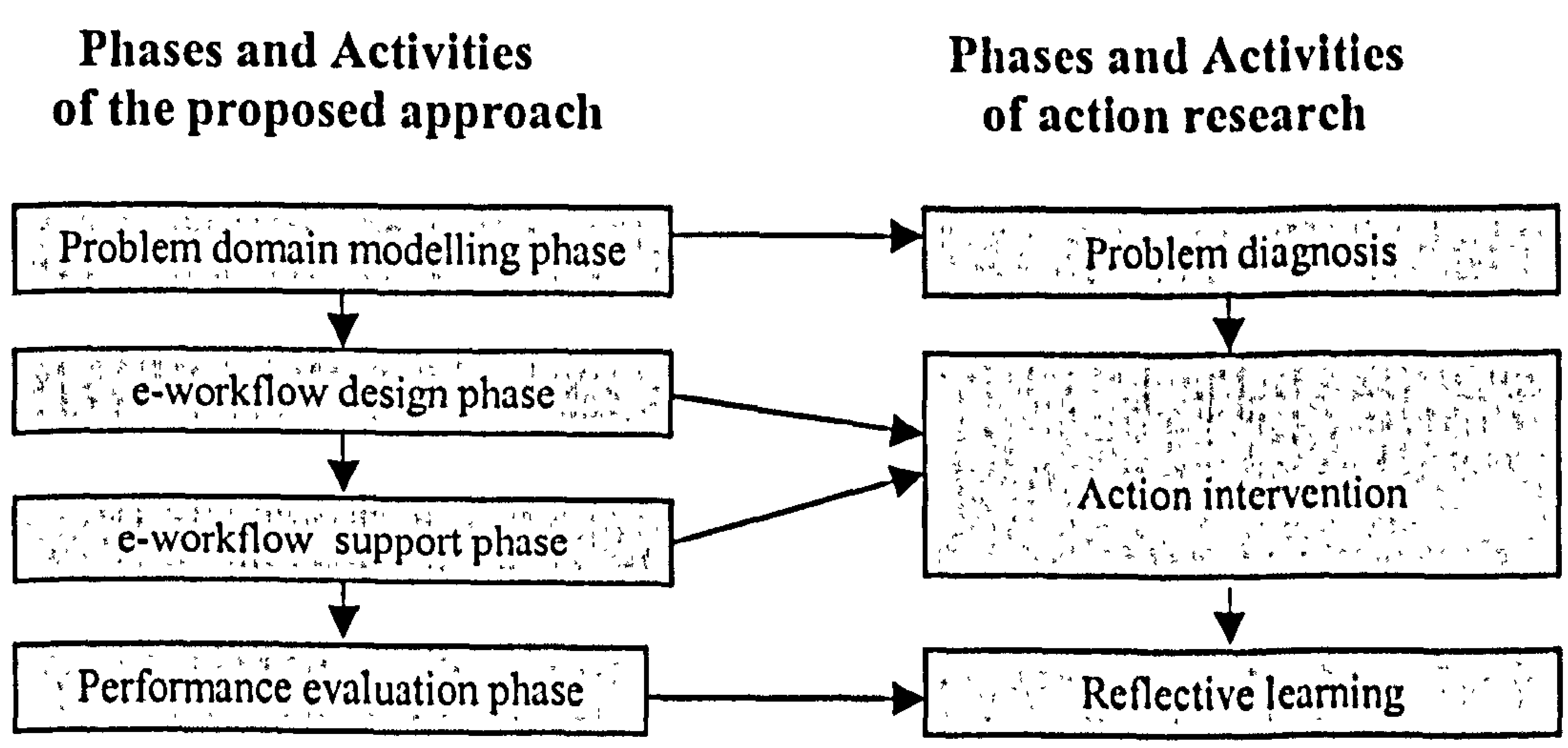

Figure 6. 1: Proposed framework mapping into action research activities

According to (Avison et al., 1999), action research is an iterative process involving researchers and practitioners acting together on a particular cycle of activities, including problem diagnosis, action intervention, and reflective learning. Figure 6.1 above shows how the proposed workflow design pattern-based approach relates to these action research activities. As mentioned earlier, the approach that we are proposing is for workflow modelling in the e-business environment. The research goal that we are aiming at is to investigate the approach that supports e-workflow designers with complicated e-workflow modelling tasks. We hypothesise that the proposed approach, facilitates process design by overcoming much of e-workflow process designer's burden while automating much in the development workflow.

6.2 Analysing Expedia e-workflow model through the proposed framework approach

Workflow modelling and design involves the translation of high-level business requirements into workflow schemas that can be executed by appropriate workflow engines. Specifying a workflow model is a knowledge intensive venture because development of a typical workflow model requires detailed knowledge and understanding of the business process logic, the organisational chart, and the information systems accessed by the workflow.

The workflow design pattern repository development efforts in the proposed framework have focused on acquiring design patterns in the area of customer relations management (CRM), business process reengineering (BPR), product development, supply chain management, workflow and business process management initiatives. We have developed a suitable ontology based on existing business best practices in these functional domains, available design template descriptions for these functions in commercial workflow design tools, previous research, knowledge and lessons learned on developing process repositories at higher level of abstraction, such as business process management (BPM) and workflow handbooks (BPM & Workflow handbook, 2007). See appendix H for samples of some of the workflow design patterns in the knowledge repository.

It is vital to note that the proposed framework approach has been enhanced with a knowledge repository, which stores human experience, best practices, previous cases and stories in the form of workflow design pattern. The repository supports explicit reuse, customisation and instantiation of partial possibly incomplete, experiential knowledge stored as pattern templates for solving unstructured and complex cognitive tasks such as the design of Expedia.com's workflow model. Past knowledge and experience stored in the form of workflow design patterns may be reused to explore the e-workflow design phase within the framework approach in other to synthesis new workflow solutions for Expedia.com. Thus a cooperative paradigm for e-workflow applications domain knowledge reuse is proposed. Since knowledge is in the human domain, human interpretation of templates is needed to maximise the benefits from knowledge reuse, necessitating explanation and exploration of domain templates (Sutcliffe & Maiden, 1993). We believe that an important part of workflow requirements engineering is to understand the workflow application by reference to its immediate context and by reference to similar context.

Two types of workflow design patterns are stored in the workflow design pattern repository within the proposed framework. Workflow schemas are stored as knowledge and solutions to previous problems in the form of workflow design patterns and sub-workflow design patterns templates, see figure 4.3 on page 79 for indexing and retrieval scheme. Workflow design patterns and sub-workflow design patterns embed the overall sequence of activities that must be executed to fulfil a business requirement or goal. When a workflow schema is modified or updated it is stored in the form of a template as a new workflow design pattern in the repository. These workflow design patterns are represented in the proposed framework with well-defined syntactic and semantic elements, which have been discussed in the preceding sections.

There is a wide range of interchange amongst the terms workflow schemas, process models, process definitions and workflow models as used in this research. Workflow modelling, design and evolution involves the definition of a workflow model from scratch or selection of appropriate tasks possibly from a repository, sequencing of the tasks to satisfy data and logical dependencies, allocation of resources consumed by the tasks, allocation of agents to execute tasks, scheduling of tasks considering concurrency, and finally, validating and verifying the workflow model. Manual workflow design is supported by graphical user interfaces, where the workflow model is defined as a graph. Modelling Expedia.com workflow involves searching through a knowledge repository populated with workflow design patterns from different business settings and the selection and retrieval of appropriate pattern templates to solve Expedia.com business problems or goal. If there are no workflow design patterns in the knowledge repository to fulfil Expedia's business problem or goal, it is suggested to design new (from scratch) workflow solutions taking into account all the perspectives including knowledge perspective proposed in our framework for knowledge enhanced e-workflow modelling (Ndeta et al., 2005; Casati et al., 1999).

6.2.1 The study

To study the benefits and limits of the proposed framework approach, we have chosen the illustrative example of e-business based on Expedia.com. The proposed framework approach will be use to reverse engineer Expedia's workflow model in order to identify problems and also to provide possible solutions. Conceptually this transaction can be demonstrated by the following example.

Expedia.com is the UK's largest online travel agent where customers can book their holidays. The travel agency sells flight tickets, reserves hotel rooms and provides car rental services to its customers. In order to provide these services for its clients, Expedia needs to establish business links with other organisations or business service providers (BSP), i.e. airlines, car rental and hotels. The customer can select a service from the following services via Expedia.com's web site (flight only, hotel only, car only, flight + car, flight + hotel, flight + hotel+ car) via the Internet. In this context, a financial institution, i.e. a bank is required to facilitate the financial transaction.

This scenario is complex and may run into difficulties due to the following situations.

Firstly, the business process may require change due to the need to capture some new business requirements. Schema evolution due to changed business requirement can be provided by the proposed framework for schema evolution, due to changed requirements. The framework can accommodate schema changes, which affect current workflows by defining an alternative flow redefining a portion of the schema. Specifically the framework can deal with minor changes such as the *insertion of a new task in parallel with another one, insertion of a control task at the end of a task.*

Secondly, the customer two months later (after the initial booking) two weeks before the departure date, decides that they wish to change some aspects of the transaction, such as upgrades, extend, amend or cancel. This will trigger varying interactions between the service providers or business partners involved in the transaction. Beside the difficulties of actually changing details of the transaction, there are many difficulties concerning the service providers involved in the contract. Some will require compensation or have set procedures for going about amendment of their part of the contract. This exceptional situations added by the scenario presents many difficulties and issues concerning the modelling and implementation of Expedia's e-workflow virtual applications.

6.2.2 Expedia.com domain analysis

Customer: Internet users who will select and order services. Through a series of web pages the customer will be able to browse and purchase products and services. The ordering process will be achieved through an HTML based input form. Some aspects of the business processes (its logic and its data) that are triggered as a result remain hidden from the customer. For example, consider the following variation on the Expedia workflow process. In the transaction Expedia makes a call out to four external services providers in order to make a decision. The decision logic to enable the decision is clearly defined in the workflow process, even though properties of it remain hidden from one partner to another.

For instance, Expedia does not know the details about the customer's credit card (such as credit limit, current balance, or purchase history), only whether it can handle the purchase. Similarly, the customer does not know the full details of Expedia decision logic, only whether or not the requested service is available. Furthermore, if there is a breakdown in the workflow process, the customer is not aware of some of the internal process logic that will be used to handle the breakdown. Internal (private) implementation details should not be leaked outside of a service boundary. Leaking implementation details into the service boundary will most likely result in a tighter coupling between the service and the service's consumers. Service consumers should not be privy to the internals of a service's implementation because it constrains options for versioning or upgrading service (Evdemon, 2005).

BSP (Business Service Provider): This is the interface of the other e-business service providers (airlines, hotels, car rentals and banks). They must negotiate with Expedia.com over the Internet to provide services that meets the needs of the customer.

Expedia.com: Through the Internet, they provide the customer with an interface with which to order services. They will then negotiate service contracts with other **BSP**'s (airlines, hotels, car rentals and banks) to provide the services requested.

The workflow application development process of the online travel agent mainly consists of the following phases within the proposed knowledge enhanced framework for the design and development of adaptive e-workflows (see Figure 3.2):

6.2.3 Phase1: Problem domain modelling phase

In order to develop a workflow specification for Expedia.com, we need to investigate their business requirements, and then we move on to the design and implementation phase of the workflow application. Figure 6.2 below presents a simplified use case diagram for the virtual travel agency and its business partners showing the business model.

In figure 6.2 below, a customer that plans to make a trip, accesses the web site of a virtual travel agency that sells flight tickets, provides car rentals and room reservations. The customer enters his requirements. The travel agency receives the requirements of the customer and send them to the airline, car-hire and hotel. The travel agency receives the possibilities from the three partners and chooses the most appropriate solutions for flights, cars and hotels based on the requirements of the customer. It sends them to the customer who chooses, reserves and pays for the flight, car and hotel room. The payment is made with the support of a bank. Business process modelling, optimisation is encourage at this phase.

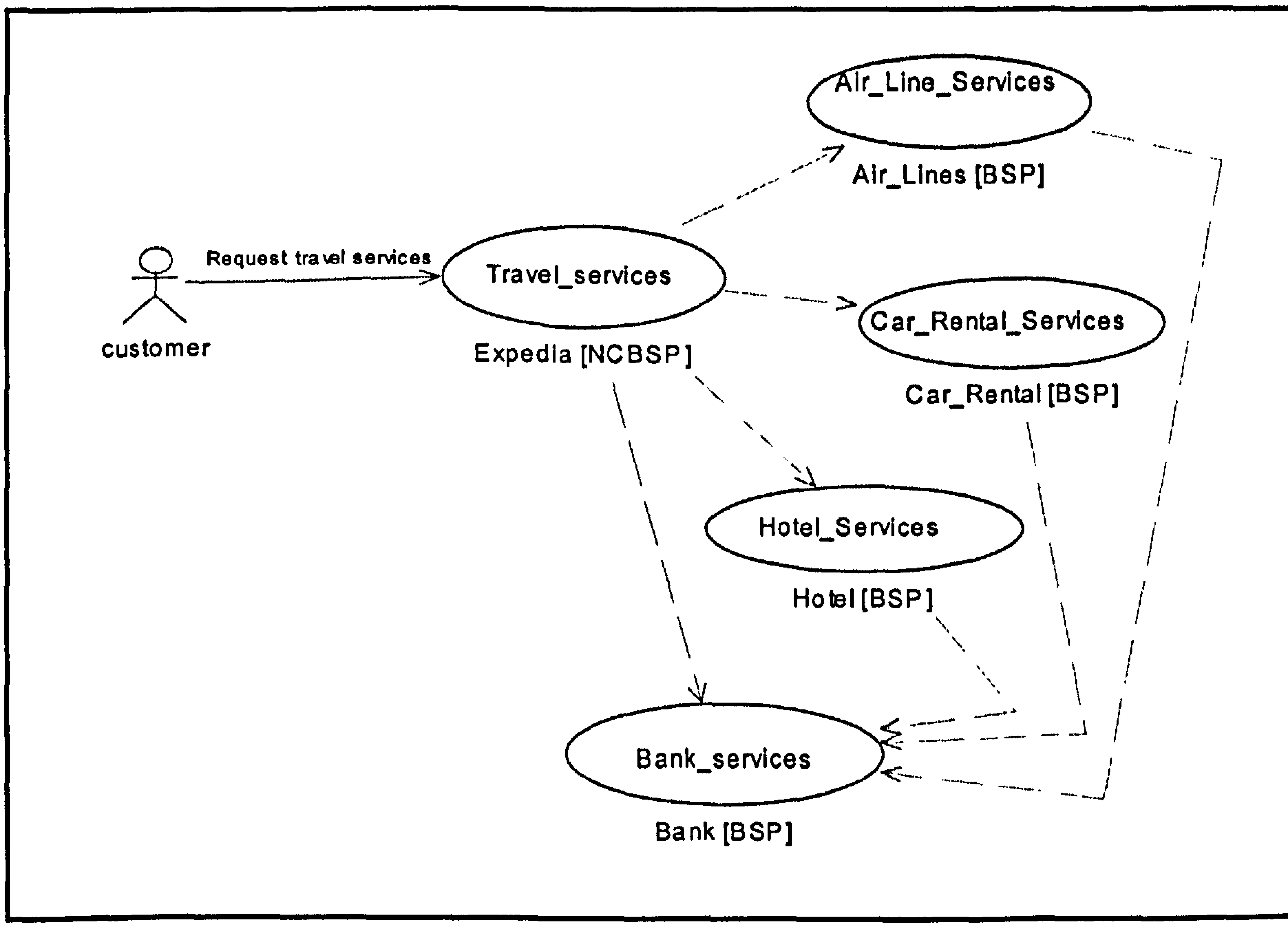

Figure 6. 2: Use case diagram for the online travel agency

In order to understand the flow of information and various responsibilities attached to different personnel within Expedia workflow model, we will use sequence diagram to identify the actors (stakeholders) involved and the time required to achieve the business process.

Figure 6.3 below is the sequence diagram, for Expedia workflow model. It models the interaction sequence between the business service providers (BSP) or stakeholders involved in the business process in terms of a sequence diagram. It specifies the messages that are exchanged and the ordering of events associated with sending and receiving messages. In most cases the design of an e-workflow virtual organisation starts with the specification of the communication structure (van der Aalst et al., 2006). Clearly, a description in terms of UML activity diagram is too detailed to start with. Therefore, another technique is needed. We use sequence diagrams for this purpose.

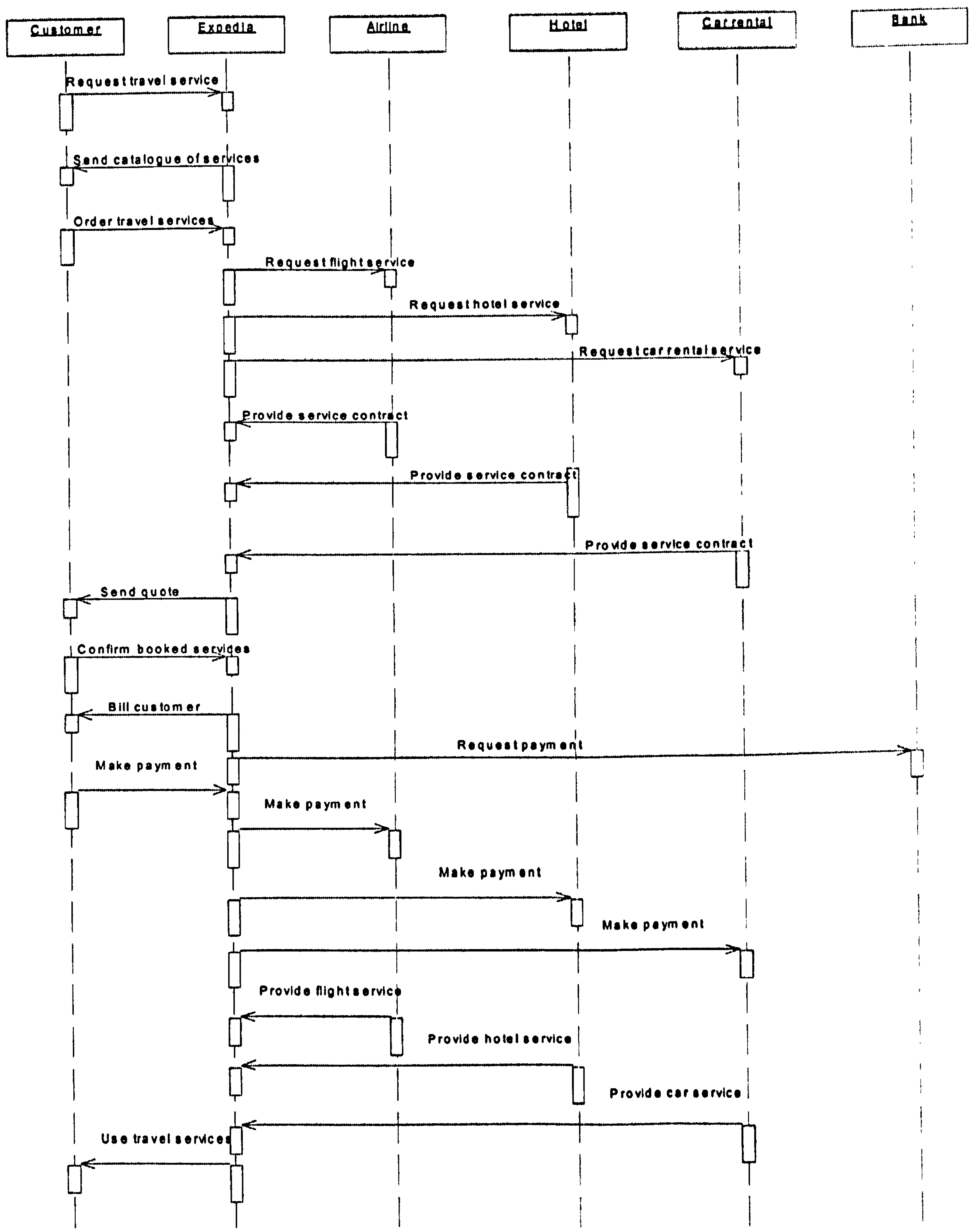

Figure 6. 3: Sequence diagram for Expedia online travel management

If Expedia's workflow application breaks down, a sequence diagram can be one of the possible ways of showing who is responsible for the breakdown. In order to identify the activities involved in Expedia's workflow process, we will use activity diagrams. The activity diagrams are based on extensive reuse of design knowledge in the form of workflow design patterns from the proposed knowledge repository and they specify the internal behaviour of the online e-travel agency workflow application. It also specify which tasks or activities need to be executed and in what order (i.e., the routing or control flow).

6.2.4 Phase 2: e-workflow design phase

The design of the e-workflow application actually starts from here. This phase should also be enhanced with knowledge and experience from the workflow design patterns and sub-workflow design pattern in the repository, which is considered to be a knowledge repository within the proposed framework. Patterns are included in a workflow schema, by reusing (i.e., selecting and customising) a set of pre-defined generic templates stored in the workflow design pattern repository as patterns. The proposed framework for knowledge enhanced e-workflow modelling (see figure 3.2 on page 59) should also be used here as a guide for the specification of the various workflow perspectives from scratch if there is no available workflow design pattern template in the repository that matches the workflow requirements. The workflow model should be platform independent. This phase also consists of the following sub steps:

6.2.4.1 Step 1: Definition of the e-workflow functional perspective

We describe the ontology for representing the workflow schemas of the web-based travel agency (Expedia.com) as required in the following discussions in our process ontology. We assume the existence of primitive tasks in a given business domain (as mentioned earlier). These primitive tasks may be combined into complex workflows. A workflow schema defines the internal structure of a composite task, which can be customised or reused in the form of workflow design pattern templates during the design of new workflow requirement in Expedia.com business environment.

For any given task there may be several possible workflow design patterns in the knowledge repository, expressing different ways of achieving the tasks for different situations. In this research we focus on the patterns in business problem domains, were control flow and data flow interact. We select the Unified Modelling Language (UML) activity diagram as the structural representational language for the workflows schemas within Expedia, since it allows the modelling and design of the various perspectives i.e., functional, behavioural, organisational informational and knowledge. Consider the design and development of Expedia.com workflow schemas shown as UML activity diagrams in figures 6.4 – 6.9, which depict the structural representations of the business process workflow design patterns diagrams for Expedia.com.

The workflow schemas depict simple definition (schemas) for the business process of booking travel services from Expedia.com, where the customer can select from the following services *(flight only, hotel only, car rental only, flight+car, flight+hotel, flight+hotel+car)* via the Internet. The workflow schemas have three other sub-workflow schemas relating to partners (associates) business services providers i.e., airline reservations, hotel reservations and car rental reservations. Three additional sub-workflow design patterns are required in the knowledge repository for achieving the airline reservation, hotel and car rental reservations sub-workflow during the design of Expedia.com workflows.

The UML activity diagrams are only used for illustrative purposes and depict the activities and control flow including concurrency nodes (such as forks and joins) for the model schemas. As shown at the top of the figures are the various organisational roles (swimlanes), which are involved in executing the activities or tasks. Activities may be performed by a single agent or teams of agents associated with the business process. For example check availability and receive request for travel services is performed by all the roles involved in the choice of travel services selected by the customer. Each of the activities could be represented by a primitive or composite task. All the above workflow schemas can be stored as knowledge from past experience in the form of workflow design pattern templates in the knowledge repository.

The workflow design process start on when new business needs or requirements are provided and used to initiate a search of the workflow design pattern repository. During the design of Expedia.com workflow model, a knowledge workflow designer should be able to retrieve suitable patterns from the repository using text query mechanisms for unstructured data and domain specific mechanisms for proprietary data structures. The e-workflow design phase of the proposed framework should ensure that the retrieved patterns contain the relevant knowledge that may be useful to model the new business requirement for *Expedia.*

During the design phase, a retrieved workflow design pattern chosen possibly from a number of alternatives may be reused or modified. Suitable domain knowledge may be employed to alter Expedia.com workflow process sequence; new tasks may be added or removed. After tasks sequencing, resource allocation may be taken into consideration in other to enable concurrent execution and infrastructural issues such as data location and agent's location to Expedia.com workflow model.

Retrieved patterns are analysed manually or possibly automated to determine if any of the retrieved knowledge, particularly workflow design patterns, is suitable for further modification or a new solution to the Expedia's problem needs to be generated from scratch by using the framework for knowledge enhanced e-workflow modelling.

The booking flight only business process workflow design pattern diagram below was develop from first principle by reverse engineering Expedia.com workflow models from their website since there are no workflow design pattern template in the knowledge repository that can be reuse to develop Expedia workflow models.

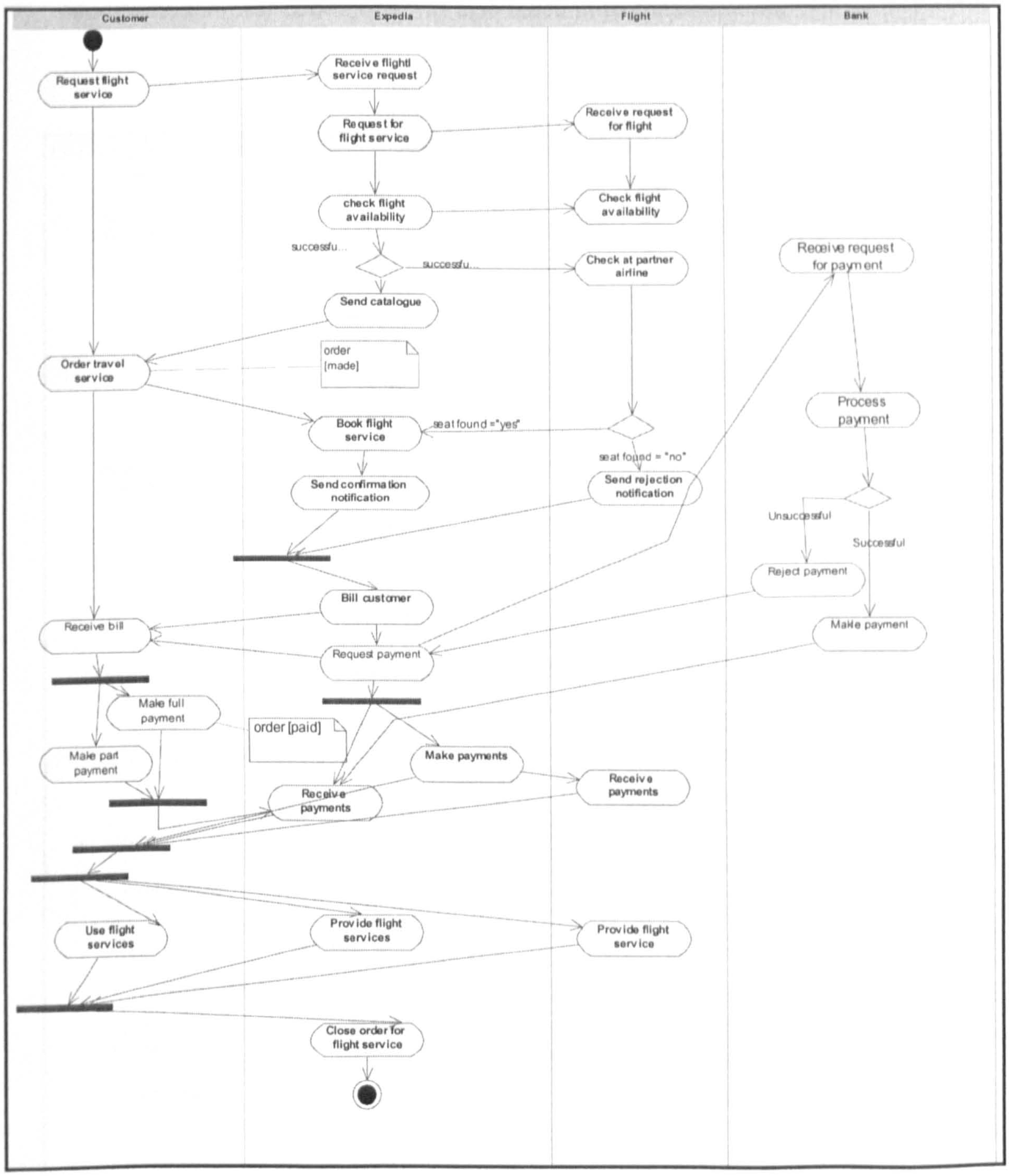

Figure 6. 4: Booking Flight only business process workflow design pattern diagram

In order to develop the hotel only business process workflow design pattern as shown below, the flight only business process workflow design pattern was reused by instantiating and specialising it with activities and resources in the context of hotel only business process workflow design patterns. This was made possible by instantiating and specialising resources like *flight* with *hotel* and activities like *receive request for flight* with *receive request for hotel*, *check flight availability* with *check hotel availability*, etc. After tasks sequencing, resource allocations, pre-conditions and post-conditions was also taken in to consideration.

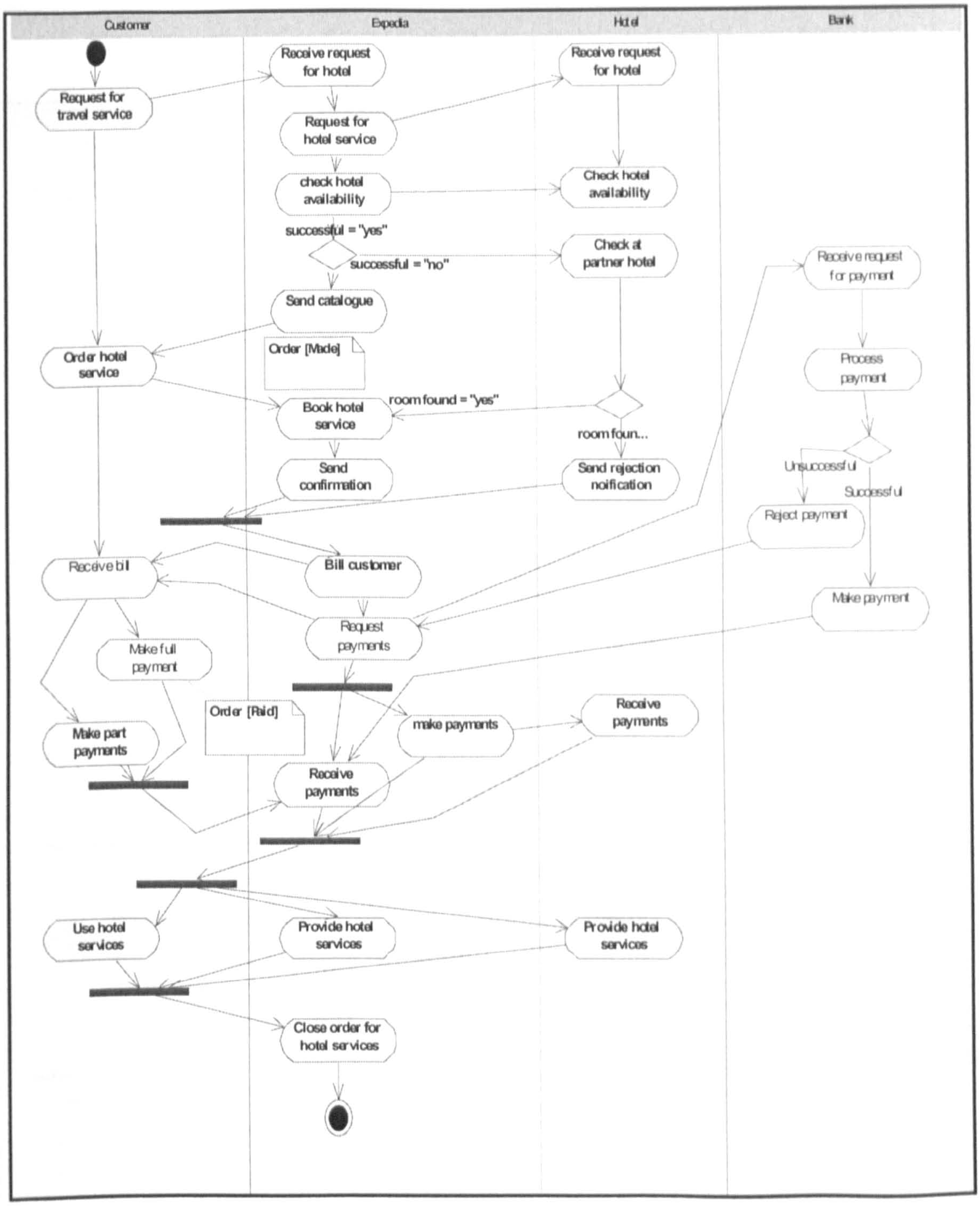

Figure 6. 5: Booking Hotel only business process workflow design pattern diagram

Similarly, to compose the car only business process workflow design pattern below we had to select and customise, instantiate and specialise some of the activities and tasks from the hotel only business process workflow design pattern templates. This was made possible by instantiating and specialising resources like *hotel* with *car* and activities like *receive request for hotel* with *receive request for car*, *check hotel availability* with *check car availability*, etc. After tasks sequencing, resource allocations, pre-conditions and post-conditions were also taken in to consideration.

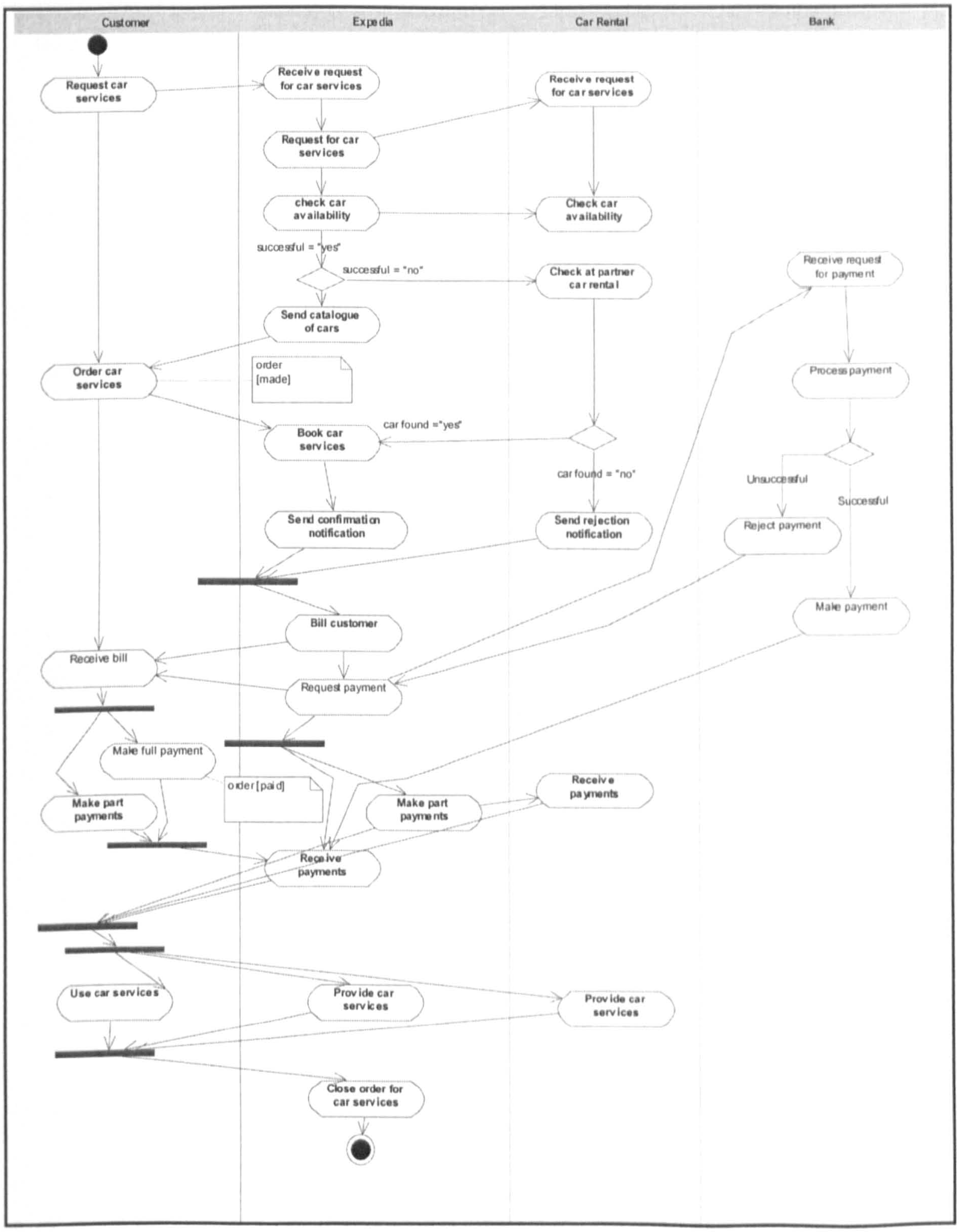

Figure 6. 6: Booking Car only business process workflow design pattern diagram

Also, to compose the flight + hotel business process workflow design pattern diagram below, we had to adapt and customise the flight and hotel only business process workflow design pattern above by extending it with some activities from the hotel only and flight only business process workflow design patterns and specialise them in the context of flight + hotel business process workflow design pattern. After tasks sequencing, resource allocations, pre-conditions and post-conditions were also taken in to consideration.

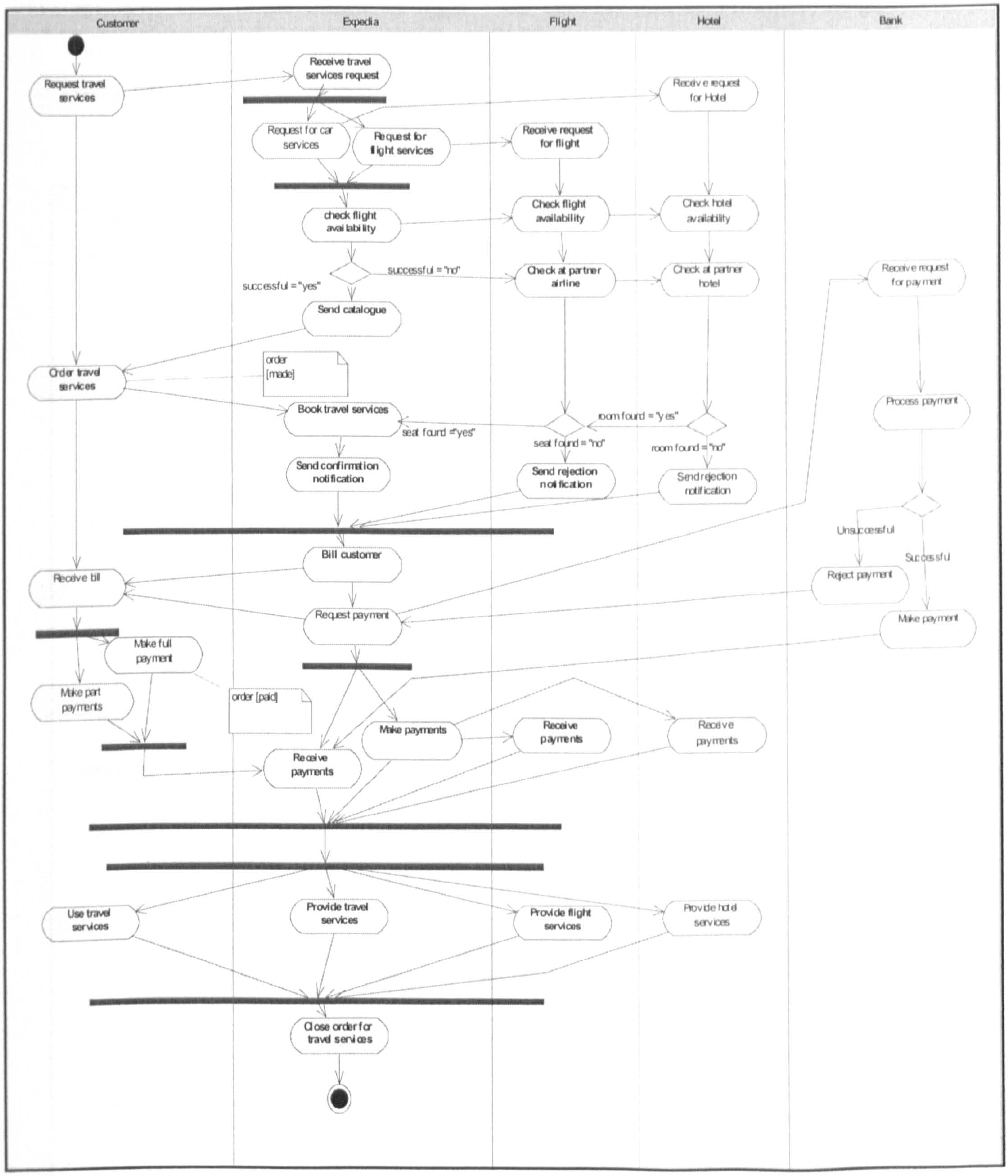

Figure 6. 7: Booking Flight + Hotel business process workflow design pattern diagram

Furthermore, the flight + car business process workflow design pattern below was composed by selecting and reusing some of the activities, tasks and resources from the flight only and car only business process workflow design pattern diagrams and specialise them in the context of flight + car business process workflow design pattern. After tasks sequencing, resource allocations, pre-conditions and post-conditions were also taken in to consideration.

