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**A Pattern –Based Approach for Business  
Process Modeling**

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*With love to my parents...*

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## LIST OF ABBREVIATIONS AND ACRONYMS

BPEL4WS	Business Process Execution Language for Web Services
BPM	Business Process Management
BPMI	Business Process Management Initiative
BPML	Business Process Modeling Language
BPMN	Business Process Modeling Notation
CIMOSA	Computer Integrated Manufacturing Open System Architecture
EER	Enhanced-Entity-Relationship
EBNF	Extended Backus-Naur Form
EPC	Event-Driven Process Chains
IT	Information Technology
MIT	Massachusetts Institute of Technology
OASIS	Organization for the Advancement of Structured Information Standards
OMG	Object Management Group
RUP	Rational Unified Process
TMBP	Transactional Metamodel of Business Process
TMWP	Transactional Metamodel of Workflow Process
UML	Unified Modeling Language
WfMC	Workflow Management Coalition
WIDE	Workflow on Intelligent Distributed database Environment Model
WSFL	Web Service Flow Language
YAWL	Yet Another Workflow Language



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## ABSTRACT

Modern organizations have demands related to the automation of their business processes since such processes are highly complex and need to be efficiently executed. Within this context, the workflow technology has shown to be very effective, mainly in the business process automation. However, as it is an emergent technology and in constant evolution, workflow presents some limitations.

Though several workflow (meta) models have been proposed in recent years, their sub-models for organizational structure aspects representation show limited power of expression. On the other hand, most of the current workflow modeling tools do not provide functionalities that enable users to define, query, and reuse workflow patterns properly. One of the main problems is the non-availability of a consolidated mapping between patterns based on recurrent functions found in business processes (e.g., request for activity execution, notification, decision, or approval) and workflow (meta) models or workflow modeling tools.

Relying on these problems, the first contribution of this thesis is a Transactional Metamodel of Business Process (TMBP) with support to organizational structure aspects. The metamodel makes feasible to create business (sub-)processes from the reuse of organizational –based workflow patterns. An additional feature of TMBP supports the generation of business (sub-)processes through the Business Process Execution Language for Web Services (BPEL4WS).

Other important contribution of this thesis is a set of workflow patterns represented as block activity patterns. Each pattern refers to a recurrent business function frequently found in business processes. The mining of 190 workflow processes of more than 10 different organizations has evidenced the existence of the set of workflow patterns with high support in the workflow processes analyzed. Moreover, it became clear through this study that the set of patterns is both necessary and enough to design all 190 processes that were investigated. As a consequence of the mining process, a set of association rules was identified too. The rules not only help to better define specific workflow patterns, but also combine them with existent control flow patterns. These rules can be useful for building more complex workflows.

**Keywords:** business and workflow process modeling, organizational structure aspects, workflow (meta) model, workflow pattern, block activity, workflow process mining, association rules.

# Uma Abordagem Baseada em Padrões para Modelagem de Processos de Negócio

## RESUMO

Organizações modernas apresentam demandas relacionadas à automação dos seus processos de negócio devido à alta complexidade dos mesmos e à necessidade de maior eficácia na execução. Neste contexto, a tecnologia de workflow tem se mostrado bastante eficiente, principalmente para a automatização dos processos de negócio. No entanto, por ser uma tecnologia emergente e em evolução, workflow apresenta algumas limitações.

Ainda que diversos (meta) modelos de workflow tenham sido propostos nos últimos anos, seus sub-modelos para representação dos aspectos estruturais da organização apresentam baixo poder de expressão. Além disso, a maioria das ferramentas para modelagem de workflow não provêm funcionalidades para definição, consulta e reuso de padrões. Um dos principais problemas é falta de um mapeamento consolidado entre padrões de funções recorrentes em processos de negócio (ex: solicitação de execução de atividade, aprovação de documentos) e (meta) modelos e/ou ferramentas para modelagem de processos de negócio e workflow. Além disso, a maioria das abordagens em padrões de workflow não exploram a completude e necessidade dos seus padrões para modelagem de workflow.

A primeira contribuição desta tese é um Modelo Transacional de Processos de Negócio (MTPN) com suporte aos aspectos estruturais da organização. O metamodelo possibilita a criação de (sub-)processos de negócio a partir do reuso de padrões, principalmente com base nestes aspectos. Adicionalmente, o metamodelo sugere a geração automática de padrões através da Linguagem de Execução para Web Services (BPEL4WS).

Outra importante contribuição da tese é um conjunto de padrões de workflow representados como atividades de bloco. Cada padrão descreve uma função recorrente em processos de negócio. A mineração de 190 processos de workflow de mais de 10 organizações diferentes provou a existência dos padrões com alto suporte nos processos de workflow analisados. Além disso, o estudo mostrou que o conjunto de padrões é suficiente e necessário para modelar todos os 190 processos investigados. O estudo também resultou em um conjunto de regras de associação. As regras não apenas contribuem para uma melhor definição dos padrões de atividade de bloco, mas também para a combinação destes com padrões de controle de fluxo.

**Palavras-Chave:** modelagem de processos de negócio e workflow, aspectos estruturais da organização, (meta) modelo de workflow, padrões de workflow, mineração de processos de workflow, regras associativas.

# 1 INTRODUCTION AND MOTIVATION

A business process is a set of either one or more dependent procedures or activities that are structured in some way in order to, collectively, fulfill a business objective of some organization (FISCHER, 2001), (WFMC, 1999). Organizations achieve their business goals through the execution of business processes. In this context, a business sub-process is a process integrated to as well as controlled by another workflow process.

Business processes have an important role in how organizations are structured. Most of the researchers and professionals agree that the designing of an organizational structure comprises at least two steps (DAVIS, 1996). In the first step, the business processes executed in the organization are identified. In the second step, concerning the business processes identified, specific values are assigned to a set of organizational structural aspects (e.g., scalar chain, work coordination mechanism and decision-making structure) (DAVIS, 1996), (MINTZBERG, 1995). It is important to observe that in a real organization these steps may be executed repeatedly. In most of the cases, the organization must continuously evaluate and adapt its structure according to its business processes (JONES, p.33, 2001).

The workflow technology, through the automation of business processes executed in organizations contributes to the reduction of costs, execution time, errors as well as redundancy in the processes execution. At the same time, it improves the control over them. These advantages has drawn continuing interest of academic and scientific communities to the workflow technology (IOCHPE, 2001), (THOM, 2005a).

Currently, different consortia including the Business Process Management Initiative (BPMI) (OMG, 2005b), (OMG, 2005c), (OMG, 2006), the Workflow Management Coalition (WfMC) (HOLLINGSWORTH, 1995), (WfMC, 2005) the Workflow on Intelligent Distributed Database Environment Model (GREFEN, 1999) and the Organization for the Advancement of Structured Information Standards (OASIS, 2006) have proposed not only (meta) models but also notations and languages for both business and workflow process modeling in order to improve the design phase of the workflow project. However, these (meta) models, notations and languages present some limitations.

One of the limitations refers to the limited use of patterns based on organizational structure aspects. The work presented in (THOM, 2002), (THOM, 2003), (THOM, 2005a) shows that there exists a strong relationship between one or more aspects of the organizational structure (e.g., centralization on decision-making) and specific workflow constructs (e.g., document approval process). In a document approval process, for example, an approval activity is repeated according to the level of centralization on decision-making (less or more centralized) in high positions (e.g. manager, president) of the organization. In this context, the knowledge about organizational structure aspects is

fundamental to better represent the real business processes as they are executed in the organization (IOCHPE, 2002).

Other problem related specifically to existent (meta) models is that their sub-models to organizational structure aspects representation show limited power of expression. Most of them just consider the use of such aspects in the assignment of performers to workflow activities execution (e.g., the Workflow Management Coalition Reference Model (HOLLINGSWORTH, 1995), the Workflow on Intelligent Distributed Database Environment Model (GREFEN, 1999 p. 39)). Moreover, though numerous patterns related to control flow (AALST, 2003a), data flow (RUSSELL, 2004a), workflow resources (RUSSELL, 2004b) and exception handling (RUSSELL, 2006) have been introduced so far, there is not yet a consolidated mapping of activity patterns (e.g., activity request execution, information request, document approval) onto workflow (meta) models and workflow modeling tools. One of the most expressive approaches is proposed in the scope of the Oracle Business Process Execution Language for Web Services (BPEL4WS) (BRADSHAW, 2005), (EINDHOVEN, 2005).

Going further into details, Business Processes and respective workflow models frequently include a variety of fragments which can be understood as self-contained activity blocks with a specific and well-defined semantics. In particular, a certain *process fragment* (or *recurrent business function*) may occur several times within one process definition. At runtime, in turn, different logical copies of the same process *fragment* may have the same or different parameter values. As an example consider the workflow process to collect material to a newsletter in Figure 1.1. It includes the following partial order of activities: (a) send to the Editor the material for the Edition; (b) review section of the Newsletter and; (c) increases activity priority and notify delay in its execution. This sample process comprises *fragments* which are related to the specific process structures (or patterns) such as *request for activity execution* (either activity *a* or *c*) and *approval* (activity *b*). The semantics and benefits of these patterns will be explained later in this thesis.

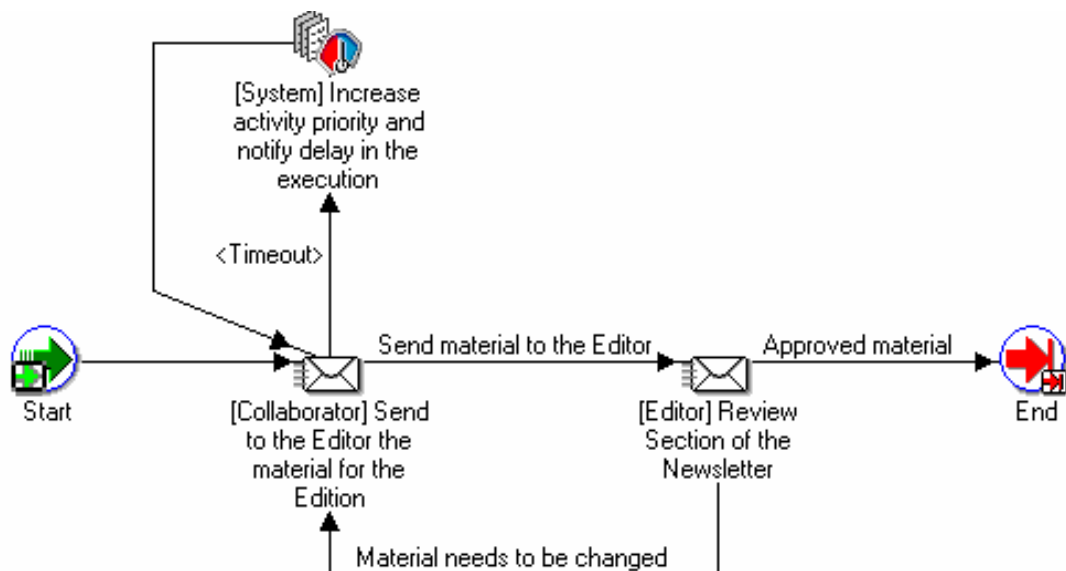


Figure 1.1: Example of a process to collect material to a newsletter

Figure 1.2 shows another workflow process concerning the evaluation of the cash amount application of a supermarket. This process comprises the following partially ordered activities: (a) request for additional approval (yes or no), (b) evaluation of the cash amount application (resulting in either approval or disapproval), and (c) notification about evaluation delay to the administrator. In particular, the workflow process contains fragments which are related to the activity patterns *decision* (activity a), *approval* (activity b), and *notification* (activity c) (THOM, 2006a), (THOM, 2006b).

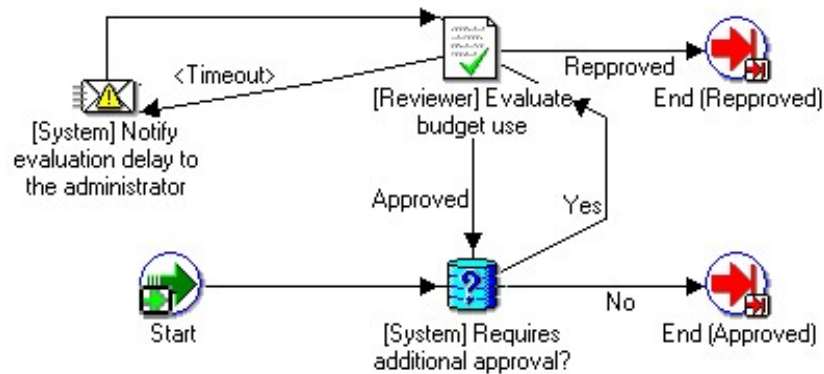


Figure 1.2: Example of evaluate of cash amount application of a supermarket

Though one can precisely characterize their semantics, there is only little research relating this kind of process structures to workflow patterns. Usually, such process *fragments* (FLORES, 1988), (MEDINA-MORA, 1992), (MALONE, 2004), (MUEHLEN, 2002), (BRADSHAW, 2005) are re-designed for practically every workflow application. Such a procedure can be consider inefficient, error-prone undesirable from a maintenance perspective. Additionally, there is non-known work evidencing the existence of recurrent patterns in real workflow applications as well as their necessity and completeness for the business and workflow process modeling. Beyond that, contemporary workflow modeling tools do not provide functionalities that enable users to define, query, and reuse such patterns in a proper way.