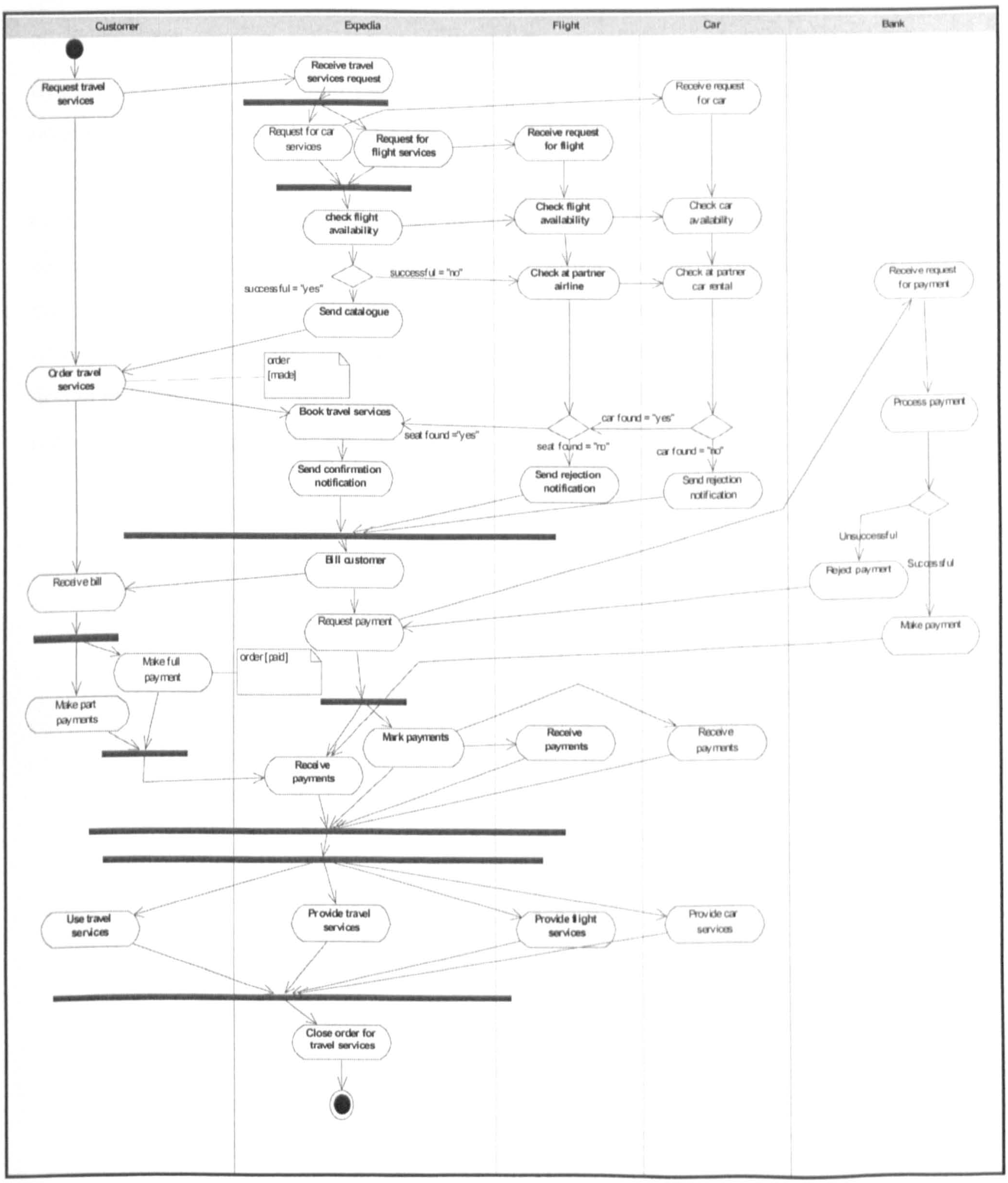

Figure 6. 8: Booking Flight + Car business process workflow design pattern diagram

Finally, the flight + hotel + car business process workflow design pattern diagram below was composed by selecting and adapting activities and tasks from across all the combinations of workflow design patterns above. The reuse was achieved by instantiating and specialising some of the activities and task in the context of flight + hotel + car business process workflow design pattern. After tasks sequencing, resource allocations, pre-conditions and post conditions were also dealt with. Thus the proposed framework approach aims at workflow applications scenarios requiring flexible and build time modifiable workflows, which may cross-organisational boundaries

On the other hand, it is vital to note that the design phase of the proposed knowledge enhanced framework approach relies heavily on product design knowledge such as memorisation of successful stories, best practices and previous cases in the form of workflow design patterns residing in the process knowledge repository. These design patterns can be reuse to dynamically evolve and provide flexibility during the redesign of Expedia's workflow model.

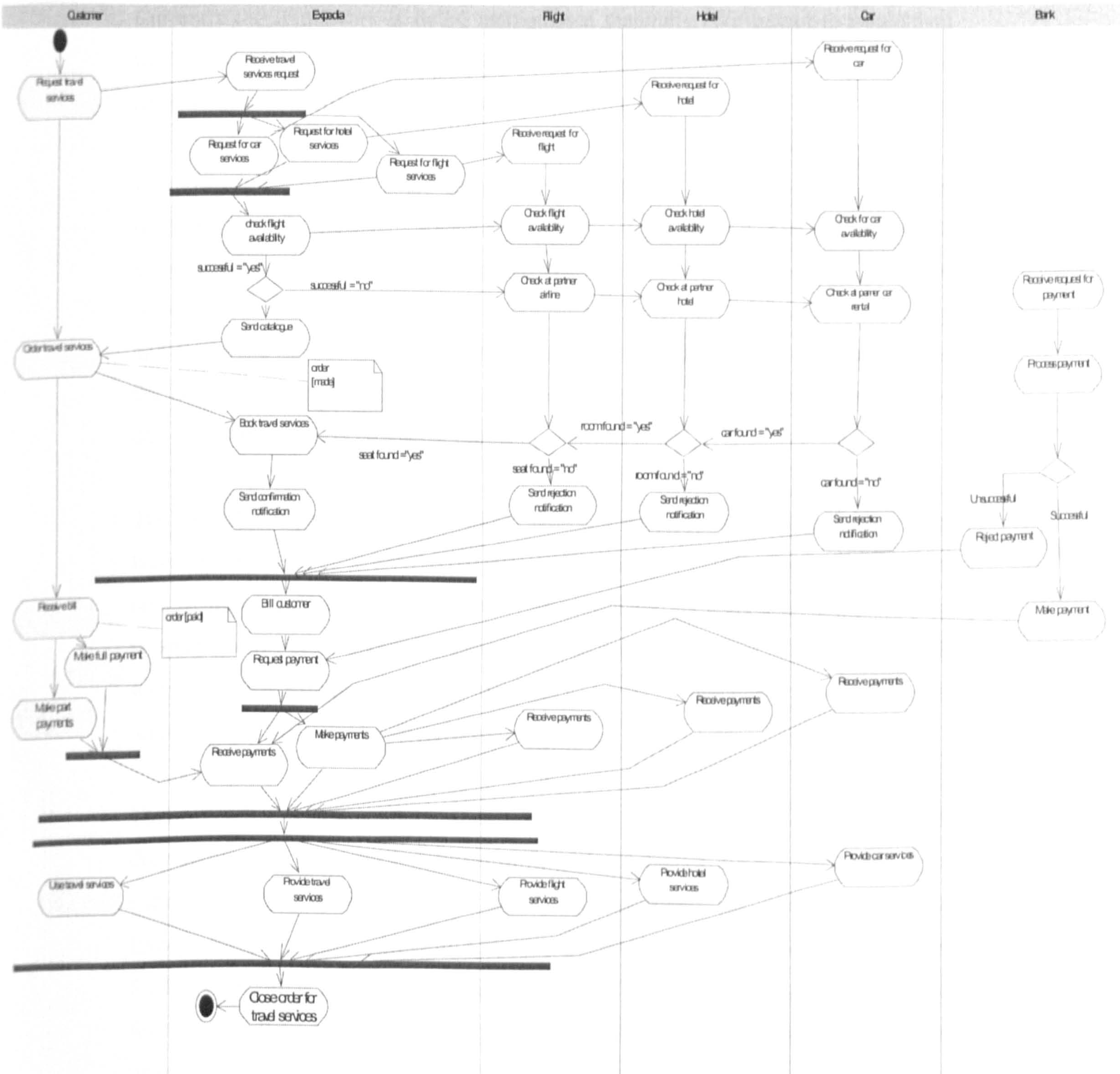

Figure 6. 9: Booking Flight + Hotel + Car business process workflow design pattern diagram

Successful completion of the e-workflow design phase will result in Expedia's workflow schemas that fulfil their business requirements, which may then be executed by Expedia WFMS. We observe that each step of the e-workflow design phase may be executed manually or supported by automated design systems. Currently the framework is being manipulated manually. We intend to implement the automated aspect of the proposed knowledge enhanced framework for the development of adaptive e-workflow systems in the near future.

A knowledge designer of the Expedia.com workflow model can configure such workflow design patterns dynamically, with decisions being based on the current situation at hand and which of the alternative breakdown is more appropriate. A similar process of instantiation and specialisation may then be applied to structure and customise each of the sub-workflow within the chosen breakdown. For example, the hotel reservation sub-workflow may have several different available workflow design patterns in the knowledge repository.

The workflow design pattern repository provides support for carrying out common tasks in any one of a number of standard ways. Knowledge creation, sharing, collaboration and reuse is enhanced by the provision of workflow design pattern templates at different level of abstraction, so that each workflow designer can work with patterns expressed at the necessary level, without having to commit unnecessarily to particular lower-level of details.

This refined workflow model is then reviewed or validated based on Expedia.com domain business rules, by simulation or formal approaches. If the review process is successful, the workflow model should be deployed for execution on the Expedia.com workflow engine. In addition, this newly developed workflow solution for Expedia.com is stored textually in the knowledge repository for future use in the form of workflow design pattern templates. These business process workflow design pattern templates may be used to compose workflow solutions for different workflow problems within different business context or settings.

6.2.4.2 Step 2: Definition of the organisational perspective

In the e-workflow model, role view identifies the roles that will participate in the execution of workflow. Usually a role corresponds to a position that is filled by one or several stakeholders. Analysing roles allows the elimination of effort duplication and bottlenecks in the workflow process. Figure 6.10 below presents the workflow resource pattern of the organisational perspective. A role is associated with responsibility to fulfil a service, using different resources.

In figure 6.10 below, service class depicts such responsibilities. Performing a role's service means implementing a service tasks to achieve a particular business process within the workflow. A service always represents a business process in which a number of different organisations and tasks are involved and these web services are always distributed across these various organisations (Xiao & Zheng, 2007). Actor class represents a physical entity that will play a role. Requirements class describes the features, which are required to fulfil a role e.g., expertise, years of experience, background etc. Finally, credential class stands for actors' or stakeholders' capabilities to meet role requirements. The organisational perspective can inherit properties of the workflow resource patterns from the algorithmic and textual representations of the business process workflow design patterns templates stored in the knowledge repository.

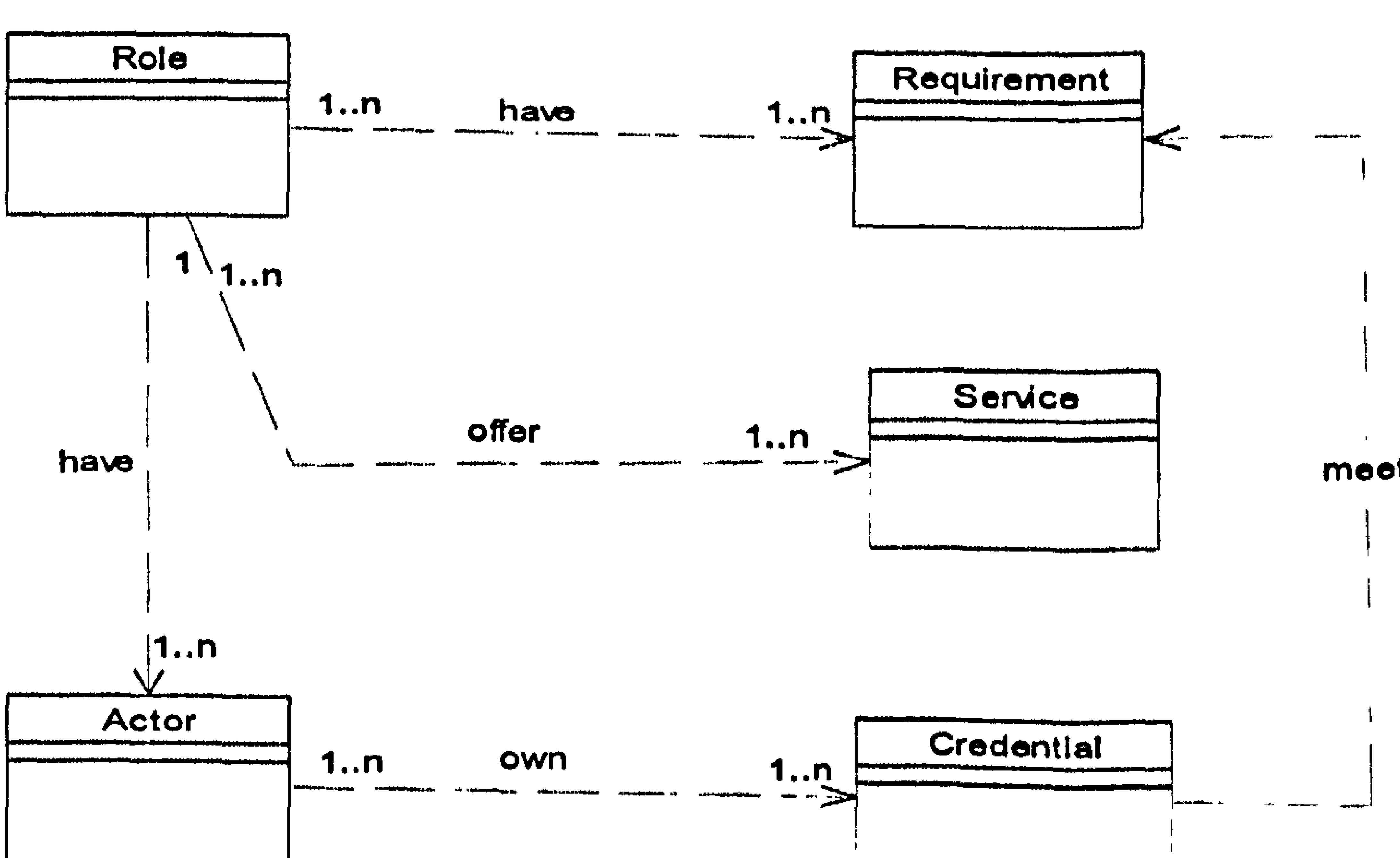

Figure 6. 10: Workflow resource pattern

The workflow resource pattern may be reuse as design knowledge from the knowledge repository during the design and evolution of complex e-workflow applications for different workflow problems within different business domains.

When a process-agent initiates a task, it identifies potential actors from the organisation's database (organisation perspective) that correspond to the roles specified in the task abstract description. The process-agent selects the appropriate actors via their respective role-agents such as actor's availability, actor's workload, task's deadline, and task's priority. The proposed e-workflow framework provides appropriate mechanisms such as negotiation, and assessing the characteristics of the environment in which the business evolves. These mechanisms are used by the process-agents to assign tasks to appropriate actors.

6.2.4.3 Step 3: Definition of the behavioural perspective

The information required for the behavioural perspective has already been listed in the task list of each Expedia workflow schemas. This perspective defines the routes and rules involved in the execution of Expedia.com workflow schemas. Routes define the way information is routed through the different steps of the process. It can either be routed serially, in parallel or conditionally based on the business rules and policy. Rules are the blend of policies and practices and can be triggered by the information on the process.

This work uses ECA rules to control the routing of activities and the selection of e-workflow providers. When a workflow process is initiated, a fork node fires all output arrows in parallel, whereas a branch node fires the output arrows that satisfy the routing conditions. ECA rules can be used to describe the routing decisions. In e-workflow applications, the completion of preceding e-business processes is regarded as an event of routing rules.

The behavioural perspective can also inherit the workflow control flow patterns from the algorithmic and textual representations of the business process workflow design patterns templates in the knowledge repository. The workflow control flow pattern may be reuse as design knowledge from the knowledge repository during the design and evolution of complex e-workflow design problems for different workflow problems within different business settings.

To help further understanding of the behaviour of the workflow model, animated models may provide better temporal representation than static visual diagrams and therefore are suitable as a communication tool for both the knowledge workflow designer and users. While tasks sequencing rules defined in the workflow schemas specify when a task needs to be done, organisational policies determine, in real time, which procedure is to be executed to accomplish the task, who to assign the responsibility and providing access to the required tools and information entities.

6.2.4.4 Step 4: Definition of the informational perspective

The workflow data pattern of the information perspective shown on Figure 6.11 below, describes the documentations involved in a workflow process definition and in its enactment. Such elements are information variables, available to all tasks in the workflow schemas within the functional perspective i.e., forms, documents, and folders. The proposed e-workflow uses these information variables about the e-service to establish the communication relationship between the various e-agent of that e-service.

This could be a table or a class structure defining the business entities and the e-services or tasks that they provide. In the e-workflow model, information view describes the data that a workflow for Internet will manipulate and generate. Manipulation of data takes place during workflow execution while generation of data occurs at the end of execution. In the e-workflow model generation of data implies updating data.

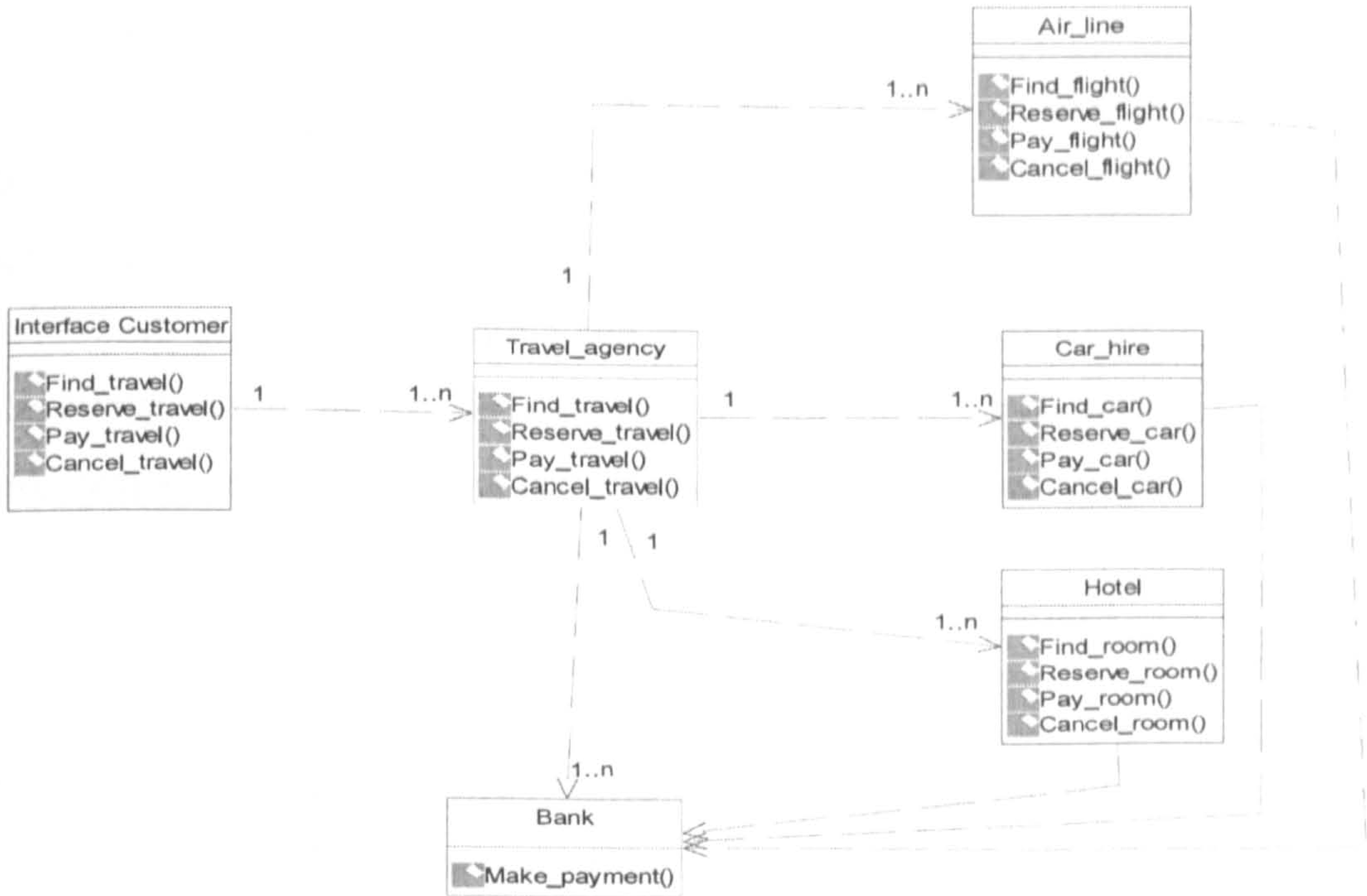

Figure 6. 11: Workflow data pattern

Also, studying the workflow domain allows the structuring of data and permits a better appreciation of the context in which the workflow will take place. It may be possible that different tasks, from independent e-processes, are executed in parallel. Hence, these tasks could have to manipulate the same data simultaneously; however any deadlock in accessing this critical data is avoided by the concurrency control of the underlying database systems. In the e-workflow model, data coherence is ensured, through the information agents.

The informational perspective can also inherit workflow data patterns from the algorithmic and textual representation of the business process workflow design patterns templates stored in the knowledge repository. Furthermore, the workflow data pattern may be reuse as design knowledge from the knowledge repository during the design and evolution of complex e-workflow applications for different workflow problems within different business domains.

6.2.5 Phase 3: e-workflow support phase

Design and implement the specific services of every federation (business partner or business service provider (BSP)) of the application, and then add them to the run-time e-workflow virtual support mechanism. The next step is to evaluate the application to see whether it meets the requirements of Expedia's workflow application. In case the requirements are not met, the proposed e-workflow framework provides an iterative and incremental mechanism (using the knowledge repository) to enhance the design and build process until it meets Expedia requirements thus completing the life cycle of the workflow design

6.3 Algorithmic representations for Expedia workflow schemas in the workflow design pattern repository.

Figures 6.12 - 6.17 represents the algorithmic (pseudo code) and textual representations of the workflow schemas or business process workflow design pattern diagrams above in the form of workflow design pattern templates in the workflow design pattern repository or knowledge repository. The book flight only business process design pattern template below was composed from scratch from the book flight only business process workflow design diagram (see figure 6.4 above).

Name: Book Flight only business process workflow design pattern template

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 12/05/2008

Intent: This pattern template allows the definition of a workflow schema for achieving the flight only reservation business process

Classification: Sub workflow design pattern

Template:

```
Get request for travel
Get customer details
Check flight availability
IF flight available
    THEN Book flight seat
         Send confirmation letter
    ELSE
        Check flight availability at Partner airline
        IF seat available
            THEN Book flight seat
                 Send confirmation letter
                 Request payment
            ELSE
                 Send rejection letter
        ENDIF
ENDIF
```

Keywords: Book Flight only business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflow schemas for different workflow problems within different business context or setting

Figure 6. 12: Booking Flight only business process workflow design pattern template

In order to develop the hotel only business process workflow design pattern template as shown below, the flight only business process workflow design pattern template was reused by instantiating and specialising it with activities and resources in the context of hotel only business process workflow design patterns. This was made possible by instantiating and specialising resources like *flight* with *hotel* and activities like *receive request for flight* with *receive request for hotel*, *check flight availability* with *check hotel availability*, etc. After tasks sequencing, resource allocations, pre-conditions and post-conditions was also dealt with.

Name: Book Hotel only business process workflow design pattern template

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 12/05/2008

Intent: This workflow design pattern template allows the definition of a workflow schema for achieving the hotel room reservation business process

Classification: Sub workflow design pattern

Template:

```
Get request for travel
Get customer details
Check  Hotel_Room availability
IF Hotel_Room  available
      THEN Book Hotel_Room
               Send confirmation letter
      ELSE
            Check Hotel_Room availability at Partner hotel
            IF Hotel_Room available
                 THEN Book Hotel_Room
                         Send confirmation letter
                         Request payment
            ELSE
                 Send rejection letter
          ENDIF
ENDIF
```

Keywords: Book Hotel only business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflow schemas for different workflow problems within different business context or setting

Figure 6. 13: Booking Hotel only business process workflow design pattern template

Similarly, to compose the car only business process workflow design pattern template below we had to select, instantiate and specialise some of the activities and tasks from the hotel only business process workflow design pattern template above. This was made feasible by instantiating and specialising resources like *hotel* with *car* and activities like *receive request for hotel* with *receive request for car*, *check hotel availability* with *check car availability*, etc. After tasks sequencing, resource allocations, pre-conditions and post-conditions were also dealt with.

Name: Book Car only business process workflow design pattern template

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 12/05/2008

Intent: This workflow design pattern template allows the definition of a workflow schema for achieving the car only reservation business process

Classification: Sub workflow design pattern

Template:

```
Get request for travel
Get customer details
Check for Car availability
IF Car available
      THEN Book Hotel_Room
               Send confirmation letter
       ELSE
             Check car availability at Partner hotel
             IF car available
                   THEN Book car
                            Send confirmation letter
                           Request payment
              ELSE
                    Send rejection letter
          ENDIF
ENDIF
```

Keywords: Book Car only business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflow for different workflow problem within different business context or setting

Figure 6. 14: Booking Car only business process workflow design pattern template

In addition, the flight + car business process workflow design pattern template below was composed by selecting and reusing some of the activities, tasks and resources from the flight only and car only business process workflow design pattern templates by instantiating and specialising them in the context of flight + car business process workflow design pattern templates. After tasks sequencing, resource allocations, pre-conditions and post-conditions were also dealt with.

Name: Book Flihgt + Car business process workflow design pattern template

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 12/05/2008

Intent: This workflow design pattern template allows the definition of a workflow schema for achieving the Flight + Car reservation business process

Classification: Sub workflow design pattern

Template:

```
Get request for travel
Get customer details
Check flight availability
IF flight available
    THEN Book flight seat
         Send confirmation letter
    ELSE
        Check flight availability at Partner airline
        IF seat available
            THEN Book flight seat
                 Send confirmation letter
            ELSE
                 Send rejection letter
        ENDIF
ENDIF

Check for Car availability
IF Car available
    THEN Book car
         Send confirmation letter
    ELSE
        Check car availability at Partner car rentals
        IF car available
            THEN Book car
                 Send confirmation letter
                 Request payment
            ELSE
                 Send rejection letter
        ENDIF
ENDIF
```

Keywords: Book Flight + Car business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflow schemas for different workflow problems within different business context or setting

Figure 6. 15: Booking Flight + Car business process workflow design pattern template

Name: Book Flight + Hotel business process workflow design pattern

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 12/05/2008

Intent: This workflow design pattern template allows the definition of a workflow schema for achieving the Flight + Hotel room reservation business process

Classification: Sub workflow design pattern

Template:

```
Get request for travel
Get customer details
Check flight availability
IF flight available
      THEN Book flight seat
             Send confirmation letter
      ELSE
            Check flight availability at Partner airline
            IF seat available
                  THEN Book flight seat
                         Send confirmation letter
               ELSE
                         Send rejection letter
            ENDIF
ENDIF

Check  Hotel_Room availability
IF Hotel_Room  available
      THEN Book Hotel_Room
             Send confirmation letter
      ELSE
            Check Hotel_Room availability at Partner hotel
            IF Hotel_Room available
                  THEN Book Hotel_Room
                         Send confirmation letter
                         Request payment
               ELSE
                     Send rejection letter
            ENDIF
ENDIF
```

Keywords: Book Flight + Hotel business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflows schemas for different workflow problems within different business context or setting

Figure 6. 16: Booking Flight + Hotel business process workflow design pattern template

Furthermore, to compose the flight + hotel business process workflow design pattern template above, we had to adapt and customise the flight and hotel only business process workflow design pattern above by extending it with some activities from the hotel only and flight only business process workflow design pattern template and specialise them in the context of flight + hotel business process workflow design pattern template. After tasks sequencing, resource allocations, pre-conditions and post-conditions were also dealt with.

Finally, the flight + hotel + car business process workflow design pattern template was composed by selecting and adapting activities and tasks from across all the combinations of workflow design pattern templates above. The reuse was achieved by instantiating and specialising some of the activities and task in the context of flight + hotel + car business process workflow design pattern. After tasks sequencing, resource allocations, pre-conditions and post conditions were also dealt with.

Name: Book Flihgt + Car + Hotel business process workflow design pattern

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 12/05/2008

Intent: This design pattern template allows the definition of a workflow schema for achieving the car only reservation business process

Classification: Workflow design pattern

Template:

```
Get request for travel
Get customer details
Check flight availability
IF flight available
    THEN Book flight seat
         Send confirmation letter
    ELSE
         Check flight availability at Partner airline
         IF seat available
             THEN Book flight seat
                  Send confirmation letter
             ELSE
                  Send rejection letter
         ENDIF
ENDIF

Check for Car availability
IF Car available
    THEN Book car
         Send confirmation letter
    ELSE
         Check car availability at Partner car rentals
         IF car available
             THEN Book car
                  Send confirmation letter
             ELSE
             Send rejection letter
         ENDIF
ENDIF

Check Hotel_Room availability
IF Hotel_Room available
    THEN Book Hotel_Room
         Send confirmation letter
    ELSE
         Check Hotel_Room availability at Partner hotel
         IF Hotel_Room available
             THEN Book Hotel_Room
                  Send confirmation letter
                  Request payment
             ELSE
             Send rejection letter
         ENDIF
ENDIF
```

Keywords: Flight + Car + Hotel business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflow schemas for different workflow problems within different business context/setting

Figure 6. 17: Booking Flight + Car + Hotel business process workflow design pattern template

During the design of a new e-workflow application, the workflow designer should be able to search, retrieve and reuse these workflow design pattern templates from the knowledge repository thereby reducing the workflow application development time and cost, and also increase productivity (Magg, 1997). This workflow design pattern templates may be reuse to compose workflow schemas for different workflow problems within different business contexts or settings.

Finally, these business process workflow design pattern templates may be reuse as design knowledge from the knowledge repository to compose workflow schemas during the design and evolution of complex e-workflow design problems for dissimilar workflow problems within different business settings.

6.4 Chapter summary

This chapter has presented a case study through action research in order to provide a qualitative evaluation of the proposed knowledge enhanced framework for the development of e-workflow systems adapted to the new e-business environment. The chapter also introduces the experience gained by reverse engineering Expedia.com website through the action research case study. The next chapter presents the quantitative evaluation of the proposed framework through online survey questionnaire.

Chapter 7

Quantitative Evaluation of the Proposed Framework

This chapter presents the quantitative evaluation of the proposed framework approach through web-based survey questionnaires. Workflow Management Coalition (WFMC) - A Process Thought Leadership Organisation who provided us with the opportunity to collect data from workflow researchers, users and developers globally, hosted the questionnaires online. Before hosting the questionnaires online a pilot study was carried out with workflow designers and researchers from Workflow Management Coalition in order to evaluate the appropriateness of the questionnaires. This was done through Nathaniel Palmer who is the current CEO for WFMC. The feedbacks and suggestions from the dry run were used to further enhance the quality of the questionnaires. The chapter also presents the percentage distributions and statistical analysis of the responses from the respondents. A summary of the findings and results drawn from the questionnaires and action research is also included. Finally, it presents the verification of the results of the online survey.

7.1 Electronic survey

The purpose of a survey is to produce statistics (quantitative or numerical descriptions of some aspects of the study population) by asking a sample or a fraction of the population questions, and to analyse the responses (Fowler, 1993). Standardised measurement, consistent across all respondents, ensures comparable information in order to discover patterns of association. Recent developments in communication technologies have created alternative survey methods through the web. Using the Internet to conduct quantitative and qualitative research presents challenges not found in conventional research. Paper-based survey quality criteria cannot be completely adapted to electronic formats. Electronic text communications require fewer resources, and provide faster responses than traditional paper-based methods. Web-based surveys have distinctive technological, demographic and response characteristics which affect their design, use and implementation.

7.2 Electronic survey questionnaire

Electronic survey questionnaire will be used to gain the views of workflow developers, workflow users and workflow researchers. The questionnaire will be based on themes identified in the literature and this will assure its content validity. It will contain a mixture of 'closed' attitude measurement questions (Likert Scaling) and open questions (Siakas, 2002), and a section at the end of the questionnaire instrument for additional comments.

The questionnaires will be designed to capture the following workflow issues: Methodological approaches to e-workflow projects, the level of organisational support in e-workflow projects, acceptance issues, organisational issues, informational issues, Intra/inter organisational business process issues, social and quality aspects (flexibility, reusability, scalability, time & cost), usability of the proposed approach, Internet issues, success factors for the implementation of e-workflow management systems and knowledge management issues. It was felt that using such a variety of questions would help to maintain the interest of respondents, gain qualitative and quantitative data in order to enhance the breadth of the study.

7.3 Electronic survey questionnaire design

Cold fusion, Microsoft Access and HTML will be used to construct the electronic survey questionnaires in this research. The following design criteria will be addressed in designing the electronic survey questionnaires in this research - support for multiple platforms and browsers/email clients, controls for browser settings, detection of multiple submissions automatically, presents questions in a logical and adaptive manner, allows saving responses before completion, collect qualitative and quantitative data, provide automatic feedback after completion, provide automatic transfer to responses in a database, provide response control, displays appear quickly to participants, does not require familiarity with electronic surveys, tracking of response source from response failure.

Quality criteria across five important methodological components that must be addressed include: (1) survey design, (2) participant privacy and confidentiality, (3) sampling and participant selection, (4) distribution and response management, and

(5) survey piloting. However, web-based survey methodologies also generate problems involving sampling, response consistency and participant's motivation. Empirical studies need to be done to address these issues as researchers implement electronic survey methods.

7.4 Analysis of section 1 of the questionnaire

In this section, respondents were asked to provide information about their institution such as the name of the institution, the country in which it is based, they geographic scope of the institution and the status of the institution (See appendix D for questionnaire).

There were 36 respondents from a total of 13 different countries. This consists of 24 universities, 7 private (profit) organisations, 2 voluntary (non-profit) organisations, 2 specialised Masters College, 1 specialised Engineering college/Regulatory body. The following are the list of the respondents' countries:

1. Unites States of America --- 9 respondents
2. United Kingdom-------------- 7 respondents
3. Australia---------------------- 4 respondents
4. Pakistan---------------------- 1 respondent
5. Denmark---------------------- 1 respondent
6. China ------------------------ 1 respondent
7. Canada ----------------------- 1 respondent
8. The Netherlands ------------ 2 respondents
9. Italy -------------------------- 1 respondent
10. Germany -------------------- 4 respondents
11. Greece ----------------------- 1 respondent
12. Brazil ------------------------ 3 respondents
13. Egypt ------------------------ 1 respondent

- **Distribution of respondents by continents**

From the surveyed population, it was also observed that approximately 44% of the respondents were from Europe, 11% from Australia, 28% from North America, 6% from Asia and 3% from Africa.

7.5 Coding of responses from section 2 of the questionnaire for the thesis

In this section respondents were asked to provide information about themselves such as previous work experience and current position in their institution (See appendix D for questionnaire).

Table 7.1 below shows the coding responses from Section 2 of the questionnaire for the thesis. In this table, the responses have been grouped in such a way that the results are better interpreted at a glance. Furthermore, a more detail analysis of the results from this section of the questionnaire is presented below.

Institutions	Section 2.1 (1-5)	Section 2.2 (1-6)
Manchester Metropolitan University	2	1, 20%, 2yrs
Faculty of Computers and Information (Egypt)	1,2,3	2, 60%, 2yrs 5, 80%, 3yrs
Penn State University	1	1, 100%, 17yrs
Ford Motor Company	1,3,5	1, 10%, 2yrs 2, 80%, 9yrs 4, 20%, 2yrs 5, 10%, 2yrs
London Metropolitan University	1,2	1, 30%, 12yrs 5, 80%, 12yrs
Universidade Federal do Estado do Rio de Janeiro (Brazil)	5	1, 40%, 12yrs 5, 60% 17yrs
Department of computing and Mathematics, Manchester Metropolitan University	5	1, 60%, 3yrs 5, 60%, 5yrs
Aalborg University, Department of Production	1,2,3	1, 50%, 12yrs 4, 60%, 5yrs 5, 50%, 17yrs

Inform Consultant LTD	1,2	2, 20%, 10yrs 4, 90%, 17yrs
Queensland University of Technology	1,2	1, 20%, 3yrs
HU Berlin	1	1, 100%, 5yrs
PatientKeeper Inc	1,2,3	6, 100%, 5yrs
Glasgow Caledonian University	5	6
University of Wollogong	1,3	1, 100%, 3yrs 5, 100%, 8yrs
Queensland University of Technology	1,2,3	2, 80%, 10yrs 5, 20%, 5yrs
Future Strategies Inc (USA)	3	5, 30%, 5yrs
Hunan University of Science and Technology	1,2,3	1, 70%, 20yrs
University of Twende	1,2	1, 40%, 8yrs
University of Arizona	1,2	5, 100%, 10yrs
University of Ulm (Germany)	1,2,3,5	1, 50%, 12yrs 5, 50%, 12yrs
Federal University of Rio de Janeiro	1,3,5	1, 40%, 20yrs 4, 10%, 20yrs 5, 40%, 20yrs 6, 20%, 20yrs
Quaid-e-Azam University	2	6, 80%, 2yrs
University of Maryland	3	1, 30%, 17yrs 5, 80%, 17yrs
Cimtech Ltd (UK)	1,3	4, 70%, 5yrs 5, 40%, 7yrs
Stevens Institute of Technology	1,3	1, 40%, 0yrs 5, 60%, 0yrs
PEO (Canada)	1,3	2, 30%, 7yrs 4, 80%, 4yrs
University of Genoa	1,3	2, 20%, 5yrs 5, 80%, 5yrs 6, 100% 3yrs
Arizona State University	1,2	5, 80%, 17%
European Research Centre for Information	1,2	1, 30%, 4yrs

System, University of Munster		2, 10%, 4yrs 5, 60%, 4yrs 6, 30%, 4yrs
Technical University Eindhoven	2	1, 10%, 4yrs 2, 100%, 7yrs 4, 10%, 7yrs 5, 100%, 4yrs
Alexandreio Technological Educational Institute of Thessaloniki	-	6, 0%, 4yrs
European Business School (eds)	1	1, 20%, 2yrs 4, 40%, 2yrs 5, 40%, 2yrs
University of Oxford	1,2,3,5	1, 50%, 17yrs 5, 50%, 17yrs
eVisory Consulting	1,2,3,4,5	4, 90%, 17yrs
State University of Campinas	5	1, 60%, 17yrs 5, 50%, 17yrs
Swinburne University of Technology	1,2,3	1, 100%, 17yrs 4, 30%, 5yrs 5, 100%, 4yrs

Table 7. 1: Coding of the responses for Section 2 of Questionnaire

7.6 Statistical analysis of the coding categories of section 2.1 and 2.2 of the questionnaire

Table 7.2 below depicts the categories under 'previous work experience' from the questionnaire distributed online for the purpose of this thesis.

Code	Category
1.	Workflow developer
2.	Software development
3.	Management
4.	Software quality
5.	Other

Table 7. 2: Categories of previous work experience categories

Furthermore, a more detail statistical analysis of the results from this section of the questionnaire is presented in figure 7.1 below.

As can be observed from figure 7.1 below, only 97% of the total 36 participants from 13 different countries had previous work experience in line with the categories supplied for the questionnaire. Only 9% of the respondents had previous workflow development experience. The same percentage had previous experience only in software development. In addition, 6% of the respondents had only management experience whilst another 6% of the respondents had previous work experience within management, workflow development, engineering and consulting. The same 6% again had previous work experience in workflow development, software development, management and the 'other' category such as operations management and technology development, founding a spin-off in BPM area.

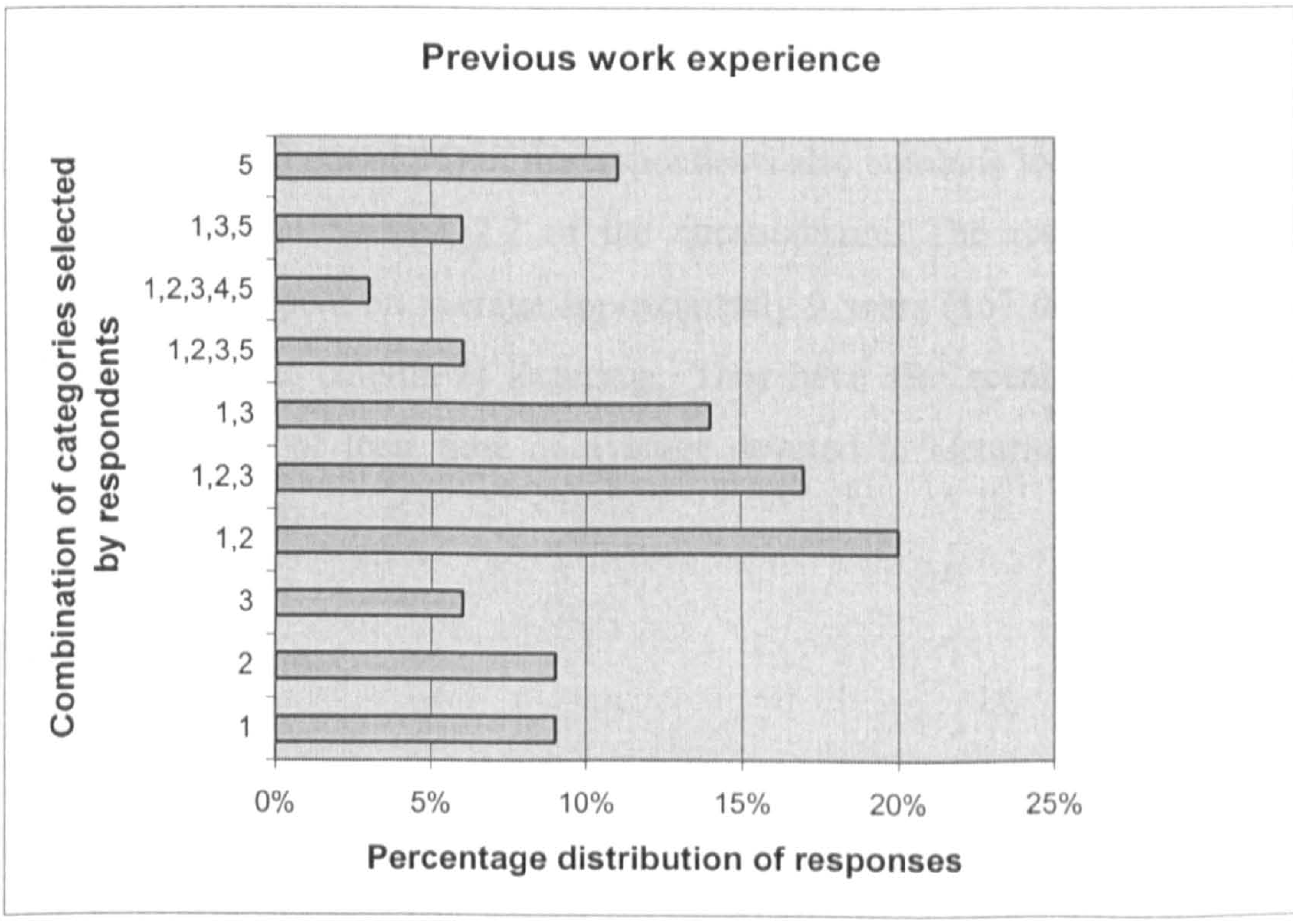

Figure 7. 1: Percentage distribution of section 2.1

Also 20% of the respondents had previous work experience in workflow development and software development, whilst 17% also had management experience on top. Another 14% of the respondents had previous experience in workflow development and management. Only 3% of the respondents had previous work experience in workflow development, software development, management, software quality and the 'other' category such as imaging and document management.

And finally, 11% of the respondents choose the 'other' category and worked previously as workflow researcher, teaching/researchers, computing research in HCI, and technical writing in computer industry.

- **Lecturers**

Only 4 respondents reported that their sole job was as Lecturers. This constitutes 18% of the total population of this survey (4 divide by 22, see Table 7.1, column 3). The average number of years that these 3 respondents have been teaching equates to approximately 12 years (37 divided by 3, see Table 7.1 above, column 3).

Exactly 50% (18 out of 36) of the respondents also combine lecturing with other jobs as listed in Section 2.2 of the questionnaire. The respondents in this category have spent on average approximately 9 years (167 divided by 18, see Table 7.1 above, column 3) lecturing. They have also spent about 37% (670 divided by 18) of their time on average devoted to lecturing (see Table 7.1 above, column 3).

- **Technicians**

On average 8 of the 36 respondents spent approximately 7 years as Technicians, spending on average 50% of their time in the position (see Table 7.1 above, column 3).

- **Entrepreneur**

There were no respondents who have worked as Entrepreneur (see Table 7.1 above, column 3).

- **Managers**

Only 8 respondents have previously worked as managers during the completion of this questionnaire. On average the respondents have spent 8 years, as managers and this constitutes exactly 50% of their time (see Table 7.1 above, column 3).

- **Researchers**

In total 23 of the respondents are currently working as researchers, 62% of their time was spend as researchers. The average numbers of years spend, as researcher is almost 9 years (see Table 7.1 above, column 3).

- **Other category**

Under the category of 'Other', there were 8 respondents as follows, 2 were students, 1 administrator, 1 software engineer, 1 chief technology officer, 1 managing research group as professor, I consultant and 1 was unable to identify their current role (see Table 7.1 above, column 3).

7.7 Coding of responses from section 3 of the Questionnaire for the thesis.

In this section respondents were asked about the approach they adopt during the development of Internet workflow applications (See appendix D for questionnaire). Table 7.3 below shows the coding responses from Section 3 of the questionnaire for the thesis.

Sections / Institutions	3.1 (1-3)	3.2 (1 - 5)	3.3 (1 - 6)	3.4 (1 - 14)	3.5 (1 - 8)	3.6 (1 - 8)	3.7 (1 - 7)
Manchester Metropolitan University	1,2	1,2,3	1	2,3,5,6	1	1,2,3,6	3,4,5,6
Faculty of Computers and Informations (Egypt)	2	1,2,3,4	1,4,5	1,2,3,6	7	2,6,7	2,4,5,6
Penn State University	1	1,2,3,4	3	5,9	1,2,7	1,2,3,4, 5,6	3,4,5,6
Ford Motor Company	1,2	1,2,3	1,3	1,3,5,7,8,11	4	6	3,4,5,6
London Metropolitan University	1	1,2,3,4,5	2,4,5	1,2,3,6,13	7	1,2,4,6,7	2,4,6
Universidade Federal do Estado do Rio de Janeiro (Brazil)	3	1,2,3,4	5	1,2,6,12	3	3,6	3,4
Dept of comp & Maths Manchester Metro University	3	-	-	-	-	2,3,4	-
Aalborg University, Department of Production	3	5	4,5	4,9	1,2,3,4, 6,7	1,2,3,4 5,6,7	-
Inform Consultant LTD	1	1,2	4	3,4,9	1,2,3,4,5	2,3,6	3
Queensland University of Technology	1	1, 2, 3, 4	3, 5	14	2,3,4,6,7	1,2,3	4,6
HU Berlin	1	1,2,3,4	5	1,2,3,5,6,7	4	1	3
Patient Keeper Inc	1	1,2,3,4	6	3,14	1,2,3,4,5,6,7,8	1,2,3,4, 5,6,7,8	4,6
Glasgow Caledonian Univ	3	1,2,3,4	2,6	3,4,5	1,2,3,4,5,6,7	6	3,6
University of Wollogong	1,2	1,2,3	1,3,5	3,5,7	1,2,4,7	2,3,5,6	2,3,4,5,6
Queensland University of Technology	1,2	2,4	3,4	5,14	1,3	5,6	2,3,4,5
Future Strategies Inc	1	1,2,3,4,5	4,5	1,2,6	5	1,3,7	1,4

Hunan University of Science and Technology	1,2	1,2,3,4	2,5	3	1,2,5,6	1,2,3,5,6	3,6
University of Twende	3	1,2,3,4,5	3,5,6	7	1,2,4,5,6,7,8	1,2,6,7,8	3,4,5,7
University of Arizona	1,2	1,2,3,4	6	3,5,14	1,2,3,4,5,6,7	8	7
University of Ulm	1,2,3	1,2,3,4,5	3,5,6	1,3,5,12,14	8	2,5,6	3,4,7
Federal University of Rio de Janeiro	1	1,2,3	3	1,2,6,12	2	1,2,6	4,6
Quaid-e-Azam University	2	1	5,6	14	1,2,4,7	2,6	4
University of Maryland	2,3	1,2,3,4	1	3	1,4	3,4,5,6	2,3
Cimtech Ltd	1	1,2,3,4	2,3,4	1,2,3,6,10,14	1	1,2,3,6,7,8	2,4,5
Stevens Institute of Technology	1,2	1,2,3,4,5	3,4,5	4,9	1,2,3,4,6,8	8	3,4,5,6
PEO (Canada)	1,2	1,2,3	1	3,9,11	4	2,6	2,4
University of Genoa	3	1	1	3,5,14	1	3	7
Arizona State University	2	2,3,4	3,5	3	1,2,3,4,5,6	1,2,3,4	-
European Research Centre for Info System, University of Munster	1	1,2,3,4	1,4,5	5	2,3,4,6	1,2,6	3,4,6
Technical University Eindhoven	1,2	1,2,3	1,3,4,5	14	1,2,3,4,7	1,3,6,7	4,5,6
Alexandreio Techno Edu. Institute of Thessaloniki	1	1,2	1,2	3,5,7	1,2,4,6	1,2,6,7	3,4,5
European Business School (eds)	1	1,2,3	1	3,5,9	1,2,4,6	1,6	3,4,5
University of Oxford	3	1,2,3,4	1,4,5	3,8,9,11	1	5	3,4,6
eVisory Consulting	1,2	1,2,3,4,5	4,5,6	1,2,5,6,14	4	2,4,6	1,2,3,5
State University of Campinas	3	1	6	5,9	1,2,6	5	6
Swinburne University of Technology	1	1	4	4	1,2,6	4,5	6

Table 7. 3: Coding of the responses for section 3 of the questionnaire

7.8 Statistical analysis of the coding categories of section 3.1 of the questionnaire

In this subsection, respondents were asked about the tasks they perform in relation to e-workflow application development projects (See appendix D for questionnaire).

Table 7.4 below depicts the categories under 'tasks performed in relation to workflow application development projects' from the web-based questionnaire for this thesis. 36 out of a total of 36 respondents responded to this question (see Figure 7.3 column 1). A more succinct statistical analysis of the results from this section of the questionnaire is as shown on figure 7.2 below.

Code	Category
1	e-workflow designer
2	e-workflow developer
3	Other

Table 7. 4: Categories of tasks perform in workflow application development projects

As can be observed from figure 7.2 below, 36% of the 36 respondents performed the task of e-workflow designer during workflow application development projects. Only 8% of the respondents performed the task of e-workflow developers during workflow application projects, and 3% of the respondents performed the task of e-workflow designer as well as managing a group of programmers.

Approximately 28% of the respondents performed the tasks of e-workflow designer as well as e-workflow developer. Another 3% performed the task of e-workflow designer and e-workflow developer as well as developer of enabling technologies for e-workflow. The remaining 22% of the respondents performed the tasks of either a researcher in P2P workflow / focusing on organising workflow / researcher / grid application porting – portal design/research and consulting / research and trainer / researcher.

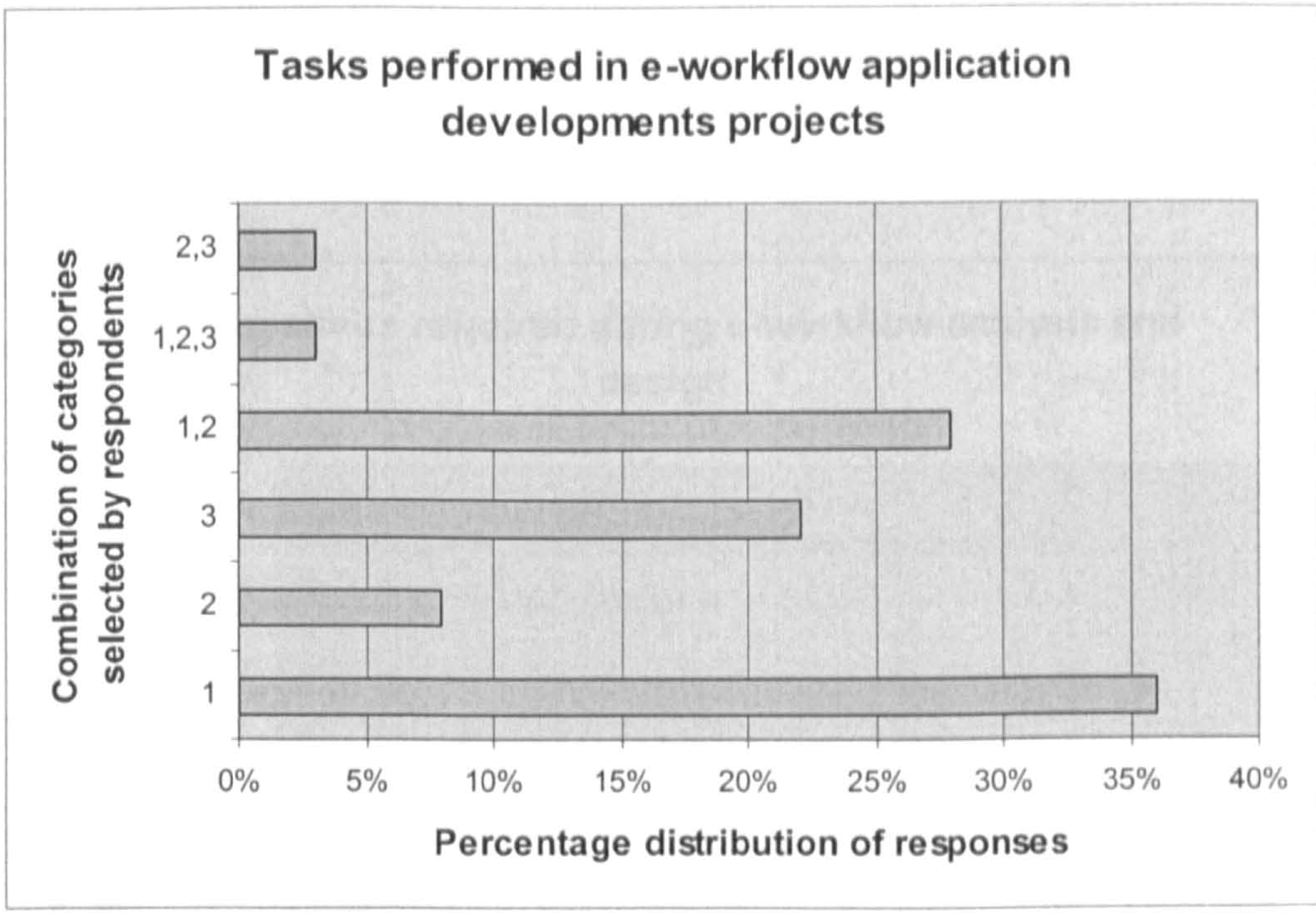

Figure 7. 2: Percentage distribution of section 3.1

7.9 Statistical analysis of the coding categories of section 3.2 of the questionnaire

In this subsection, respondents were asked about the perspectives required during e-workflow analysis and design (See appendix D for questionnaire).

Table 7.5 below describes the categories under 'perspectives adopted during e-workflow modelling and analysis' from the web based survey questionnaire for this study. Only 35 out of a total of 36 respondents responded to this question (see Table 7.3 above, column 2).

Code	Category
1	Functional perspective
2	Organisational perspective
3	Informational perspective
4	Behavioural perspective
5	Other

Table 7. 5: Categories of perspectives required during e-workflow analysis and design

An in-depth statistical analysis of this part of the questionnaire (see Table 7.3 above, column 2) is as presented on figure 7.3 below. Approximately 37% of the respondents adopted the traditional workflow modelling and analysis perspectives, which comprises of the functional, organisational, informational and behavioural perspectives.

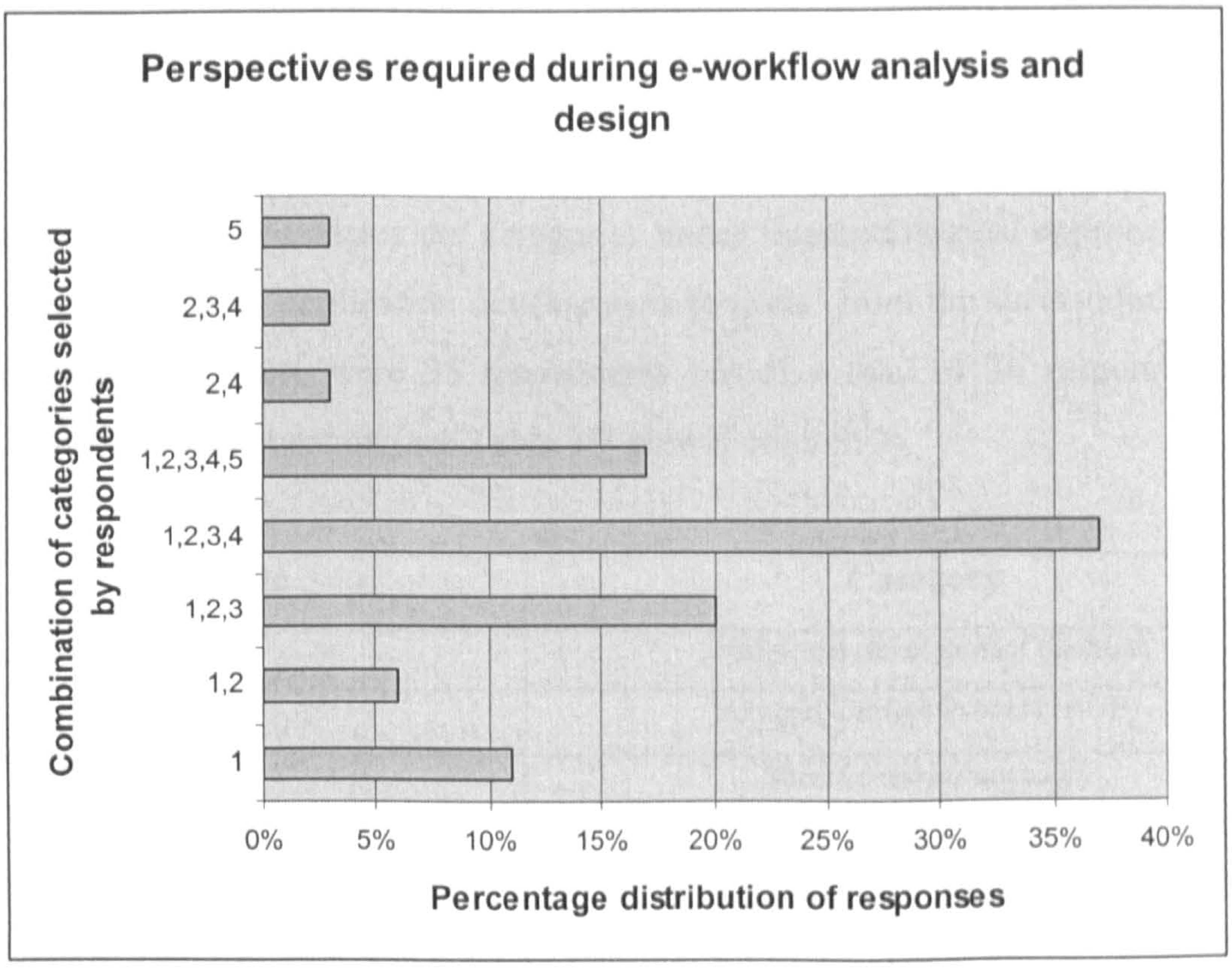

Figure 7. 3: Percentage distribution of section 3.2

Furthermore, about 11% adopted only the functional perspectives, and just about 20% adopted the functional, organisational and informational perspectives. Also 6% of the respondents adopted the functional and organisational perspectives and another 17% again adopted the functional, organisational, informational, behavioural and 'other' category which consists of knowledge perspective, knowledge engineering, temporal, compliance, flexibility, cognitive logic, adaptability, collaboration, flexibility, causal, historical, operational, information and knowledge flow perspectives.

In addition, 3% of the respondents adopted the organisational and behavioural perspectives; another 3% adopted the organisational, informational and behavioural perspectives, while the remaining 3% adopted the 'other' category, which comprises of primary the order and information flow perspectives.

7.10 Statistical analysis of the coding categories of section 3.3 of the questionnaire

In this subsection, respondents were asked about the methodological approach adopted in their institutions during e-workflow application development projects (See appendix D for questionnaire).

Table 7.6 below elucidates the categories under 'methodological approach adopted during e-workflow application development projects' from the survey questionnaire for the thesis. There were 35 respondents out of a total of 36 respondents who responded to this question (see Table 7.3 above, column 3).

Code	Category
1	Traditional development methods
2	Rational Unified Process (RUP)
3	Specific modelling tools
4	Prototyping / RAD
5	Business process reengineering (BPR)
6	Other

Table 7. 6: Categories of methodological approach adopted during e-workflow application projects

As can be observed from figure 7.4 below, 13% of the respondents adopted traditional development methods or approach to e-workflow (internet-mediated) application development projects. Approximately, 3% adopted the traditional development methods and the Rational Unified Process (RUP), 3% also adopted the traditional development approach and specific modelling tools (in-house methodology or methods).

Roughly speaking again, 3% adopted the traditional development methods, specific modelling tools and business process reengineering (BPR), about 3% adopted the traditional development methods, specific modelling tools, prototyping / RAD and business process reengineering, almost 9% adopted the traditional development methods, prototyping/RAD and business process reengineering (BPR). Approximately 3% adopted Rational Unified Process (RUP) and business process reengineering (BPR), 5% adopted Rational Unified Process and 'other' categories such as XML-based technologies, and 5% adopted only specific modelling tools, while 3% adopted specific modelling tools and prototyping/RAD.

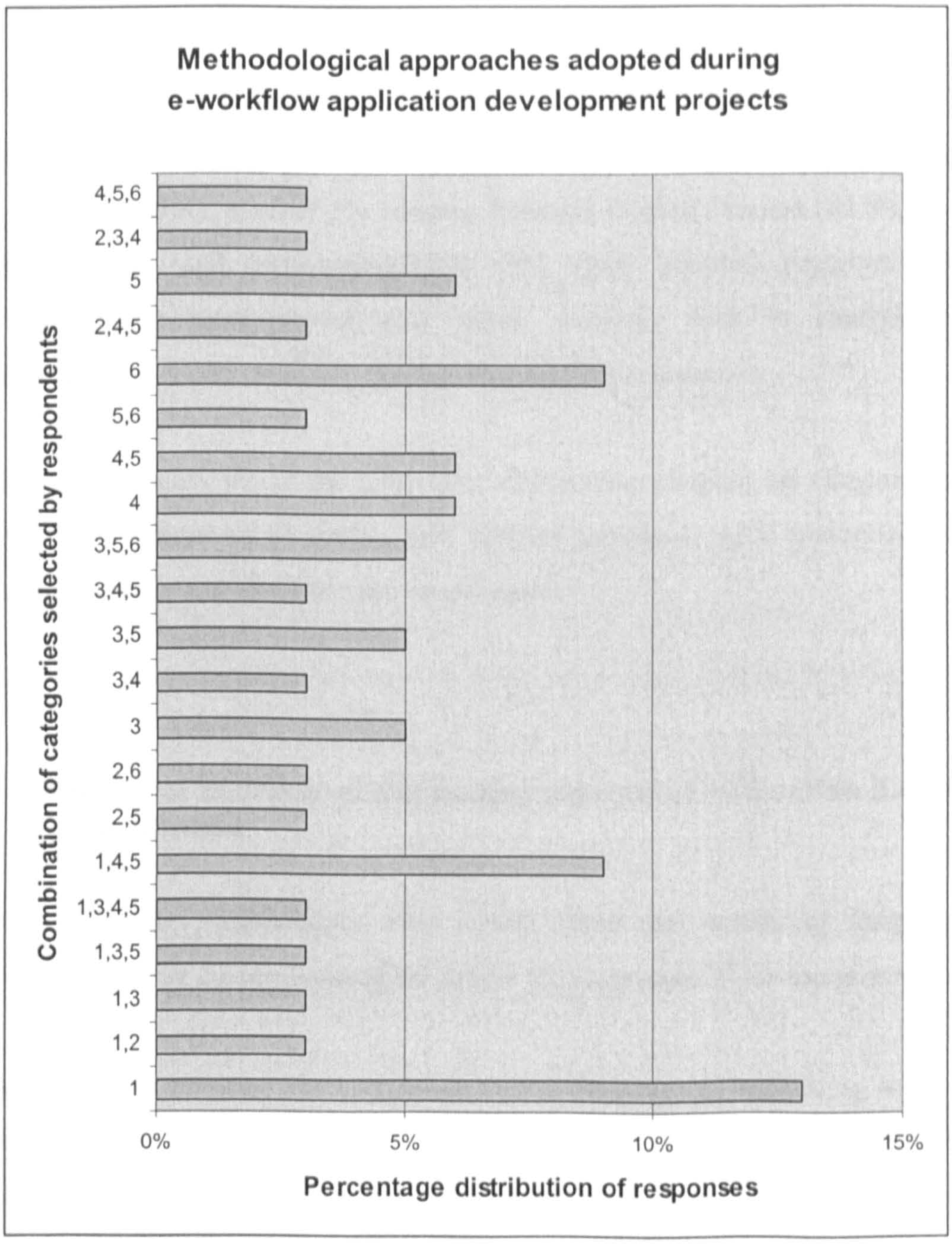

Figure 7. 4: Percentage distribution of section 3.3

It was also observed that 5% of the respondent adopted specific modelling tools and business process reengineering (BPR), and 3% adopted specific modelling tools, prototyping/RAD and business process reengineering, 5% again adopted specific modelling tools, business process reengineering and 'other' category which comprises of process management tools and using a plug and play workflow engine

(ArisaFlow BPM Suite) while 6% adopted only prototyping/RAD during e-workflow application development projects. In addition, only 6% of the respondents adopted prototyping/RAD and business process reengineering, 3% again adopted business process reengineering (BPR) and 'other' category.

Approximately 3% adopted Rational Unified Process (RUP), prototyping/RAD and business process reengineering (BPR), 6% again adopted business process reengineering (BPR), another 3% adopted Rational Unified Process (RUP), specific modelling tools and prototyping/RAD, 3% again adopted prototyping/RAD, business process reengineering and 'other' category such as chant/internally developed as the AIIM standard, flexible and adaptable approach.

While approximately 9% of the remaining respondents adopted the category 'other' category that comprises of scrum, soft systems approach, agile methods, process management tools and all of the above and more.

7.11 Statistical analysis of the coding categories of section 3.4 of the questionnaire

In this subsection respondents were asked about the modelling language or techniques adopted during e-workflow design (See appendix D for questionnaire).

Table 7.7 below clarifies the categories under 'language or modelling techniques adopted during e-workflow design' from the survey questionnaire for this thesis. There were 35 respondents out of a total of 36 respondents who responded to this question (see Table 7.3 above, column 4).

Code	Category
1	Business process modelling notation (BPMN)
2	Business process execution language (BPEL)
3	UML activity diagram (AD)
4	Action workflow language / Action perspective
5	Petri-net
6	XML process description language (XPDL)
7	Formal modelling technique (Mathematical)
8	IDEF
9	Work breakdown structure (WBS)
10	Lovem
11	PERT chart
12	ARIS
13	RAD
14	Other

Table 7. 7: Categories of language / modelling techniques used during e-workflow design

As can be seen on figure 7.5 below which represents the percentage distribution of the combinations of the various categories of responses from question 3.4 of the questionnaire, approximately 3% of the respondents adopted Business Process Modelling Notation (BPMN), UML activity diagram, Petri-net, formal modelling techniques (Mathematical), IDEF and Pert chart.

Also 8% of the respondent's embraced only UML activity diagrams, about 3% embraced UML activity diagram, action workflow language/action perspectives and Petri-net, while 3% of some of the respondents adopted UML activity diagram, Action workflow language / Action perspective and work breakdown structure.

Another 5% of the respondent's embraced UML activity diagram, Petri-net and formal modelling techniques (mathematical), 3% adopted UML activity diagram, Petri-net and Work breakdown structure. Approximately, 9% adopted UML activity diagram, Petri-net and 'other' category such as each of them is incomplete in their own way, 3% adopted UML activity diagrams and 'other' category such as OSWorkflow, 3% again adopted only Action workflow or Language/Action perspective, while 5% adopted Action workflow or Language/Action perspective and Work breakdown structure.

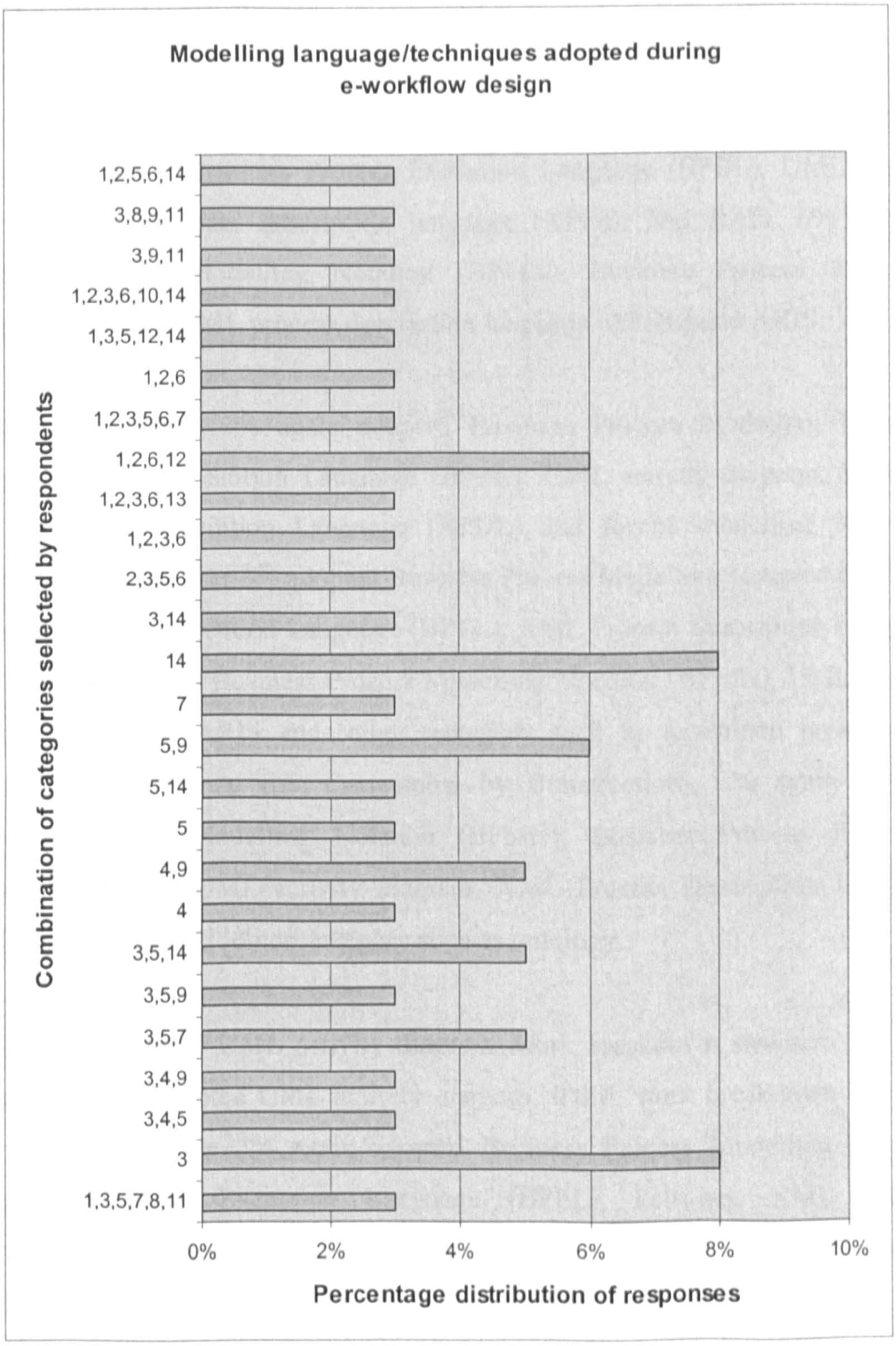

Figure 7. 5: Percentage distribution of section 3.4

In addition, 3% embraced only Petri-net, 4% again embraced Petri-net and 'other' category such as ORM, 6% of the respondents' also embraced Petri-net and Work breakdown structure whilst 3% again embraced only formal modelling techniques

(Mathematical). Furthermore, 3% adopted Business Process Execution Language (BPEL), UML activity diagram, Petri-net and XML process description language (XPDL), 3% adopted Business Process Modelling Notation (BPMN), Business Process Execution Language (BPEL), UML activity diagram and XML process description language (XPDL), 3% again adopted Business Process Modelling Notation (BPMN), Business Process Execution Language (BPEL), UML activity diagram, XML process description language (XPDL) and RAD, 6% adopted Business Process Modelling Notation (BPMN), Business Process Execution Language (BPEL), XML process description language (XPDL) and ARIS.

On the other again, 3% again adopted Business Process Modelling Notation, Business Process Execution Language (BPEL), UML activity diagram, Petri-net, XML Process Description Language (XPDL) and formal modelling technique (Mathematical), another 3% adopted Business Process Modelling Notation (BPMN), Business Process Execution Language (BPEL), XML Process Description Language (XPDL), 3% adopted Business Process Modelling Notation (BPMN), UML activity diagram, Petri-net, ARIS and 'other' category such as formalism provided by AristaFlow BPM Suite (i.e. Correctness by Construction), 3% again adopted Business Process Modelling Notation (BPMN), Business Process Execution Language (BPEL), UML activity diagram, XML Process Description Language (XPDL), LOVEM and 'other' category such as ontology.

Another 3% adopted UML activity diagram, work breakdown structure and Pert chart, 3% again adopted UML activity diagram, IDEF, work breakdown structure and Pert chart, while 3% again adopted Business Process Modelling Notation (BPMN), Business Execution Language (BPEL), Petri-net, XML Process Description Language (XPDL) and 'other' category such as expressiveness and capability to accommodate change, the remaining 8% embraced the 'other' category which comprises of BPMN, EPC, BPEL, YAWL, Even-Driven Process Chain and each of them is incomplete in their own way.

7.12 Statistical analysis of the coding categories of section 3.5 of the questionnaire

In this subsection, respondents were asked about what they consider to be the most critical success factors for the implementation of e-workflow management projects (See Appendix D for questionnaire).

Table 7.8 below depicts the categories under 'Critical success factor for the implementation of e-workflow projects' from the web-based survey questionnaire for this research. There were 35 respondents out of a total of 36 respondents who responded to this question (see Table 7.3 above, column 5). A more detail descriptive statistical analysis of the results from this section of the questionnaire is as shown on figure 7.6 below.

Code	Category
1	User participation
2	Senior management commitment
3	User commitment
4	A clear set of objectives
5	Senior management participation
6	Realistic budget and time scale
7	Selection of appropriate e-workflow development approach
8	Other

Table 7. 8: Categories of critical success factor for the implementation of e-workflow projects

As can be observed from figure 7.6 below, 11% of the respondents adopted user participation as the critical success factor for the implementation of e-workflow projects, 3% adopted Senior management commitment, 3% again adopted user commitment, another 11% adopted a clear set of objectives, 3% again adopted senior management participation and 3% also the 'other' category such as definition of clear interfaces and strategies for dealing with exceptions from the norm as the critical success factor for the implementation of e-workflow projects. Also, 3% adopted user participation, senior management commitment and selection of appropriate e-workflow development approach, 3% again adopted user participation, senior management commitment, user commitment, a clear set of objectives and senior management participation.

Furthermore, 5% of the respondents adopted user participation, senior management commitment, user commitment, and a clear set of objectives, senior management participation, realistic budget and timescale and selection of appropriate e-workflow projects, while 5% also adopted selection of appropriate e-workflow projects as the critical success factor for the implementation of e-workflow projects.

Another 3% adopted all of the above categories and the 'other' category such as 'use of an agile process', the same percentage adopted user participation, senior management commitment, user commitment, a clear set of objectives, realistic budget and time scale, and selection of appropriate e-workflow development approach, while 6% adopted user participation, senior management commitment, a clear set of objectives and selection of appropriate e-workflow development approach as the critical success factor for the implementation of e-workflow projects.

It was observed that only, 3% of the respondents adopted user participation and user commitment, 3% adopted user participation, senior management commitment, senior management participation and realistic budget and time scale, the same 3% adopted user participation, senior management commitment, a clear set of objectives, senior management participation, realistic budget and time scale, selection of appropriate e-workflow development approach and the 'other' category such as 'Requirement analysis, Adequate treatment of flexibility issues' as the critical success factor for the implementation of e-workflow projects.

The same 3% again adopted user participation, senior management commitment, user commitment, a clear set of objectives, realistic budget and time scale and the 'other' category such as 'integration capabilities of chosen technology', another 3% adopted user participation, senior management commitment, user commitment, a clear set of objectives, senior management participation and realistic budget and time scale, 3% again adopted user participation and a clear set of objectives as the critical success factor for the implementation of e-workflow projects.

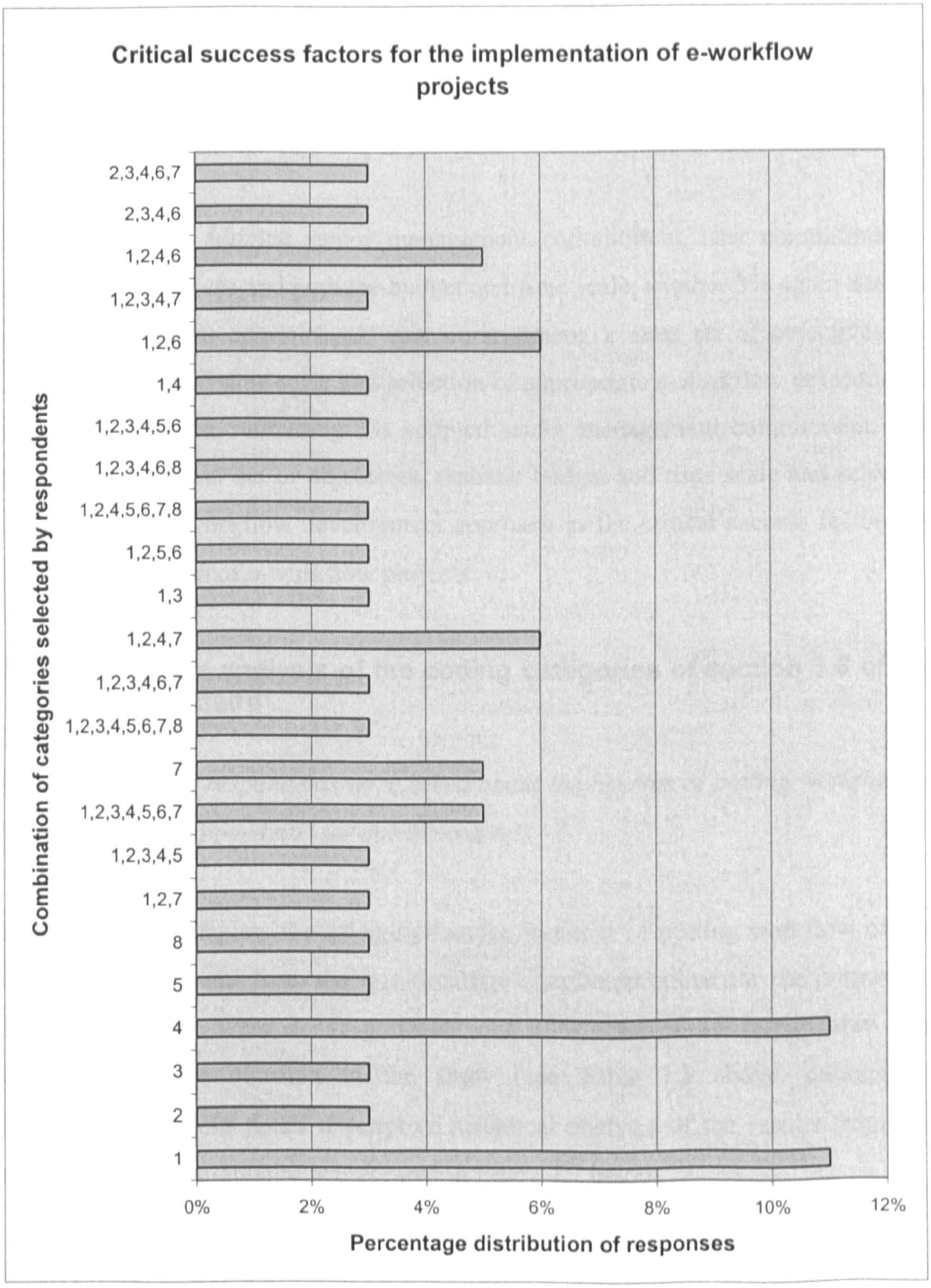

Figure 7. 6: Percentage distribution of section 3.5

Approximately 6% adopted user participation, senior management commitment and realistic budget and time scale, 3% user participation, senior management commitment, user commitment, a clear set of objectives and selection of appropriate e-workflow development projects, another 5% again adopted user participation, senior management commitment, a clear set of objectives and realistic budget and time scale as the critical success factor for the implementation of e-workflow application projects.