## 1.1 Goals

This thesis has three main goals:

1. to investigate patterns based on organizational structure aspects;
2. to develop a business process metamodel with support to organizational structure aspects as well as a catalogue of patterns;
3. to search patterns based on different kinds of business process.

In order to achieve the first goal, some of the rules introduced in (THOM, 2002), (THOM, 2003) were represented as organization –based workflow patterns. Each rule expresses the relationship between either one or more aspects of the organizational structure and specific workflow (sub-)processes. Afterwards, the existence of the patterns was evidenced in a case study where 33 workflow processes from one organization were analyzed.

At this stage of the research it was observed that most of the existent (meta) models and notations for both business process and workflow process modeling use knowledge



about structural aspects in a limited way. Furthermore, none workflow (meta) model integrating a catalogue of patterns was found. These facts were the main motivations for the development of the Transactional Metamodel of Business Processes (TMBP) (THOM, 2005b).

TMBP is a derivation of the Transactional Model of Workflow Processes (TMWP) (GREFEN, 1999) with support to structural aspects (THOM, 2005a), (THOM, 2005b). The reasons why TMWP was chosen in spite of other existent (meta) models are discussed in Chapter 5. The main objective of TMBP was not only to enhance the expression power of the organizational sub-model but also to provide a catalogue of business and/or workflow patterns.

Such catalogue can be used in the development of a repository of patterns integrated to some workflow design tool. In order to implement the repository as well as to test the catalogue, it would be necessary to define mechanisms not only to store, but also to query and classify patterns in the catalogue (EBXML, 2001), (GAMMA, 2000), (AALST, 2005b), (EINDHOVEN, 2005). However, at this point of the research some limitations were faced: a) difficulty to obtain a large set of organization –based workflow processes that could lead to the discover of new patterns and; b) difficulty to get detailed knowledge about organizational structure aspects.

Considering these difficulties, two alternatives were defined to continue the research:

- a. to continue with the catalogue development based on the existent set of organization –based patterns as well as other existent patterns (e.g., (AALST, 2003a), (RUSSELL, 2004a), (RUSSELL, 2004b), (MALONE, 2004));
- b. to search patterns based on recurrent functions frequently found in business processes.

The second alternative showed to be the most promising mainly because patterns based on recurrent business functions have not been extensively explored. Furthermore, they could be identified in elements of workflow languages and tools. Thus, a study about different kinds of business processes was conducted. Afterwards, the workflow processes were represented as block activity patterns.

Through the cooperation with a workflow company 190 real workflow processes from more than 10 organizations were obtained. These workflow processes were mined in order to verify whether they could really be considered as patterns with high probability of reuse in business as well as workflow process design.

## 1.2 Contributions

In summary, the main contributions of this thesis are:

- A transactional metamodel (TMBP) with support to organizational structure aspects and business process patterns (THOM, 2004), (THOM, 2005b);
- A first insight towards a methodology for business process design. The methodology includes the mapping of workflow process to Business Process Execution Language for Web Services (BPEL4WS) process (THOM, 2005a).
- A set of workflow patterns represented as block activity patterns. Each pattern represents a recurrent business function frequently found in business processes.

The patterns are classified as follow: *organization –based workflow patterns* (patterns related to structural aspects). *domain application –based workflow patterns* (patterns feasible to be present in specific application domains) and *recurrent business functions –based workflow patterns* (patterns related to recurrent functions in business processes) (THOM, 2002), (THOM, 2003), (THOM, 2005a), (THOM, 2006a), (THOM, 2006b).

- Through the mining of 190 workflow processes from more than 10 different organizations related to different application domains, evidences that the workflow patterns exist in real workflow application with high probability. Furthermore, the set of patterns showed to be both necessary and sufficient to design all 190 processes analyzed.
- Other result of the workflow process mining was a set of association rules that not only helps to better define the workflow patterns being proposed but also combine them with existent control flow patterns.

### 1.3 Organization of the Text

The outline of this thesis is organized as follows:

- Chapter 2 presents related works. The most well known approaches on (meta) models, notations and patterns for business and workflow process modeling are reviewed and compared with the approach being proposed in this thesis.
- Chapter 3 presents the key terminology in Business Process Management (BPM) as well as workflow used in this text.
- Chapter 4 presents a set of organization –based workflow patterns. It also describes the methodology used to discover the patterns. Additionally, a case study is presented in order to prove the existence of the workflow patterns in a real workflow application.
- Chapter 5 describes a Transactional Metamodel of Business Process (TMBP). The metamodel includes both an organizational sub-model with support to structural aspects and a pattern catalogue sub-model. The Chapter also introduces a methodology for business and workflow process modeling based on TMBP.
- Chapter 6 presents a study about different kinds of business processes. Based on this study, a classification of patterns is introduced too. The classification comprises three categories of patterns (organization –based patterns, domain application –based patterns and recurrent process functions –based patterns). Moreover, it presents the patterns inherent to each category represented as block activity patterns.
- Chapter 7 brings the results of a case study where 190 workflow processes were mined in order to prove the existence of workflow patterns. Furthermore, it presents a set of rules that define the workflow patterns and combine them with existent control flow patterns.
- The work is concluded in Chapter 8 with a summary of main contributions, list of publications and discussion of future work.

## 2 RELATED WORK

Dozens of approaches concerning (meta) models and notations for both business and workflow process modeling have been proposed in the last years. Moreover, there exist some consolidated approaches about workflow patterns. This Chapter reviews some of these approaches comparing them with the approach being proposed in this thesis.

### 2.1 Workflow (Meta) Models

Research on workflow design has focused in the last years mainly on modeling issues. Little effort has been devoted to increase the expression power of the organizational sub-models. Moreover, most of the existent notations and (meta) models for both business process and workflow process modeling do not support the reuse of workflow patterns. This Section discusses some of the existent works in this context.

#### 2.1.1 The Workflow on Intelligent Distributed Database Environment Model

WIDE is the acronym for Workflow on Intelligent Distributed database Environment. It is a project in the fourth ESPRIT framework, a European IT project partially funded by the European Commission in 1995. The overall goal of the WIDE project was to develop extended database technology to support process-centered application environments, like workflow management systems (GREFEN, 1999, p. 14).

One of the most important results of the project is the WIDE model. The model is structured into three different sub-models (GREFEN, 1999 p. 39), (GUTIÉREZ, 1997):

- the *organization model*: describes the part of the organization involved in workflow execution;
- *information model*: describes the information items that are managed by the workflow engine) and;
- *process model*: defines how the partial order of activities within a process. It also defines how the organization and information models are combined with the process model.

The project also proposes a reference model for the specification of patterns. The model, as shown Figure 2.1, includes the following elements (CASTANO, 1997):

- the *specification pattern*: description of either an exception or application, which includes a set of textual fields and specific aspects, related to the implementation of the pattern in the Chimera language. Chimera is a conceptual language for specifying object-oriented rule-based applications;

- *sample usage patterns*: specific instantiations of patterns related to an application domain;
- *template interface*: it is the input for generating the specification in Chimera according to the pattern template.

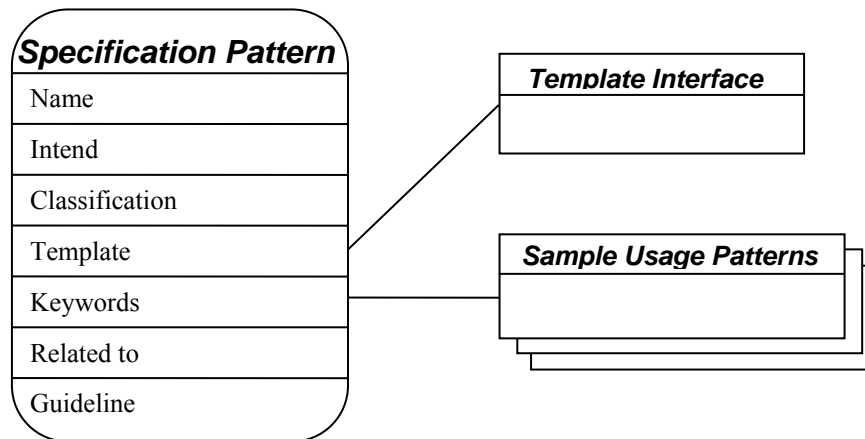


Figure 2.1: WIDE reference model

In general, the main focus of the WIDE project was on a methodological approach to design workflow processes. Thus, the organizational model is used to assign performers to workflow activities. The organizational sub-model proposed in this thesis supports the representation of structural aspects which may be used to define the structure of specific workflow (sub-)processes (e.g., the structure of a document approval process). On the other hand, while the patterns proposed by WIDE represent exception handling which may occur during the execution of a workflow instance, the patterns proposed in this thesis focus specially the design time. In this context, each pattern represents a recurrent business function frequently found in business processes (e.g., notification, decision, approval, information request).

### 2.1.2 The Reference Model of the Workflow Management Coalition

The Workflow Management Coalition (WfMC) founded in August 1993, is a non-profit, international organization of workflow vendors, users, analysts and academic groups (FISCHER, 2001). The main goal of the Coalition is to develop standards for the workflow area.

The WfMC proposes a Metamodel (cf. Figure 2.2) for workflow process definition. As shown Figure 2.2, the *Workflow Process Definition* entity describes the process itself. It consists of one or more activities (*Workflow Process Activity*). Each activity represents the work to be performed by a workflow participant (*Workflow Participant Specification*). The metamodel defines three kinds of activities: (*Sub-*)*process*, *atomic* or *Loop*. Activities are connected to one another through control flows (*Transition Information*).

The *Workflow Application Declaration* entity describes the IT applications invoked during the workflow execution. The *Workflow Relevant Data* entity, in turn, defines the data both created and used within a process execution. It may contain *System & Environmental Data* that are most of the times maintained by the workflow

management system (WfMS). Finally, the *Organizational Model* may be referenced by the *Workflow Participant Specification*.

The *Organizational Model* (cf. Chapter 3, Figure 3.2) in this context is only used as a reference to define the participants in charge of the activities execution. Furthermore, the Metamodel (cf. Figure 2.2) has no support to workflow patterns. Other difference from the metamodel being proposed in this thesis refers to the business transaction concept that is not applied in the WfMC metamodel. Such concept helps to show the state transformations of a workflow object.

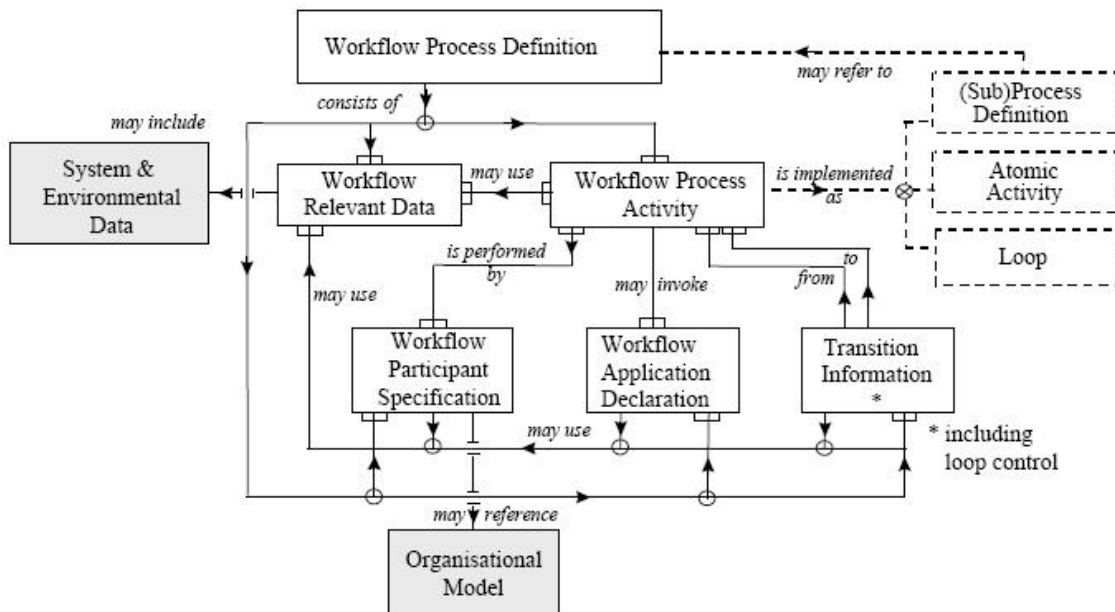


Figure 2.2 : WfMC reference metamodel

### 2.1.3 The Business Process Modeling Notation

The Business Process Modeling Notation (BPMN) was developed by the Business Process Management Initiative (BPMI). The primary goal of BPMN is to provide a notation readily understandable by all business users, from business analysts to technical developers as well as to business people who will manage and monitor those processes (WHITE, 2004a), (OWEN, 2003).

Based on their notation, BPMI proposed the Business Process Definition Metamodel, which combines the BPMN elements one to another as well as with specific control flow and dataflow patterns (OMG, 2005c). Besides that, BPMI developed Business Motivation Model (OMG, 2005b). The model provides a structure for developing, communicating, and managing business plans in an organized manner. Its main functionalities are:

- identify factors that motivate the establishing of business plans;
- identifies and defines the elements of business plans and;
- indicates how all these factors and elements interrelate.

BPMN is becoming one of the most popular and used notations for business process modeling. However, workflow tools based on BPMN (e.g. Intalio) do not support the design of business and workflow process from patterns reuse. BPMN elements are important to add detailed semantic to the processes. Thus, they must be used as a complement to the patterns being proposed in this thesis.

#### **2.1.4 Other Initiatives**

Besides the above-mentioned approaches there are several other proposals including the Computer Integrated Manufacturing Open System Architecture (CIMOSA) (BRUNO, 1999), (CIMOSA ASSOCIATION, 1996), the Activity Diagrams of UML (FOWLER, 2000) and the model of Casati (CASATI, 1995).

In (MUEHLEN, 1999), a metamodel for the evaluation of different workflow management systems is described. Additionally, an organizational reference model to help users specify their requirements for a workflow management system is introduced.

In (EINDHOVEN, 2006) is proposed an interesting pattern meta-model based on existent workflow patterns (e.g., control flow patterns (AALST, 2003a), dataflow patterns (RUSSELL, 2004a), resource patterns ((RUSSELL, 2004b)). The metamodel describes patterns that belong to different perspectives for workflow modeling in an implementation-independent way. The authors argue that the metamodel can be used to implement a pattern repository to support the modeling phase of the workflow project.

Although the majority of these metamodels is largely recognized by BPM and workflow community, the use of organizational structural aspects is of limited used. Most of them use such aspects only to define the activity performers. Moreover, they do not comprise a workflow pattern sub-model that could be used to implement a pattern repository. The pattern meta-model proposed by (EINDHOVEN, 2006) is not sufficiently integrated with the both business process and organizational sub-models.

## **2.2 Patterns for Workflow Design**

A pattern is the abstraction from a concrete form which keeps recurring in specific non-arbitrary contexts (GAMMA, 2005). Patterns capture existing, well-proven experience in software development and help to promote good design practices (BUSCHMANN, 96, p.19), (ERIKSSON, H., 2001). They have been used for many different domains ranging from organizations and processes to teaching and architecture. However, patterns for business and workflow(sub-) processes modeling are still subject of discussion and research. This section reviews some works in this context comparing them with the patterns being proposed in this thesis.

### **2.2.1 Workflow Patterns**

With the purpose of systematically address workflow requirements, from basic to complex, in order to identify useful routing constructs Will van der Aalst has proposed 21 workflow patterns for describing process behavior (AALST, 2002), (AALST, 2003a), (AALST, 2005a). Each pattern represents a routing element (e.g., sequential, parallel and conditional routing) to be used in workflow definitions (c.f. Chapter 3, Section 3.6). In the meantime these workflow patterns are additionally used for evaluating workflow languages and workflow modeling tools (AALST, 2003b).

Recently, a set of 39 workflow data patterns was proposed with the aim at capturing the various ways in which data can be represented and used in workflow definitions (RUSSELL, 2004a). The patterns are based on a series of characteristics that occur repeatedly in different workflow modeling paradigms. Examples are the data visibility (relating to the manner in which data elements can be viewed by various components of a workflow process) and the data interaction (focusing on the manner in which data is communicated between active elements within a workflow).

In (RUSSELL, 2004b) is presented a set of resource workflow patterns, where each pattern describes a way through which resources are represented and utilized in workflows. In this context, a resource is an entity that is capable of doing work. It can be either human (e.g., a worker) or non-human (e.g., equipment). Examples of resource patterns are *Direct Allocation* (used to specify at design time the identity of a resource that will execute a task) and *Role-Based Allocation* (used to specify at design time that a task can only be executed by resources that correspond to a given role).

In (RUSSELL, 2006) it is presented a pattern-based classification framework for characterizing exception handling in workflow systems. The framework has been used to examine the capabilities of eight workflow systems and business process modeling and execution languages. As a result of the examination, the authors point out the limited support for exception management in these workflow systems.

Although the workflow patterns proposed in the present work have as main focus the business and workflow process modeling, they differ from the patterns mentioned above because they are based on specific business functions frequently found in business processes. Moreover, the existence of these patterns was proved in this work with high-probability through the mining of a large set of real workflow processes (cf. Chapter 7). In this context, they showed to be both necessary and enough to the modeling of all workflow processes analyzed. Another difference is that the workflow patterns being proposed in this thesis focus specially on the workflow process design in the level of the business process.

### **2.2.2 The Interaction Patterns of BPEL and the Oracle Workflow Patterns**

The Business Process Execution Language (BPEL) is an XML-based language for enabling task sharing across multiple enterprises with a combination of Web Services (BRADSHAW, 2005). BPEL provides enterprises with an industry standard for business process orchestration and execution. It was created by an ad hoc collaboration between BEA Systems, IBM, and Microsoft, and has been submitted to OASIS (HOHPE, 2004), (CHRISTENSEN, 2001).

In (BRADSHAW, 2005) it is proposed common interaction patterns between a BPEL process and another application. Examples of these patterns are the *One-Way Message* (where the client sends a message to the service, and the service does not need to reply) and the *Asynchronous Interaction with Timeout* where a client send a request to a service and waits until it receives a reply, or until a certain time limit is reached.

Some of the interaction patterns, in special the two examples mentioned above are semantically similar with the workflow patterns being proposed in this work (e.g. *unidirectional and bi-directional performative patterns* (cf. Chapter 6)). However, while the interaction patterns focus on the integration of BPEL processes and other applications, the workflow patterns presented in this thesis focus on atomic structures frequently found in business processes. Another difference is that the existence of the

workflow patterns proposed in this work was proved through the mining of a set of 190 workflow processes related to different application domains, which let clear that the set of patterns was sufficient to model all workflow processes (cf. Chapter 7).

The Oracle BPEL Process Manager (BRADSHAW, 2005) provides a library of workflow patterns. Based on business requirements the user selects the pattern that best match to those requirements. Some of these patterns (e.g., the *For your information task* oracle pattern which is related to the *notification pattern* proposed in Chapter 6) present similarities with the workflow patterns proposed in this work. However, there is no known study stating whether the set of oracle workflow patterns are both necessary and sufficient to describe a large variety of workflow processes. Additionally, the activity patters proposed in this thesis are theoretical based in existent types of business processes found in the literature.

Table 2.1 summarizes some of the relations between the pattern approaches reviewed in this Section and the workflow patterns proposed in this work (cf. Chapter 6). The table focuses on the level of abstraction as well as on semantic similarities.

Table 2.1: Related works with the patterns approach being proposed in this work

<b>Main pattern approaches reviewed in this Chapter</b>		<b>Possible relation with the workflow patterns being proposed in this work</b>
Control Flow patterns		Similar level of abstraction but different purpose
Data Patterns		Different purpose
Exception Handling patterns		Different level of abstraction and purpose
Interaction Patterns	One-Way message	Similar with the Unidirectional Performative pattern
	Asynchronous Interaction without timeout	Similar with the Bi-directional Performative pattern
Oracle BPEL Library	For your information pattern	Similar with the notification pattern

### 2.2.3 Other Initiatives

SAP has developed a cross-application engine called SAP Business Workflow (SAP, 2006). This tool enables the process-oriented integration of business objects and applications including a workflow wizard with workflow templates and process reference models. Similarly, in 1991 the Massachusetts Institute of Technology (MIT) started its development of the *Process Handbook*, an online knowledge base with entries for more than 5000 business together with an extensive set of software tools for viewing and modifying the knowledge base (MALONE, 2004). The approach includes generic models of typical business activities (e.g., buying and selling), specific case examples of interesting solutions companies have applied so far, and frameworks for classifying business knowledge. Following this rationale, the ECOMO research project developed a process library consisting of patterns for procurement and sales process (FRANK, 2004).

The developers of this library include inbound logistics as part of the procurement function, and outbound logistics as well as service processes as part of the sales function. Note that, the workflow patterns being proposed in this thesis are considered



by their proponents as being more application-independent when compared to the patterns provided by SAP, MIT and ECOMOD (FRANK, 2004). However, the mining results (cf. Chapter 7) have shown that, in principle, most of these patterns are suitable to be used in whatever application domain.

In (COOPLIEN, 2004) it is proposed four interrelated architectures of an organization. Each one has its own pattern language. For example, while the *Piecemeal Growth Pattern Language* offers patterns to strengthen and tune an organization using feedback and insight the *Organizational Style Pattern Language* offers patterns of roles and communication links between different organizations. Even though most of the patterns these Pattern Languages comprise are somehow connected with organizational structure aspects their purpose (i.e., software development) is different from the purpose of the of the organizational –based workflow patterns being proposed in this thesis.

Eriksson (2001) also presents an approach concerning a set of business patterns. The patterns address problems within the business domain, typically analysis situations such as how to model and structure business resources that include invoices, organization, information, and so on. Business patterns also address how to organize and relate business processes, business rules, corporate visions, and goals. The most interesting patterns in the context of this thesis are the process patterns. Process patterns are behavioral and functional patterns whose intention is to increase the quality of workflow models and other process-oriented models. The process patterns differ from the patterns being presented in this thesis because their interest is on how to achieve specific goals with a set of predefined resources and rules. Furthermore, there is non-known study proving how necessary are these process patterns for both business process and workflow process design.

### 2.3 Final Considerations of this Chapter

This Chapter reviewed a large body of methodological approaches to workflow design, each of them based on either particular (meta) models or business process notations. Although most of them bring notable contributions to both BPM and workflow areas none of them achieve broad usage of organizational structure aspects as well as supporting for workflow patterns reuse.

Besides, this Chapter presented extensive approaches concerning workflow patterns. Some of these not only focus on the improvement of the modeling phase of the workflow project but also on the comparing of workflow modeling languages. Although most of these approaches present significant contributions in the context of workflow patterns reuse, they differ from the workflow patterns proposed in this work in the following:

- The approaches do not explore patterns based on organizational structure aspects.
- Workflow patterns based on recurrent functions frequently found in business processes are explored in a limited way. None of the approaches let clear that the patterns they propose are both sufficient and necessary to design a large variety of workflow processes related to different application domains.

The next Chapter presents core background concepts in BPM and workflow areas.

## 3 CORE WORKFLOW CONCEPTS

According to the Workflow Management Coalition (WfMC) (1999), a workflow process is the automation of a business process. Based on a metamodel, a workflow process groups all elements required for the business process automation. These elements comprise not only dynamic aspects (e.g., tasks/activities and transitions) but also static aspects (e.g., data, application and participants). Therefore, a workflow process model can contain aspects not represented in the corresponding business process model (FRANK, 2004).

The execution as well as the coordination of a business process may be either partially or fully automated by a Workflow Management System (WfMS) (WfMC, 1999). A WfMS is a system that (partially) automates the definition, creation, execution, and management of work processes through software use. Such software is able to interpret the process definition, interact with workflow participants and invoke tools and applications required for an activity execution. In addition, the system provides the ability of monitoring the progress of the activities execution throughout the process generating statistics on how efficient is the execution.

The Workflow Management Coalition relates a WfMS (WFMC, 1998) to three functional levels:

- the Process definition level concerned with defining, and possibly modeling, the workflow process and its constituent activities;
- the Run-time control level concerned with managing the workflow processes in an operational environment and sequencing the various activities to be handled as part of each process;
- the Run-time interaction level with human participants and application tools for processing the various activity.

The following sections present an overview of further workflow concepts used throughout this text.

### 3.1 Activity, Role, Participant and Work List

A description of a piece of work forming a logic step within a process is called *activity* or *task* (WfMC, 1999). An activity may be manual or automated. A manual activity does not support computer automation (cf. Figure 3.1 Evaluate request of price adjustment). An automated one is capable of computer automation through a WfMS (cf., Figure 3.1 the activity Is it a shopping order?).

Each activity is assigned to a specific role (cf. Figure 3.1, *System* and *Manager*). A role is a group of actors or participants, which has a specific set of attributes, qualifications and/or skills (WfMC, 1999), (GREFEN, 1999).

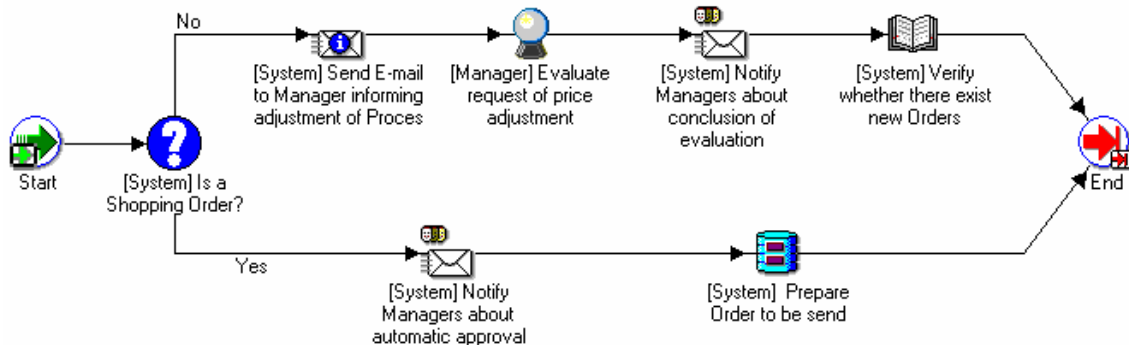


Figure 3.1: Activity and role examples

The representation of the work to be processed by a workflow participant in the context of an activity within a process instance (a single enactment of a process) is called *work item*. The work items are presented to the participant via a *work list*.