Furthermore, 3% adopted senior management commitment, user commitment, a clear set of objectives and realistic budget and time scale, another 3% again adopted senior management commitment, user commitment, a clear set of objectives and realistic budget and time scale and selection of appropriate e-workflow development approach, while the remaining 3% adopted senior management commitment, user commitment, a clear set of objectives, realistic budget and time scale and selection of appropriate e-workflow development approach as the critical success factors for the implementation of e-workflow projects.

7.13 Statistical analysis of the coding categories of section 3.6 of the questionnaire

In this subsection, respondents were asked about the benefits of putting workflow on the Internet (See appendix D for questionnaire).

Table 7.9 below depicts the categories under 'benefits of putting workflow on the Internet environment' from the questionnaire distributed online for the purpose of this thesis. There were 36 respondents out of a total of 36 respondents who responded to this question in the study (see Table 7.3 above, column 6). Furthermore, a more detail descriptive statistical analysis of the results from this section of the questionnaire is presented in figure 7.7 below.

It was perceived that approximately 2% of the respondents adopted reduction in cost as the benefits of putting workflow on the Internet, 3% of the respondents were of the opinion that reduction in cost, fast response to customer enquiries and increase in the scalability of workflow applications are the benefits of putting workflow on the

Internet, the same 3% again embraced reduction in cost, fast response to customer enquiries, increase in the scalability of workflow applications and uniform interface throughout the globe, about 5% were of the view that reduction in cost, fast response to customer enquiries and improve collaboration, coordination and communication within and between organisations as the benefits for putting workflow on the Internet.

Code	Category
1	Reduction in cost
2	Fast response to customer enquiries
3	Increase the scalability of workflow application
4	Uniform interface throughout the globe
5	Ease of installation and use
6	Improve collaboration, coordination and communication within and between organisations
7	Improve the competitiveness of the company
8	Other

Table 7. 9: Categories of the benefits of putting workflow on the Internet

In addition, 2% of the respondents were of the view that reduction in cost, fast response to customer enquiries, increase in the scalability of workflow applications, uniform interface throughout the globe, ease of installation and use, improve collaboration, coordination and communication within and between organisations are the benefits of putting workflow on the Internet, 3% reported that reduction in cost, fast response to customer enquiries, increase in the scalability of workflow applications, uniform interface throughout the globe, ease of installation and use, improve collaboration, coordination and communication within and between organisations, improve the competitiveness of the company as the benefits of putting workflow on the Internet.

It was also noted that 4% of the respondents choose reduction in cost, fast response to customer enquiries, increase in the scalability of workflow applications, uniform interface throughout the globe, ease of installation and use, improve collaboration within and between organisations, improve the competitiveness of the company and the 'other' category such as 'Patient Safety in Healthcare', another 3% were of the view that reduction in cost, fast response to customer enquiries, increase in the scalability of workflow applications and ease of installation and use as the benefits of putting workflow on the Internet.

Of these, 3% selected reduction in cost, fast response to customer enquiries, improve the collaboration, coordination and communication within and between organisations and improve the competitiveness of the company, 3% again selected reduction in cost, fast response to customer enquiries, improve collaboration, coordination and communication within and between organisations, improve the competitiveness of the company and the 'other' category such as 'be able to react more rapidly to business process change, process performance management', as the benefits of putting workflow on the Internet.

Another 3%, selected reduction in cost, increase in the scalability of workflow applications, improve collaboration, coordination and communication within and between organisations and improve the competitiveness of the company; only 3% selected reduction in cost and improve collaboration, coordination and communication within and between organisations, while 3% selected fast response to customer enquiries, increase in the scalability of workflow applications and uniform interface throughout the globe as the benefits of putting workflow on the Internet. Some 3% of the respondents were of the view that fast response to customer enquiries, increase in the scalability of workflow applications and improve collaboration; coordination and communication within and between organisations are the benefits of putting workflow on the Internet.

Another 3% selected fast response to customer enquiries, increase in the scalability of workflow applications, ease of installation and use, and improve collaboration, coordination and communication, about 5% selected fast response to customer enquiries and improve collaboration, coordination and communication within and between organisation, while only 3% selected increase in the scalability of workflow application.

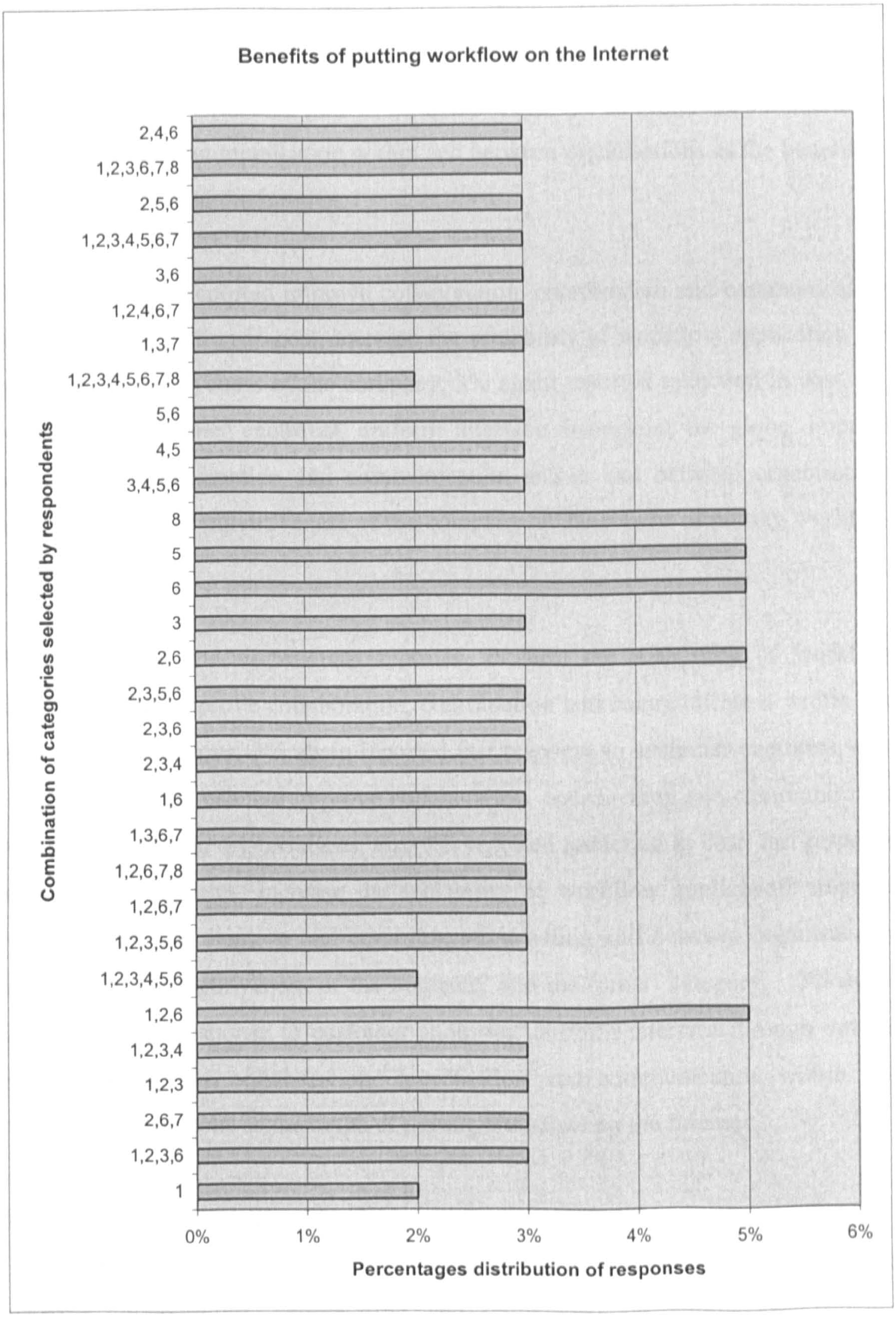

Figure 7. 7: Percentage distribution of section 3.6

As noted previously, 3% of the respondent's embraced increase in the scalability of workflow application, uniform interface throughout the globe, ease of installation and use and improve collaboration, coordination and communication within and between organisations. Also, 3% adopted uniform interface throughout the globe and ease of installation and use, only 3% embraced ease of installation and use while the remaining 3% embraced ease of installation and use and improve collaboration, coordination and communication within and between organisations as the benefits of putting workflow on the Internet.

Furthermore, 5% reported improve collaboration, coordination and communication, 3% reported reduction in cost, increase the scalability of workflow application and improve competitiveness of the company, 3% again reported reduction in cost, fast response to customer enquiries, uniform interface throughout the globe, improve collaboration coordination and communication within and between organisations and improve the competitiveness of the company as the benefit of putting workflow on the Internet.

Another 3% of the respondents reported increase the scalability of workflow application and improve collaboration, coordination and communication within and between organisations, 3% again reported fast response to customer enquiries, ease of installation and use and improve collaboration, coordination and communication within and between organisations, also 3% reported reduction in cost, fast response to customer enquiries, increase the scalability of workflow application, improve collaboration, coordination and communication within and between organisations, improve the competitiveness of the company and the 'other' category, 3% again highlighted fast response to customer enquiries, uniform interface through out the globe and improve collaboration, coordination and communication within and between organisations as the befits of putting workflow on the Internet.

It was also perceived that 3% of the respondents adopted reduction in cost, fast response to customer enquiries, increase the scalability of workflow applications and improve collaboration, coordination and communication within and between organisations, 3% again adopted fast response to customer enquiries, and improve collaboration, coordination and communication within and between organisations, improve the competitiveness of the company and finally another 5% embraced the category 'other', which comprises of 'depends on individual project objectives and All of the above'.

7.14 Statistical analysis of the coding categories of section 3.7 of the questionnaire

In this subsection, respondents were asked about the problems faced during the move from conventional workflow (client/server) to Internet-mediated workflow (e-workflow), (See appendix D for questionnaire).

Table 7.10 below describes the categories under 'problems faced during the movement from conventional workflow (client/server) to Internet-mediated workflow (e-workflow?)', from the web-based questionnaire distributed for the purpose of this research work. There were 33 respondents out of a total of 36 respondents who responded to this question in the study (see Table 7.3 above, column 7). In addition, a more detail analysis of the results from this section of the questionnaire is presented in figure 7.8 below as follows.

Code	Category
1	Time difference
2	Culture gaps
3	Security issues (authentication & authorisation)
4	Complex inter-organisational process management
5	Synchronising the processes of participating organisations
6	Technological infrastructure difference
7	Other

Table 7. 10: Categories of Problems faced during the movement from conventional workflow to e-workflow

It was observed that, 3% of the respondents reported that culture gaps and security issues (authentication and authorisation) are the problems they faced in moving from conventional workflow (client/server) to Internet-mediated workflow, 3% again reported culture gaps, security issues (authentication & authorisation), complex inter-organisational process management, synchronising the processes of participating organisations, another 3% reported culture gaps, security issues (authentication & authorisation), complex inter-organisational process management, synchronising the processes of participating organisations and technological infrastructure difference. Approximately, 12% selected security issues (authentication & authorisation), complex inter-organisational process management, synchronising the processes of participating organisations and technological infrastructure difference, another 6% selected security issues (authentication & authorisation), complex inter-organisational process management and synchronising the processes of participating organisations,

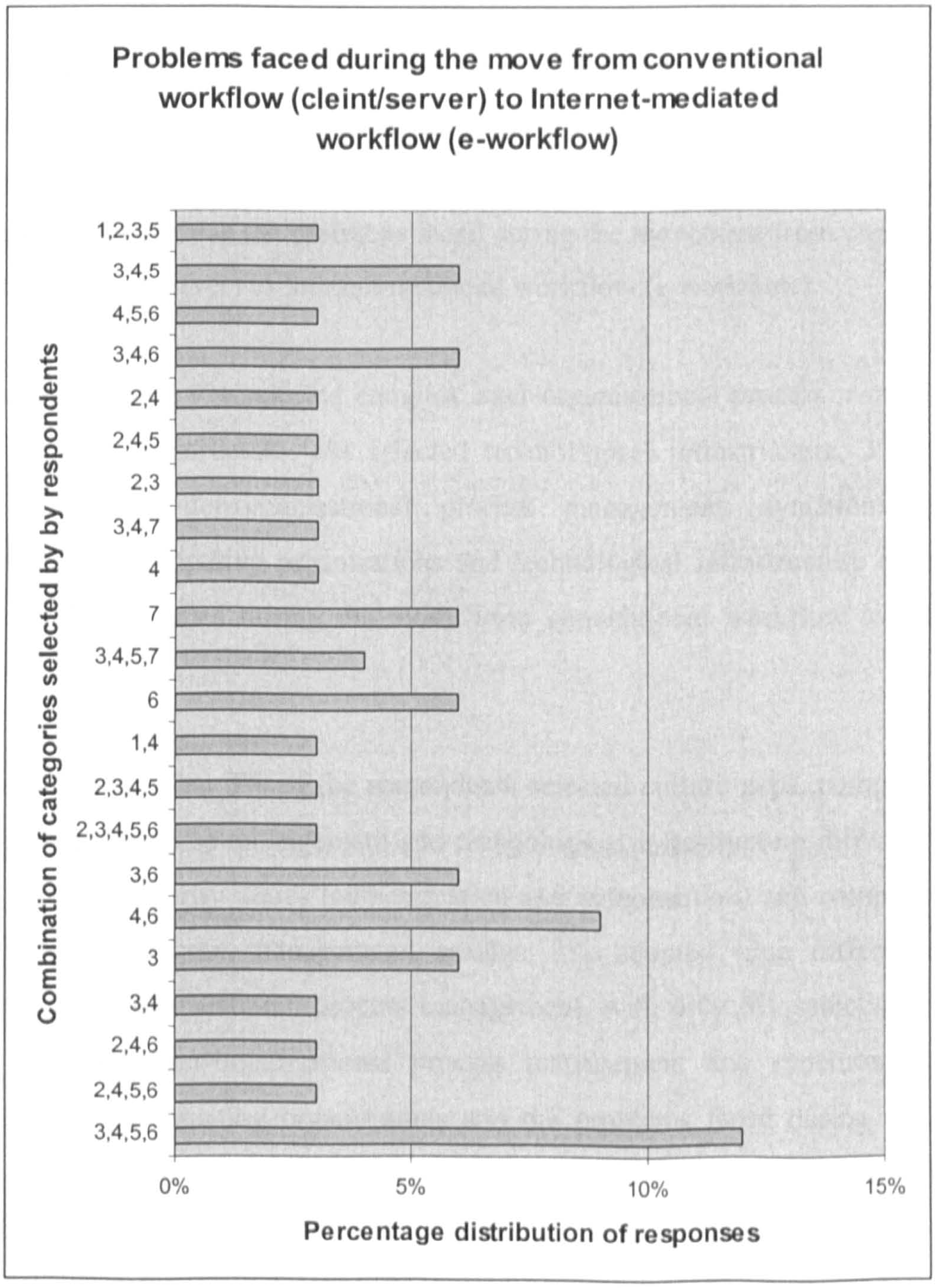

Figure 7. 8: Percentage distribution of section 3.7

while 6% selected security issues (authentication and authorisation), complex inter-organisational process management and technological infrastructure as the problem faced when moving from conventional workflow (client/server) to Internet-mediated workflow (e-workflow).

It was noted that 6%, choose security issue (authentication & authorisation) and technological infrastructure, 6% choose only security issues (authentication & authorisation), 4% again choose security issues (authentication & authorisation), complex inter-organisational process management, synchronising the processes of participating organisations and the 'other' category such as 'dealing with change and with exceptions', while the remaining 3% choose only complex inter-organisational process management as the problems faced during the movement from conventional workflow (client/server) to Internet-mediated workflow (e-workflow).

On the other hand, 9% selected complex inter-organisational process management, technological infrastructure, 6% selected technological infrastructure, 3% culture gaps, complex inter-organisational process management, synchronising the processes of participating organisations and technological infrastructure difference as the problems faced during the move from conventional workflow to internet-mediated workflow.

It was also noted that 3% of the respondents selected culture gaps, complex inter-organisational process management and technological infrastructure difference, 3% again selected security issues (authentication and authorisation) and complex inter-organisational process management, another 3% adopted time difference and complex inter-organisational process management, with only 3% selecting culture gaps, complex inter-organisational process management and synchronising the processes of participating organisations and the problems faced during the move from conventional workflow (client/server) to Internet-mediated workflow (e-workflow).

Furthermore, 3% of the respondents choose security issues (authentication and authorisation), complex inter-organisational process management and the 'other' category such as 'inflexibility of private workflows', another 3% selected culture gaps and complex inter-organisational process management, 3% again selected complex inter-organisational process management, synchronising the processes of participating organisations and technological infrastructure difference, on top of that another 3% selected time difference, culture gaps security issues (authentication and authorisation), synchronising the processes of participating organisations, and finally 10% selected the 'other' category which comprises of 'All of the above and more and no experience'.

7.15 Discussions of the findings from the descriptive statistics of the online survey questionnaire and action research case study

In order for the discussions of the research findings to be meaningful, they are related to the research aims and objectives. Whilst the descriptive statistics above provides a summary of the responses from the surveyed population, an in-depth discussion of the results and findings from the online survey questionnaire and action research case study is also provided here.

7.15.1 Workflow modelling perspectives

In-depth analysis of the perspectives adopted during the development of e-workflow applications from the online survey questionnaire (as highlighted on Table 7.3 above, column 2 and Figure 7.3 above), revealed that majority (27/35) 77% of the respondents adopted traditional workflow modelling perspectives, namely functional, organisational, information and behavioural. These perspectives are suitable for modelling traditional Intra-organisational workflows and not for contemporary Inter-organisational e-workflows in the emerging e-business era. The adoption of these perspectives led to difficulties in capturing process-oriented knowledge and appropriate levels of abstractions of workflow models.

Approximately (8/35) 23% of the respondents suggested or implied that the perspectives they used can be categorised under temporal, causal, historical flexibility, knowledge perspective, knowledge engineering, compliance, cognitive logic, collaboration, information and knowledge flow and primarily the order and information flow. These suggested perspectives are directly or indirectly linked to the knowledge management initiatives. Within our proposed knowledge enhanced framework for the development of adaptive workflow systems, knowledge is incorporated in the form of workflow design patterns which can be reused during the design of e-workflow applications rather that starting from scratch each time that we want to develop a workflow application, thereby reducing the time, cost and effort spend during the development process.

It is arguable in relation to the action research case study that Expedia was launched during the BPR and TQM initiatives of the 90s. Thus Expedia must have adopted some or all of the above-mentioned traditional workflow modelling perspectives during the design of their existing e-workflow application. Documents collected from Expedia's website has shown that Expedia's workflow model is based on Enterprise Resource Planning (ERP) architecture developed through the business process reengineering (BPR) principles. Examples of technologies that are based on a high level of integration and internal focus such as ERP represents a workflow model that is based upon the work process and information processing perspectives. However given a radical and discontinuously changing business environment, these technologies fall short of sensing changes that they haven't been pre-programmed to sense and accordingly unable to modify the logic underlying their behaviour (Malhotra, 2000).

We argue that the five workflow modelling perspectives i.e., functional, organisational, informational, behavioural and knowledge within the proposed framework approach is superior to the traditional four perspectives used for the design and development of conventional workflow applications, which are normally suitable for static business processes or environment. The proposed framework is unique in that it extends the traditional workflow modelling perspectives with the knowledge perspective in the form of a knowledge repository and suits current e-business environment characterised by agile business processes within the global and knowledge economy (Nunes et al., 2009).

7.15.2 Methodological approaches adopted

As indicated on the descriptive statistical analysis (see Table 7.3 above, column 3 and Figure 7.4 above), a majority (27/35) 77% of the respondents from the online survey questionnaire adopted methodological approaches that are data centric/driven. More specifically, it can be seen that traditional structured development approaches, such as Structured System Analysis and Design methods were used within workflow application projects inappropriately as these are specifically design for software development. Similarly the Rational Unified Process (RUP), Business Process Reengineering (BPR) and Rapid Application Development (RAD) approaches are incorrectly used during the design and development of e-workflow applications. All these methodological approaches are likely to be unsuccessful when implemented in contemporary e-business environment.

There are specific modelling tools or proprietary tools used by some institutions and business organisations for the development of workflow applications. It is also known from the literature that the adoption of proprietary tools will lead to problems of integrations of different workflow applications. With respect to BPR which was proposed in the 1990s, there has been numerous criticism towards the approach since it turns to focus more on technological issues and ignore human aspects which are highly relevant during the design and development of workflow applications and specifically even more so within the context of e-workflow applications (Wetzel & Klischewski, 2004).

Just about 23% (8/35) of the surveyed population again adopted methodological approaches such as SCRUM and XML-based technologies, agile methods, process management tools, plug and play workflow engine (AristaFlow BPM Suite), soft systems approach, chant/internally developed as the AIIM standards, flexible and adaptable approach, with one of them suggesting all of the above and more. These methodological approaches are directly or indirectly linked to knowledge management and Internet concepts and as a consequent this will result in reduction in cost and time spent during workflow application development projects (Nunes et al., 2009). Scrum is an agile method for project management. Scrum was named as a project management style in auto and consumer product manufacturing companies by (Takeuchi and Nonaka, 1986), who are authorities in knowledge management initiatives.

Scrum works because it is a highly empowering process that allows requirements and self-organising teams to emerge. In thier book Schwaber and Beedle describe Scrum as an empirical process that uses frequent inspection (daily meetings), collaboration and adaptive responses. They contrast this to defined processes in which every task and outcomes is defined. Defined processes work only when the input to the process can be perfectly defined and there is very little noise, ambiguity or change. The adoption of Scrum and XML led to reduction in time spent during adaptability and reusability thereby improving the competitiveness of the company.

Our analysis and literature review on e-business applications through action research case study with Expedia provided us with evidence that the workflow approach adopted by Expedia is based on BPR. This was also found to be true during the analysis of documentation collected from Expedia's website. The BPR movements emphasised IT-intensive radical redesign of business process and workflow processes. They propose a clean-slate approach to rebuild the company's information architecture by rethinking the company's business in terms of business processes rather than discrete functions and hierarchies.

Too much reliance on information technology at the expense of human involvement and commitment resulted in major implementation failures of BPR initiatives at the rate of 70%. Thus Expedia needs to shift to a paradigm, which takes human and knowledge management issues in to consideration. Their methodological approach is suitable for structured and not for ill-structured workflow problems within e-business environment. Expedia needs an approach that is flexible, adaptable and reusable in order to handle frequent changes in e-business environment

Within our proposed framework approach that consists of a number of related components such as the five perspectives for e-workflow modelling, design pattern environment and the knowledge repository to support the framework, a macro workflow application development process or life cycle etc. The proposed framework for e-workflow modelling and the design pattern environment incorporates critical and important 'soft' issues such as human aspects and knowledge management initiatives which are vital during the development of workflow applications within e-business environments in the global and knowledge economy characterised by rapid, dynamic, agile and disconcerting change. Furthermore, by combining the knowledge perspective in the form of a knowledge repository within the proposed framework for knowledge enhanced e-workflow modelling with other existing perspectives for workflow modelling, e-workflows (cross-organisational workflows) can be modelled in an implementation-independent manner.

We argue that our proposed framework approach has the flexibility and adaptability that is required during the design, development and evolution of e-workflow applications in contemporary e-business environment characterised by complex and unpredictable business processes. The proposed framework approach can be used to abstract a richer view of the subject world than can be captured in conceptual models of traditional structured development methods e.g. JSD, SSADM. We further claim that the soft issues embedded within the proposed framework approach will help researchers and industries to develop robust, reusable and adaptable workflow applications to support the growing demand for e-business applications (Ndeta & Farhi, 2005).

7.15.3 Workflow language/modelling techniques

From the descriptive statistics (see Table 7.3 above, column 4 and Figure 7.5 above), a majority (25/35) 71% of the surveyed population adopted traditional workflow modelling techniques such as PERT/CPM, work breakdown structure (WBS), IDEF, formal methods (mathematical) and simulation techniques such as Petri-net etc. The adoption of traditional structured modelling techniques for the design, modelling and evolution of e-workflow applications in contemporary e-business environment led to problems such as insufficient expressive power such that full conceptualisation is not possible (van der Aaslt et al., 2003; Barros, and ter Hofstede, 1998). These techniques are generally referred to in the literature as semi-formal methods, which are prone to misinterpretation, vagueness, and ambiguity amongst stakeholders in the context of e-workflow thereby increasing the cost and time spent on workflow application development.

Some of the aforementioned problems were due to the fact that, traditional structured techniques were successful for the conceptualisation and development of software/information systems applications, which are largely data centric and not for workflow systems that are process centric. For instance the use of Petri-net technique for workflow conceptualisation is limited in that it tends to focus more on behavioural aspects and ignore the organisational, informational and knowledge aspects which are also critical during the design, modelling and evolution of complex internet workflow applications.

Round about (10/35) 29% of the respondents adopted workflow conceptual modelling techniques such as BPMN, EPC, XPDL, YAWL and BPEL, OSWorklow, ORM, WSM Nets (similar to PetriNets, but more flexible, see ADEPT project), formalism provided by AristaFLow BPM (i.e. Correctness by Construction), ontology, Event-Driven Process Chain, with one of them suggesting that each of the techniques is incomplete in their own way, and expressiveness and capability to accommodate change, which are well established and widely used for the development of e-workflow applications, and also have the potential to become successful in the future. Some of these techniques are directly or indirectly linked to the literature on knowledge management concepts. Consequently these techniques have helped improve e-workflow conceptualisation by enhancing the expressive power of workflow conceptualisation on the Internet. They are more comprehensive to improve communications, and easy to accommodate the requirements of stakeholders. This has also served to improve workflow requirement acquisition and the flexibility of analysis for different workflow problem situations.

It was also found through documents collected and analysis of Expedia workflows through action research case study strategies, that Expedia focus on BPR since their e-business and workflow applications were developed during the BPR and TQM movements. BPR and TQM assume structured methodology and modelling techniques for business process re-engineering, e-workflow modelling and automation, as well as business process mapping and analysis (Wetzel &

Klischewski, 2004). Structured workflow modelling techniques were suitable for traditional business characterised by predictable and stable processes and not for complex, unpredictable and dynamically changing processes in the e-business environment. Thus Expedia needs to adopt and adapt contemporary workflow modelling techniques and strategies, which are knowledge-aware so as to capture and reflect realities within the e-business environment i.e., flights, hotels, car rentals and other rival organisations so as to gain some competitive edge within the emerging global and knowledge economy.

We argue that whilst the general structure of the proposed framework for e-workflow modelling and design (which incorporates knowledge in the form of workflow design patterns in a knowledge repository) is based on conceptual modelling techniques known from information and software engineering process models. The specific properties of e-workflow applications and their implications to the development processes of e-workflow applications in the new e-business environment characterised by global and knowledge economy are well taken care of as they are embedded within the proposed knowledge enhanced framework.

7.15.4 Critical success factors for the implementation of e-workflow projects

The surveyed population was also asked to list the critical success factors that contributed to the successful implementation of e-workflow projects. Given the categories in Table 7.8 above, which depicts the critical success factors for the implementation of e-workflow projects, respondents have actually re-categorised based on what they perceived to be critical success factors. Consequently, they have regenerated a different coding scheme which has a combination of the original categories specified with the web-based questionnaire as shown in Table 7.8 above.

The orders of precedence chosen by respondents of the online survey questionnaire for this study to be critical success factors are as follows: 'user participation', followed by 'user participation and senior management commitment' followed again by 'realistic budget and time scale and selection of appropriate e-workflow development approach' followed again by 'senior management commitment and a clear set of objectives' followed again by 'senior management participation' and finally the least being 'user commitment'. This provides further empirical evidence confirming the earlier findings from the literature that there are combinations of organisational supporting factors influencing the successful implementation of e-workflow applications.

It is interesting to note that, whilst there is some variability with regards to the methods, tools and techniques employed for the development and implementation of Workflow Management Systems (WFMSs), there is a high level of unanimity about the need for organisational support. This therefore provides further strong evidence that WFMS technology cannot be developed in isolation from the organisational context in which it will ultimately be used. Some of these critical success factors have already been taken care of within the proposed knowledge-enhanced framework for the design, development and evolution of complex e-workflow applications in the global and knowledge economy characterised by dynamic, complex and unpredictable business processes and e-business environment.

Approximately (5/35) 14% of the respondents choose the category 'other' which comprises of use of an agile process, requirements analysis, adequate treatment of flexibility issues, all of the above, definition of clear interfaces and strategies for dealing with exceptions from the norm and integration capabilities of chosen technology. These chosen categories are also directly or indirectly linked to the knowledge management initiatives, which goes further to justify our claim that knowledge management is a vital aspect in e-workflow design, development and evolution in the new economy.

7.15.5 Benefits of putting workflow on the Internet

As indicated on (Table 7.3 above, column 6 and Figure 7.7 above), when asked about the benefits of putting workflow on the Internet most of the respondents were quick to highlight 'reduction in cost of transaction', 'fast response to customer enquiries' 'increase the scalability of workflow applications' improve collaboration and communication within and between organisations' and 'improvement of the competitiveness of the company'.

It was also interesting to note that only 16% of the respondents highlighted other categories as the benefits of putting workflow on the Internet, which comprises of the following: depends on the individual project objectives, global competitiveness, be able to react more rapidly to business process changes, process performance management, patient safety in healthcare, all of the above and all are relevant, but some more than others. Some of these categories are also related to the literature on knowledge management initiatives. Therefore, we argue that any contemporary organisation including Expedia should consider some of these benefits during the design, development and evolution of their e-workflow applications.

7.15.6 Problems faced during the move from conventional workflow to e-workflow

From the statistical analysis (see Table 7.3 above, column 7 and Figure 7.8 above) with problems faced during the move from conventional workflow (client/server) to Internet-mediated workflow (e-workflow). This study further revealed that Inter-organisational process management is currently an issue that needs to be addressed. Our empirical study, guided by the responses from the online survey questionnaire suggests that a number of institutions and organisations face problems such as synchronising the processes of participating organisations, complex inter-organisational process management, technological infrastructure difference and security issues (authentication and authorisation). Workflow allows coordinative and collaborative aspects of enterprises to be explicitly specified, thereby making it possible to integrate not only the information from multiple business partners and processes but also the inherent information and knowledge flow. Ultimately multi-organisational value chains are facilitated through well-synchronised e-workflows.

After exploration and thorough analysis of Expedia workflow model and documents collected from their web site through action research, we found that during the travel booking process their e-workflow system could not provide us with the option of '*pick-up services*' from the arrival airport to the booked hotels. Even after making numerous phone calls to Expedia customer relations employees it was clear from our conversation that the employees had limited knowledge of how to solve the problem. This was also assumed to be a problem with Expedia's workflow model because the employees couldn't tell us exactly how to go about solving the problem. Due to the above-mentioned problems it is arguable that the inter-organisational processes between Expedia and its partner organisations are not properly synchronised.

Roughly speaking 36% (13/36) of the respondents adopted culture gaps (8 respondents) and the category 'other' (5 respondents) which comprises of the following: tasks are being decentralised, often without providing resources and systems introduction, dealing with change and exceptions, all of the above and more, inflexibility of private workflows and no experience. These suggested problems are also directly or indirectly linked to the knowledge management initiatives and goes further to justify the claim that knowledge management initiatives plays an important role in diagnosing and managing e-business-driven changes in organisational work processes (Fahey et al., 2001)

The traditional workflow systems including Expedia's failed to provide support for knowledge workers in order to assist them in performing their every day tasks. This often causes delays in the work process when an exception occurs or during the design of a workflow problem due to the fact that the workflow participant is not empowered with context specific knowledge about some of the tasks within the workflow process (Nunes et al., 2009).

In the light of these views and the reported failures, it is perhaps not surprising that the BPR movement appears to be losing its momentum. However, the need that drove BPR still exists in the context of e-workflow development, that is the need for contemporary organisations to design their e-workflow applications appropriately in order to survive in an increasingly competitive global and knowledge economy characterised by complex, dynamic and unpredictable business processes and business environment.

Yet there is evidence that a business process focus can contribute to improve performance of an organisation and therefore how this might be capitalised upon and better achieved requires further consideration. In this thesis we put forward the argument that knowledge management (KM) provides one useful vehicle for doing so. The enterprise resource planning (ERP) systems with its internal focus (Malhotra, 2000), developed by BPR vendors compliments the external focus of customer relationship management (CRM) and supply chain management (SCM) to provide a base for creating workflows for seamless E-business applications.

Call centres are the preferred and established way for many companies including Expedia.com to communicate with their customers, but perhaps the greatest challenge of running a call centre, is to ensure that customers are provided with the right information in a timely fashion (Rasooli and Albadvi, 2007). Existing implementations of workflow applications based on ERP systems fails to take the knowledge perspective into consideration which is crucial in providing customers with the right information at the right time. The knowledge perspective materialised into a knowledge repository in the proposed e-workflow framework could help call centres or customer relations employees to provide accurate information at the right time.

We argue that our proposed framework approach, which is knowledge and Internet aware, will help Expedia to develop inter-organisational workflows, which are properly synchronised in order to improve collaboration with partner organisations so as to meet customer needs at the right time (Malhotra, 2005) in the emerging global and knowledge economy. The main attributes/roles of knowledge management within the proposed framework are as follows: knowledge acquisition, utilisation, adaptation, dissemination and generation.

In support and customer service departments like call centres, knowledge management refers to the strategies and tasks associated with developing and delivering relevant knowledge, efficiently and quickly, to meet evolving customer and support needs (Rasooli & Albadvi, 2007). Furthermore, we argue that effective support of knowledge management initiatives by adopting and adapting the proposed framework for e-workflow design and evolution will optimise knowledge creation, knowledge dissemination, and consequently knowledge utilisation within Expedia workflow model and e-business strategies.

7.16 Verification of the results of the online survey

In order to verify the results of the web-based survey questionnaire, respondents were presented with the traditional framework and the proposed framework for their comments and suggestions. The responses from the respondents were very informative and contain a mixture of positive and negative comments and suggestions, which was expected (see Appendix G). Some of the comments and suggestions have been used to further enhance the proposed framework. The e-mail that was send to the respondents is as shown below:

Dear Sir / madam,

Thank you for responding to my original workflow management systems research questionnaire few months ago. I am now at the stage of verifying the new framework that I have developed as one of the major contributions to my PhD thesis.

I attached for your information, the traditional and the newly proposed framework for my PhD research work, specifically for e-workflow design and evolution in the global and digitised economy.

I would be grateful to you if you could comment on both frameworks in a sentence paragraph and respond before the 20th of December 2008, as your comments are valuable and essential for the analysis of the questionnaire and the completion of my PhD thesis. Note that your comments should state clearly which of the framework is more appropriate for workflow design and evolution in the new digitised economy.

Yours Faithfully,
Mr. John Ndeta

Researcher / Visiting Lecturer
London Metropolitan University

7.17 Chapter summary

This chapter has presented the quantitative evaluation of the proposed knowledge-enhanced framework for the development of adaptive e-workflow applications through online survey questionnaires. It also presents the percentage distributions and statistical analysis of the responses from the respondents. An in-depth discussion of the results and findings from the online survey questionnaire and action research case study is also included. The chapter also includes the verification of the results of the online survey questionnaire. The next chapter presents some experiments that were conducted with the proposed knowledge-enhanced framework and methods.

Part Four

Experimenting with the Proposed Framework and Thesis Conclusion

Chapter 8

Experimenting with the proposed framework

This chapter presents some of the experiments that were conducted with the proposed framework for the development of e-workflow systems adaptable to the new e-business environment. The experiments include a reuse example through workflow design patterns templates and inflexibilities in Expedia and easy jet.com workflow processes.

8.1 Experiment 1: An example of design or specification reuse through workflow design pattern templates

The Reuse example is between an e-travel agency and an online mortgage provider. The potential of reusing existing specifications to develop new systems has been brought closer by the case tool revolution (Maiden, 1991). Software reuse promises advantages such as reduction in development time, reduction in cost, and increase in productivity. Software reuse can be attempted at various stages in the life cycle of a software component. However, reuse will be more effective when it is attempted at a higher level of abstraction such as workflow requirements specification or design. The reason is that at a higher level of abstraction one can easily understand the functionality and behaviour of the reusable workflow specification and can therefore justify its reusability. Code reuse has been in practice for quite some time (Jeng and Cheng, 1994). Design reuse is also practiced by some software organisations, particularly when a new product is being developed.

The reuse example presented here describes a scenario which supports extensive reuse between a *source* e-travel management design specification and a *target* online mortgage processing design specification. Figure 8.1 and 8.2 below depicts the business models and the structural and behavioural similarities between the reusable source (online travel agent) and target problem (Agent link) business domains. The e-travel agency and the online mortgage processing systems share significant similarities, which makes design specification reuse possible. Reuse is possible between the two domains because they are all doing business online; they involve inter-organisational workflows with independent business partners, they also involve real time processes. And finally, they share the same domain knowledge since they are both operating within the e-business environment. However, domain knowledge is essential to requirements analysis, and hence a theory of design specification reuse must consider domain knowledge (Maiden, 1991).

The pattern-based cycle for e-workflow design and evolution (see Figure 4.2, page 76), which consists of the following steps: retrieve, reuse, revise and retain within the proposed framework and methods supports extensive reuse between the *source* solution e-travel agency specification and the *target* problem online mortgage processing specification. Extensive reuse is possible at a lower level between the business process workflow design patterns, resource patterns (actors or swimlanes), data patterns and control flow patterns, which are organised and stored in the knowledge repository as generic workflow design pattern templates (see appendix H).