Figure 3.2 shows the organizational model proposed by the WfMC (WfMC, 1998) through EER ((Enhanced-Entity-Relationship) notation. The model illustrates that a Workflow Participant may be an Organizational Unit, Person/Human, Role/function or Resource (e.g., program or machine). The *Organizational Unit* lists the members of an org. unit or the hierarchical ordered of superior units. It is related to the *Person/Human* entity that describes both all roles a human can assume and all Org. Units he belongs to. Finally, the *Person/Human* refers to the work functions a person has within an organization (*Role/Function*).

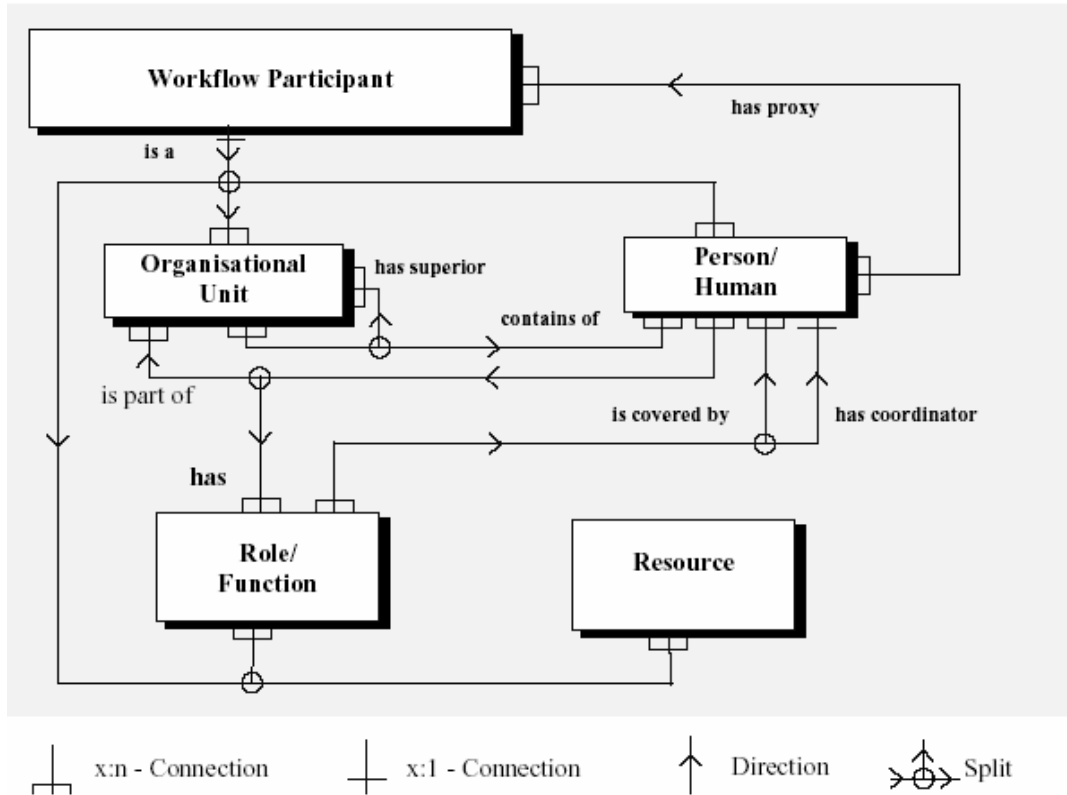


Figure 3.2: Organizational model of WfMC

### 3.2 Block Activity

An activity set (or embedded sub-process) denotes a self-contained set of activities and control transitions (i.e., control edges), which can be modeled as a block activity (WfMC, 1999). Block execution starts with the first activity of the block, which has no incoming transition, and continues with the other sub-activities according to their partial order. Finally, block execution will be completed when an exit activity is reached. After block completion, the execution of the superordinated workflow continues with the activities directly succeeding this block. A general structure is depicted in Figure 3.3.

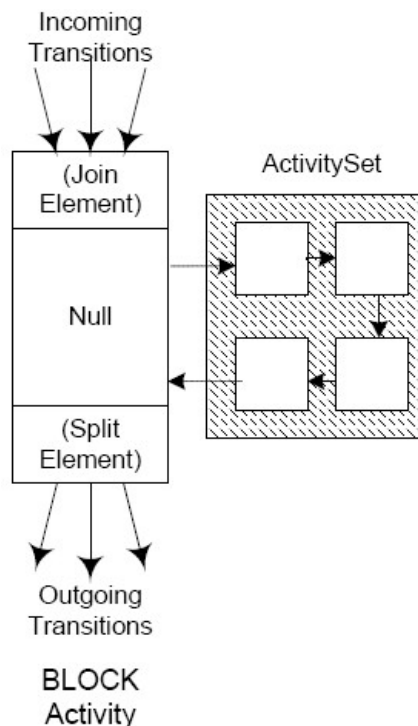


Figure 3.3: Block activity general structure

Each workflow pattern proposed in this work (cf. Chapter 6) is represented as a block activity. The block activity concept is suitable for representing the referred patterns because it allows to encapsulate their well-defined semantics and to represent their atomic characteristics. This means that all activities defined inside a block activity pattern must be completed before the superordinated workflow can continue its execution. The software components called process beans could also be an alternative to represent the patterns (NARTOVICH, 2002). Black-box beans, per example, are useful to encapsulate smaller software components (e.g., a class or a method). However, by defining the patterns as block activities it is expected to provide the base for their implementation and their use in workflow modeling tools. Moreover, the block activity can be mapped to the *transactional business sub-process* concept proposed in the context of the BPMN (OMG, 2006).

The subflow concept is not suited as the block activity concept because it is a container for the execution of a (separately specified) process definition, which may be executed locally within the same service or on a remote service. The process definition identified within the subflow contains its own definition of activities, internal transitions, resource, and application assignments (although these may be inherited from a common source) (OMG, 2006).

### 3.3 Event

An event is something that happens during the course of a business process (WfMC, 2005). Examples of event are the cancellation of an order by a customer, the delivery of material, or the misplacement of a specific resource. Furthermore, an event has two elements: trigger (which causes a particular action start execution) and action (the system response for a satisfied trigger condition) (WfMC, 1999).

The Object Management Group (OMG) (2006) defines three types of event: *Start*, *Intermediate* and *End*. The Start event indicates in which point of the process the execution will start. Intermediate events (e.g., message, timer, rule) occur between a Start and End events. It will affect the flow of the process, but will not start or (directly) terminate the process. The End event, in turn, indicates the point of the process where the execution must ends.

### 3.4 Swimlane and Message Flow

Swimlanes are used to partition the process. Each swimlane (e.g., org. unit, human, system) represents a process participant responsible for the execution of one or more activities (OMG, 2006). In this context, message flow is used to show the flow of messages between two process participants in different swimlanes (OMG, 2006).

Figure 3.4 shows a swimlane example where two organizational units (Financial Institution and Manufacturer) communicate through message exchange. The Manufacturer unit sends the Financial Institution a *Credit Request*. The Financial Institution, then sends the Manufacturer a *Credit Response*.

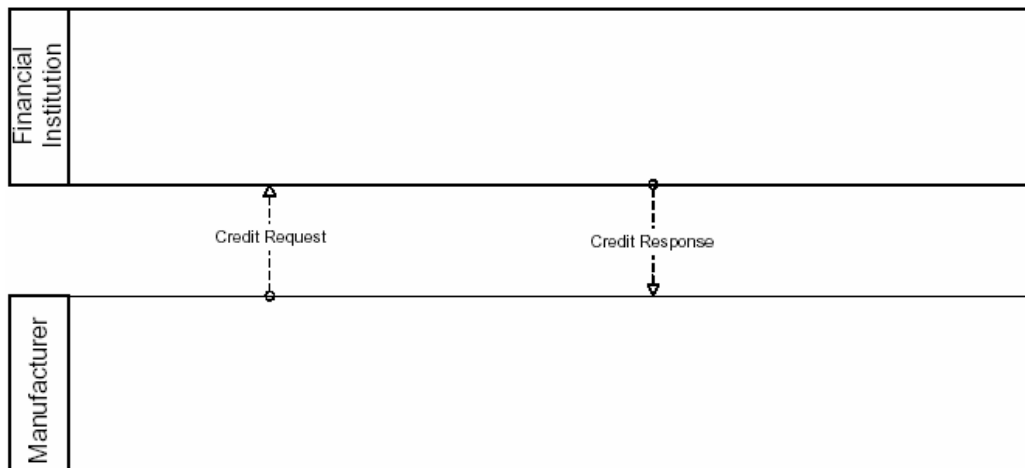


Figure 3.4: Example of Swimlane

Table 3.1 displays core BPMN objects and shows how these objects can connect to one another through Message Flow. The ↗ symbol indicates that the object listed in the row connect to the object listed in the column.

Table 3.1: Message Flow Connection Rule (OMG, 2006)

From\To	Start Event	Swimlane	Activity	Subprocess	Intermediate Event	Final Event
Start Event						
Swimlane	↗	↗	↗	↗	↗	
Activity	↗	↗	↗	↗	↗	
Subprocess	↗	↗	↗	↗	↗	
Intermediate Event						
Final Event		↗	↗	↗	↗	

### 3.5 Control Flow

Process activities are each other connected through transitions (WfMC, 1999). A transition (also called control flow or routing) can have a condition. A condition is a logical expression that generally evaluated by a workflow engine to decide the activities order of execution within a process (AALST, 2003a).

There are several kinds of control flows or transitions (AALST, 2003a). The basic kinds are:

- **Sequence:** an activity in a workflow process is enabled after the completion of its predecessor activity in the same process.

*Example:* In Figure 3.2, the activity Evaluate request of price adjustment is executed after the activity Send E-mail to Manager informing adjustment of Process.

- **AND-Split (also Parallel Split or for):** a single thread of control splits into multiple threads of control that can be executed in parallel, thus allowing activities to be executed simultaneously or in any order.

*Example:* After registering an insurance claim two subprocess are triggered: one for checking the policy of the customer and one for assessing the actual damage.

- **AND-Join (also called synchronizer):** a point in the workflow where two or more parallel executing activities converge into a single common thread of control.

*Example:* Insurance claims are evaluated after the policy has been checked and the actual damage has been assessed.

- **OR-Split (also called conditional routing, selection):** a point in the workflow where a single thread of control makes a decision upon which branch to take when encountered with multiple alternative workflow branches.

*Example:* After executing an activity “Evaluate damage”, an activity “Contact fire department” or an activity “Contact insurance

company" is executed. At least one of these activities is executed. It is also possible that both need to be executed.

- **OR-Join (also called conditional ):** comprises a point within the workflow where two or more alternative activities workflow branches re-converge to a single common activity as the next step within the workflow.

*Example:* In Figure 3.2, the process ends either after the activity `Verify whether there exist new Orders` completes or when activity `Prepare Order to be send` completes.

- **XOR-Split (also called asynchronous, join, merge):** a point in the workflow process where, based on a decision or workflow control data, one of several branches is chosen.

*Example:* Is a Shopping Order? (cf. Figure 3.2). This activity results in a Boolean value (yes or no).

- **XOR-Join (also called Simple Merge):** a point in the workflow process where two or more alternative branches come together without synchronization. In this control flow, none of the alternative branches is ever executed in parallel

*Example:* After a payment be received or a credit is granted the car can be delivered to the customer.

- **Iteration:** used when an activity must be recursively executed.

*Example:* activity, which needs to be repeated until the result of the subsequent check task, is satisfactory.

### 3.6 Final Considerations of this Chapter

This Chapter presented core concepts used throughout this work. Most of these concepts are standardized by WfMC and have been used not only by the academy but also across the industry (WfMC, 1999).

In the present work, the *block activity concept* for example is used to represent the workflow patterns being proposed in Chapter 6. On the other hand, the logic of specific kinds of *events* is detail defined in terms of the workflow patterns proposed in this Chapter.

Some of the workflow patterns proposed in Chapter 6 are based on specific kinds of *message flow*. Thus, in order to better understand these patterns the message concept is fundamental. No less important, the *Swimlane* concept is used to organize the roles involved in each workflow pattern proposed in Chapter 6.

Control flows are used in all workflow processes as well as workflow patterns presented in this work. Moreover, the routing metamodel proposed in this work (cf. Chapter 5) is based on the control flow types presented in this Chapter. They are also used in the association rules proposed in Chapter 7.

The next Chapter presents the first initiative of this research towards a set of organization –based workflow patterns.



## 4 ORGANIZATION -BASED WORKFLOW PATTERNS

Chapter 2 of this thesis pointed out that most of the existent organizational sub-models use knowledge about structural aspects only to assign performers to process activities. However, the work presented in (THOM, 2002) showed that there are much more relations between those aspects and workflow (sub-)processes.

Per example, the number of times an approval activity is repeated within the same approval process is strongly related to the level of *centralization of decision-making* (less or more) existent in the organizational unit(s) where it is executed. Other example refers to the *standardization of skills*, which helps to define the most suitable workflow participant to solve doubts inherent to the execution of the workflow process activities. Such structural aspect is used by some organizations in order to define employees with specialized knowledge.

Relying on these relations, this Chapter introduces a set of organization –based workflow patterns. Each pattern represents a relationship between one or more structural aspects an specific workflow processes (THOM, 2002), (THOM, 2003).

The outline of this Chapter describes how the patterns were discovered. Furthermore, it illustrates their existence in a real workflow application.

### 4.1 Discovering Organization -Based Workflow Patterns

To discover the organization –based workflow patterns a technique composed of the following phases was used:

- (a) General study about organizational structure aspects. This study is completely presented in (THOM, 2002). Section 4.2 describes the aspects used in this thesis.
- (b) Due to the significant number of structural aspects found with the general study, the investigation was restricted to a sub-set of those aspects (c.f. Section 4.2). For each possible combination of one or more selected aspects, the main activities related to them were identified in the business process of a real governmental organization.
- (c) For each activity or business process *part* (e.g., an approval process), the set of (sub-)activities (e.g., sequence of authorization activities) that implement it in the process was identified.
- (d) Either through the study of workflow systems already existent or, when there were none, through the experience of experts in workflow projects the most suitable workflow constructs to represent each set of (sub-)activities was

investigated. It is important to note that the knowledge about the workflow processes with the experts was obtained through informal talks. Figure 4.1 shows a *Document Approval* process within an *Environmental* process. Relying on the results of a *Technical Analyses* sub-process the *head of the division* where the sub-process is executed can either sign the document containing the analyses results (proving his agreement) or he can ask for improvement. This approval construct depicted in the figure characterizes the centralization of authority present in the organization. In case of decentralization, probably this construct would not be included in the process.

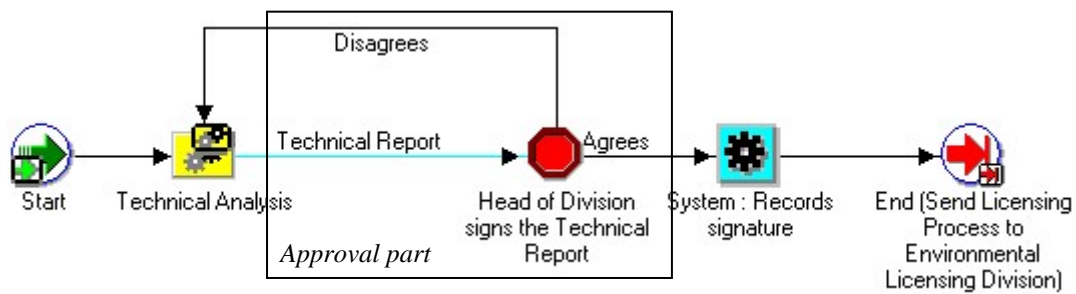


Figure 4.1: Example of document approval process

These phases were applied in a case study where 33 workflow (sub-)processes were analyzed aiming at evidencing the existence of the organization –based workflow patterns. The (sub-)processes as well as all the other workflow processes presented in this thesis are modeled in Oracle Workflow Cartridge (ORACLE, 2001) within the scope of a Workflow Project developed in the governmental organization. The Section 4.2 presents main structural aspects of the organization as well as a brief description of its workflow system. Section 4.3 describes the patterns. Afterwards, Section 4.4 illustrates the patterns existence in some of the workflow processes executed in the organization.

## 4.2 Profile of the Governmental Organization

By tuning or adjusting some structural aspects to the desired performance, the organization gets its final structure (DAVIS, 1996). Among the most important aspects to be dealt with in the designing of an organizational structure, authors point out the degree of differentiation as well as the degree of centralization on decision-making, the types of co-ordination mechanisms used, and the degree of dependencies between activities (CROWSTON, 1994). In the studied organization the majority of these aspects were identified. For example, several activities are accomplished in the organization, most of them are bureaucratic, referring to a specific activity branch. Responsibility for the activities execution is distributed through four hierarchical levels that form the organization’s hierarchical structure, besides representing the prevalent *vertical differentiation* in the organization (cf. Figure 4.2).

Different organizational units such as departments, directories, and divisions make the *horizontal differentiation* of the organization. These units are set in the organizational chart according to the organizational scalar chain, which specifies who is subordinated to whom (CHIAVENATO, 2000). Thus, at the top of the organizational

chain, representing the higher level of authority for decision-making is the Presidency. At the second level, there are the administrative and technical directorates. Below, with a limited authority, there are the departments, divisions, and services (cf. Figure 4.2).

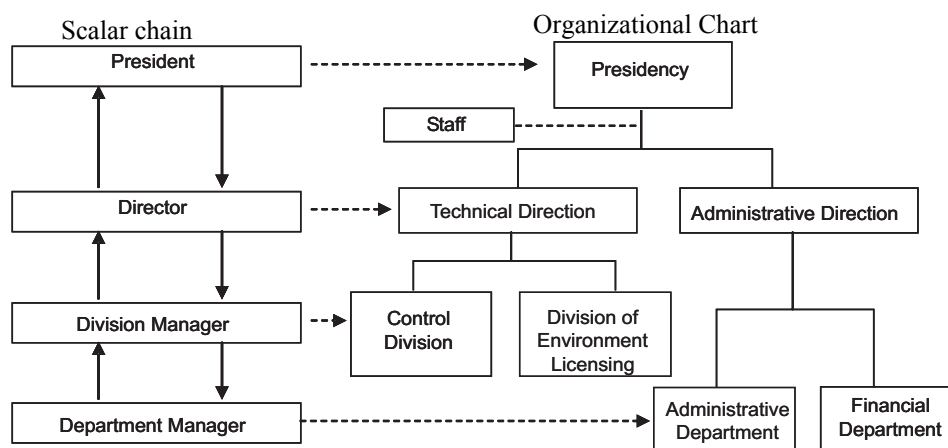


Figure 4.2: Scalar chain and organizational chart of the governmental organization

The authority to make decisions in organizations can be less or more centralized. In the first case, individuals at the top of the organizational chart has the highest authority to make decisions and authority of other individuals is delegated, top-down, according to his/her position in the organizational chart (DAVIS, 1996). Note that the hierarchical structure characterized in Figure 4.2 contributes to the high *centralization of decision-making* on higher positions of the organizational chart, such as, for example, the presidency and directorate. The delegation of authority, that is, *decentralization*, seldom happens between a department chief and a staff member of the same department.

In order to minimize the effects caused by the high vertical differentiation, the organization uses certain *co-ordination mechanisms* (MINTZERG, 1995) as, for example, direct supervision and *standardization of skills*. In the first case, an immediate superior co-ordinates the work of one or more subordinates. The other case involves the previous specification of abilities necessary to the human resources for the process execution.

#### 4.2.1 Workflow System

The workflow system executed in the organization was developed by a consortium between that organization and a team of researchers of the Federal University of Rio Grande do Sul (Brazil). The project involved a series of technological innovations aiming at increasing the efficiency and productivity of the organization and improving services offered to users.

The core functionalities of the system are both the automation of the main business processes executed in the organization and the creation of a digital document base comprising several documents used during the workflow execution.

The system comprises approximately 60 workflow processes modeled in Oracle Workflow Builder (ORACLE, 2001). The processes include a large variety of activities such as user notification, document elaboration, scanning and electronic signature. Figure 4.3 brings a process example referred to the request approval of overtime work.

Depending on the result of the activity Evaluate and sign request of work overtime, either the approval recording function is executed (Records approval) or the disapproval recording function will be executed (Records disapproval). The icons in the Figure are just illustrative, having no semantic.

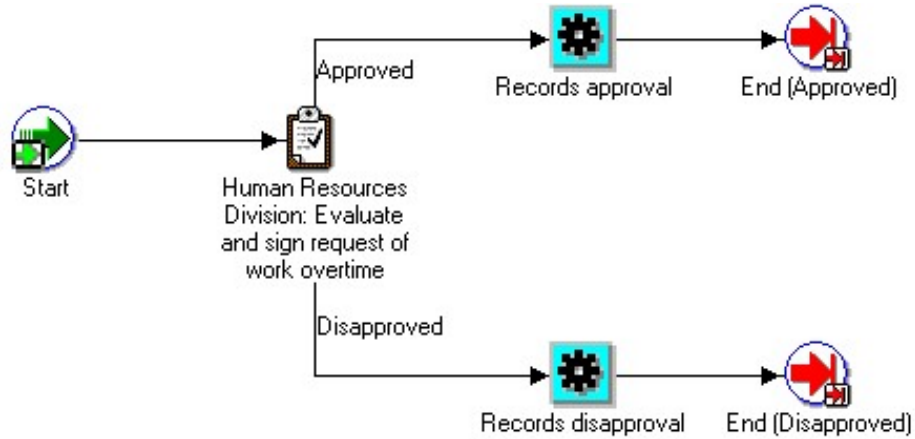


Figure 4.3: Example of workflow process

### 4.3 Organization -Based Workflow Patterns

This Section presents the organization –based workflow patterns described through Buschmann notation (BUSCHMANN, 96, p.19) and illustrated via activity with actions diagram of UML 2.0 (OMG, 2005a) (THOM, 2004), (THOM, 2005a). Figures 4.5 and 4.6 must be read according to the legend presented in Figure 4.4.

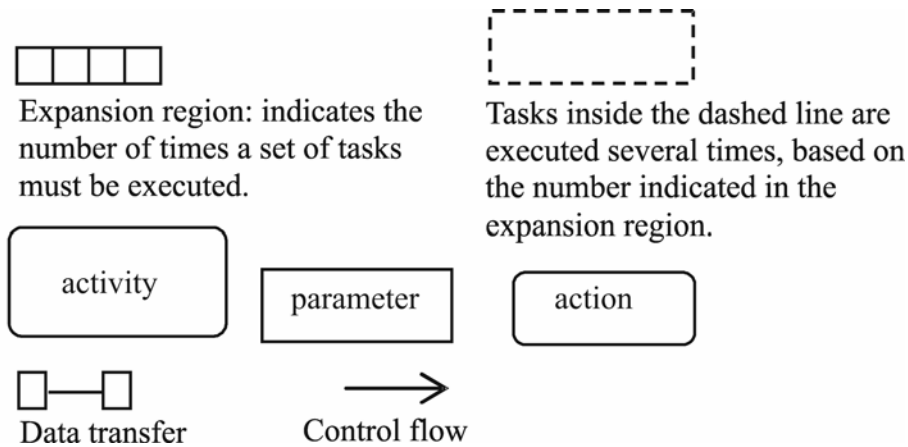


Figure 4.4: Action semantics notation

#### 4.3.1 Document Approval Pattern

The document approval pattern is a sequence of agreements. A specific organizational role performs each agreement. The process ends when all organizational roles have performed their approvals or one of them does not agree with the document content.

**Name:** Document Approval

**Context:** To approve means to make a decision about a situation requiring evaluation. Thus, the approval process comprises at least two parameters: an item (e.g., document) and an organizational role responsible for the decision activity.

**Problem:** The structure of a document approval process or the number of times the approval activity is repeated within the same approval process may vary depending on the level of centralization of authority (less or more) as well as the direct supervision of work (e.g., the approval activity is executed following the scalar chain of the organization).

**Solution:** To include in the workflow, at each point of decision-making on the sub-product in question (e.g. a document requiring approval), the process construct shown in Figure 4.5.

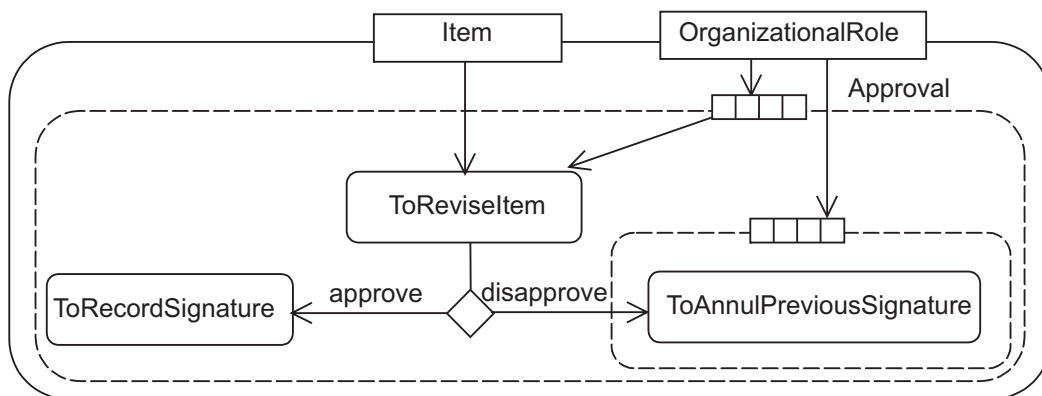


Figure 4.5: Structure of the document approval pattern

In Figure 4.5, an organizational role performs a document review (ToReviewItem). In case it agrees with the document content its signature (proving his approval) is recorded (ToRecordSignature). In case it disagrees, all previous signatures (in case they exist) are annulled and the process must end (ToAnnulPreviousSignature). The activities inside the dashed line are repeated in the number of organizational roles given by input parameters (OrganizationalRole) or some disapproval occurs.

#### 4.3.2 Question-Answering Pattern

The results of more complex activities can not be always standardized. This makes the organization to standardize skills of the performers. That is why they usually end to be experts in specific points of the work. The standardization of skills implies actions of problem solving (with help of some expert of the organization) in the context of a complex activity (MINTZBERG, 1995).

The question-answering pattern concerns the identification of specific skills needed for a specific activity execution. Based on the required skills, a particular organizational role and corresponding actor are assigned for both activity execution and question-answering within the context of the activity execution.

**Name:** Question-Answering

**Context:** During the execution of an activity, questions concerning its execution may occur. Thus, it is desirable to have activity performers with appropriate skills to answer such questions. Therefore, two parameters are included in the question answering-pattern: a *task* description and a *question* to be answered.