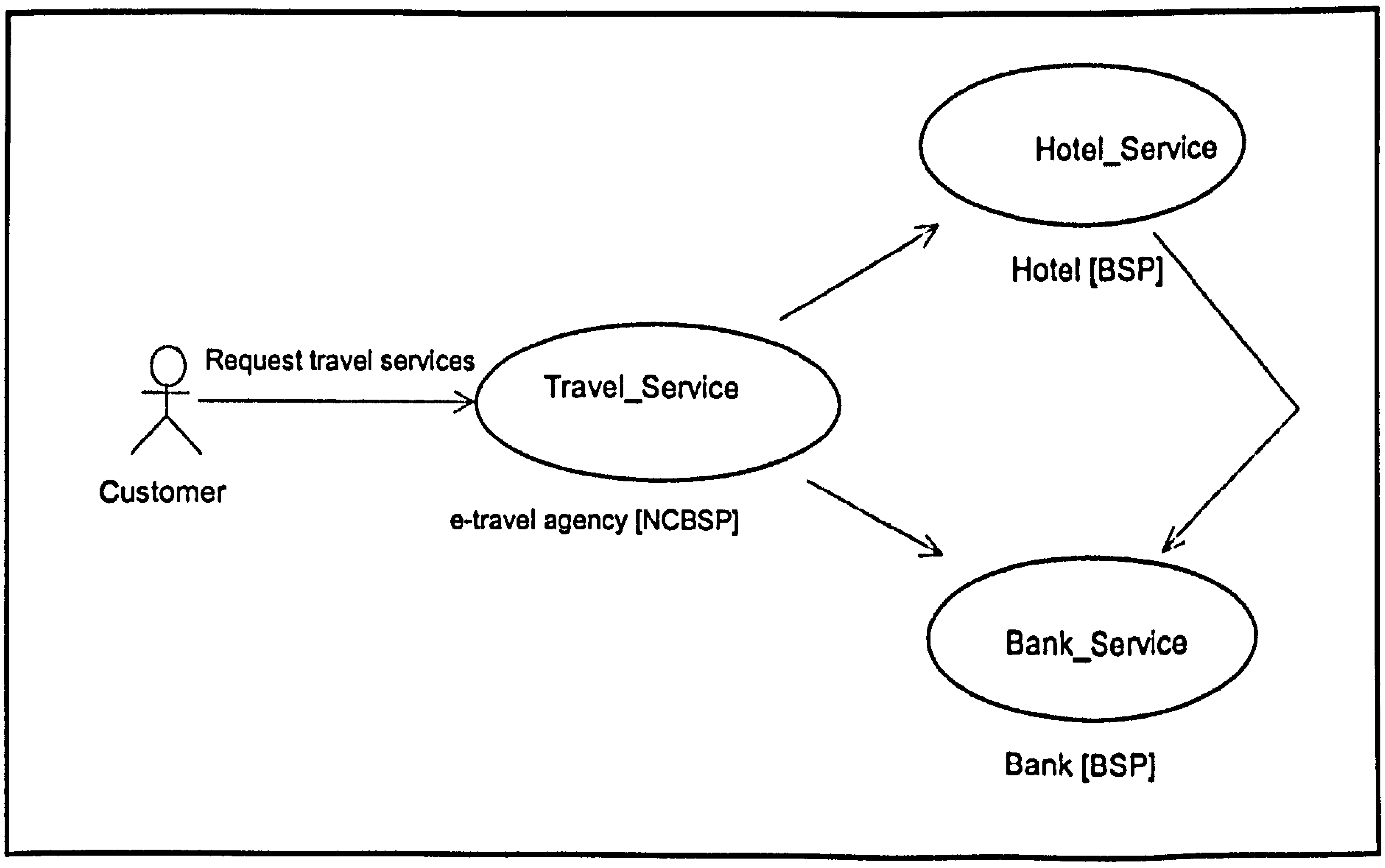

Figure 8. 1: Use case diagrams showing the business model and context of the e-travel agency

Agent Link

Agent link is an online estate agent, which offers customers with the opportunity to enquire and purchase properties online. Agent link is made up of a confederation of independent chains of estate agents. In order to provide sales to its clients, Agent link needs to establish business link with these independent estate agents (BSP). The customer can select a property from a brochure of properties via Agent links web site. If the customer is interested in any of the properties in the brochure, then Agent link will book a visit with the customer to view the property. If the customer is happy with the property, then necessary arrangements to sell the property will commence. In this context, a financial institution, i.e., a lender is required to facilitate and finance the mortgage.

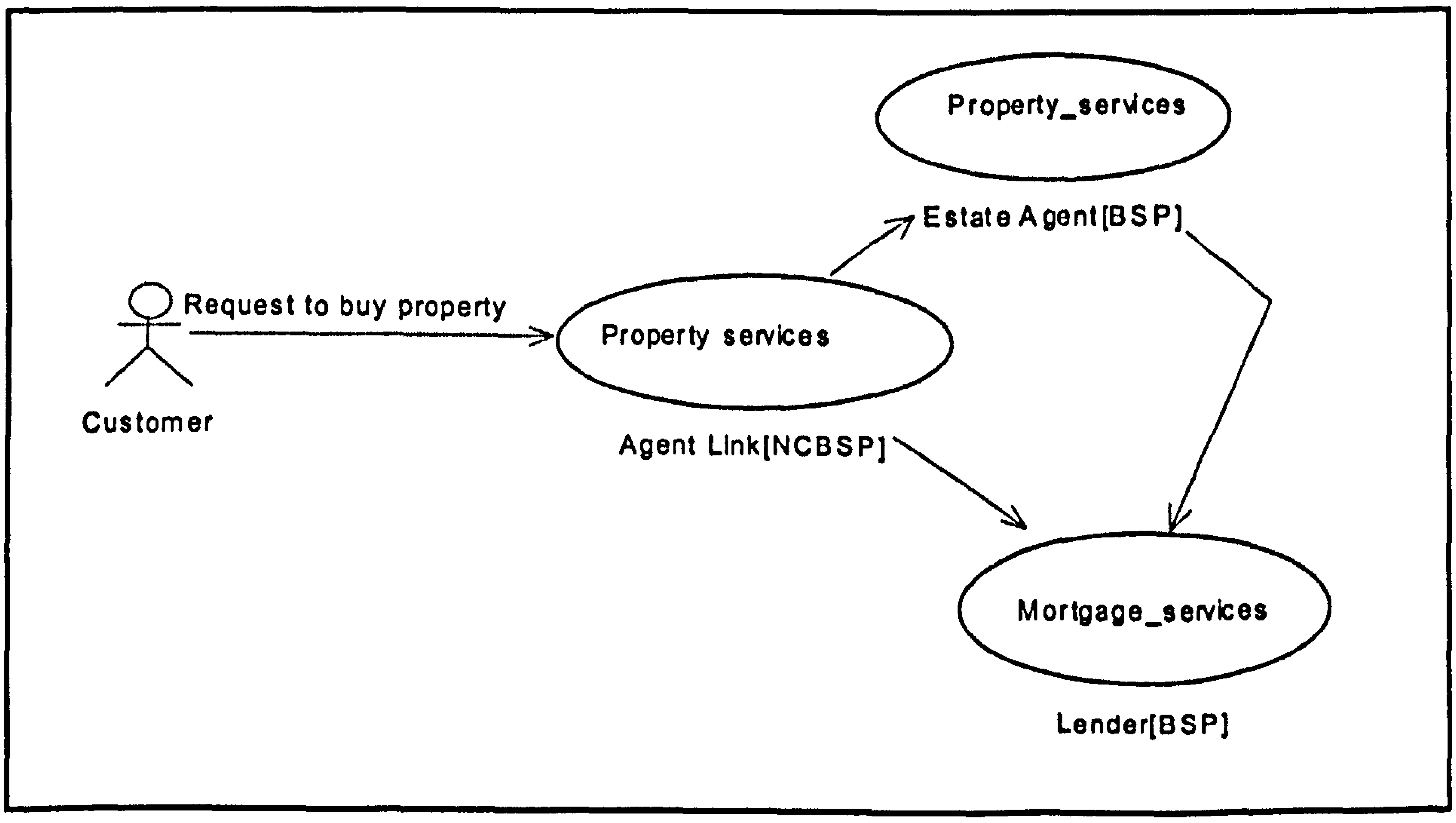

Figure 8. 2: Use case diagrams showing the business model and context of the online mortgage provider

The design specification of a workflow model describes its structure and behaviour. A workflow design pattern template from the knowledge repository can be reused if and only if its structure and behaviour are similar with those of the new workflow model that has to be developed. It is also advisable to develop the requirements of the new workflow model using the same formal notations in which the functionalities of the reusable workflow model are specified. This will make the reasoning process effectively reduced to pattern-matching.

In order to design a new workflow model for the online mortgage provider the knowledge designer may search through the knowledge repository for appropriate workflow design pattern templates related to online mortgage processing. The initial search may also be performed using key word (such as 'mortgage processing'), which may match or partially match the relevant terms in the textual template descriptions of the business process workflow design pattern diagrams and templates in the knowledge repository.

In this scenario, the retrieved workflow design pattern may include workflows in which the 'mortgage processing service' is modelled as a primitive or composite task. One of the retrieved generic business process workflow design pattern from the knowledge repository could be the 'book hotel only business process workflow design pattern' (see figure 8.3, appendix H, pages 292-309), which may then be selected and adapted to compose a new workflow model for Agent Link. Modular and extendible workflow definitions are possible due to the object-orientation of the proposed framework approach. The reuse is done by obtaining valuable parts of the old definition and deleting or adding new activities and task in order to achieve the desired workflow design patterns. Thus workflows are defined in an object-oriented way and maybe easily reused, extended and adapted to re-engineered workflows.

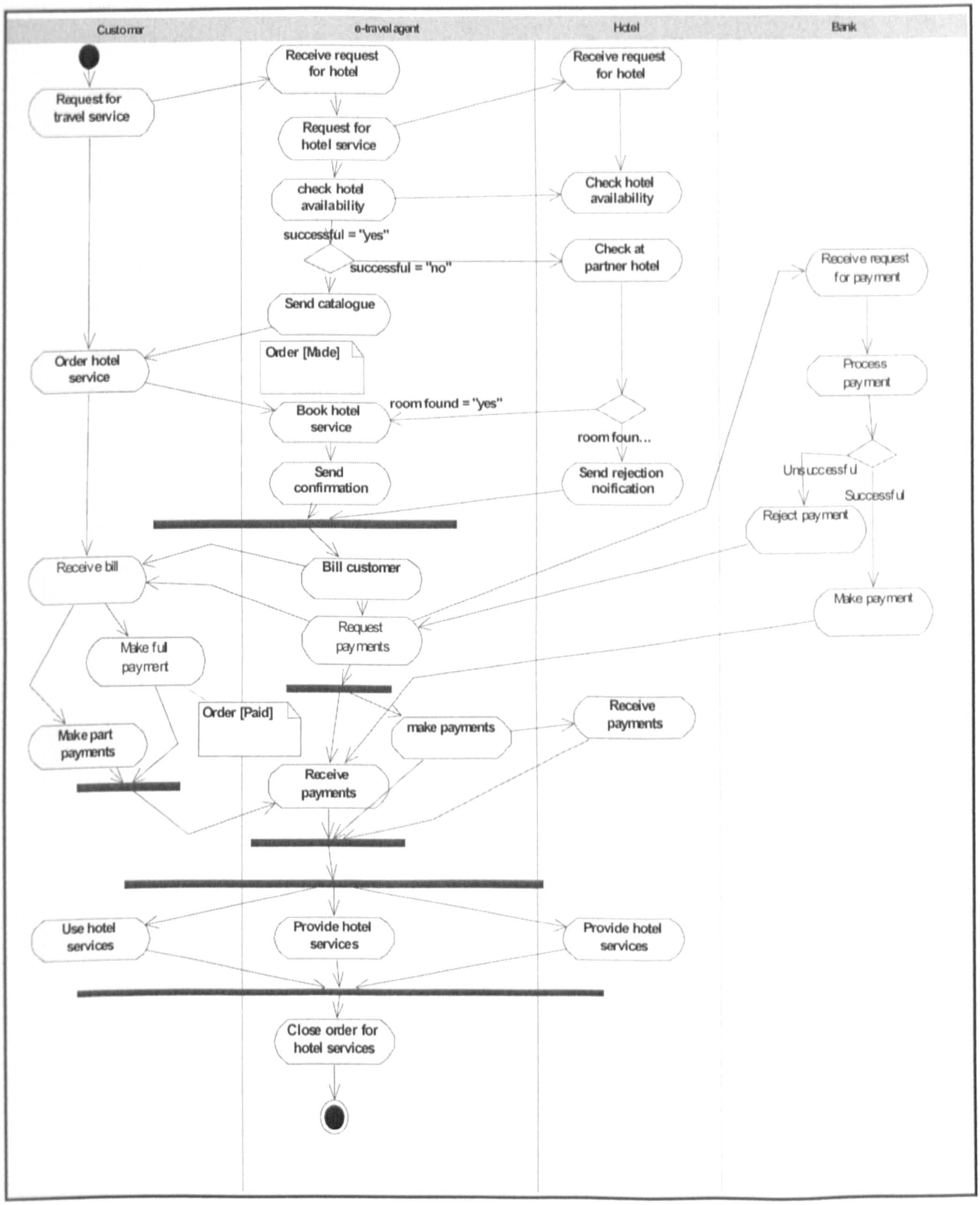

Figure 8. 3: Book hotel only business process workflow design pattern diagram

The adaptation process to develop the new workflow model for Agent Link see figure 8.4 below was carried out as follows: firstly the *role or actor object i.e., e-*

travel gent, hotel and bank from the book hotel only business process workflow design pattern was selected and instantiated with *Agent Link, Estate agent and* lender on the online mortgage provider workflow model. Secondly, the *check hotel availability* and *check at partner hotels* activities from the book hotel only business process workflow design pattern was selected and instantiated with *find property* and *find property from partner estate agents* on the online mortgage provider workflow model.

Thirdly, the *send catalogue* activity from the book hotel only business process workflow design pattern was also selected and instantiated with *send brochure* on the online mortgage provider's workflow model. And finally, the *book hotel service* from the book hotel only business process workflow design pattern was selected and instantiated with the *book to view property* on the online mortgage provider's workflow model. Furthermore, the knowledge workflow designer may also resolve pre-conditional and post-conditional needs as required and also modify tasks inside the composite tasks to ensure Agent Link's workflow model validity

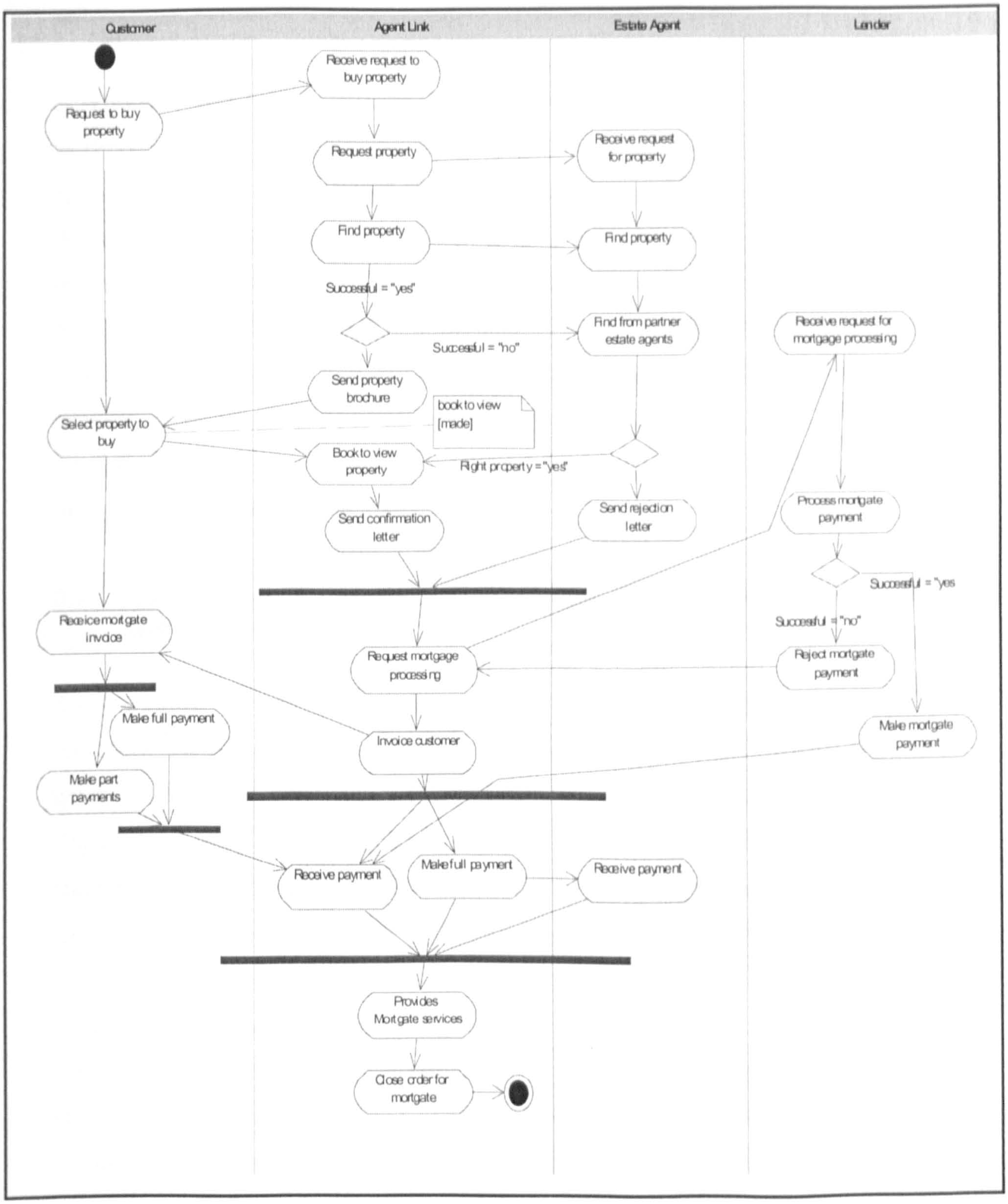

Figure 8. 4: Mortgage business process workflow design pattern diagram

Often it is difficult to find a design pattern template from the knowledge repository that completely satisfies the requirements of the target workflow model to be developed. Therefore, the reuse process must also define partial matches whereby a workflow design pattern template from the knowledge repository can be adapted to suit the requirements of the new workflow model to be developed

e- Workflow design or specification reuse involves two problems: (1) the knowledge workflow designer has to retrieve the correct specification from the knowledge repository through pattern-based reasoning techniques, and (2) adapt and customise that specification to fit the new problem domain. Both retrieval and adaptation of a reusable workflow specification are knowledge intensive processes, for example considerable domain and method knowledge is required to understand the e-travel booking and the online mortgage processing workflow domains and the analogy between them (Maiden and Sutcliffe, 1991). After thorough review this newly developed workflow model can be stored in the form of workflow design pattern in the knowledge repository for future reuse.

8.2 Experiment 2: A change business scenario model with the proposed framework

To exemplify the use of the proposed knowledge-enhanced framework for e-workflow modelling, design and evolution, consider a scenario where business needs evolve over time and where changes or adaptations are required to the Expedia.com workflow schemas above. An e-travel agency that is considering a strategic change whereby the associate or partner hotel should be able to provide 'pick-up services' to customers from the airports to their hotel destinations will need to include a new task on Expedia.com workflow schema called "pick-up service" in order to gain some competitive advantages. Currently Expedia.com seems not to provide this service on their website. How should Expedia.com workflow model or schemas be modified such that the 'pick-up service' or task may be included in their workflow? Many alternatives might be feasible. A possible solution scenario is delineated with the use of the proposed framework approach through the reuse of design knowledge stored in the form of workflow design pattern templates in the knowledge repository as shown in figure 8.5 below.

Firstly, a knowledge workflow designer may search the knowledge repository for suitable workflow design pattern templates, which are similar or related to 'pick-up service'. The initial search may be performed using keywords (such as 'pick-up service'), which may match the relevant terms in the textual template descriptions of the workflow design pattern template representations in the repository. The retrieved workflow design patterns may include workflows whereby 'hotel pick-up service' is modelled as a primitive or composite task. One of the retrieved workflow design pattern template from the knowledge repository may be 'book hotel only business process workflow design pattern template' (see Figure H. 8, Appendix H), which may then be selected and adapted or customised to develop a new workflow process model which include the 'hotel pick-up service' as shown in figure 8.5 below.

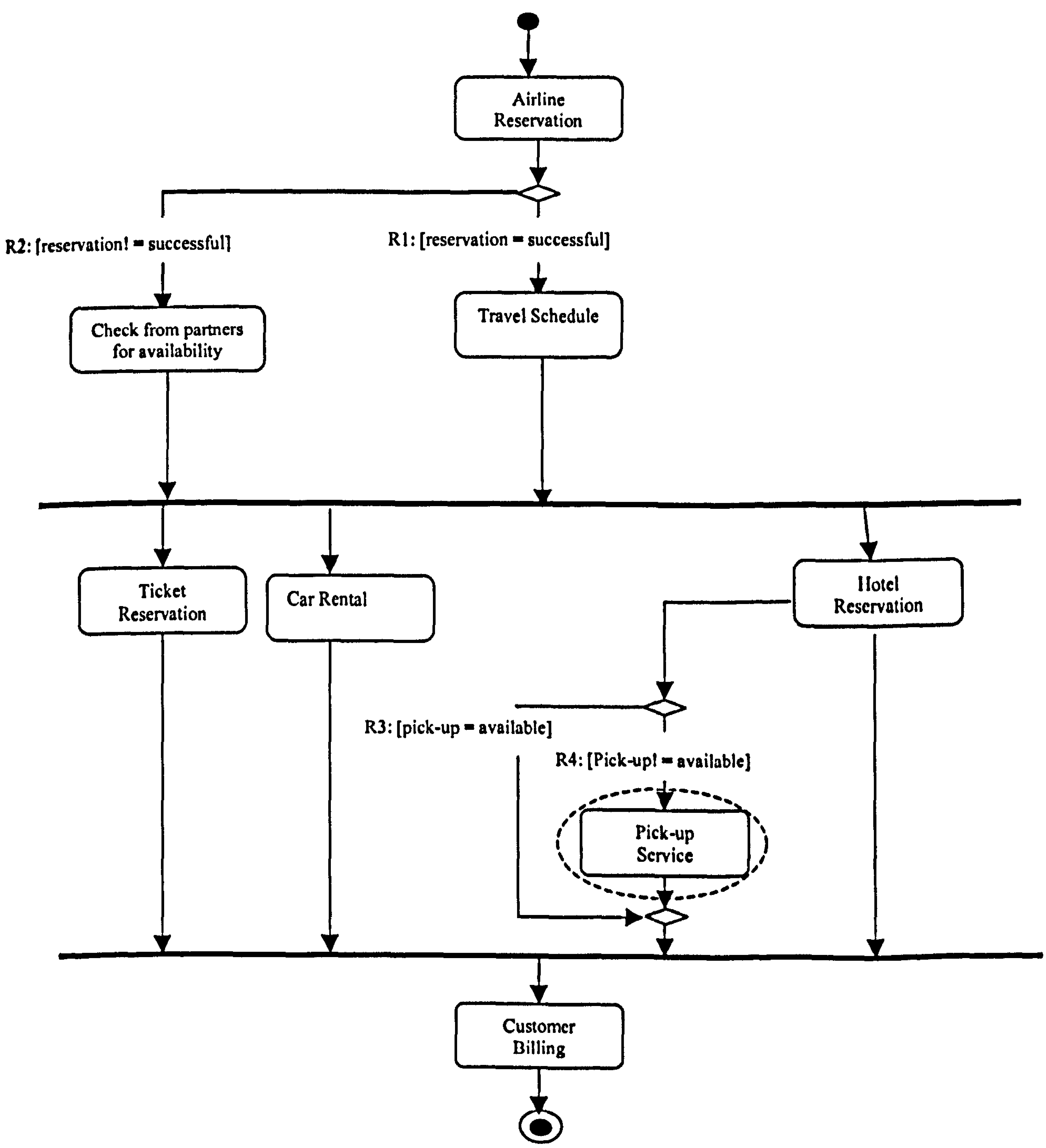

Figure 8. 5: A modified Expedia workflow process

The instantiation of the primitive task to include the 'hotel pick-up service', task into the initial Expedia workflow process is performed manually. During this step, the knowledge workflow designer may resolve pre-conditional and post-conditional needs as required and also modify tasks inside the composite tasks to ensure Expedia workflow process validity. Notice that 'hotel pick-up service' has been included in the new workflow process (shown in the dashed circle box in Figure 8.5), through the reuse of a workflow design pattern templates from the knowledge repository. The development of the new Expedia workflow process exemplifies how a particular type of 'pick-up service' task may be retrieved from the knowledge repository and instantiated in the context of Expedia. Additionally, the workflow design pattern repository may inherently contain a design pattern related to online travel agency with 'hotel pick-up service' that may be retrieved and instantiated for the new Expedia workflow model.

The new Expedia workflow model, designed to incorporate 'hotel pick-up service' illustrates the manual execution of the pattern-based cycle for e-workflow design (see Figure 4.2, Page 76). The pattern retrieval and adaptation step of the pattern-based cycle provides a fertile source of workflow process modification possibilities (leading to large design search space), in contrast to traditional approach to workflow design (Madhusudan et al., 2004).

Manually designing Expedia workflow model that handles each conceivable task, resource and product combination for different business contexts while capturing all business rules, policies and constraints is a daunting endeavour. Automated support in the proposed framework would facilitate design steps such as identifying and substituting tasks with appropriate workflows or composing individual workflow design patterns into new workflow processes. Automated support for pattern retrieval and synthesis is essential for effective utilisation of the pattern-based cycle for e-workflow design and evolution by other organisations.

8.3 Experiment 3: Inflexibilities on easyjet.com's flight + hotel workflow process

The purpose of this case study is to demonstrate that there are some inflexibilities on easyjet.com's workflow process when booking for flight + hotel. The problem here is that during the booking process the customer is not given the possibility to alter the number of days required to spend in the hotel as shown below. For example, the customer might have a friend in Morocco who is willing to accommodate him/her for three days. Meaning that the customer would like to split his/her stay in Morocco between the hotel and a friend i.e., three days in the hotel and four days in a friend's apartment. But during the booking process, eassyjet.com's flight+hotel workflow process doesn't give the customer the option to alter the number of days that they would like to stay in the hotel (see Figure 8.6-8.8).

This is considered to be a problem since the workflow process is rigid and compels the customer to book and pay for seven days in the hotel rather than three days. This is considered to be inflexibility problem on easyjet.coms workflow process model.

We argue that our proposed framework, which integrates the four traditional workflow-modelling perspectives with a new knowledge perspective, can be used to provide flexibilities to easyjet.com flight+hotel business workflow processes. The new knowledge perspective within the proposed framework approach can be used to monitor the changes that are happening on easyjet.com's e-business workflow processes and reflect the changes on their e-business workflow processes. As a consequence easyjet.com will be loosing some of its customers due to this inflexibility of its workflow process. Easyjet.com must set up effective strategies on how to incorporate feedbacks from it customer or e-business environment in other to be more competitive in today's global and knowledge economy.

The knowledge repository within the proposed framework approach can be used to monitor and deduce knowledge from the data and information flowing between easyjet.com's business workflow processes. This knowledge about the business processes can be used to dynamically evolve and provide flexibility to easyjets e-business workflow processes to reflect immediate changes required in the new e-business environment in the new economy.

The proposed framework, which is knowledge and Internet aware, will enable easyjet.com to develop cross-organisational workflows that are properly synchronised in order to improve collaboration and coordination of process and domain related knowledge with partner organisations so as to meet evolving customer needs in the new economy. Knowledge management refers to the strategies, techniques and tasks associated with developing and delivering business relevant knowledge, efficiently and quickly to meet evolving customer and support need such as the aforementioned problems with easyjet.com.

Step 1: Flight booking from 10 – 17 Jan 2009

This step is concern with flight bookings.

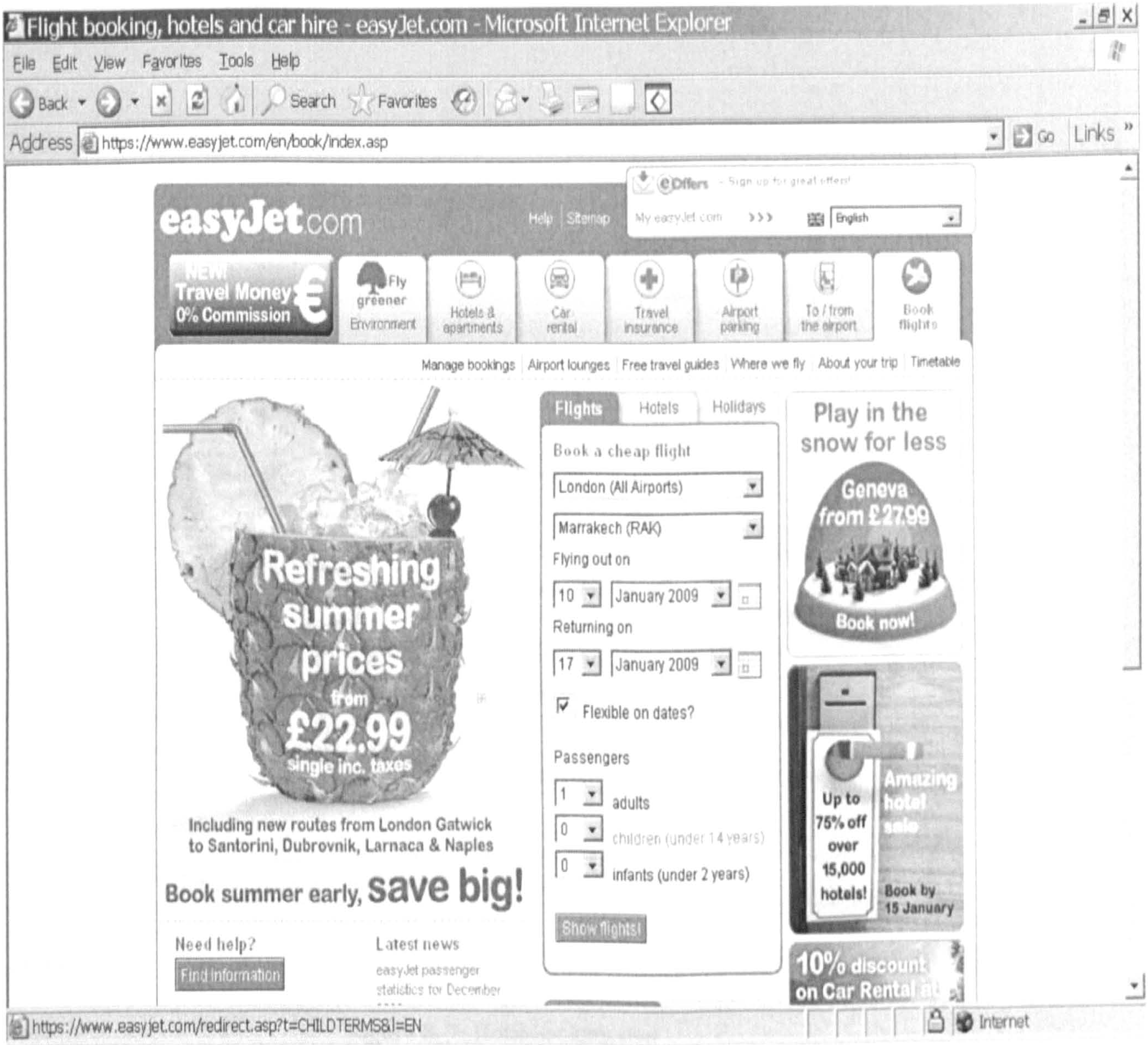

Figure 8. 6: Flight booking step

Step 2: Hotel booking from 10 – 17 Jan 2009

This step is concern with hotel booking.

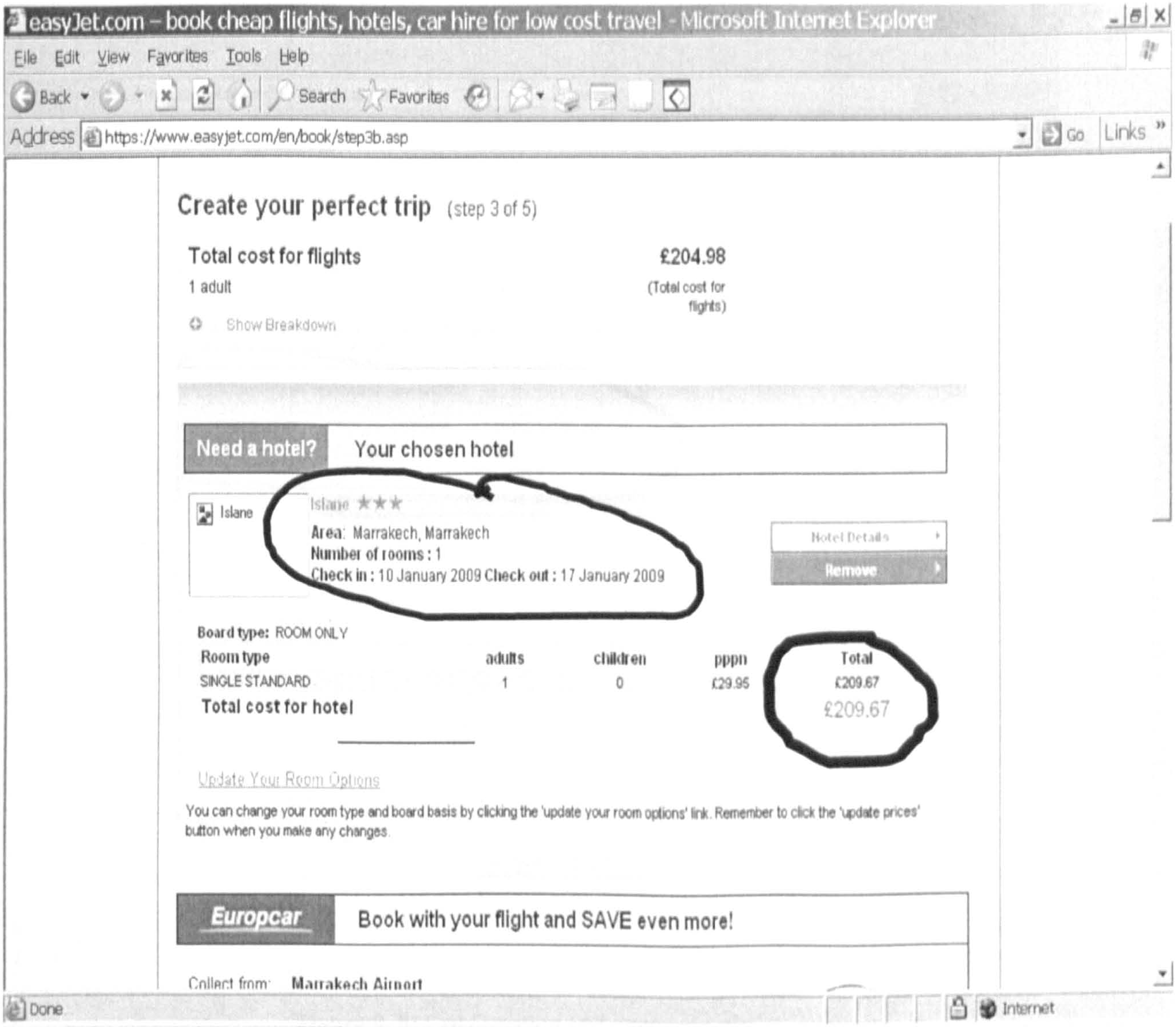

Figure 8. 7: Hotel booking step

Step 3: Confirmation and payment step for 10 – 17 Jan 2009

This step deals with payments (partial or full payment)

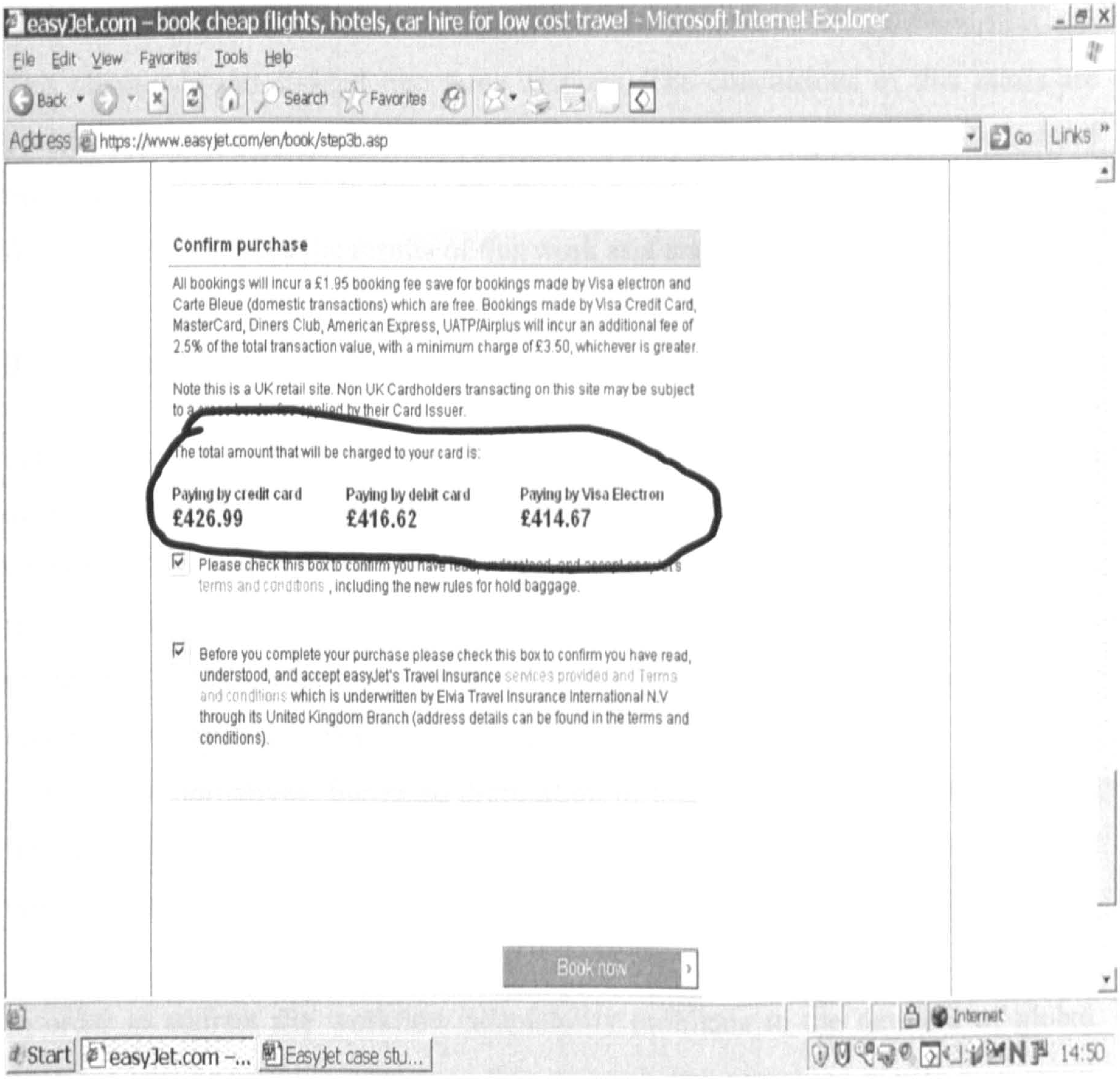

Figure 8. 8: Confirmation and payments step

8.4 Chapter summary

This chapter has presented some experiments that were conducted with the proposed knowledge enhanced framework for e-workflow design and evolution in the new economy. The next chapter presents the conclusions, discussions, and proposals for future work.

Chapter 9
Conclusions, discussions and proposals for further work

This chapter is sub-divided into three sections. The conclusions of this thesis are presented in section 9.1. Section 9.2 is a discussion about the major contributions of this research and its limitations. Finally section 9.3, proposes the directions for further work that takes the results of this work as a starting point.

9.1 Conclusions

Knowledge management is not solely an academic topic anymore; it is an important necessity for most contemporary organisations operating in the global and digitised economy. Recently, interests in the notion of process-oriented knowledge management (PKM) from academia and industry have been significantly increased (Jung et al., 2006). Many areas, especially the information systems and workflow community have also predicted some benefits from the result of knowledge management initiatives. Increased digitisation of business processes with inter- and intra-enterprise virtual value chains is shifting the focus of knowledge work beyond the formal and rigid boundaries of traditional organisations and their workflows.

In order to address the workflow adaptability problems in the new era of global, digitised and knowledge economy, this research has presented a new framework which will enhance all the traditional workflow modelling perspectives i.e., functional, organisational, informational and behavioural with an new knowledge perspective. The conceptual framework, also integrates knowledge-based planning techniques (knowledge memory/knowledge repository) in the form of workflow design patterns with an Internet workflow so as to increase the flexibility of workflow design and evolution in the global, e-business and knowledge management era. The processes, methods, concepts and modelling techniques used in conventional workflow systems, software and information systems engineering, management science as well as knowledge-based planning techniques was adopted and adapted for the development of the novel knowledge enhanced framework for the internet to enhanced flexibility, adaptability, scalability, customisation and reusability.