**Problem:** Questions related to the execution of an activity can occur.

**Solution:** To include in the workflow, at each point of a document preparation or revision, the process construct Figure 4.6 illustrates.

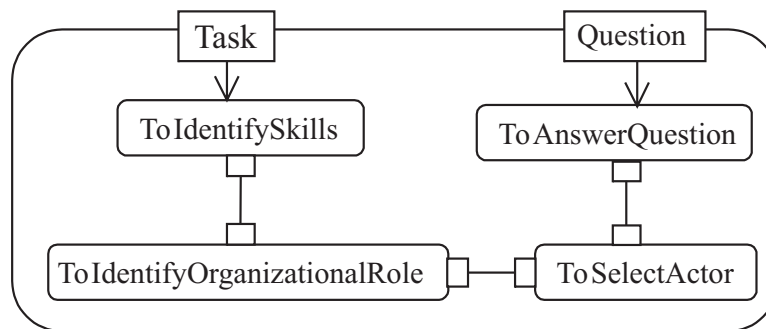


Figure 4.6: Structure of the question answering pattern

As shown in Figure 4.6, not only desirable skills needed for a specific activity execution are identified (*ToIdentifySkills*) but also the corresponding organizational role (*ToIdentifyOrganizationlRole*). Based on the organizational role, the best actor is assigned to an activity execution (*ToSelectActor*). The small squares between the activities represent parameters passing from one activity to another.

#### 4.4 Evidencing the Existence of Organization –Based Workflow Patterns in a Real Workflow Application

The existence of the organization –based workflow patterns was evidenced through a case study where 33 workflow (sub-)processes related to the workflow system described in Section 4.2.1 The number of occurrences of each pattern in all workflow processes was counted. From these (sub-) processes, 48% of them contain at least one occurrence of the *document approval pattern*. In contrast, 3% contain one occurrence of the *question-answering pattern*. This high-probability of the approval pattern is partially explained by the high centralization of decision-making in the organizational units where the approval processes are executed. On the other hand, questions related to the activities execution were less frequent in the processes analyzed. This fact justifies the low probability of the *question-answering pattern*.

Figure 4.7 shows a juridical analyses subprocess in the context of a law infraction judgment process. First, an administrative employee receives the document inherent to the law infraction (*Receives process of law infraction*). After that, a Lawyer performs a juridical analysis and writes a report based on the analyses results (*Performs juridical analyses and writes a report*). The Law Division head can than either agree with the report or disagree (*Head of Law*

Division signs the report). In case of an agreement, its signature is recorded (Record signature). Otherwise, the Lawyer who wrote the report must redo the document.

The sub-process matches to the *approval pattern* because of two main reasons: First, the approval activity results in one of two possibilities (approval or disapproval). Second, the signature is recorded in the database. Moreover, the need of this approval activity is strongly related to the centralization of decision-making existent in the organizational unit where the sub-process is executed.

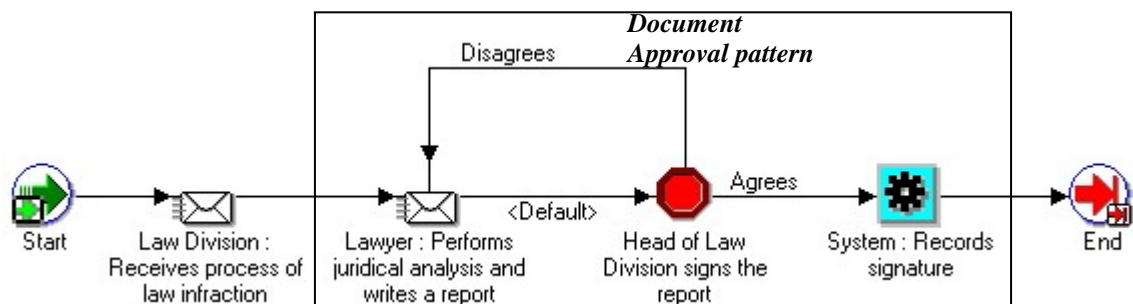


Figure 4.7: A real process that follows the document approval pattern

On the other hand, the standardization of skills was only identified in those subprocesses concerning both the preparation and revision of documents. Such subprocesses present the same structure in all workflows analyzed. A position with expert's knowledge performs the question-answering activity. In Figure 4.8, this position corresponds to a technician of the Licensing division.

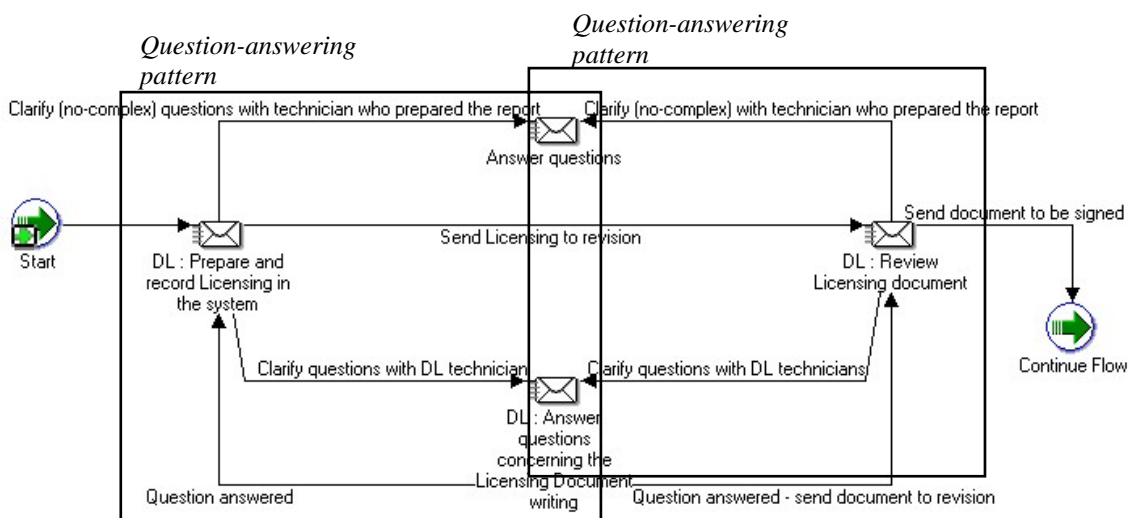


Figure 4.8: A real process that follows the question-answering pattern

## 4.5 Final Considerations of this Chapter

The correct representation of business processes executed in organizations through a suitable design technique is key for the success of any workflow project. This Chapter

showed that some structural aspects (e.g., centralization on decision-making, direct standardization of skills) are strongly related to specific business (sub-)process (e.g. document approval, question-answering).

Although the use of the patterns presented in this Chapter has not been tested in practice, i.e. in the modeling of workflow process of real applications, they seem to be useful for a better representation of the business processes as they are executed in the organization (THOM, 2003).

It is important to note that the research presented in this Chapter faced some difficulties in its beginning. It was difficult to find cooperation with business professionals whose knowledge could help the understanding of structural aspects. On the other hand, in order to identify new patterns, a larger set of workflow processes from both different organizations and application domains should be investigated.

These limitations as well as the absence of a workflow (meta) model with support to both structural aspects and workflow patterns based on such aspects were the main motivations for the development of the Transactional Metamodel of Business Process (TMBP) proposed in the next Chapter.



## 5 TRANSACTIONAL METAMODEL OF BUSINESS PROCESS

By analyzing several organizational workflow sub-models (WMC, 1998), (GREFEN 1999, p. 32), (MUEHLEN, 2004), (KRADOLFER, 2000) it was observed that most of them describe only the part of the organization to be involved in workflow enactment. Particularly, these sub-models focus on how process activities are assigned to workflow participants and, eventually how authority is delegated to them. In general, they show limited power of expression in terms of structural aspects representation. Moreover, none of the workflow metamodels studied in the context of this thesis (c.f. Chapter 2) support workflow patterns at least based on structural aspects.

Considering these facts, this Chapter proposes a Transactional Metamodel of Business Process (TMBP). TMBP is a derivation of the Transactional Model of the Workflow Processes - TMWP (GREFEN 1999, p.39) with support to structural aspects. The derivation mainly focus on: (a) to increase the expression power of the organizational sub-model; (b) to provide a catalogue of patterns based on structural aspects.

TMWP was chosen to be derived because from existent (meta) models (CASATI, 1995), (HOLLINGSWORTH, 1997), (GREEFEN, 1999, p.25), (MUEHLEN, 1999), (OMG, 2005b), (OMG, 2005c), (EINDHOVEN, 2005), (KRADOLGER, 2000) the WfMC (HOLLINGSWORTH, 1997) and WIDE (GREEFEN, 1999) models are the ones that most use the knowledge about structural aspects in their organizational sub-models. However, the reference model of WfMC was created with the aim of being a reference model that makes feasible the interchanging of process definitions among different workflow products (THOM, 2004). The following Sections introduce TMWP and describe TMBP respectively.

### 5.1 Wide's Transactional Model of Workflow Processes

The Transactional Model of Workflow Processes (TMWP) is a process model extended with transactional features. The model comprises the following five levels (GREFEN, 1999, p.38):

**Workflow level:** This level describes the entire workflow process, which consists of a number of supertasks and or tasks (task in this context can be understood as an atomic activity (WfMC, 1998)). Usually, multiples actors execute a workflow. The workflow level has the same semantics as the subprocess level, i.e. a subflow is part of a workflow. It is the top-level subprocess, with some additional attributes.

**Business transaction level:** A business transaction describes an indivisible part of work from an application point of view. It cannot be part of another business transaction i.e., business transactions cannot be nested. A business transaction is executed in strict isolation with respect to other business transactions. Each task within an specific workflow model must be part of a business transaction (or be a business transaction on its own), i.e. there are no leaves in the process hierarchy tree without business transaction semantics.

**Subprocess level:** A subprocess describes part of a workflow process that forms a conceptual unit of execution above the business transaction level from the application point of view. A subprocess consists of a number of other subprocesses or business transactions. Additionally, multiple actors can execute it.

**Supertask level:** it describes a part of a workflow process that forms a conceptual unit of execution beneath the business process level from the application point of view.

**Task level:** a task describes a single step in a supertask (or workflow) that cannot be decomposed in the WIDE process model as Figure 5.1 shows. A single actor is responsible by the task execution. Figure 5.1 shows the structure in the EER notation.

Grefen (GREFEN, 1999 p. 39) explains that the five levels provide a framework for hierarchically decomposing workflow application process, thus forming a tree structure with a workflow at the root and tasks at the leaves. Figure 5.1 illustrates the framework. The description of the processing entities allowed to perform a specific task is represented by a role (see Figure 5.2).

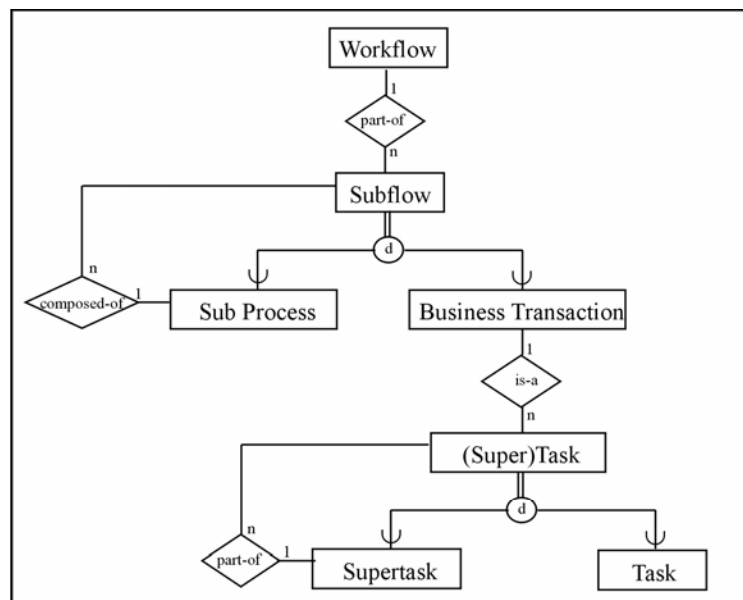


Figure 5.1: Transactional workflow process model (GREFEN, 1999, p. 39)

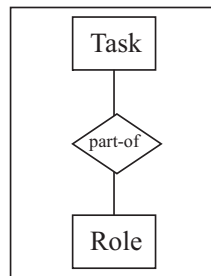


Figure 5.2: The WIDE process model (GREFEN, 1999, p. 34)

Although TMWP provides some important advantages for business process modeling, such as the high flexibility in the process definition and in the assignment of tasks to agents as well as in the definition of the information items associated to the process, it supports to structural aspects in very limited way. Moreover, it does not support the reuse of business and workflow (sub-)process patterns.

## 5.2 Transactional Metamodel of Business Process

This Section presents the Transactional Metamodel of Business Process (TMBP). The main characteristic of TMBP is its support to structural aspects as well as workflow patterns. Transaction in this context refers to the business transaction concept, i.e., the smallest business process unit of work (THOM, 2004), (THOM, 2005b), (THOM, 2005c).

TMBP makes feasible the modeling of business (sub-)processes based on organizational structure aspects. To describe the metamodel the Unified Modeling Language (UML) (FOWLER, 2000) is applied mainly because of the high power of expression UML provides (e.g., classes diagram, use cases diagram and activities with actions diagram) (OMG, 2005a).