The conclusions of this thesis are that the objectives of the thesis have been achieved. The hypothesis proposed in chapter 1 has been shown to be true in this particular situation, and the proposed framework has been developed and evaluated with a case study through action research and also through web-based survey questionnaires in collaboration with *workflow management coalition.* Workflow management coalition is a non-profit organisation whose role is to set standards within the workflow community. The details of these conclusions are presented in the following paragraphs

a) The thesis suggested that e-workflow systems and the problem domain it is addressing, in this context the business processes and e-business environments are examples of systems characterised by an increasing pace of radical, discontinuous, complex and unforeseen changes. This has led to a re-conceptualisation of the traditional workflow approaches, as they have been understood in conventional workflow systems practice and research as discussed in chapter 1. One such conceptualisation has been proposed in this thesis in the form of a new knowledge enhanced framework for the development of adaptive e-workflow systems in the e-business environment. A significant contribution of the proposed framework is that it integrates the functional, organisational, behavioural, informational and the new knowledge perspectives into a single framework for knowledge enhanced e-workflow modelling. The framework approach also extends some of the features offered by traditional workflow approaches (as discussed in chapter 3) by extending it with Internet and knowledge management concepts.

b) A key motivation of this thesis was to address the critical process of creating new knowledge and renewal of existing knowledge and to suggest a conceptual approach for better representation and design for knowledge enhanced e-workflow systems. It has been proven that application of the proposed framework through action research case study in order to reverse engineer *expedia.com* workflow process will facilitate the development of workflow systems that are knowledge-aware and better suited for competitive advantage in the new Internet business environment characterised by dynamic, discontinuous and radical pace of change.

c) A modelling mechanism was used within the proposed knowledge enhanced framework for the development of adaptive e-workflow systems, which allowed for management of complexity in both the e-business and workflow systems domain. The e-workflow models were developed at five abstraction levels, namely functional perspective, organisational perspective, behavioural perspective, information perspective and knowledge perspective (in the form of workflow design patterns templates as described in chapter 4).

d) The framework is technology neutral. The reasons for developing technological neutral models are that building business process and workflow models consume large amount of resources and the business processes and workflow systems continually change. Technology neutral model would be an initial investment, which could be the starting point to multiple e-workflow application development and can adapt as the business changes, rather than building workflow models from scratch or for specific applications. ***The framework approach is language and implementation-independent.***

e) The hypothesis suggested in chapter 1 can now be confirmed and presented as a thesis as follows:

The Thesis: "*The framework approach which integrates knowledge-based planning techniques in the form of workflow design patterns from a knowledge repository can be used for the modelling, design, evolution and development of complex e- workflow systems in the global, digitised and knowledge economy*"

f) Starting with the hypothesis of workflow modelling and design, the framework has been developed through *action research* case study strategies by reverse engineering the travel e-agency (Expeida.com) and their website in order to model their workflows and also to iteratively and incrementally develop the proposed framework, the knowledge repository and the macro e-workflow application development process or life cycle which together forms the proposed framework.

The action research was successful in that a workable framework has been developed as a case study and usefully applied in the e-travel agency (Expedeia.com). This is an indication that the proposed framework is *viable* and *useful*. The proposed knowledge enhanced framework for the development of adaptive e-workflow systems and its constituent models are presented in Chapter 3, 4 and 5.

g) Subjective/Argumentative evaluation on the characteristics of the proposed knowledge enhanced framework design and evolution with regards to other existing workflow modelling and design approaches described in chapter 2, 3, 4, and 5 was carried out using theoretical evaluation and through web-based surveys. This evaluation has shown that the proposed framework is an approach, which comprehensively extends the four traditional workflow-modelling perspectives to five perspectives of workflow design and evolution in the Internet and knowledge era.

The perspectives of the new framework which extends the traditional framework by adding a knowledge perspective are discussed throughout the thesis, *functional, behavioural, organisation, informational and knowledge management (in the form of workflow design patterns)* perspectives. Also the theoretical evaluation has demonstrated that the framework overcomes some of the complexities and shortcomings of the traditional framework and workflow-modelling approaches described in chapter 1, 2 and 3.

h) ***The case study carried out with the proposed knowledge enhanced framework for the development of e-workflow systems within academia*** titled " Towards Understanding Workflow Management Systems: Presenting A Postgraduate-Level Course Development and Validation Example" (Ndeta et al., 2007) has shown that the proposed framework approach built for customer relation management (CRM) domain can be ***reused*** in academia.

i) It was found through experiences of using the proposed framework through the action research case study that the most appropriate and useful level for workflow model reuse is at the schema or representational level. At this level generic workflow design patterns are identified which are common across most industry sectors, e.g. customer relationship management (CRM), business process reengineering, supply chain management etc.

9.2 Discussions

This section discusses the contribution to the industry and academia and the limitations of the new knowledge enhanced framework for the development of e-workflow systems adapted to the new e-business environment

9.2.1 Contributions to the industry and academic community

The contributions of this research work to academia and industry are discussed in terms of the novel solution to some of the problems in traditional workflow modelling approaches. These solutions also form some of the characteristics of the proposed framework as discussed in chapter 3. The proposed framework adds value to the conventional framework for workflow development approaches as described in chapter 3, 4and 5. This is presented in the following paragraphs:

- The new framework, which extends the traditional workflow modelling framework and approaches by adding the knowledge perspective is appropriate for workflow design and evolution in the global, digitised and knowledge economy characterised by dynamic, complex, and disconcerting business processes and business environment. In a final analysis, managers need to develop a greater appreciation for their intangible human asserts captive in the minds and experiences of their knowledge workers, because without these assets, the companies are simply not equipped with a vision to foresee or imagine the future while being faced with a cloud of unknowingness.

  As noted by (Strassmann, 1997), elevating computerisation to the level of magic bullet may lead to the diminishing of what matters the most in any enterprise: education, committed, and imaginative individuals working for organisations that place greater emphasis on people than on technologies.

Thus the human aspects within the proposed framework is vital for innovation and creativity

- Some of the processes, methods, concepts and modelling techniques used in conventional workflow systems, software and information systems engineering as well as knowledge management techniques was adopted and adapted for the development of a novel knowledge enhanced framework for the development of adaptive e-workflow systems for e-business environments in order to enhance flexibility, adaptability, scalability, customisation and reusability. The use of the above concepts and techniques allowed for the development of reusable workflow models in the form of workflow design pattern templates.

- ***The proposed knowledge memory or repository and the mechanism for storage and retrieval of design or process related knowledge*** in this thesis is one of the possible ways to assist knowledge workflow designer and users in building their workflow model efficiently, while avoiding re-inventing the wheel. The knowledge repository is based on the memorisation of successful stories, best practices, past experience, previous case and feedbacks organised in the form of workflow design patterns. These workflow design patterns will be reused to continuously evolve and provide flexibility of e-business process to reflect changes in the new economy. ***The use of knowledge-based planning techniques in the form of workflow design patterns***, developed specifically for e-workflow systems was a valuable concept that was employed and exploited in the proposed framework.

- The framework enables the use of the object-oriented modelling constructs at both the business and workflow modelling levels. Object-orientation provides a powerful mechanism for dealing with complexity in the e-workflow design and its problem domain, which in this thesis is the business domain. This mechanism is referred to as abstraction mechanism in this thesis and enables the development of various models at different modelling levels namely the problem domain modelling phase, and the e-workflow virtual design phase. The problem domain-modelling phase consist of models such as the *business model* and the *process model.* The new e-workflow design phase consist of models such as the *functional, organisational, behavioural, information and knowledge* perspectives.

- The proposed e-workflow design and development methods within the proposed framework that can be used as a guideline for the development of e-workflow systems adapted to the new e-business environment

- The results of the survey have also shown through statistical analysis of the responses from workflow researchers and developers that the framework and its applications development process or life cycle is ***understandable, useful, viable, complete, important, and can be used as a basis for workflow applications development within different organisational settings.***

- The action research case study through the application of the proposed framework, the *problem domain modelling phase* has been used to abstract models such as the business models and process models, whilst in the e-workflow design phase the abstraction mechanism has been used to abstract the *functional, behavioural, organisational, information and the knowledge* perspectives. The gap between the business and workflow systems is reduced by the use of object-oriented modelling language UML to represent consistently all of the modelling aspects and their relationships at both the problem domain level and e-workflow support level. It does this by adopting the object-oriented paradigm to conceptualise the business and workflow domain as a set of static and dynamic models.

- The proposed framework approach can be used as a guideline for managers, workflow researchers and developers, who need to model, design and implement this type of technological change.

- The proposed framework approach allows workflow developer, researchers, or users to choose the type of workflow features they need. It enables them to tailor the existing functionality through techniques specific to object systems i.e., designs patterns, and add new workflow features by composition. These characteristics represent a significant departure from the traditional workflow approaches.

- The work process and information processing emphasis of traditional framework for workflow design and evolution is constrained by its overemphasis on consistency institutionalised in the form of best practices. The proposed knowledge enhanced framework and methods for e-workflow design and evolution is expected to rupture this cycle of reinforcement of institutionalised knowledge. In the proposed framework, designers of organisational knowledge enhanced e-workflow systems can, at best, facilitate the organisations "self-designing".

  Not only do the organisation's Knowledge e-workflow designers define problems for themselves and generate solutions, they would also evaluate and revise their solution-generating processes. By explicitly encouraging experimentation and rethinking of the e-workflow solutions, this process promotes reflection-in action and creation of new knowledge that can be reused during the design and evolution of future workflow solutions to solve some of the e-workflow design problems that may arise in the new e-business environment characterised by complex, dynamic, discontinuous and unpredictable business processes.

- ***Finally, the proposed framework enables workflow models to be built independently of specific workflow application development.*** Also the proposed framework enables the framework to ***evolve through reuse of workflow design pattern templates and change*** of the various components of the models.

9.2.2 Limitations of the proposed framework and methods

The main problem in the proposed knowledge enhanced framework for the development of adaptive workflow systems is that finding well-documented case studies turned out to be challenging. Unlike other areas of computer science (e.g., operating systems, database systems, networking systems, program verification, etc.), workflow management doesn't have a classic body of examples for studying and evaluating workflow systems. Business processes are hard to get (i.e., they are classified as confidential information and knowledge) since they represent key assets of the enterprise, and are on the critical path of staying ahead of the global competition. Consequently, I had to reverse engineer the e-travel agency's (Expedia) website through action research case study in order to evaluate the proposed framework and methods.

Another limitation is that, the complexities, contents and various perspectives of the proposed knowledge enhanced framework approach means that organisations, which are involved in building workflow models and applications for e-business environments, must have a future-proof strategy to handle the evolution, customisation, reuse and consistency checking of the proposed approach over time.

Finally, workflow engineering is still a relatively immature discipline as compared to other established branches of engineering. Thus the sample population from the web-based survey questionnaire was not as large as expected, but still the data collected was very valuable as it came from workflow researchers and experts.

9.2.3 Future work

Future research work is envisaged in the following direction:

- Only a certain amount of evaluation was carried out as delineated in chapter 6 and 7. More case studies with the proposed knowledge enhanced framework for the development of adaptive e-workflow systems through action research are required in different industrial settings to design numerous e-workflow applications in order to comprehensively evaluate the proposed framework qualitatively.

- Continuous collaboration with workflow management coalition in order to collect more responses from the web-based survey questionnaire in order to further evaluate the proposed framework statistically.

- Extension of the e-workflow design pattern repository, with new patterns extracted from various application domains. Aspects related to analysis and comparison of different design patterns with possible integrations and guidance for their reuse strategies will be studied.

- Management of workflow schema changes which is a major concern in WfMS. Rules and patterns are envisioned as useful means to handle adaptation of a schema to new situations occurring in the workflow.

- Extension of the proposed framework to handle exceptional situation. Exceptional situations or unanticipated events may occur during the execution of a given workflow process i.e., task may be cancelled, a case may be terminated due to external reasons, a task or a case is not performed within its expected time limits. Such exceptional situations may be anticipated and inserted in the workflow specification. One of the points of interest in this context is the ability of inserting exception handlers within a given workflow schema

- Implementation and extension of the knowledge workflow design pattern repository to include patterns from different organisational settings.

- In the future additional ontologies may be added, to distinguish patterns. Because most of the patterns submitted are individual articles, not extensive families, one of the challenges to date is creating a coherent "language" that ties the patterns together so that the collection is greater than the sum of its parts. Also patterns were grouped and cross-linked using broader (parent / workflow design patterns), narrower (child / sub-workflow design pattern), sibling, and related relationships. Because of the large number of authors anticipated, creating these relationships can be arduous, however. In addition to navigating the patterns by category or by their relationship to other patterns, the content will also be presented in a number of ways in the future.

And to crown it all, as we are now experiencing globalisation in virtually all areas in business and economics, globalise information and process management has become an important and interesting area in both research and practice. IT has played an important role in globalisation. The advances of the Internet and mobile network computing have linked the world together and enabled corporations to take advantage of talents and services available around the globe.

Topics that can be categorised under global IT and IT-enabled services include global service outsourcing, business process and workflow management for global services, strategic issues in global services, global service development and management, distributed collaboration and communication, and global enterprise information systems. The global nature has made these topics more challenging given the technology, management, and operational issues that need to be tackled. In addition these topics are multi-disciplinary and span across such fields as computer science, industrial engineering, information systems, management science and engineering, and operational management.

Knowledge management has become a prominent subject for contemporary organisations, but often the information and knowledge that flows in a well design workflow process is not often characterised in such a way as to promote its reuse.

We argue that the knowledge perspective is a critical resource for improving how activities and interactions are understood and carried out.

Our premise is that it is important for e-business organisations that the decisions, solutions, discussions and actions executed in a workflow process should be retainable and retrievable.

Part Five

References and Appendices

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Appendices

Appendix A: Glossary

This appendix is based on The Workflow Management Coalition Terminology and Glossary document dated May 1996 and others.

- **Automate** - To automate a work process requires that the activities in the process are managed, but not necessarily carried out by a computer. The automated process is called a workflow process. Examples are damage claim procedures, application for licenses, making a tender, etc. Activities in a workflow process are initiated by means of electronic messages called workitem, which a user will find in an electronic worklist on the electronic desktop or screen. This aspect ties the theme of workflow management to computer science and data communication.

- **Activity** – A description of a piece of work that forms one logical step within a *process*. An activity may be a *manual activity*, which does not support computer automation, or a *workflow* (automated) activity. A workflow activity requires human and/or machine resource(s) to support process execution; where human resource is required an activity is allocated to a *workflow participant*.

- **Automated Activity** – An activity that is capable of computer automation using a *workflow management system* to manage the *activity* during execution of the *business process* of which it forms a part.

- **Approach** - A method of doing something or dealing with a problem (Longman Dictionary of Contemporary English).

- **Approach** – an approach is made up of concepts, methods, techniques and tools (Eric Gams and Sigi Reich, 2004).

- **Ad hoc workflow** – Unlike a predefined process, ad hoc workflow process are not defined as part of the organisational workflow modelling, but rather are created on demand by the user (Karakotas et al., 2002).

- **Business Process** - A set of one or more linked procedures or activities which collectively realise a business objective or policy goal, normally within the context of an organisational structure defining functional roles and relationships.

- **Cognition** - Knowledge from personal experience or view.

- **Collaborative workflow** – Collaborative workflow represents the core business processes that require groups of people to work as a team in order to achieve a goal (Karakotas et al., 2002).

- **Data workers** – people such as secretaries or bookkeepers, sales personnel, accountants who process and disseminate the organisation's information and paperwork (Laudon & Laudon, 1999).

- **E-workflow** – Internet-mediated-workflow (cross-organisation workflow).

- **Experience** - are sensations and emotions that we have gone through in our lives. They register knowledge and form models in our 'mental constructs' and help us to cope with the 'action world'.

- **Framework** - A framework is a meta-level model (a higher level abstraction) through which a range of concepts, models, techniques, and methodologies can either be clarified and/or integrated (Jayaratna, 1994).

- **Information work** – work that primarily consists of creating or processing information. It is carried out by information workers who usually are divided into two subcategories: knowledge workers and data workers(Laudon & Laudon, 1999).

- **Knowledge** - is gained from understanding. It helps us to understand the context in which information can become meaningful (Jayaratna, 1994).

- **Knowledge workers** – people such as researchers, engineers, scientist, architects, writers, judges who design products or services or create knowledge for the organisation (Laudon & Laudon, 1999).

- **Knowledge repository** – provides a central location for various knowledge products such as best practices, or analysis of different topics; individual and groups develop products for the repository, and they in turn provide inputs for further discussion and reflection on the part of others.

- **Manual Activity** – An activity within a *business process*, which is not capable of automation and hence lies outside the scope of a *workflow management system.* Such activities may be included within a *process definition*, for example to support modelling of the process, but do not form part of a resulting *workflow.* Fig. A-1 identifies basic concepts and terminology associated with workflow as a general topic.

- **Methodology** - A methodology is a collection of procedures, techniques, tools, and documentation aids, which will help the systems developers in their efforts to implement a new information system. A methodology will consist of phases, themselves consisting of sub-phases, which will guide the systems developers in their choice of the techniques that might be appropriate at each stage of the project and also help them plan, manage, control and evaluate information systems projects. But a methodology is more than merely a collection of these things. It is usually based on some philosophical view otherwise it is merely a method, like a recipe (Avison & Fitzgerald, 1988).

  Furthermore, (Checkland & Scholes, 1990) defines a methodology as: an organised set of principles which guide action in trying to manage real-world problem situations

- **Method** -A systematic way of doing anything. In particular, of developing systems of a certain kind (Jackson & Twaddle, 1997).

- **Model** - is a complete and coherent set of concepts, which can underpin our understanding and actions. If we can externalise it then it gives us a chance to examine, understand and analyse their relevance and completeness. They also help us to design abstract or physical things (Jaharatna, 1994).

- **Perspective** – A perspective provides a standpoint for raising questions, for anticipating breakdowns, and for inventing opportunities (Winograd, 2006).

- **Process Definition (schema)** – The representation of a *business process* in a form, which supports automated manipulation such as modelling, or enactment by a workflow management system. The process definition consists of a network of activities and their relationships, criteria to indicate the start and termination of the process, and information about the individual activities, such as participants, associated IT applications and data, etc.

- **Systems development cycle** - Outlines the steps which give rise to the birth (creation) of an 'action system' and terminates when it begins to perform (Jayaratna, 1994).

- **Systems Life cycle** - Comes into being only when a 'system' that is developed by the systems development cycle becomes operational. It includes activity sets, which enhance and help to adapt this 'system' to changes in the environment (Jayaratna, 1994).

- **Stakeholder** - describe all those who have an interest in the successful development of the system. Stakeholders include all people who stand to gain (or lose) from the implementation of the new system and managers who control the budget and require the systems for their organisation.

- **Workflow** - The automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules.

- **Workflow Management System** - A system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke appropriate IT tools and applications.

- **Work process** – is a communicative relation between a customer and a performer within which both assume responsibilities and consume time and resources. (Agostini et al., 1993).

- **Adhoc workflow** – a workflow could be a one-time-only process or adhoc workflow.

Appendix B: e-Workflow design pattern input format

- *Name,* used for uniquely identifying the pattern in the workflow design pattern repository. As this name will become part of the design vocabulary, it must be chosen carefully.
- *Author,* each pattern has one principal author;
- *Contributors,* For when there are co-authors;
- *Problem,* written in user-centred terms, i.e. what is the problem presented to the end user?
- *Intent,* This section describes in few sentences the main goal of a pattern, i.e. towards which problem it offers a solution.
- *Classification,* according to the categories and sub-categories of the workflow design pattern repository to allow users to browse by category;
- *Solution,* This section describe possible solutions to the problem
- *Related to,* establishing links among patterns to combine them in different structures;
- *Guidelines,* providing suggestions to the user about possible usage and instantiation/personalisation of patterns
- *Keywords,* which are a set of user-selected terms that can be used to refer (select, search, etc) to the available patterns in the repository; this field allows one to describe more precisely the topics of the pattern, especially to distinguish the different patterns of a given category in the classification;
- *Template,* it contains the core specification of a pattern. The specification is given in terms of events, conditions, and actions. Unlike events and conditions, which are the main parts of the patterns, the action part provides only suggestions. This reflects the fact that exception patterns focus on how to capture exceptions, rather than on how to fix reactions, which are application dependent. The template contains parametric fields (also called generic terms in the following) to be filled in with specific values provided by the designer (Casati et al., 1997)
- *Sample usage,* since the user of the repository is anticipated to be an expert of the application under design but is not required to have detailed knowledge of the exception language syntax, the repository is provided with

some user-oriented sample usage. This is a set of instantiations of patterns on specific examples. They show how patterns can be customised in different context and applications by illustrating how parameters of patterns can be supplied by the designer to produce a concrete workflow model. The sample usage description is a set of workflow-specific instantiations of patterns related to an application domain (Casati et al., 1999)

Appendix C: Workflow historical evolution

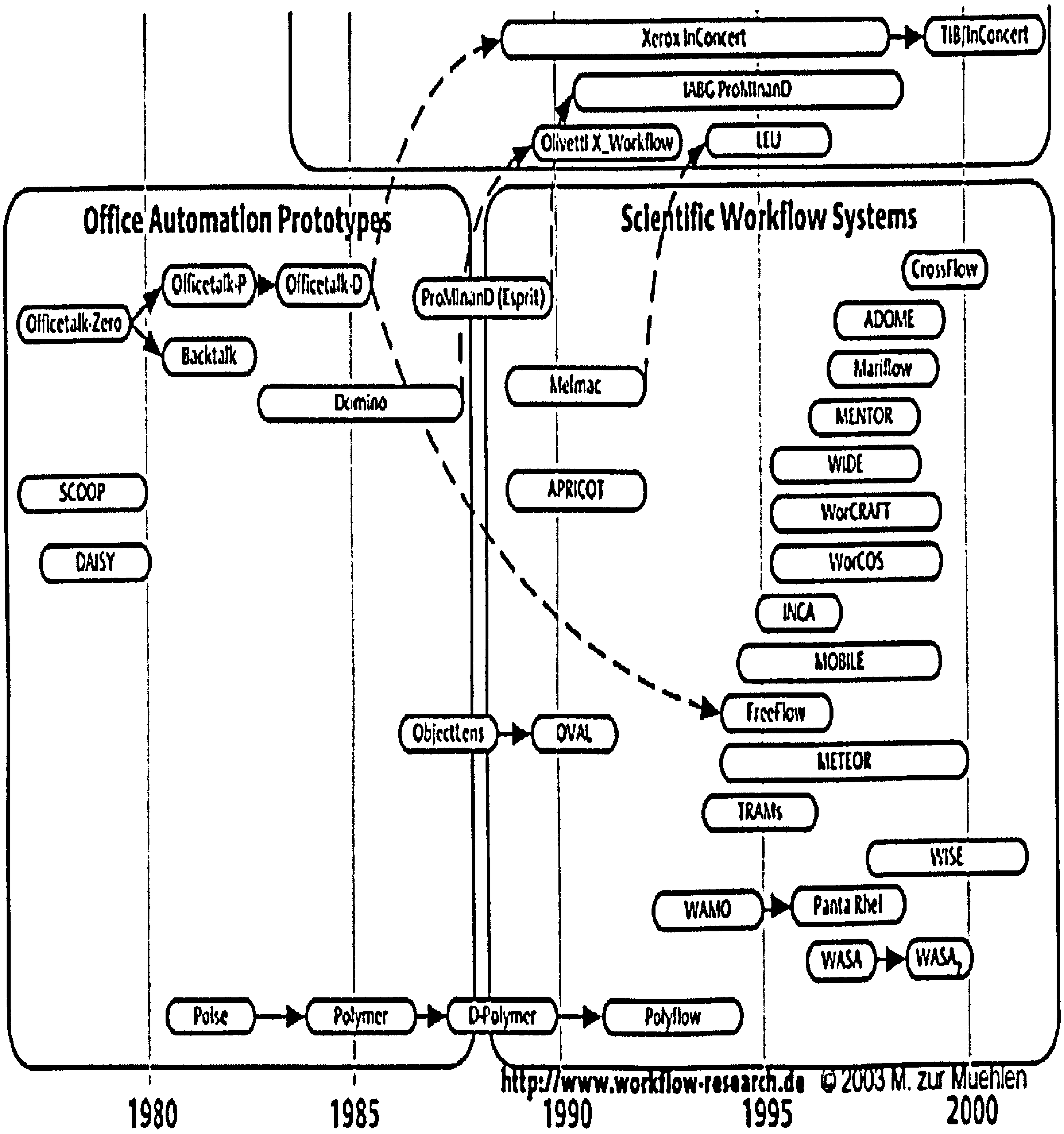

Figure C. 1: History of workflow research

(Source: Zur Muehlen, M, 2004)

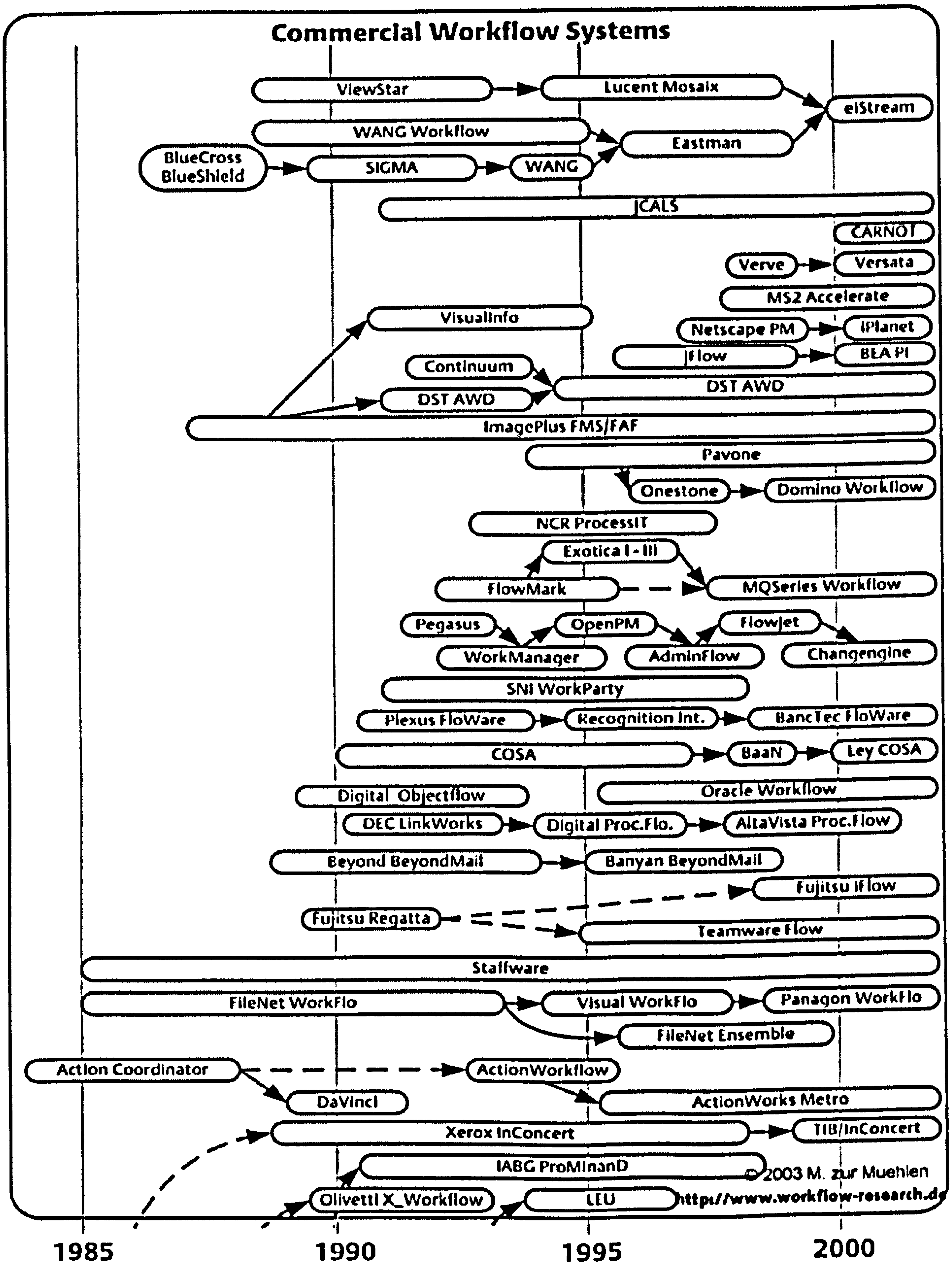

Figure C. 2: History of commercial workflow systems

(Source : Zur Muehlen. M, 2004)

Appendix D: Workflow Research questionnaires

URL for Survey Questionnaires: http://cctmdev2.londonmet.ac.uk/workflow/
URL for DB of Responses: http://cctmdev2.londonmet.ac.uk/workflow/database/

Workflow academic Researcher

Attention:

- **Lecturer**
- **Technician**
- **Entrepreneur**
- **Manager**
- **Researcher**
- **Developer**

Dear Sir/Madam,

Re: **An evaluation of a framework for e-workflow modelling and a new e-workflow development approach**

I am a visiting lecturer/Researcher at London Metropolitan University. I am qualified in computing and management and currently carrying out a research in workflow management systems.

Please, could I ask you and other people involved in workflow research in your institution to invest a little of your time in completing the attached survey questionnaire. I want to examine how to adopt effective strategies for managing the workflow development processes in general and how to take Internet into consideration within the globalising economic trend in recent years in particular.

In order to accomplish this work, I want to gather evidence from workflow academic researchers and I am writing to you for your assistance

Background Information:

The purpose of this survey is to review the experiences of some of the leading workflow researchers who are currently involved in the development and deployment of workflow applications in order to evaluate our framework for e-workflow modelling (Internet-mediated) and the new e-workflow development approach.

Benefits:

The researcher hopes to develop e-workflow models and guidelines for managers, users and developers who need to implement this type of technological change. This may help institute such as yours develop more effective selection plans, training and development plans. The results will be made available to all participating institution if they wish so.

Confidentiality:

The information from this survey will be treated as STRICTLY CONFIDENTIAL and any future publications resulting from this survey will only present this information in aggregate form and will not identify any participating individual or organisation. The findings from this study will provide the basis for John Ndeta's doctoral thesis at London Metropolitan University.

Procedure:

If you agree to be in this study, you are asked to complete any of the surveys based on extensive literature review. All questions are either single select, multiple choice with room for additional comments. It will take 15-20 minutes to complete depending on your additions and comments. Please, feel free to fill one questionnaire from each category if you have enough time to spare.

Contact and Questions:

The researcher conducting this study is John Ndeta. Please contact him with any questions:

Tel: +44 (0) 207 607 2789/7035 Fax: +44 (0) 207 753 7009

e-mail: Jon014@londonmet.ac.uk http://www2.unl.ac.uk

Section 1

Information about the academic institution

1.1 Name of institution: ....

1.2 In which country is the institution based:..................................

1.3 Please tick, which of the following best describes your institution?

[ ] Public

[ ] Private

Geographic scope of the institution

1.4 Please indicate the geographic scope of your institution operation? (check one)

[ ] Regional

[ ] National

[ ] Worldwide or global

Status of the Institution

1.5 Which of the following best describes your institution?

- O Privately held, for-profit business
- O Publicly held, for-profit business
- O Not-for-profit service institution
- O Primary or secondary school
- O Community/Technical College
- O Baccalaureate College
- O Master's comprehensive college
- O Doctorial/Research University
- O Other [ ]

Section 2

Information about the person answering the questionnaire

Please check the relevant boxes

Previous working experience

2.1 Looking back, have you had substantial (more than one year)	**yes**	**no**
Experience in:		
Workflow development	[ ]	[ ]
Software development	[ ]	[ ]
Management	[ ]	[ ]
Software quality	[ ]	[ ]
Other, please specify..	[ ]	[ ]

Your current position in the institution

2.2 **Please specify by % the extent you work in different positions**

Please specify how many years you have worked in this/these positions

	%	Years
Lecturer	[ ]	[ ]
Technician	[ ]	[ ]
Entrepreneur	[ ]	[ ]
Manager	[ ]	[ ]
Researcher	[ ]	[ ]
Other (please specify).................................	[ ]	[ ]

Section 3

Approach for the development of Internet workflow applications

Please check the relevant boxes

3.1 Which tasks do you perform in relation to workflow application development projects? Give a brief listing

3.2 Which perspectives are required during e-workflow analysis?

[ ] Functional perspective

[ ] Organisational perspective

[ ] Informational perspective

[ ] Behavioural perspective

[ ] Other (please specify)

3.3 Which methodological approach does your institution use during e-workflow application projects?

[ ] Traditional development methods

[ ] Rational Unified Process (RUP)

[ ] Specific modelling tools

[ ] Prototyping/RAD

[ ] Business Process Reengineering (BPR)

[ ] Other (please specify)

3.4 Which language or modelling techniques are useful during e-workflow design?

[ ] Object oriented techniques (UML)

[ ] Action workflow (workflow loop)

[ ] Petri-net

[ ] Formal modelling techniques (mathematical)

[ ] Work breakdown structure

[ ] Pert chart

[ ] Other (please specify)

3.5 What do you consider to be the critical success factors for the implementation of e-workflow management projects?

[ ] User participation

[ ] Senior management commitment

[ ] User commitment

[ ] A clear set of objectives

[ ] Senior management participation

[ ] Realistic budget and time scales

[ ] Selection of appropriate e-workflow development approach

[ ] Other (please specify)...

3.6 In your opinion, what are the benefits of putting workflow on the Internet

[ ] Reduction in transaction cost

[ ] Fast response to customer enquiries

[ ] Increase the scalability of workflow application

[ ] Uniform interface throughout the globe

[ ] Ease of installation and use

[ ] Improve collaboration, coordination and communication within the organisation and between organisations

[ ] Improve the competitiveness of the company

[ ] Other (please specify)..

3.7 In your opinion, what are the problems faced during the movement from conventional workflow (client/server) to Internet-mediated workflow (e-workflow)?

[ ] Time difference

[ ] Culture gaps

[ ] Security issues (authentication and authorisation)

[ ] Complex inter organisational process management

[ ] Synchronising the processes of participating organisations

[ ] Technological infrastructure difference

[ ] Others (please specify):...

Section 4

Workflow and knowledge management systems

Please tell me whether your institution is or is not doing the following things

4.1 Collecting and sharing information about best practices

- O Yes
- O No
- O Do not know

4.2 Setting up workflows or networks for transferring information between employees who interact with customers and company managers.

- O Yes
- O No
- O Do not know

4.3 Setting up a collaborating platform or workflows for transferring information between employees who interact with customers and engineers who create the product.

- O Yes
- O No
- O Do not know

4.4 Creating formal procedures to ensure that lessons learned in the course of a workflow application project are passed along to others doing similar tasks.

- O Yes
- O No
- O Do not know

4.5 Developing expert systems or workflow systems to capture and circulate special skills and knowledge

- O Yes
- O No
- O Do not know

Workflow products developers

Attention:

- **e-workflow analyst/designers (F)**
- **Project mangers (F&M)**
- **Business analysts (F)**
- **e-workflow developers (M)**

Dear Sir/Madam,

Re: **An evaluation of a framework for e-workflow modelling and a new e-workflow development approach**

I am a visiting lecturer/Researcher at London Metropolitan University. I am qualified in computing and management and currently carrying out a research in workflow management systems.

Please, could I ask you and other people involved in software/workflow product development in your organisation to invest a little of your time in completing the attached survey questionnaire. I want to examine how to adopt effective strategies for managing the workflow development processes in general and how to take Internet into consideration within the globalising economic trend in recent years in particular.

In order to accomplish this work, I want to gather evidence from successful companies or workflow vendors and I am writing to you for your assistance

Background Information:

The purpose of this survey is to review the experiences of some of the leading organisations that are currently involved in the development and deployment of workflow products in order to evaluate our framework for e-workflow modelling (Internet-mediated) and the new e-workflow development approach.

Benefits:

The researcher hopes to develop e-workflow models and guidelines for managers, users and developers who need to implement this type of technological change. This may help companies such as yours to develop more effective selection plans, training and development plans. The results will be made available to all participating company if they wish so.

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Procedure:

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e-mail: Jon014@londonmet.ac.uk http://www2.unl.ac.uk

Section 1

Information about the workflow development organisation

1.2 Name of Organisation:..

1.3 Main line of business:..

1.3 In which country is the organisation based:.................................

1.4 Please tick, which of the following best describes your organisation?

[ ] Public

[ ] Private

Revenue of the company

1.5 Please indicate the total revenues for your company (locations) in 2004 by checking the approximate line:

[ ] £100 millions or less

[ ] £100-£500 million

[ ] £500-£1billion

[ ] £1-2 billion

[ ] £2 billion or more

Geographic scope of the company

1.6 Please indicate the geographic scope of your companies operation?(check one)

[ ] Regional

[ ] National

[ ] Worldwide or global

Quality policy in your organisation

Please rank the answers in all the following questions using the scaling system

1 = strongly agree 2 = disagree 3 = agree 4 = strongly agree

1.7 **What does workflow Quality mean to you?** **(1 – 4)**

1. Conformance to requirements [ ]
2. Meeting workflow user needs [ ]
3. User satisfaction [ ]
4. Job satisfaction [ ]
5. Flexibility [ ]
6. Working within groups or teams [ ]
7. Having ongoing training [ ]
8. Having a similar vision to organisation [ ]
9. Bug-free workflow software [ ]
10. Workflow Software developed within budget and time [ ]
11. A tool for competition [ ]
12. Bigger profits [ ]
13. Higher productive [ ]
14. Empowering staffs [ ]

15 Other (please specify) [ ]

1.8 **Which factors do you thinks influence the effectiveness of a company's workflow quality system?** **(1 - 4)**

1. The culture of the company [ ]
2. The government policy [ ]
3. The national economy [ ]
4. The technological infrastructure [ ]
5. Top management commitment [ ]
6. Quality assurance group [ ]
7. The workflow developer [ ]
8. The workflow user expectation [ ]
9. The workflow project itself [ ]
10. Other (please specify)... [ ]

1.9 **How would you characterise the management structure of your organisation?**

Please tick in the position that best describes your organisation, on the scale between the opposites.

	1	2	3	4	5	
Centralised	—	—	—	—	—	Decentralised
Tight control	—	—	—	—	—	Loosely control
Management driven	—	—	—	—	—	Participative
Formalisation	—	—	—	—	—	Informal
Deep hierarchy	—	—	—	—	—	Flat hierarchy
Task-oriented	—	—	—	—	—	People-oriented
Process-oriented	—	—	—	—	—	Product-oriented

Section 2

Previous working experience

2.1 Looking back, have you had substantial (more than one year) Experience in:

		yes	no
1.	Workflow development	[ ]	[ ]
2.	Software development	[ ]	[ ]
3.	Management	[ ]	[ ]
4.	Software quality	[ ]	[ ]
5.	Other, please specify......................................	[ ]	[ ]

Your current position in the organisation

2.2 Please specify by % the extent you work in different positions

Please specify how many years you have worked in this/these positions

		%	Years
1.	e-workflow developer	[ ]	[ ]
2.	e-workflow analyst	[ ]	[ ]
3.	e-workflow designer	[ ]	[ ]
4.	Business analyst	[ ]	[ ]
5.	Project manager	[ ]	[ ]
6.	Other, please specify..............................	[ ]	[ ]

Section 3

Approach for the development of Internet workflow products
Please check relevant boxes

3.1 Which tasks do you perform in relation to workflow product development? Give a brief listing

3.2 Which perspectives do you use during e-workflow product analysis

[ ] Functional perspective
[ ] Organisational perspective
[ ] Informational perspective
[ ] Behavioural perspective
[ ] Other (please specify)...

3.3 Which methodological approach does your organisations use during e-workflow projects?

[ ] Traditional development methods
[ ] Rational Unified Process (RUP)
[ ] Specific modelling tools
[ ] Prototyping/RAD
[ ] Business Process Reengineering (BPR)
[ ] Other (please specify)...

3.4 Which language or modelling techniques do you use during e-workflow design

[ ] Object oriented techniques (UML)
[ ] Action workflow (workflow loop)
[ ] Petri-net
[ ] Formal modelling techniques (mathematical)
[ ] Work breakdown structure
[ ] Pert chart

[ ] Other (please specify)..

3.5 What do you consider to be the critical success factors for the implementation of e-workflow management projects?

[ ] User participation
[ ] Senior management commitment
[ ] User commitment
[ ] A clear set of objectives
[ ] Senior management participation
[ ] Realistic budget and time scales
[ ] Selection of appropriate e-workflow development approach
[ ] Other (please specify)...

3.6 In your opinion, what are the benefits of moving from workflow to Internet-mediated workflow (e-workflow)

[ ] Reduction in transaction cost
[ ] Fast response to customer enquiries
[ ] Improve productivity
[ ] Increase the scalability of workflow application
[ ] Uniform interface throughout the globe
[ ] Ease of installation and use
[ ] Improve collaboration, coordination and communication within the organisation and between organisations
[ ] Improve the competitiveness of the company
[ ] Other (please specify)..

Workflow Business Users

Attention:

- **e-workflow designers/analysts (F)**
- **Project mangers (F&M)**
- **Business/e-Business analysts (F)**
- **e-workflow users (F)**

Dear Sir/Madam,

Re: **An evaluation of a framework for e-workflow modelling and a new e-workflow development approach**

I am a visiting lecturer/Researcher at London Metropolitan University. I am qualified in computing and management and currently carrying out a research in workflow management systems.