TMBP is a package composed of other five packages: `PBusinessProcess`, `POrganizational`, `PResource`, `PRouting` e `PCatalogue` (Figure 5.3). Note that `PBusinessProcess` package depends on the `POrganizational`, `PResource` and `PRouting` packages. While `PCatalogue` package depends on `POrganizational` and `PBusinessProcess` packages. The next Sections discuss these five Packages.

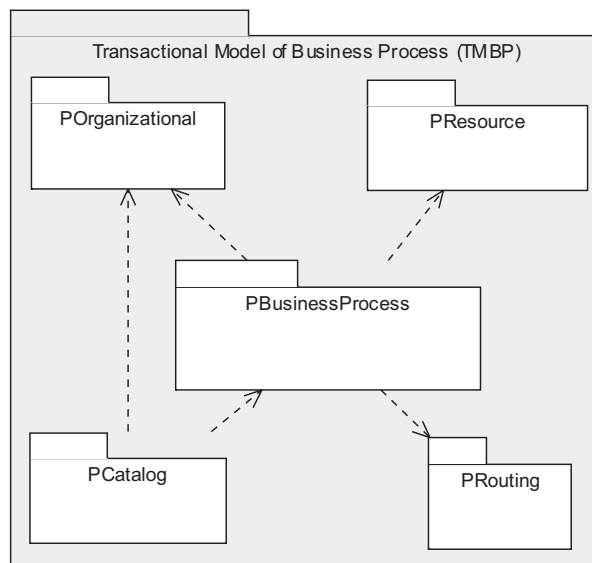


Figure 5.3: Transactional metamodel of business process

### 5.2.1 Organizational Package

Roles can be differentiated between functional (e.g., to formulate rules; to review and approve documents) and organizational roles (e.g., manager, director, president) (NEUMANN, 2002). Functional roles reflect the essential business functions that need to be performed within a certain company. Organizational roles correspond to the hierarchical organization in a company in terms of internal structures. In TMBP, an organizational role is linked to an actor. An actor executes a task. Additionally, it is associated with organizational unit (e.g., department, division). Nevertheless, it is a generalization of functional role. A functional role is associated with skill (e.g., to know how to program in Java) and competence (e.g., may sign orders > than \$ 20.000 ).

An organization is an aggregate of organizational units (cf. Figure 5.4) where each organizational unit can be related to other organizational units. This relationship may help in the identification of the organizational chart. To express multi-dimensional organizations (e.g., matrix-structure) the (0,n)-(0,n) cardinality is used. To allow the representation of external actors the relationship between Actor, OrganizationalRole and OrganizationalUnit is (0,n)-(0,n). A set of structural aspects connected with zero or more organizational units.

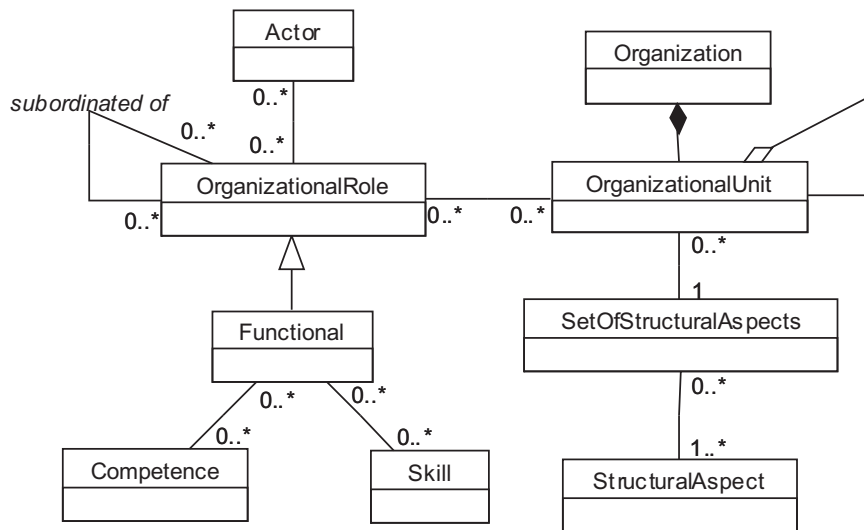


Figure 5.4: Organizational package

### 5.2.2 Resource Package

The execution of an activity may use one or more resources (e.g., the writing of a document may require a *text processor* invocation) (JUNG, 2003). The resource package (cf. Figure 5.5) distinguishes two kinds of resources: a tool (e.g., word processor, printer) and an item - instance of `ItemType` (e.g., official document).

Depending on the kind of item, it may have a structure. In case it has a structure, it is recursively composed of sub-items. Per example, if the business process final objective is to manufacture a chair, the chair, per se, is the final product, and its pieces (back, sit and legs) the items. In case of updating a Customer's Database the items could be the customer's address.

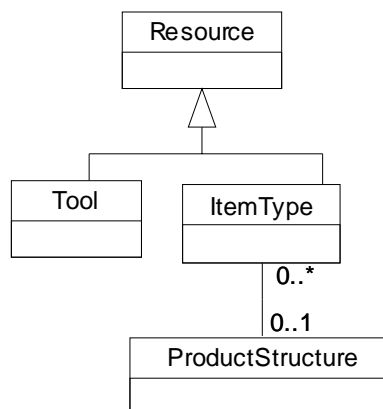


Figure 5.5: Resource package

### 5.2.3 Routing Package

Routing along particular branches determines which activities need to be performed and in which order between different constructors (e.g., sequence, split, parallelism and join synchronization) (AALST, 2002) and (AALST, 2003a). Currently, most workflow and business process languages support the basic constructs of sequence, iteration, splits (AND and OR) and joins (AND and OR) (WfMC, 1998), (AALST, 2002), (OWEN, 2003). However, the interpretation of even these basic constructs is not uniform and it is often unclear how could more complex requirements be supported.

There are several proposals concerning routing between activities (e.g. (AALST, 2002), (WMC, 1999), (GREFEN, 1999)). The present approach applies the basic routing constructs present in most of the workflow languages in the definition of the routing package (cf. Figure 5.6). Most of the constructs were proposed by the Workflow Management Coalition (WMC, 1999) and (AALST, 2003a). The semantic of these routings is the same presented in Chapter 3.

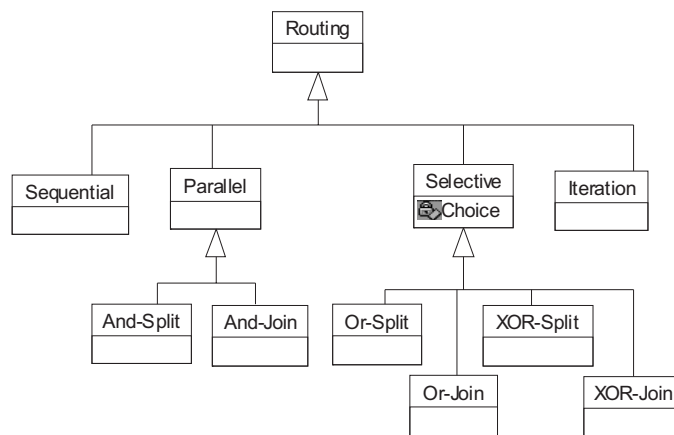


Figure 5.6: Routing package

### 5.2.4 Business Process Package

The Business Process package (cf. Figure 5.7) is the main TMBP package. Semantically, each business process transforms an item type (e.g., a document) from an initial state (e.g., under revision) into a final state (e.g., approved or disapproved). Transformations may be decomposed in smaller transformations, where each of them corresponds to a change in the item state. When there are no more transformations to be performed, the item reaches its final state. This hierarchic decomposition of transformation is similar to the one described in Grefen (1999, p. 72) for the lifecycle of a workflow object.

Due to its possible high complexity, a business process can be recursively decomposed in business subprocesses, up to the business transaction level. Under the organization's point of view, a business transaction is the smallest business process unit of work being responsible for one of the item transformations. A business transaction can be decomposed in a partial order of atomic activities and its whole execution is under the responsibility of an actor. Nevertheless, a business transaction can receive as inputs several resources to be used during the activity execution.

Each business subprocess can involve several business transactions, therefore different actors. However, the set of organizational structure aspects as well as their values should remain constant in the business subprocess. A business subprocess can involve one or more organizational units if their structural aspects do not vary. Each business subprocess has only one responsible, and it is a choice of the organization itself to define each organizational unit it will belong to. A simple task in TMBP is associated to *skill* class, as in certain stages of the business process it may be necessary to identify which are the minimal abilities an actor must have.

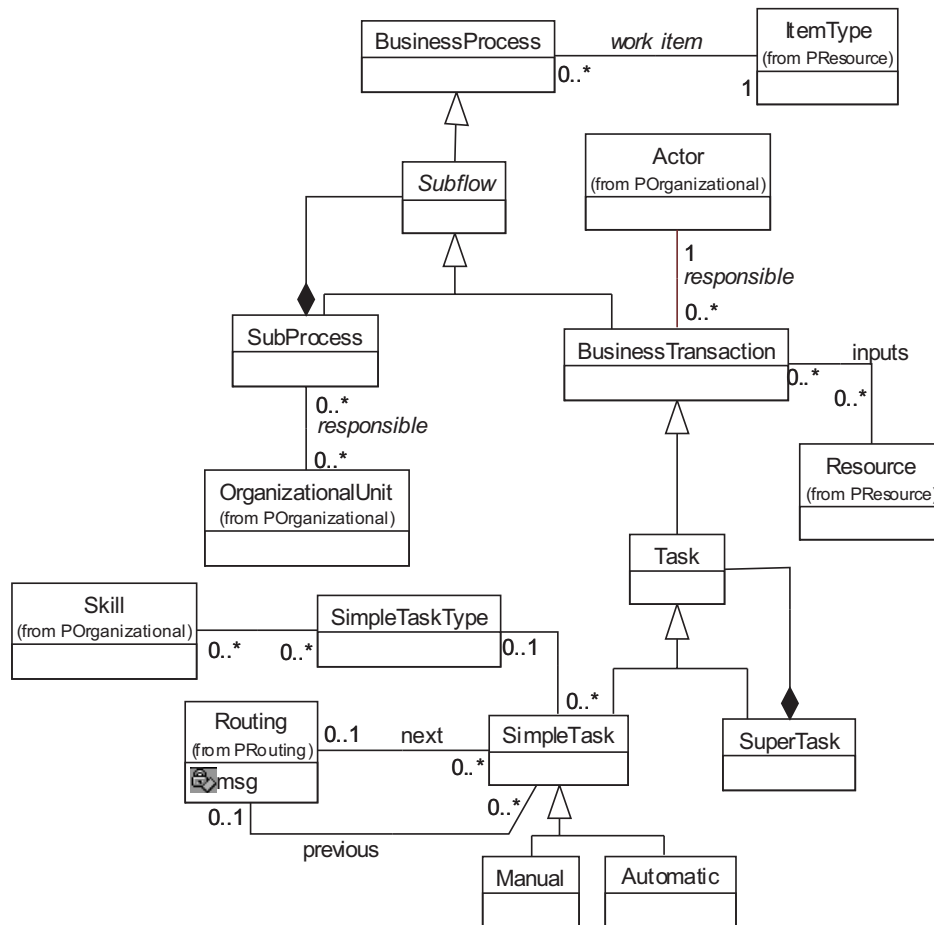


Figure 5.7: Business process package

### 5.2.5 Catalogue Package

The catalogue package (cf. Figure 5.8) describes the classes used by a catalogue manager (an agent) in the selection of the best design pattern from a catalogue of business patterns, as a basis to model a certain business (sub-)process he/she wants to accomplish. The business pattern selection is proceeded concerning a set of parameters obtained from TMBP, such as: kind of business (sub-)process (*SubProcess* class), value of structural aspects (obtained via *OrganizationalUnit* class and its associated classes) on which this business (sub-)process depends and kind of work item (*ItemType* class) used in the business (sub-)process. Note that the set of parameters may vary according to the kind of business subprocess.

After that, a business (sub-)process builder (an agent) extends the selected pattern with information on the partial order of business transactions. For each business transaction (`BusinessTransaction` class) it includes: the work item manipulated (received as parameter during the pattern selection), the input resources (`Resource` class) its internal activities use, the actor (`Actor` class) responsible for each activity execution and the partial order among them (`Routing` class).

In order to extend the business subprocess pattern the builder requires the following input parameters: the selected business subprocess pattern, the organizational unit and the kind of work item.

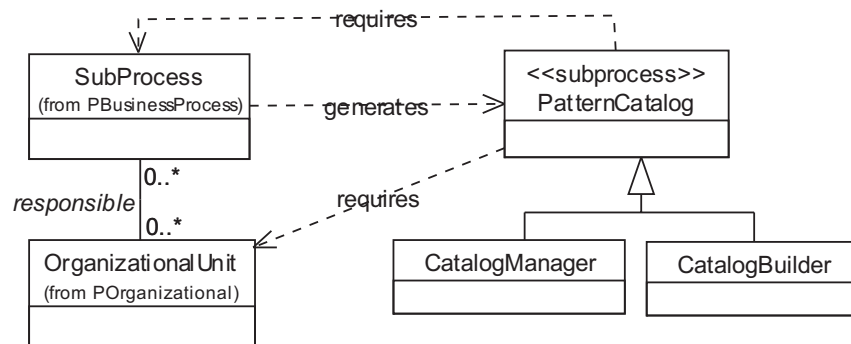


Figure 5.8: Catalogue package

The next Section brings a first insight towards a methodology for business and workflow process modeling based on TMBP.