Please, could I ask you and other people involved in software/workflow application development in your organisation to invest a little of your time in completing the attached survey questionnaire. I want to examine how to adopt effective strategies for managing the workflow development processes in general and how to take Internet into consideration within the globalising economic trend in recent years in particular.

In order to accomplish this work, I want to gather evidence from successful companies or workflow users, and I am writing to you for your assistance

Background Information:

The purpose of this survey is to review the experiences of some of the leading organisations that are currently involved in the development, deployment and usage of workflow applications in order to evaluate our framework for e-workflow modelling (Internet-mediated) and the new e-workflow development approach.

Benefits:

The researcher hopes to develop e-workflow models and guidelines for managers, users and developers who need to implement this type of technological change. This may help companies such as yours to develop more effective selection plans, training and development plans. The results will be made available to all participating company if they wish so.

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Procedure:

If you agree to be in this study, you are asked to complete any of the surveys based on extensive literature review. All questions are either single select, multiple choice with room for additional comments. It will take 15-20 minutes to complete depending on your additions and comments. Please, feel free to fill one questionnaire from each category if you have enough time to spare.

Contact and Questions:

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Tel: +44 (0) 207 607 2789/7035 Fax: +44 (0) 207 753 7009

e-mail: Jon014@londonmet.ac.uk http://www2.unl.ac.uk

Section 1

<u>Information about the organisation</u>

1.4 Name of organisation:..

1.5 Main line of business:...

1.3 In which country is the organisation based:.................................

1.4 Please tick, which of the following best describes your organisation?

[ ] Public

[ ] Private

<u>Size of organisation approximately</u>

1.5 Please indicate the total number of employee in your organisation (all locations) by checking the appropriate line:

[ ] 100 or fewer

[ ] 101-500

[ ] 501-1000

[ ] 1001-5000

[ ] 5001 or more

<u>Geographic scope of the organisation</u>

1.6 Please indicate the geographic scope of your organisation operation?(check one)

[ ] Regional

[ ] National

[ ] Worldwide or global

Revenue of the organisation

1.7 Please indicate the total revenues for your organisation (locations) in 2004 by checking the approximate line:

[ ] £100 millions or less

[ ] £100-£500 million

[ ] £500-£1billion

[ ] £1-2 billion

[ ] £2 billion or more

How would you characterise your organisation?

1.8 Please tick in the position that best describes your organisation on the scale between the opposites.

	1	2	3	4	5	
Centralised	—	—	—	—	—	Decentralised
Tight control	—	—	—	—	—	Loosely control
Management driven	—	—	—	—	—	Participative
Formalisation	—	—	—	—	—	Informal
Deep hierarchy	—	—	—	—	—	Flat hierarchy
Task-oriented	—	—	—	—	—	People-oriented
Process-oriented	—	—	—	—	—	Product-oriented
Function-oriented	—	—	—	—	—	Process-oriented

Workflow quality policy in your institution

Please rank the answers in all the following questions using the scaling system

1 = strongly agree 2 = disagree 3 = agree 4 = strongly agree

1.9 What does e-workflow system quality mean to you? (1-4)

1. Flexibility [ ]
2. Scalability [ ]
3. Adaptability [ ]
4. Interoperability [ ]
5. Reusability [ ]
6. Ease of use [ ]
7. Other (please specify).. [ ]

Section 2

Information about the person answering the questionnaire
Please check relevant boxes

Previous working experience

2.1 Looking back, have you had substantial (more than one year) yes no

Experience in:

		yes	no
6.	Workflow development	[ ]	[ ]
7.	Software development	[ ]	[ ]
8.	Management	[ ]	[ ]
9.	Software quality	[ ]	[ ]
Other, please specify.................................		[ ]	[ ]

Your current position in the organisation

2.2 Please specify by % the extent you work in different positions

Please specify how many years you have worked in this/these positions

		%	Years
1.	e-workflow user	[ ]	[ ]
2.	e-workflow analyst/designer	[ ]	[ ]
3.	Business analyst	[ ]	[ ]
4.	Project manager	[ ]	[ ]
5.	Other, please specify..............................	[ ]	[ ]

Section 3

Framework for e-workflow modelling

Please check relevant boxes

Functional perspective

3.1 Which tasks do you perform in relation to workflow application development? Give a brief listing

3.2 What kind of results/output do you produce?

[ ] Different kinds of documents

[ ] Approvals/controls

[ ] Physical products

3.3 Which tools do you use for your tasks?

[ ] Computer assisted tools

[ ] Manual tools

3.4 Which of your tasks seems most time consuming or inefficient?

Informational Perspective

3.5 For each of the tasks, which documents or other information do you need/use?

[ ] Specifications
[ ] Contracts
[ ] Orders
[ ] invoices
[ ] Procedures
[ ] Standards
[ ] Other, please specify

3.6 What format is the information in?

[ ] Text/letters
[ ] Spreadsheet
[ ] Drawing
[ ] Photos
[ ] Data from database
[ ] Sound recording
[ ] Videos
[ ] Other, please specify

3.7 How do you sort/or store this information

Organisational Perspective

3.8 For each of the above where/who do you get this information from?

[ ] Customers
[ ] Colleagues
[ ] Other departments or partners
[ ] Data from database
[ ] Sounds recording
[ ] Videos
[ ] Other, please specify

3.9 Who uses the results of your work?

- [ ] Customer
- [ ] Sub-contractor
- [ ] Supplier
- [ ] Colleagues
- [ ] Archives
- [ ] Other, please specify

3.10 Who checks the results and what kind of feedback do you get?

Behavioural Perspective

3.11 How is the information routed or transferred to you?

- [ ] Collected physically
- [ ] Posted
- [ ] Fax
- [ ] Electronic mail
- [ ] Internet
- [ ] Oral/phone
- [ ] Fileserver
- [ ] Other, please specify

3.12 How are the results passed on?

- [ ] Automatically
- [ ] Manually
- [ ] On request

3.13 How does WFMSs enhance the performance of business processes in your organisation?

- [ ] Increase speed of customer service
- [ ] Increase quality of business process
- [ ] Increase the flexibility to adapt to environmental change
- [ ] Increase reliability
- [ ] Reduce the cost of doing business
- [ ] Other (please specify)..

3.14 What are the major problems encountered during the introduction of WFMS

- [ ] Lack of management commitment
- [ ] Resistance to change and implementation issues
- [ ] Inability to agree new processes
- [ ] Other (please specify)..

Section 4

Workflow and knowledge management systems

Please tell me whether your company is or is not doing the following things

4.1 Collecting and sharing information about best practices

- O Yes
- O No
- O Do not know

4.2 Setting up workflows or networks for transferring information between employees who interact with customers, company managers and partners

- O Yes
- O No
- O Do not know

4.3 Setting up network or workflows for transferring information between employees who interact with customers, engineers who create the applications and partners

- O Yes
- O No
- O Do not know

4.4 Creating formal procedures to ensure that lessons learned in the course of a workflow application project are passed along to others doing similar tasks.

- O Yes
- O No
- O Do not know

4.5 Developing workflow/expert systems to capture and circulate special skills and knowledge

- O Yes
- O No
- O Do not know

Appendix E: Publications

(1) *Towards the Development of a Conceptual Framework for Knowledge enhanced e-workflow Modelling, Proceedings of the 6th European Conference on Knowledge management, University of Limerick, Ireland, 8-9 September, 2005*

(2) *Knowledge enhanced e-workflow modelling – a pattern-based approach for the development of Internet workflow systems, Proceedings of the 7th European Conference on Knowledge Management, Budapest, Hungary 4-5 September, 2006*

(3) *A Strategic Workflow Process Model and Its Impact on Internet Electronic Commerce, Poster Presentation, Fifth Internal Conference on Software Process Improvement Research Education and Training INSPIRE 2000*

(4) *A Strategic Workflow process Model and Its Impact on Internet Electronic Commerce, Poster Presentation, Special Reception For Britain's Younger Engineers, The House Of Commons, London, 4 December 2000*

(5) *Towards Understanding Workflow Management Systems: Presenting A Postgraduate - Level Course Development and Validation Example, TQM/ Inspire 2007Conference University of Staffordshire*

(6) *A Strategic Workflow Process Model and Its Impact on Internet Electronic Commerce. Consultants United 2007, http://www.consultantsunited.com*

(7) *An approach to e-workflow systems with the use of patterns. Accepted for publication in TQM / Inspire 2007 Conference University of Staffordshire, but due to financial constraints I didn't publish the paper.*

(8) *Workflow research agenda, ConsultantsUnited 2008, http://www.consultantsunited.com*

Appendix F: Sample of Data Collected (web-based) in collaboration with Workflow Management Coalition

Data collected from workflow researchers and academics

emailID	1_1	1_2	1_3	1_4	1_5	1_5_other
a.aldeeb@mmu.ac.uk	Manchester Metropolitan University	UK	public	global	university	
ahtealeb@gmail.com	Faculty of Computers and Information	Egypt	public	national	university	
akhilkumar@psu.edu	Penn State University	USA	public	regional	university	
eroper@ford.com	Ford Motor Company	USA	public	global	private_profit	
f.marir@londonmet.ac.uk	London Met. University	UK	public	global	0	University
flavia.santoro@uniriotec.br	Universidade Federal do Estado do Rio de Janeiro	Brazil	public	national	master_college	
g.fakas@mmu.ac.uk	Dep. of Computing and Mathematics, Manchester Metropolitan University	UK	private	national	private_profit	
hhh@production.aau.dk	Aalborg University, Departmnet of Production	Denmark	public	national	university	
ian.hunter@inform-consult.com	Inform Consult Ltd	UK	private	national	private_profit	
j.recker@qut.edu.au	Queensland University of Technology	Australia	public	global	university	
jan.mendling@wiwi.hu-berlin.de	HU Berlin	Germany	public	national	not_profit	
jeff.sutherland@computer.org	PatientKeeper Inc	US	private	global	private_profit	

ne@gcal.ac.uk	Glasgow Caledonian University	Scotland, UK	public	global	other	University - not research-led but research-active, including doctoral (I do not think your classification meets the UK situation at all, it seems to be based on the American system, which I find a bit odd!)
ishen@uow.edu.au	Univ of Wollongong	Australia	public	global	university	
l.bradford@qut.edu.au	Queensland University of Technology	Australia	public	global	university	
layna@futstrat.com	Future Strategies Inc	USA	private	global	private_profit	
ljx70@263.net	Hunan University of Science and Technology	P.R. China	public	regional	master_college	
m.u.reichert@cs.utwente.nl	University of Twente	The Netherlands	public	global	university	
madhutherani@gmail.com	Univ. of Arizona	USA	public	national	university	
manfred.reichert@uni-ulm.de	University of Ulm	Germany	public	global	university	
mborges@nce.ufrj.br	Federal University of Rio de Janeiro	Brazil	public	national	university	
me_silentwhispers@hotmail.com	Quaid-e-Azam University	Pakistan	public	national	university	
mike@umiacs.umd.edu	University of Maryland	United States	public	global	university	
myg_444@hotmail.co.uk	Cimtech Ltd	United Kingdom	private	global	private_profit	
mzurmuehlen@stevens.edu	Stevens Institute of Technology	USA	private	global	university	
paula.habas@gmail.com	PEO	Canada	private	regional	other	Engineering College/Regulatory Body
pivan@dist.unige.it	University of Genoa	Italy	public	regional	university	
Raghu.Santanam@asu.edu	Arizona State University	USA	public	national	university	
rieke@ercis.de	European Research Center for Information System, University of Münster	Germany	public	global	university	

s.till@tm.tue.nl	Technical University Eindhoven	The Netherlands	public	global	university	
stankat@it.teithe.gr	Alexandreio Technological Educational Institute of Thessaloniki	Greece	public	regional	not_profit	
Stefan.Smolnik@ebs.edu	EUROPEAN BUSINESS SCHOOL (ebs)	Germany	private	global	university	
steve.new@sbs.ox.ac.uk	University of Oxford	UK	public	global	university	
steven.carey@evisory.com	eVisory Consulting	USA	private	global	private_profit	
wainer@ic.unicamp.br	State University of Campinas	Brazil	public	national	university	
yyang@ict.swin.edu.au	Swinburne University of Technology	Australia	public	regional	university	

2_1	2_1_other
software_development	
workflow_development,software_development,software_quality	
workflow_development_development	
workflow_development,management,other	Engineering
workflow_development, software_development	
other	Researcher
	Workflow Researcher
workflow_development,software_development,management	
workflow_development,management,software_quality	
workflow_development,software_development	
workflow_development	
workflow_development,software_development,management,software_quality	
other	Computing research also HCI, also technical writing in computer industry
workflow_development,management,software_quality	
workflow_development,software_development,management,software_quality	
management	
workflow_development,software_development,management,software_quality	
workflow_development,software_development,other	Hospital Information Systems, Clinical Workflows
workflow_development,software_development	
workflow_development, software_development, management, other	Technology Development, Founding a Spin-Off in BPM Area
software_development, management, other	Consulting
software_development	
management	
workflow_development, management	
workflow_development,management	
workflow_development,management	
workflow_development,software_development	
workflow_development,software_development	

workflow_development,software_development	
software_development	
workflow_development_development	
workflow_development,software_development,management	Operations Management
workflow_development, software_development, management, software_quality, o	Imaging and document management
other	teaching/ research
workflow_development,software_development,management,software_quality	

2_2_lecturer_percent	2_2_lecturer_years	2_2_technician_percent	2_2_technician_years	2_2_entrepreneur_percent	2_2_entrepreneur_years
0	0	0	0	0	0
0	0	60	2	0	0
100	15 - 20	0	0	0	0
10	2	80	9	0	0
30	10 - 15	0	0	0	0
40	10 - 15	0	0	0	0
60	3	0	0	0	0
50	10 - 15	0	0	0	0
0	0	20	10	0	0
20	3	0	0	0	0
100	5	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
100	3	0	0	0	0
0	0	80	10	0	0
0	0	0	0	0	0
70	20+	0	0	0	0
40	8	0	0	0	0
0	0	0	0	0	0
50	10 - 15	0	0	0	0
40	20+	0	0	0	0
0	0	0	0	0	0
30	15 - 20	0	0	0	0
0	0	0	0	0	0
40	0	0	0	0	0
0	0	30	7	0	0
0	0	20	5	0	0
0	0	0	0	0	0

30	4	10	4	0	0
10	4	100	7	0	0
0	0	0	0	0	0
20	2	0	0	0	0
50	15 - 20	0	0	0	0
0	0	0	0	0	0
60	15 - 20	0	0	0	0
100	10 - 15	0	0	0	0

2_2_manager_percent	2_2_manager_years	2_2_researcher_percent	2_2_researcher_years	2_2_other	2_2_other_percent	2_2_other_years
0	0	20	2		0	0
0	0	80	3		0	0
0	0	0	0		0	0
20	2	10	2		0	0
0	0	80	10 - 15		0	0
0	0	60	15 - 20		0	0
0	0	60	5		0	0
60	5	50	15 - 20		0	0
90	15 - 20	0	0		0	0
0	0	90	3		0	0
0	0	0	0		0	0
0	0	0	0	Chief Technology Officer	100	5
0	0	0	0	Cannot answer, the question mixes up too many factors	0	0
0	0	100	8		0	0
0	0	20	5		0	0
0	0	30	5		0	0
0	0	0	0		0	0
30	5	40	9		0	0
0	0	100	10		0	0
0	0	50	10 - 15	Managing Research Group as Professor	20	5
10	20+	40	20+	Consultant	20	20+
0	0	0	0	Software Engineer	80	2
0	0	80	15 - 20		0	0

70	5	40	7		0	0
0	0	60	0		0	0
80	4	0	0		0	0
0	0	80	5	PhD student	100	3
0	0	80	10 - 15		0	0
0	0	60	4	Administration	30	4
10	7	100	4		0	0
0	0	0	0	Student	0	4
40	2	40	2		0	0
0	0	50	15 - 20		0	0
90	15 - 20	0	0		0	0
0	0	50	15 - 20		0	0
30	5	100	4		0	0

3_1	3_1_other
designer,developer	
developer	
designer	
designer,developer	
designer	
other	research, consulting
other	Research in p2p workflow
	Focus on organising flow (few it-based workflow implementaitons)
designer	
designer	
designer	
designer	
other	researcher
designer,developer	
designer,developer	
designer	
designer,developer	
other	e-Workflow Requirements (for supporting technologies)
designer,developer	
designer, developer, other	Developer of enabling technologies for e-Workflow
designer	
developer	
designer,other	manage a group of programmers
designer	
designer,developer	
designer,developer	
other	grid application porting, portal design
designer	

designer	
designer,developer	
designer	
designer	
	consultant, trainer
designer, developer	
other	
designer	

3_2	3_2_other
functional,organisational,informational	
functional,organisational,informational,behavioural	
functional,organisational,informational,behavioural	
functional,informational,behavioural	
functional, organisational, informational, behavioural	knowledge perspective
functional, organisational, informational, behavioural	
other	Primarily the order- and information flow
functional,organisational	
functional,organisational,informational,behavioural	
functional, organisational, informational, behavioural	
functional,organisational,informational,behavioural	
functional,organisational,informational,behavioural	
functional,organisational,informational	
organisational,behavioural	
functional, organisational, informational, behavioural, other	knowledge engineering
functional,organisational,informational,behavioural	
functional,organisational,informational,behavioural,other	Temporal Perspective, Flexibility!
functional,organisational,informational,behavioural	
functional, organisational, informational, behavioural, other	Temporal Perspective, Compliance, Flexibility
functional, organisational, informational	
functional	
functional,organisational,informational,behavioural	
functional, organisational, informational, behavioural	cognitive logic, adaptability, collaboration, flexibility
functional,organisational,informational,behavioural,other	See Bussler/Jablonski (1996) - Causal, Historical, Operational etc.
functional,organisational,informational	
functional	
organisational,informational,behavioural	

functional,organisational,informational,behavioural	
functional,organisational,informational	
functional,organisational	
functional,organisational,informational	
functional,organisational,informational,behavioural	
functional, organisational, informational, behavioural, other	compliance, collaboration, information and knowledge flow
functional	
functional	

3_3	3_3_other
traditional	
traditional,RAD,BPR	
specific	
traditional,specific	
RUP, RAD, BPR	
BPR	
RAD,BPR	
RAD	
specific,BPR	
BPR	
other	Scrum
RUP,other	XML-based technologies
traditional,specific,BPR	
specific,RAD	
RAD, BPR	agile method
RUP,BPR	
specific,BPR,other	Process management tools
other	All of the above and more
specific, BPR, other	Using a Plug & Play Workflow Engine (AristaFlow BPM Suite)
specific	
BPR	
traditional	
RUP, specific, RAD	soft systems approach, agile methods, scrum
specific,RAD,BPR	
traditional	
traditional	
specific,BPR	

traditional,RAD,BPR	
traditional,specific,RAD,BPR	
traditional,RUP	
traditional	
traditional,RAD,BPR	
RAD, BPR, other	chant/internally developed as the AIIM standard, flexible and adaptive approach
other	
RAD	

3_4	3_4_other
BPEL,UML,petri,XPDL	
BPMN,BPEL,UML,XPDL	
petri,work	
BPMN,UML,petri,formal,IDEF,pert	
BPMN, BPEL, UML, XPDL, RAD	
BPMN, BPEL, XPDL, ARIS	
workflow,work	
UML,workflow,work	
other	BPMN, EPC, BPEL, YAWL
BPMN, BPEL, UML, petri, XPDL, ARIS	
UML,other	OSWorkflow
UML,workflow,petri	
UML,petri,formal	
petri,other	ORM
BPMN, BPEL, XPDL	
UML	
UML,petri,other	WSM Nets (similar to Petri Nets, but more flexible), see ADEPT project
other	Each of them is incomplete in their own way..
BPMN, UML, petri, ARIS, other	Formalism provided by AristaFlow BPM Suite (i.e. Correctness by Construction)
BPMN, BPEL, XPDL, ARIS	
UML	
workflow,work	
BPMN, BPEL, UML, XPDL, LOVEM, other	ontology
UML,petri,other	EPC, BPMN, XPDL, BPEL
UML,work,pert	
UML	
petri	

other	Event-Driven PRocess Chain
UML,petri,formal	
UML,petri,work	
UML	
UML,IDEF,work,pert	
BPMN, BPEL, petri, XPDL, other	expressiveness and capability to accommodate change
petri,work	
workflow	

3_5	3_5_other
user_part	
appropriate	
user_part,user_com,manage_part,appropriate	
objectives	
appropriate	
user_com	
user_part,manage_com,user_com,objectives,realistic,appropriate	
user_part,manage_com,user_com,objectives,manage_part	
manage_com,user_com,objectives,realistic,appropriate	
objectives	
user_part,manage_com,user_com,objectives,manage_part,realistic,appropriate,	Use of an Agile process
user_part,manage_com,user_com,objectives,manage_part,realistic,appropriate	
user_part,manage_com,objectives,appropriate	
user_part,user_com	
manage_part	
user_part,manage_com,manage_part,realistic	
user_part,manage_com,objectives,manage_part,realistic,appropriate,other	Requirements analysis, Adequate treatment of flexibility issues
other	All of the above
other	Defininition of clear interfaces and strategies for dealing with exceptions from the norm.
manage_com	
user_part,manage_com,objectives,appropriate	
user_part,objectives	
user_part	
user_part,manage_com,user_com,objectives,realistic,other	integration capabilities of chosen technology
objectives	
user_part	

user_part,manage_com,user_com,objectives,manage_part,realistic	
manage_com,user_com,objectives,realistic	
user_part,manage_com,user_com,objectives,appropriate	
user_part,manage_com,objectives,realistic	
user_part,manage_com,objectives,realistic	
user_part	
objectives	
user_part,manage_com,realistic	
objectives,manage_part	

3_6	3_6_other
cost,response,scalability,collaborate	
response,collaborate,competitive	
cost,response,scalability,interface,install,collaborate	
collaborate	
cost, response, interface, collaborate, competitive	
scalability, collaborate	
response,scalability,interface	
cost,response,scalability,interface,install,collaborate,competitive	All are relevant, but some more than others.
response,scalability,collaborate	
cost,response,scalability	
cost	
cost,response,scalability,interface,install,collaborate,competitive,other	Patient Safety in healthcare
collaborate	
response,scalability,install,collaborate	
install,collaborate	
cost, scalability, competitive	global competitiveness
cost,response,scalability,install,collaborate	
cost,response,collaborate,competitive,other	be able to react more rapidly to business process changes, process performance managment
other	All of the above
response, install, collaborate	
cost, response, collaborate	
response,collaborate	
scalability,interface,install,collaborate	
cost, response, scalability, collaborate, competitive, other	
other	depends on individual project objectives
response,collaborate	
scalability	

cost,response,scalability,interface	
cost,response,collaborate	
cost,scalability,collaborate,competitive	
cost,response,collaborate,competitive	
cost,collaborate	
install	
response, interface, collaborate	
install	
interface,install	

3_7	3_7_other
security,management,synchronising,infrastructure	
culture,management,synchronising,infrastructure	
security,management,synchronising,infrastructure	
security,management,synchronising,infrastructure	
culture, management, infrastructure	,
security, management	,
	Tasks are being decentralised, often without providing resources and systems-introduction
security	
management,infrastructure	
security	,
management,infrastructure	
security,management	
culture,security,management,synchronising,infrastructure	
culture,security,management,synchronising	
time, management	,
security,infrastructure	
security,management,synchronising,other	dealing with change and with exceptions
other	All of the above and more
security, management, other	Inflexibility of private workflows,
management, infrastructure	,
management	
culture,security	
culture, management, synchronising	,
security,management,synchronising,infrastructure	
culture,management	
other	no experience

security,management,infrastructure	
management,synchronising,infrastructure	
security,management,synchronising	
security,management,synchronising	
security,management,infrastructure	
time, culture, security, synchronising	
infrastructure	
infrastructure	

Appendix G: Verification sample Comments and suggestions from Respondents of the survey

Response 1:

--------------------------- Original Message ---------------------------

Subject: Re: workflow research (Please help)

From: "Jun Shen" <jshen@uow.edu.au>

Date: Fri, November 21, 2008 11:35 am

To: "John Ndeta" <j.ndeta@londonmet.ac.uk>

Thanks for sharing your research contribution. My comment is the 2nd one may be better if human cognition do contribute the digitised economy knowledge.

Cheers

Dr Jun Shen (SMACM, SMIEEE, SMACS)
School of Information Systems and Technology
(First choice for IT education and research in Australia)
Univ of Wollongong
Wollongong, NSW, 2522

---- Original message ----

>Date: Wed, 19 Nov 2008 16:09:31 -0000 (GMT)
>From: "John Ndeta" <j.ndeta@londonmet.ac.uk>
>Subject: workflow research (Please help)
>To: jon014@londonmet.ac.uk

>Dear Sir / Madam,
>
>Thank you for responding to my original workflow management systems
>research questionnaire few months ago, I am now at the stage of validating

>the new framework that I have developed as one of the major contributions
>to my PhD thesis.
>
>I attached for your information, the traditional framework and my newly
>proposed framework for my PhD research work, specifically for e-workflow
>design and evolution in the global and digitised economy.
>
>I would be grateful to you if you could respond before 10th of December
>2008, as your comments are valuable and essential for the analysis of the
>questionnaire and the completion of my PhD thesis.
>
>Note that your comments should state clearly which of the frameworks is
>more appropriate for workflow design and evolution in the new digitised
>economy.
>

>Yours Faithfully,
>
>Mr. John Ndeta
>
>Researcher/Visiting Lecturer
>London Metropolitan University

>farhiFrameworks for validation.doc (44k bytes)

Response 2:

---------------------------- Original Message ----------------------------

Subject: Re: workflow resaerch (please help)

From: ergonology@iafrica.com

Date: Tue, December 9, 2008 5:58 am

To: "j.ndeta@londonmet.ac.uk" <j.ndeta@londonmet.ac.uk>

Hi John,

Thanks for sending me your work. Please find attached a copy with some comments.

Do come back to me if anything's unclear.

Hope this helps.

Thanks,

Chris Lawrence.

From: j.ndeta@londonmet.ac.uk
Sent:2008-12-08 19:42:12
To: jon014@londonmet.ac.uk
Cc:
Subject: workflow resaerch (please help)

Dear Sir / Madam,

Thank you for responding to my original workflow management systems research questionnaire few months ago, I am now at the stage of validating the new framework that I have developed as one of the major contributions to my PhD thesis.

I attached for your information, the traditional framework and my newly proposed framework for my PhD research work, specifically for e-workflow design and evolution in the global and digitised economy.

I would be grateful to you if you could comment on both frameworks in a sentence or paragraph and respond before 20th of December 2008, as your comments are valuable and essential for the analysis of the questionnaire and the completion of my PhD thesis.

Note that your comments should state clearly which of the frameworks is more appropriate for workflow design and evolution in the new digitised economy.

Yours Faithfully,

Mr. John Ndeta

Researcher/Visiting Lecturer
London Metropolitan University

Hi John,

More than happy to comment on what you've sent.

However it's quite difficult to do this without a bit more context, because of the risk of making false assumptions as to what is intended.

Your first diagram is called 'Traditional Framework for workflow modelling'. But where does it come from? Does the diagram itself come from established literature on workflow, or is it your own representation of what you conclude the traditional approach to workflow modelling boils down to? (Forgive my ignorance if this is already public domain.)

I can understand that the entities in the framework might all have relevance in a workflow initiative, but it's not obvious (without more explanation) how someone might actually use the framework to do workflow modelling.

For example, are you claiming that in the 'traditional' framework, an analyst or modeller might gather information (facts, requirements, rules etc) from each perspective (organisational, functional etc) – such that if one or more perspectives are under-researched or ignored the result would be suboptimal?

Because if so, I'm not sure that's true. But that may not be what you're claiming.

I think my main concern is that it's not obvious what takes priority – and whether the directions of the arrows are meant to indicate this?

In most of the contexts I work in (principally financial services, but I'm sure the same applies to most administration contexts, which is where workflow & BPM tend to predominate) the most important components are data and rules. By 'rules' I don't mean just 'routing rules', but anything that could be used as a rule. At a logical level even a 'process' is a rule – a rule of the form 'when an event of type x occurs, respond to it in such & such a way...'.

Once the data & rules are understood, a workflow or process solution can then be designed. Things like actors, roles, routings, functionality etc are what they are because the data & rules are what they are. So it's not obvious to me how using a model like the 'traditional framework' diagram helps you focus on what's important & in what sequence.

For example the 'organisational perspective' may well be important for transition/transformation purposes – eg in determining how much change is possible, and what obstacles there might be – but that might not be what the diagram is intending to say.

Also a key perspective in many scenarios is that of the customer, but there is no customer in the diagram – unless customer is assumed to be a subtype of 'actor' &/or role?

So when I then turn to the 'knowledge enhanced framework', I can see it's different, but because it's not obvious how the traditional framework would be used, it's not clear how the knowledge enhanced framework would be used either, and therefore whether it's any better & why.

In terms of context, it's not clear what 'e-workflow' actually means, if it's intended as something distinct. Many business processes have both web components and back office components, with the end-to-end sequence needing to accommodate both. I can't see that you'd want to use a different framework for modelling the two different domains, because ultimately the process is the same, it's just the interface technology that's different.

That's unless 'e-workflow' is intended to mean something quite specific, to do with the greater fluidity, complexity and interconnectedness which web technology can provide, and the relationship between this and any business process which may be initiated or interacted with by the web user?

By distinguishing 'e-actors', 'e-processes', 'e-roles' etc it seems as if you intend to mean something different from 'actors', 'processes', 'roles' etc. But if so, it's not obvious what differences you had in mind.

Hope this helps. Please come back to me if you want more feedback or if anything I've said here doesn't seem to make sense.

You might be interested in my website www.makeworkmakesense.com and my blog www.thinkingmakesitso.wordpress.com.

Thanks,
Chris Lawrence.

Response 3:

---------------------------- Original Message ----------------------------
Subject: Re: workflow resaerch (please help)
From: "Ahmed G. Tealeb" <ahtealeb@gmail.com>
Date: Tue, December 9, 2008 11:10 am
To: "John Ndeta" <j.ndeta@londonmet.ac.uk>

Dear Dr. John Ndeta,

Thank you for your mail. My opinion that your new Extention Framework concerned with [Knowledge Perspective] is very important.

My comments are:

- Knowledge perspective is concerned with all information taken from user at run-time of workflow.
- Furthermore, knowledge perspective can be used as major factor in mining the workflow model to improve it as Business Process Re-engineering (BPR).

Best Regards
Ahmed G. Tealeb

On Mon, Dec 8, 2008 at 7:08 PM, John Ndeta <j.ndeta@londonmet.ac.uk> wrote:

> Dear Sir / Madam,
>
> Thank you for responding to my original workflow management systems
> research questionnaire few months ago, I am now at the stage of validating
> the new framework that I have developed as one of the major contributions
> to my PhD thesis.

>
> I attached for your information, the traditional framework and my newly
> proposed framework for my PhD research work, specifically for e-workflow
> design and evolution in the global and digitised economy.
>
> I would be grateful to you if you could comment on both frameworks in a
> sentence or paragraph and respond before 20th of December 2008, as your
> comments are valuable and essential for the analysis of the questionnaire
> and the completion of my PhD thesis.
>
> Note that your comments should state clearly which of the frameworks is
> more appropriate for workflow design and evolution in the new digitised
> economy.
>
>
> Yours Faithfully,
>
> Mr. John Ndeta
>
> Researcher/Visiting Lecturer
> London Metropolitan University
>

--

Ahmed G. Tealeb

Software Quality Engineer - ThebeTechnology

Teaching Assistant, Department of Information Systems - Al-Obour High Institute for Management & Informatics

BSc of Information Systems 2003,

ORACLE Certified Professional Developer (OCP) 2005

Response 4:

--------------------------- Original Message ---------------------------

Subject: RE: workflow resaerch (please help)

From: "David Bowen" <David.Bowen@Audata.co.uk>

Date: Wed, December 10, 2008 7:16 pm

To: "'John Ndeta'" <j.ndeta@londonmet.ac.uk>

Sorry, John, but I do not think there is enough difference between the two models to be useful.

My detailed comments are on the paper, attached. In terms of building and running a digital workflow, I'd day the important issues are:

Starting triggers: document; time; person (ad hoc)

Progress tracking: relaxed; time limited; depends on outsiders; ...

Monitoring: Ad hoc, regular, by exception.

And I think knowledge grows from the monitoring.

Regards, David

David V. Bowen Tel: +44 (0)7771 802 836
Managing Director Fax: on request
30 Salisbury Road
Canterbury, Kent CT2 7HH Mobile: +44 (0)7771 802 836

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-----Original Message-----
From: John Ndeta [mailto:j.ndeta@londonmet.ac.uk]
Sent: 08 December 2008 17:09
To: jon014@londonmet.ac.uk
Subject: workflow resaerch (please help)

Dear Sir / Madam,

Thank you for responding to my original workflow management systems research questionnaire few months ago, I am now at the stage of validating the new framework that I have developed as one of the major contributions to my PhD thesis.

I attached for your information, the traditional framework and my newly proposed framework for my PhD research work, specifically for e-workflow design and evolution in the global and digitised economy.

I would be grateful to you if you could comment on both frameworks in a sentence or paragraph and respond before 20th of December 2008, as your comments are valuable and essential for the analysis of the questionnaire and the completion of my PhD thesis.

Note that your comments should state clearly which of the frameworks is more appropriate for workflow design and evolution in the new digitised economy.

Yours Faithfully,

Mr. John Ndeta

Researcher/Visiting Lecturer
London Metropolitan University

Response 5:

--------------------------- Original Message ---------------------------

Subject: RE: workflow research (please help)

From: "Raghu Santanam" <Raghu.Santanam@asu.edu>

Date: Sun, December 14, 2008 10:57 pm

To: "John Ndeta" <j.ndeta@londonmet.ac.uk>

John

It would be hard for one to judge a framework without knowing the precise definitions of the constructs used. For example, the processes box and the "routes" term in the middle of the framework seem to have the same meanings. What would be the definition of a process and how would you separate it from "routes"? In a sense, process encompasses all of the things you capture in the framework.

Also, it is a bit surprising to see human cognition only on the information side - surely motivation and incentives may influence the functional aspects of the process as well.

Hope you take the comments in the right spirit...I don't remember the survey right now, I am sure there were other details in the survey that I am forgetting now.

Raghu

-----Original Message-----

From: John Ndeta [mailto:j.ndeta@londonmet.ac.uk]

Sent: Monday, December 08, 2008 9:41 AM

To: jon014@londonmet.ac.uk

Subject: workflow research (please help)

Dear Sir / Madam,

Thank you for responding to my original workflow management systems research questionnaire few months ago, I am now at the stage of validating the new framework that I have developed as one of the major contributions to my PhD thesis.

I attached for your information, the traditional framework and my newly proposed framework for my PhD research work, specifically for e-workflow design and evolution in the global and digitised economy.

I would be grateful to you if you could comment on both frameworks in a sentence or paragraph and respond before 20th of December 2008, as your comments are valuable and essential for the analysis of the questionnaire and the completion of my PhD thesis.

Note that your comments should state clearly which of the frameworks is more appropriate for workflow design and evolution in the new digitised economy.

Yours Faithfully,

Mr. John Ndeta

Researcher/Visiting Lecturer
London Metropolitan University

Response 6:

--------------------------- Original Message ---------------------------

Subject: RE: Workflow Research (Pl;ease Help)

From: "Akhil Kumar" <akhilkumar@psu.edu>

Date: Wed, December 17, 2008 5:49 pm

To: "John Ndeta" <j.ndeta@londonmet.ac.uk>

John,

I like both figures. I do see the value of adding the knowledge perspective in figure 2, but it is not clear what you mean by human cognition. It is not an entity in the same sense as the other entities in the figure.

So, if you expand on this box in the narrative adequately then figure 2 may be better else I would go with figure 1. Moreover, in figure 2, the "e-" before actors, roles, documents, data is not necessary. I think it is implied. After all data is always in electronic form!

Another thing I would do is to connect roles to processes/tasks rather than actors. So I would switch the boxes for actors and roles because tasks are assigned to roles. A loan is approved by a vice-president, while joe, john and jane are actors in the role of v-p.

Finally, I like this general approach because I have also been advocating more work on a holistic view of workflows and business processes (see attached article). I see your work as a step in that direction.

Cheers,
Akhil

-----Original Message-----

From: John Ndeta [mailto:j.ndeta@londonmet.ac.uk]

Sent: Monday, December 15, 2008 9:18 AM
To: Akhil Kumar
Subject: Workflow Research (Pl;ease Help)

Dear Sir / Madam,

Thank you for responding to my original workflow management systems research questionnaire few months ago, I am now at the stage of validating the new framework that I have developed as one of the major contributions to my PhD thesis.

I attached for your information, the traditional framework and my newly proposed framework for my PhD research work, specifically for e-workflow design and evolution in the global and digitised economy.

I would be grateful to you if you could comment on both frameworks in a sentence or paragraph and respond before 20th of December 2008, as your comments are valuable and essential for the analysis of the questionnaire and the completion of my PhD thesis.

Note that your comments should state clearly which of the frameworks is more appropriate for workflow design and evolution in the new digitised economy.

Yours Faithfully,

Mr. John Ndeta

Researcher/Visiting Lecturer
London Metropolitan University

Companies Act 2006 : http://www.londonmet.ac.uk/companyinfo

Appendix H: Samples of generic business process workflow design pattern diagrams and templates in the proposed knowledge repository for future use

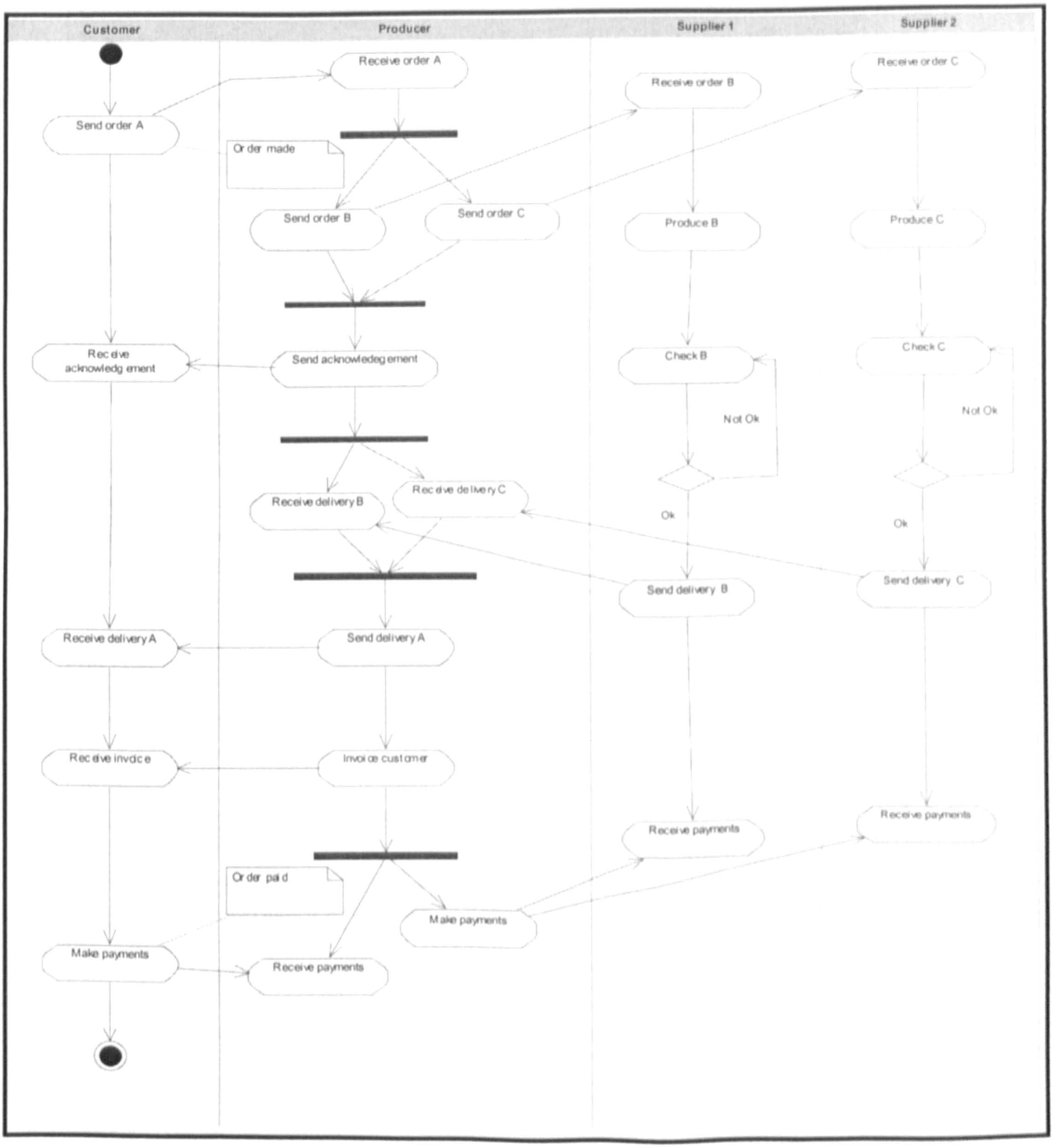

Figure H. 1: Production planning business process workflow design patterns diagram

Name: Production planning business process workflow design pattern template

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 28/05/2009

Intent: This workflow design pattern template allows the definition of a workflow schema for archiving the production planning business process

Classification: Workflow design pattern

Template:

Receive order for product A
Get customer details
Order for product **b** from supplier 1
Receive product **b** from supplier 1
Check quality of product **b** from supplier **1**
IF quality of product **b** OK
    THEN retain product **b**
        Send acknowledgement
    ELSE
        Reject product **b**
ENDIF

Order for product **c** from supplier 2
Receive product **c** from supplier 2
Check quality of product **c** from supplier 2
IF quality of product **c** OK
    THEN retain product **c**
        Send acknowledgement
    ELSE
        Reject product **c**
ENDIF
Manufacture product A
Check quality of product A
IF quality of product A OK
    THEN Send delivery note to customer
        Invoice customer
        Receive payment
        Deliver product A to customer
    ELSE
        Send rejection notice
ENDIF

Keywords: Production planning business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflow schemas for different workflow problems within different business context or setting

Figure II. 2: Production planning business process workflow design pattern template

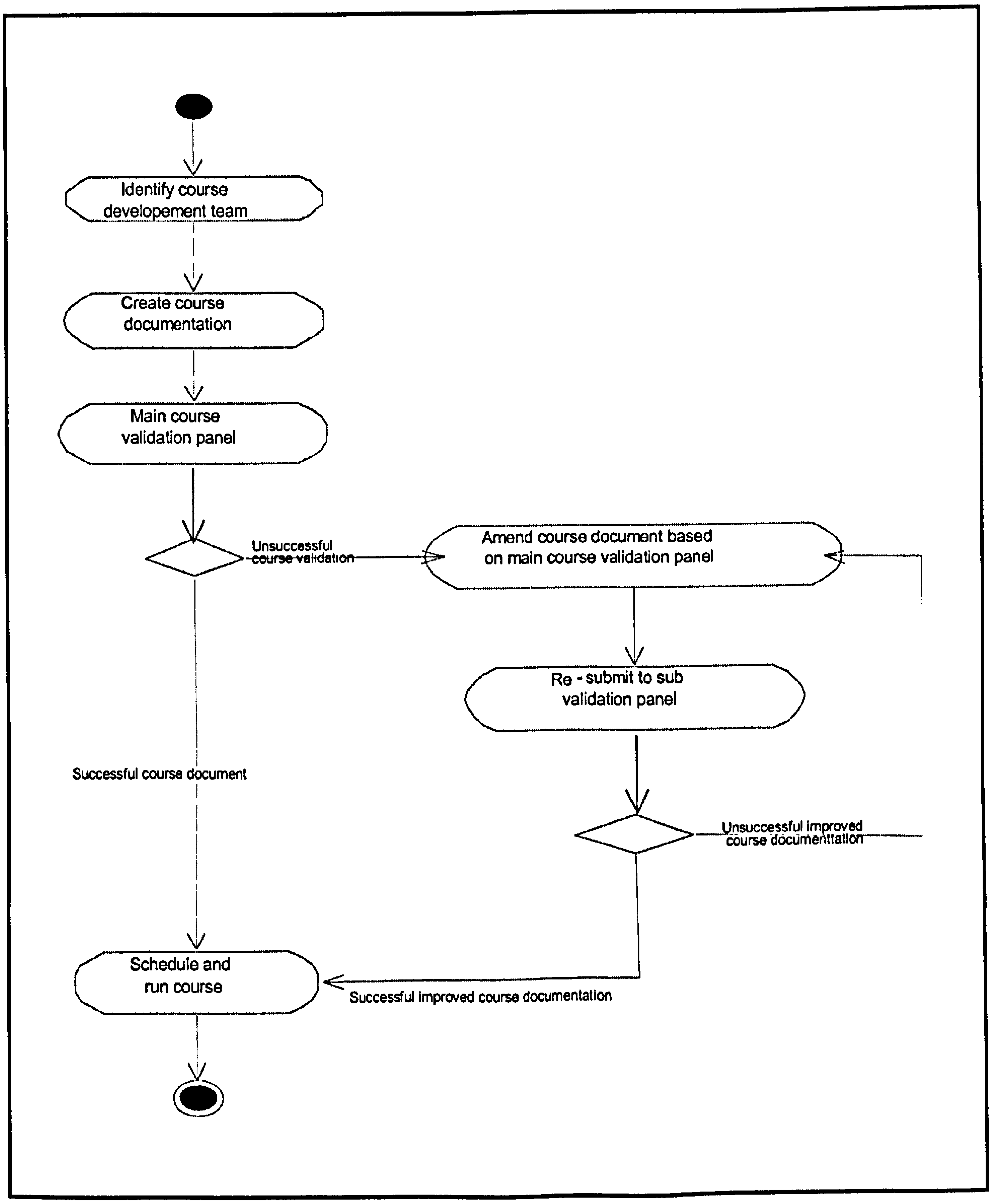

Figure H. 3: Course development and validation workflow design pattern diagram

Name: Postgraduate-level course development and validation workflow design pattern template

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 01/06/2008

Intent: This workflow design pattern template allows the definition of a workflow schema for achieving the postgraduate-level course development and validation workflow process

Classification: Workflow design pattern

Template:

COURSE LEADER *(Get appropriate qualified Course Leader)*

IF existing STAFF TEAM have relevant COURSE LEADER SKILLS

  THEN select COURSE LEADER from existing STAFF TEAM

ELSE

  Advertise for COURSE LEADER

  Interview for COURSE LEADER

  Appoint COURSE LEADER

ENDIF

MODULE LEADERS (*Get appropriate qualified Course Leaders*)

IF existing STAFF TEAM have relevant MODULE LEADER SKILLS

  THEN select required MODULE LEADERS from existing STAFF TEAM

ELSE

  Advertise for appropriate STAFF MEMBERS for the COURSE

  Interview STAFF MEMBERS for the COURSE

  Appoint MODULE LEADERS from STAFF MEMBERS selected at interview

ENDIF

CREATE COURSE DOCUMENTATION *(Get appropriate course documentation)*

IF appropriate MODULE LEADERS are available

  MODULE LEADER provides MODULE specification

  COURSE LEADER collects all MODULE specification

  COURSE LEADER produce COUSE DOCUMENTATION for validation

  SCHEDULE COURSE DOCUMENTATION for VALIDATION

ENDIF

VALIDATE COURSE DOCUMENTATION

(Get appropriate course documentation for validation)

IF COURSE DOCUMENTATION successful

  THEN run COURSE

ELSE

Resubmit COURSE DOCUMENTATION to VALIDATION SUB_PANEL

ENDIF

Keywords: Postgraduate-level course development and validation workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflow schemas for different workflow problems within different business context or setting

Figure II. 4: Course development and validation workflow design pattern template

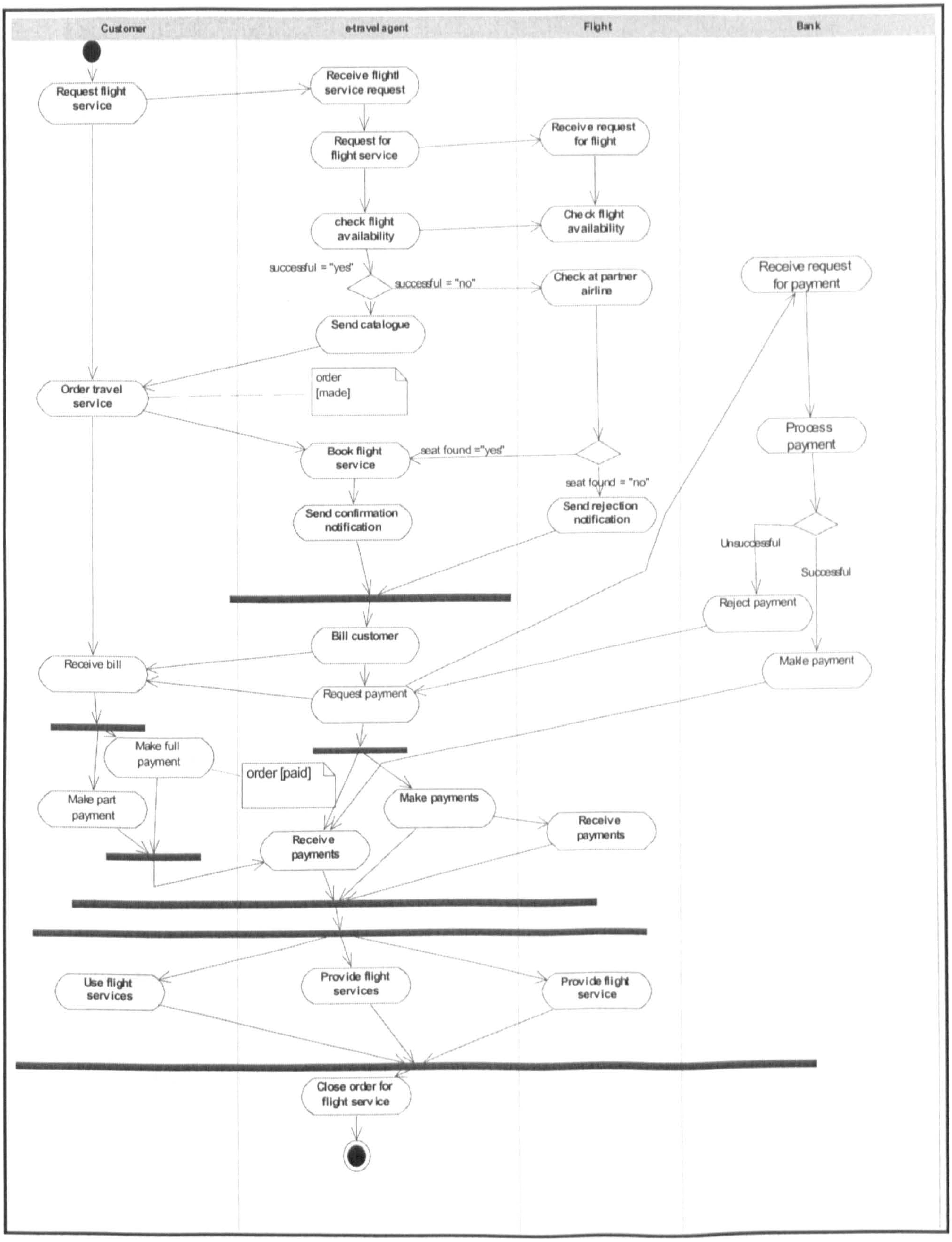

Figure H. 5: Booking Flight only business process workflow design pattern diagram

Name: Book Flight only business process workflow design pattern template

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1
Date: 12/05/2008

Intent: This pattern template allows the definition of a workflow schema for achieving the flight only reservation business process

Classification: Sub workflow design pattern

Template:

```
Get request for travel
Get customer details
Check flight availability
IF flight available
    THEN Book flight seat
         Send confirmation letter
    ELSE
         Check flight availability at Partner airline
         IF seat available
             THEN Book flight seat
                  Send confirmation letter
                  Request payment
         ELSE
                  Send rejection letter
         ENDIF
ENDIF
```

Keywords: Book Flight only business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be reuse to compose workflow schemas for different workflow problems within different business context or setting

Figure II. 6: Booking Flight only business process workflow design pattern template

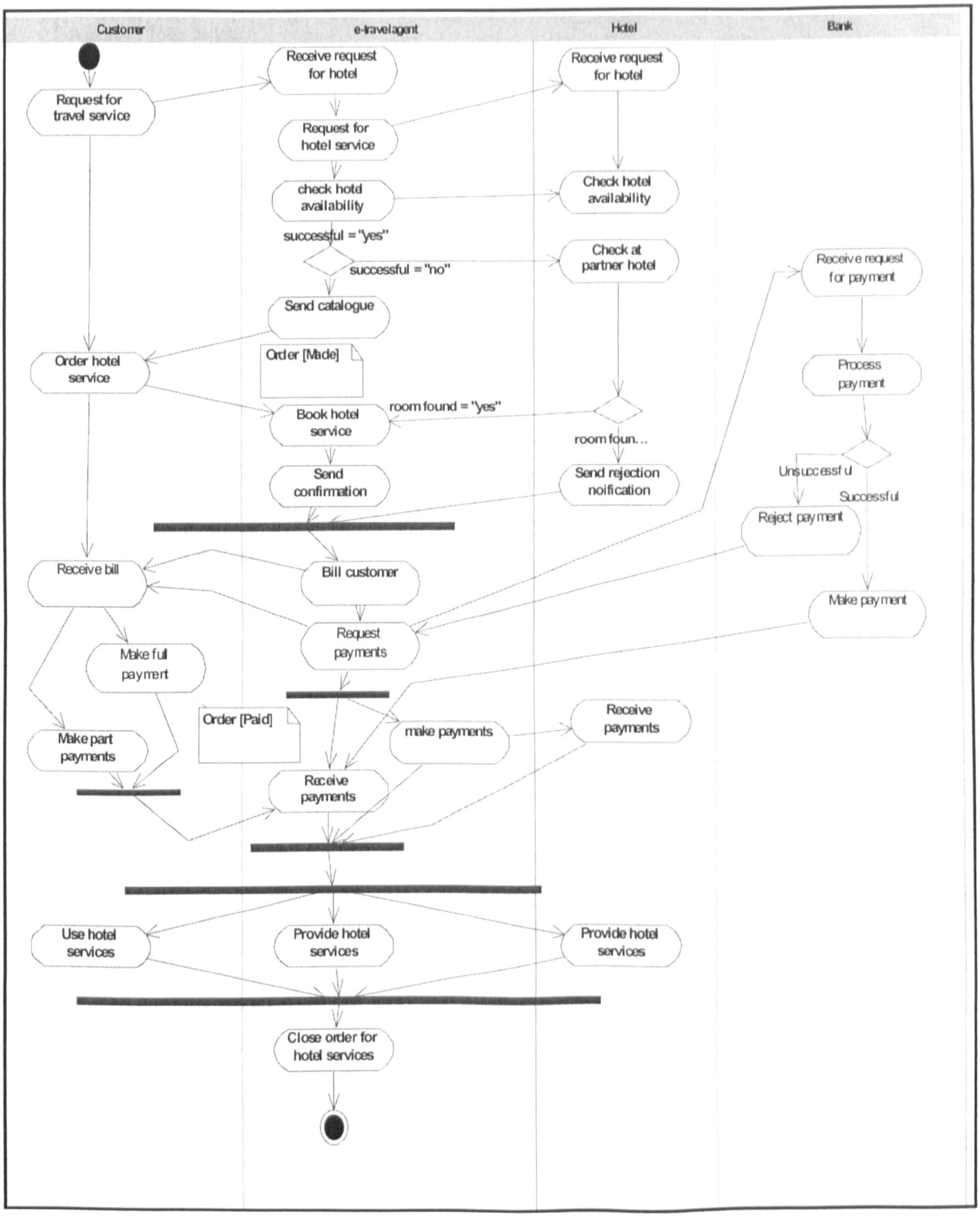

Figure H. 7: Booking Hotel only business process workflow design pattern diagram

Name: Book Hotel only business process workflow design pattern template

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 12/05/2008

Intent: This workflow design pattern template allows the definition of a workflow schema for achieving the hotel room reservation business process

Classification: Sub workflow design pattern

Template:

```
Get request for travel
Get customer details
Check  Hotel_Room availability
IF Hotel_Room  available
      THEN Book Hotel_Room
               Send confirmation letter
       ELSE
             Check Hotel_Room availability at Partner hotel
             IF Hotel_Room available
                  THEN Book Hotel_Room
                           Send confirmation letter
                           Request payment
              ELSE
                    Send rejection letter
          ENDIF
ENDIF
```

Keywords: Book Hotel only business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be reuse to compose workflow schemas for different workflow problems within different business context or setting

Figure II. 8: Booking Hotel only business process workflow design pattern template

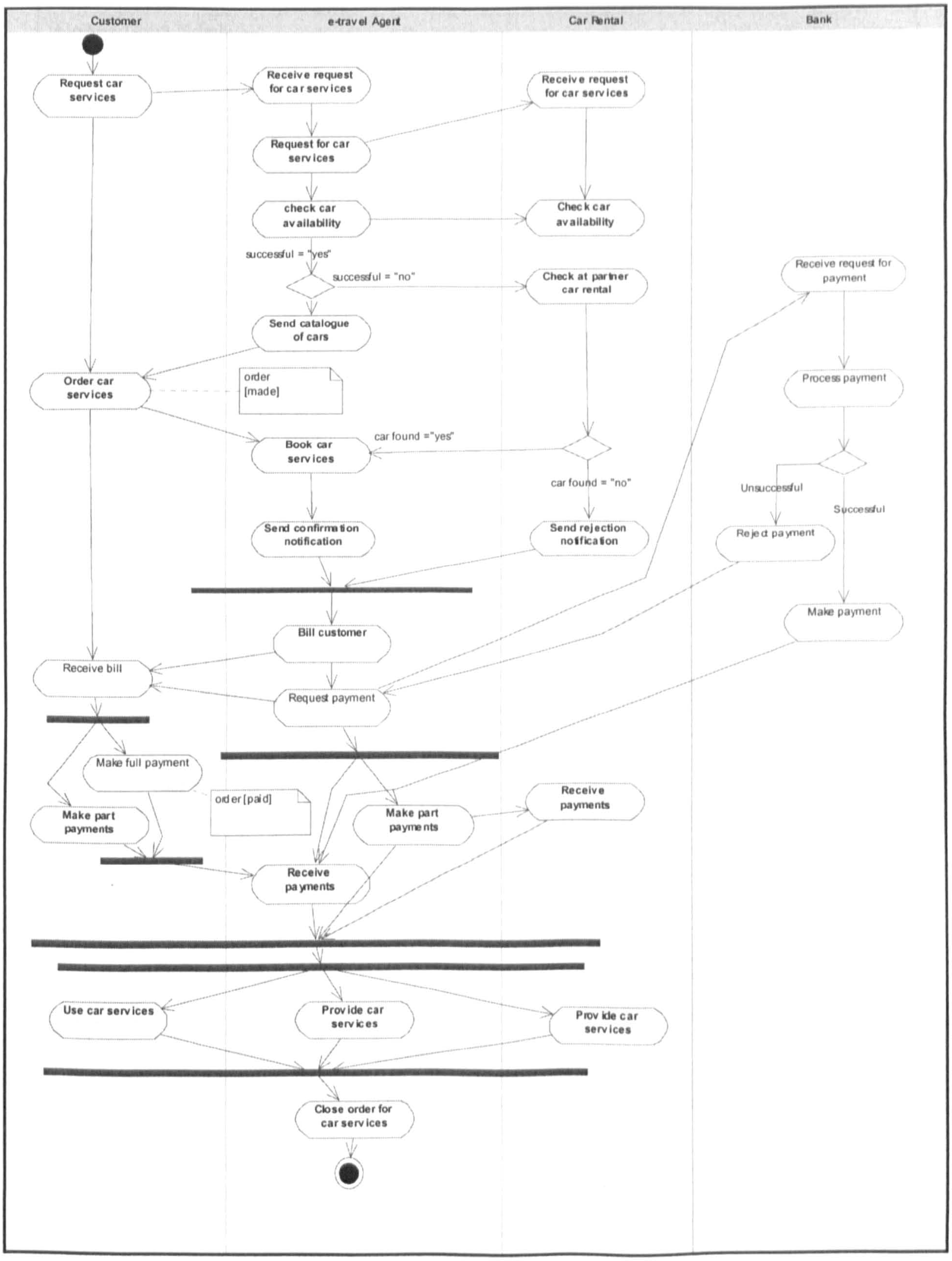

Figure H. 9: Booking car only business process workflow design pattern diagram

Name: Book Car only business process workflow design pattern template

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 12/05/2008

Intent: This workflow design pattern template allows the definition of a workflow schema for achieving the car only reservation business process

Classification: Sub workflow design pattern

Template:

```
Get request for travel
Get customer details
Check for Car availability
IF Car available
    THEN Book Hotel_Room
         Send confirmation letter
    ELSE
        Check car availability at Partner hotel
        IF car available
            THEN Book car
                 Send confirmation letter
                 Request payment
        ELSE
            Send rejection letter
        ENDIF
ENDIF
```

Keywords: Book Car only business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflow for different workflow problem within different business context or setting

Figure II. 10: Booking car only business process workflow design pattern template

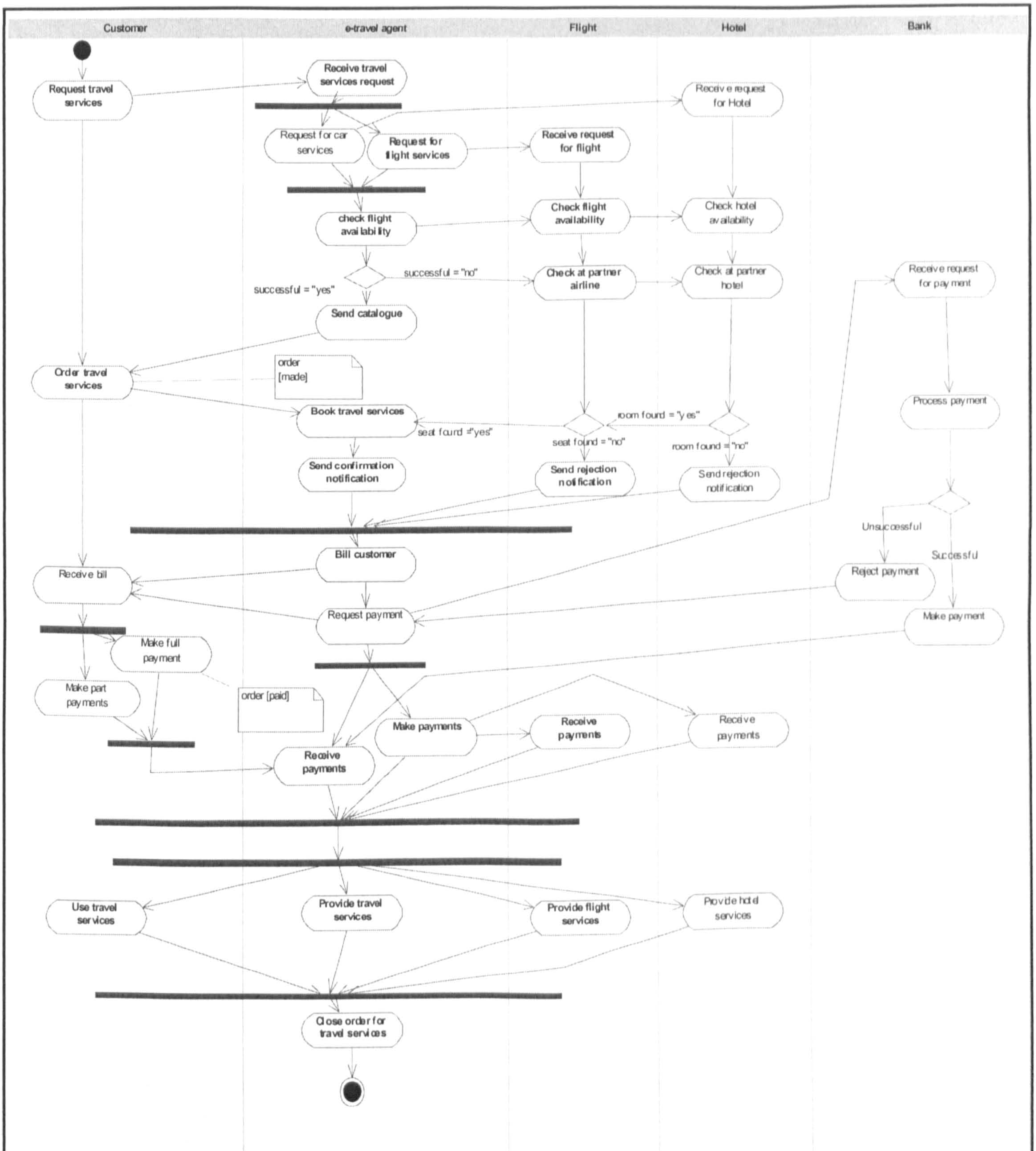

Figure H. 11: Booking Flight + Hotel business process workflow design pattern diagram

Name: Book Flight + Hotel business process workflow design pattern

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 12/05/2008

Intent: This workflow design pattern template allows the definition of a workflow schema for achieving the Flight + Hotel room reservation business process

Classification: Sub workflow design pattern

Template:

```
Get request for travel
Get customer details
Check flight availability
IF flight available
    THEN Book flight seat
            Send confirmation letter
    ELSE
        Check flight availability at Partner airline
        IF seat available
            THEN Book flight seat
                    Send confirmation letter
            ELSE
                    Send rejection letter
        ENDIF
ENDIF

Check  Hotel_Room availability
IF Hotel_Room  available
    THEN Book Hotel_Room
            Send confirmation letter
    ELSE
        Check Hotel_Room availability at Partner hotel
        IF Hotel_Room available
            THEN Book Hotel_Room
                    Send confirmation letter
                    Request payment
            ELSE
                Send rejection letter
        ENDIF
ENDIF
```

Keywords: Book Flight + Hotel business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflows schemas for different workflow problems within different business context or setting

Figure II. 12: Booking Flight + Hotel business process workflow design pattern template

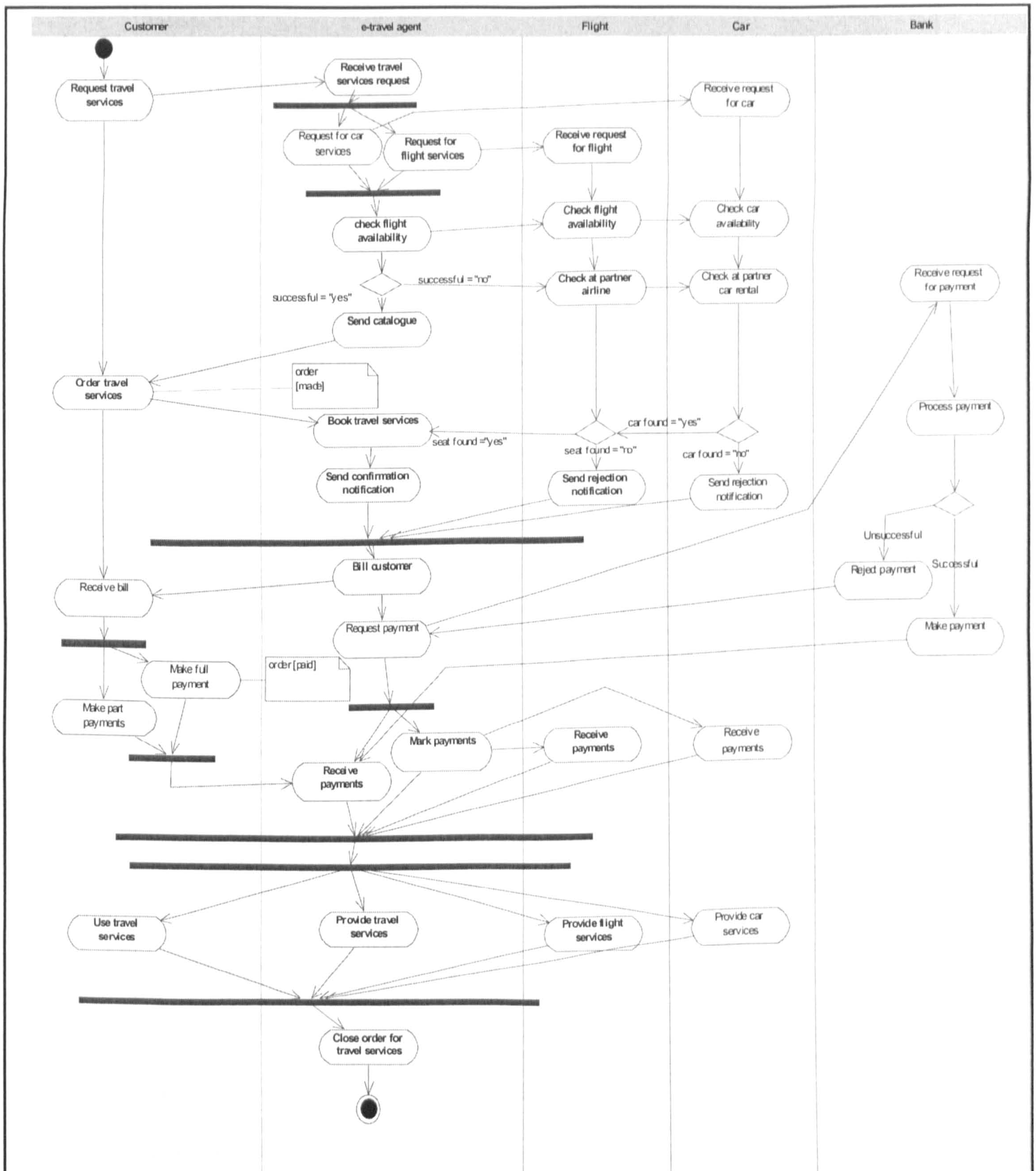

Figure H. 13: Booking Flight + Car business process workflow design pattern diagram

Name: Book Flihgt + Car business process workflow design pattern template

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 12/05/2008

Intent: This workflow design pattern template allows the definition of a workflow schema for achieving the Flight + Car reservation business process

Classification: Sub workflow design pattern

Template:

```
Get request for travel
Get customer details
Check flight availability
IF flight available
    THEN Book flight seat
         Send confirmation letter
    ELSE
         Check flight availability at Partner airline
         IF seat available
             THEN Book flight seat
                  Send confirmation letter
             ELSE
                  Send rejection letter
         ENDIF
ENDIF

Check for Car availability
IF Car available
    THEN Book car
         Send confirmation letter
    ELSE
         Check car availability at Partner car rentals
         IF car available
             THEN Book car
                  Send confirmation letter
                  Request payment
             ELSE
                  Send rejection letter
         ENDIF
ENDIF
```

Keywords: Book Flight + Car business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflow schemas for different workflow problems within different business context or setting

Figure II. 14: Booking Flight + Car business process workflow design pattern template

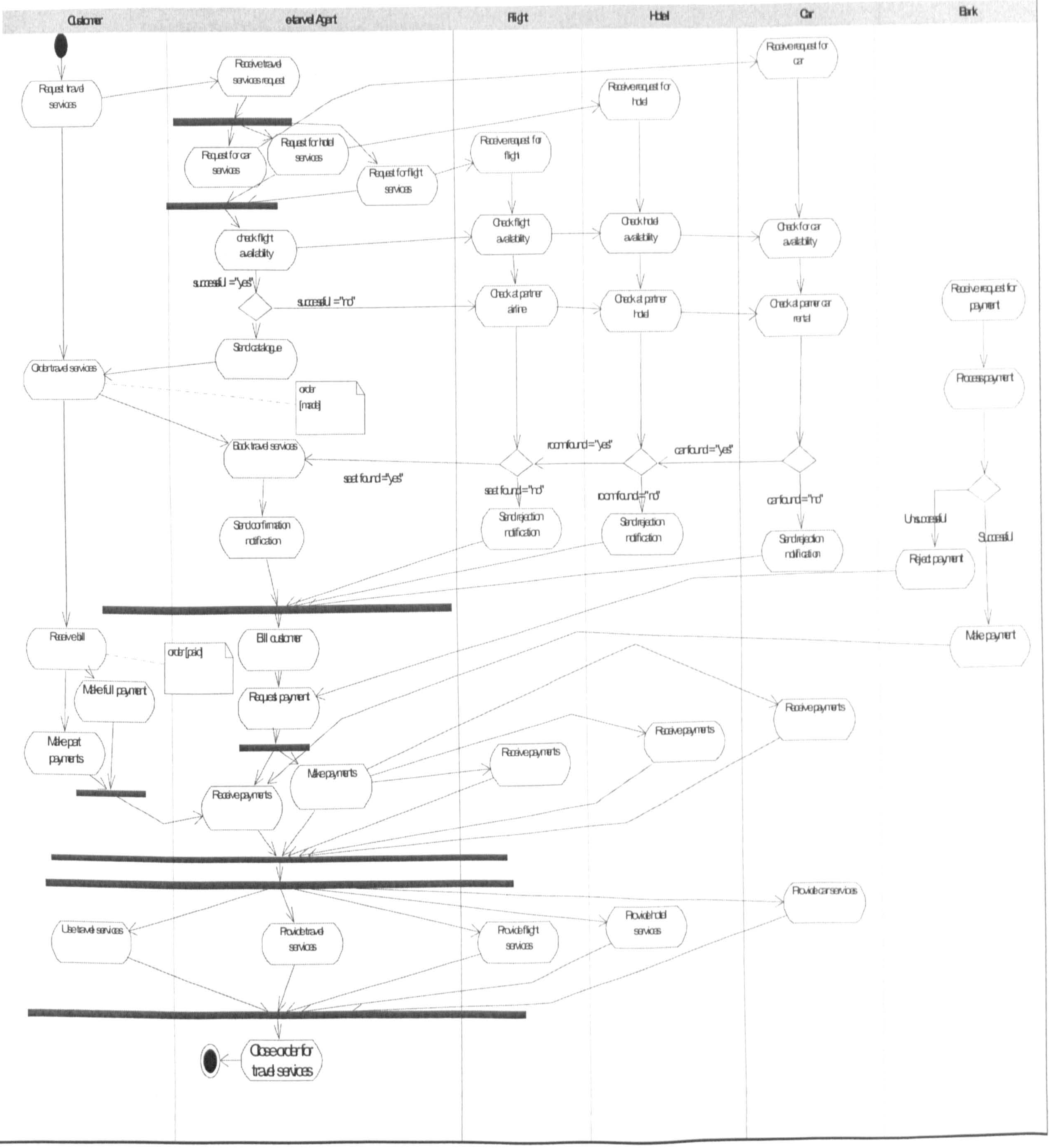

Figure H. 15: Booking Flight + Hotel + Car business process workflow design pattern diagram

Name: Book Flihgt + Hotel+ Car business process workflow design pattern

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Version: 1

Date: 12/05/2008

Intent: This design pattern template allows the definition of a workflow schema for achieving the Flight+Hotel+Car reservation business process

Classification: Workflow design pattern

Template:

```
Get request for travel
Get customer details
Check flight availability
IF flight available
    THEN Book flight seat
         Send confirmation letter
    ELSE
         Check flight availability at Partner airline
         IF seat available
             THEN Book flight seat
                  Send confirmation letter
             ELSE
                  Send rejection letter
         ENDIF
ENDIF
Check for Car availability
IF Car available
    THEN Book car
         Send confirmation letter
    ELSE
         Check car availability at Partner car rentals
         IF car available
             THEN Book car
                  Send confirmation letter
         ELSE
             Send rejection letter
         ENDIF
ENDIF
Check  Hotel_Room availability
IF Hotel_Room  available
    THEN Book Hotel_Room
         Send confirmation letter
    ELSE
         Check Hotel_Room availability at Partner hotel
         IF Hotel_Room available
             THEN Book Hotel_Room
                  Send confirmation letter
                  Request payment
             ELSE
             Send rejection letter
         ENDIF
ENDIF
```

Keywords: Flight + Hotel + Car business process workflow design pattern

Related to:

Guideline: This workflow design pattern template may be used to compose workflow schemas for different workflow problems within different business context/setting

Figure II. 16: Booking Flight + Hotel + Car business process workflow design pattern template

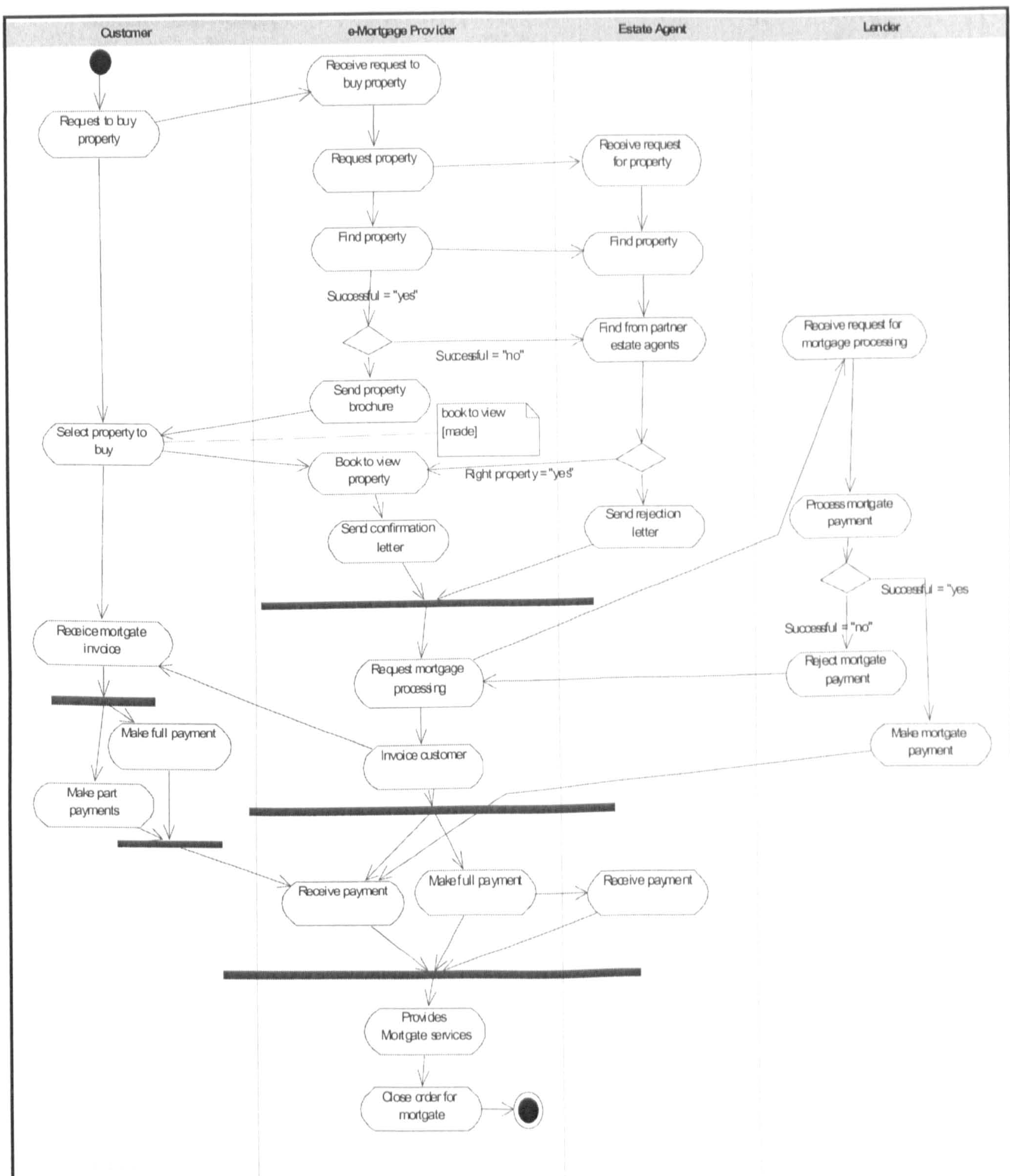

Figure H. 17: Mortgage processing business process workflow design pattern diagram

Name: Mortgage processing business process workflow design pattern template

Author: John Ndeta

Co-authors: Farhi Marir, Islam Choudhury, Peter Oriogun

Intent: This design pattern template allows the definition of a workflow schema for achieving the mortgage processing business process

Classification: Workflow design pattern

Template:

```
Get request to buy property
Get customer details
Find required property
IF Property available
    THEN Book to view property
             Send confirmation letter
    ELSE
            Find property from partner Estate agent
             IF required property available
                   THEN Book to view property
                            Send confirmation letter
                   ELSE
                            Send rejection letter
                   IF right property choice
                        THEN process mortgage payment
                                 Successful mortgage processing
                                 Provide mortgage services
                        ELSE
                                Reject mortgage application
                   ENDIF
             ENDIF
ENDIF
```

Keywords: Mortgage processing business process workflow design pattern

Related to:

Guideline: This design pattern template may be used to compose workflow for different workflow problem within different business context or setting

Figure II. 18: Mortgage processing business process workflow design pattern template