### 5.3 Specifying Organization -Based Workflow Patterns via Business Process Execution Language for Web Services (BPEL4WS)

Looking forward to implementation issues needed for automatic generation of business (sub-)process from patterns stored in TMBP catalogue, this Section presents a first initiative towards a methodology for either business process or workflow process modeling on the bases of TMBP. The methodology is based on the ECOMOD methodology (cf. Figure 5.9) (FRANK, 2004). TMBP methodology comprises the following steps (Figure 5.10):

1. Creation of business processes from TMBP.
2. Automatic generation of BPEL4WS processes corresponding to the business process models defined in step 1. Section 5.4.1 introduces a TMBP business process (as shown in Figure 5.12) described as a BPEL4WS process.
3. Execution of BPEL4WS processes through whatever workflow engine.



The decision for BPEL4WS in favor of other languages (as e.g., the Business Process Modeling Language – BPML (ARKIN, 2002), the Web Service Flow Language – WSFL 1.0 (LEYMANN, 2000); the Process Specification Language (SCHLENOFF, 2000)) comes first because of the reuse properties of BPEL4WS. Second, BPEL4WS is becoming one of the most popular and emergent execution languages for business (sub-)processes with tool support and platform independency. Besides that, the advantages of BPEL4WS has been recognized by the UML community through the mappings from UML to BPEL4WS. It is a flexible language that also enables the mapping of an UML process to a BPEL4WS process. Such a mapping can be useful when thinking about implementation issues (GARDNER, 2003), (LEYMANN, 2004).

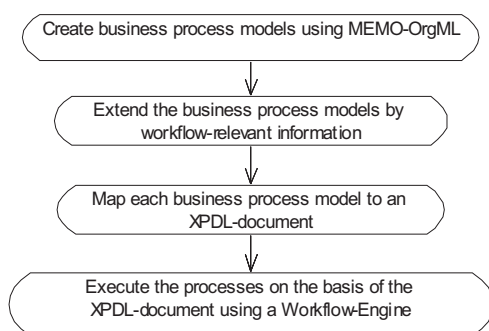


Figure 5.9: ECOMOD methodology

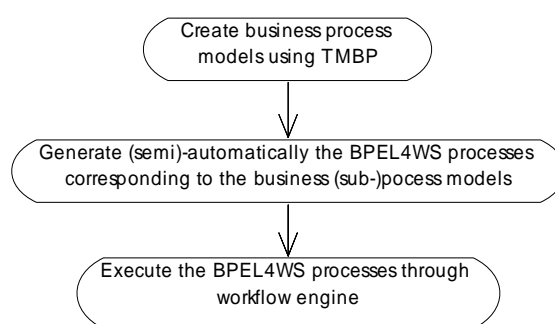


Figure 5.10: TMBP methodology

### 5.3.1 Creation of Business Process Models from TMBP

The Rational Unified Process (RUP) is a prescriptive, well-defined system development process, often used to develop systems with object- and/or component-based technologies (AMBLER, 2005, p.13). Moreover, it is an iterative software development process created by Rational Software Corporation. It is designed and documented using UML. According to (KRUCHTEN, 2001), RUP is both general and comprehensive enough to be used by many small-to-medium software development organizations, especially those that do not have a very strong process culture.

This Section demonstrates how the Catalogue Package could be used in practice. To do so, RUP is considered. Furthermore, imagine that the patterns catalogue contains the approval pattern presented in Chapter 4 (cf. Figure 4.5).

Creation of business (sub-)processes from the reuse of the document approval pattern involves the use case represented at Figure 5.11 bring. A *catalogue manager* inserts the patterns in a repository, indexing and updating them. As input parameters it uses: (a) the pattern category; (b) pattern description; (c) the pattern diagramming and; (d) the corresponding pattern codification (e.g., BPE4WS) and the indexation.

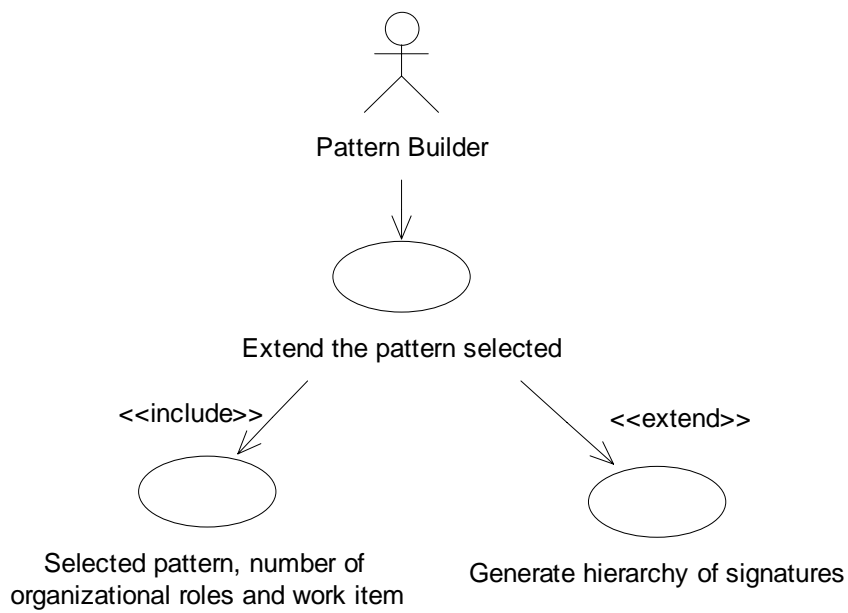


Figure 5.11: Use case diagram concerning the Pattern Manager functions

Based on the patterns stored, a pattern builder selects the best pattern and expands it to complete the modeling. To do so, it uses as input parameters: (a) the selected pattern; (b) the number of organizational roles involved in the process and (c) the kind of work item manipulated in the process (e.g., a document). As output parameter, it presents the complete pattern (expansion) equivalent to the pattern Figure 4.5 shows.

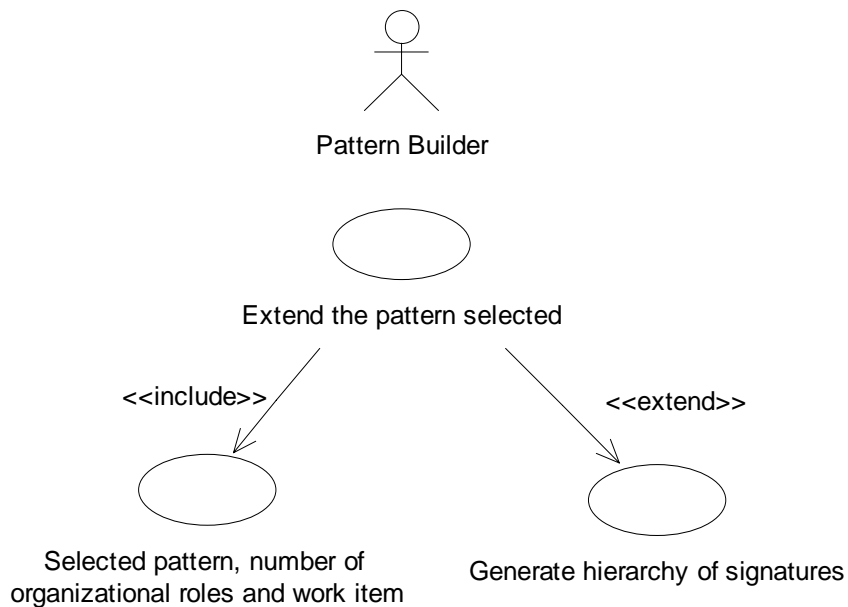


Figure 5.12: Use case diagram concerning the Pattern Builder functions

### 5.3.2 Mapping TMBP Business Process to BPEL4WS Process

This Section introduces some rules for mapping a TMBP process (e.g., the pattern illustrated Figure 4.5) to a correspondent BPEL4WS process.

#### **Rule for *parameter mapping***

An organizational role in Figure 4.5 (responsible for a document approval) is received as input parameter. In BPEL4WS this situation is represented with an `invoke` activity (as shown in number 1 of Figure 5.12).

#### **Mapping rule for *decision activity***

The decision node (illustrated as a diamond in Figure 4.5) corresponds to a `switch` statement in to BPEL4WS.

#### **Mapping rule for *record activity***

As Figure 4.5 shows, the result of a decision can be either an approval or disapproval. In case of approval, an electronic signature is recorded (proving the approval). This situation is mapped in BPEL4WS through an operation (`recordSignature`). On the other hand, in case of disapproval, a variable counts the number of signatures (cf. number 2 in Figure 5.12).

#### **Mapping rule for *cancellation of performed task***

In case of disapproval, all previous signatures (in case they exist) must be annulled. In BPEL4WS this situation can be expressed through a `while` statement and through an operation (cf. Figure 5.12, number 3 and 4 the statement `annulSignature`).

Process Description (e.g., as port type description and message description) are left out.

```

<process name="documentApproval">

(1)<invoke partnerLink="reviewer"
  portType="itemReviewerPT"
  operation="reviewItem"
  variable="review"
  <correlations>
  <correlation set= "itemID" initiate="yes"/>
  </correlations> </invoke>
  <switch>
    <case condition =
      "bpws:getVariableProperty('review')="true"
      <sequence>
(2)    <invoke partnerLink="requester"
      portType="signaturePT"
      operation= "recordSignature"
      from expression=
        "bpws:getVariableData('signatureCount') +
        bpws:getVariableProperty('auxSignatureCount'
        )to variable='signatureCount'/"> </invoke>
      </sequence> </case>

    <otherwise>
(3)    <while condition =
      "bpws:getVariableProperty('signatureCount')>0
      <sequence>
(4)    <invoke partnerLink="requester"
      portType="signaturePT"
      operation= "annulSignature"
      from expression=
        bpws:getVariableData('signatureCount') -
        bpws:getVariableProperty('auxsignatureCount'
        ) "/></invoke></sequence></while>
      "bpws:getVariableData('signatureCount')= 0
    </otherwise>
    from expression=
      "bpws:getVariableData('numberOfOrganizationalRoles') -
      bpws:getVariableProperty('auxnumberOfSuperiorPositions')
      "/></switch></process>

```

Figure 5.13: TMBP process as BPEL4WS process

## 5.4 Final Considerations of this Chapter

This Chapter positioned the patterns presented in Chapter 4 in the context of a workflow metamodel (TMBP) and showed how process patterns designed using a metamodel compliant language can be transformed into BPEL4WS processes. Such transformation may increase the patterns portability because BPEL4WS is supported by the most popular workflow tools (e.g., Intalio (INTALIO, 2006), Oracle BPEL Manager (BRADSHAW, 2005)). Though, neither TMBP nor the corresponding methodology were applied in the modeling of real workflow applications. Both rely on structured aspects for the definition of additional characteristics (different from performer assigning) of the process structure (e.g., approval process).

At this point of the research development was found non workflow tool which could be extended with a catalogue of patterns. Because of that, this thesis brings a conceptual approach of how the patterns could be applied in the design of workflow processes.

In order to continue with the catalogue development it would be necessary a larger number of patterns than the existent set presented in Chapter 4. In this context, to discover new patterns it would be necessary to investigate a larger number of real workflow processes executed in different organization.

Considering both the non-availability of a larger set of workflows to be analyzed, at least at this point of the research, and that there exists little research on patterns based on recurrent functions frequently found in business process, this research continued through the investigation of patterns based on different business process found in the literature.

The next Chapter summarizes the result of this study. Additionally, it categorizes and describes a set of patterns based on this investigation as well as in the organization –based patterns.

## 6 WORKFLOW PATTERNS

The operative system of an organization is the environment in which the *financial*, *logistic* and *information* processes take place (MUEHLEN, 2002, p. 54). These processes support the *dynamic structure of the organization* taking goods and services as inputs factors and transforming them into goods and services as output factors, in order to satisfy customer's demands (cf. Figure 6.1).

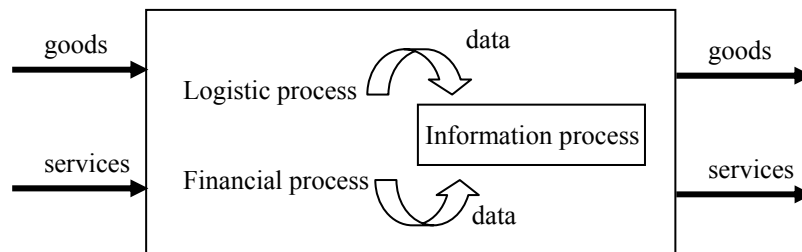


Figure 6.1: Dynamic structure of the organization

These processes as well as correlated ones (e.g., *communication process*, *decision process*) are frequently found in real business processes. However, there is little research relating them to workflow patterns. Thus, most of the existent workflow (meta)models and tools do not support this kind of patterns.

The following Section presents a review of these processes (or patterns). Afterwards, Section 6.2 introduces a classification of patterns based on the reviewed processes as well as in the organization –based workflow patterns presented in Chapter 4. Section 6.3, in turn, presents the patterns of each category represented as block activity patterns.

### 6.1 Survey on Business Process Types

Business processes are prevalent in almost all application domains. Prominent examples include *logistics*, *finance* and *information processes*. While *logistic processes* (or *material processes*) are performed with the goal of manipulating a physical object (e.g., transportation of goods) (MEDINA-MORA, 2002) or with the goal of provisioning a service (e.g., the manufacturing of a product and both selling and buying of goods), *financial processes* are performed when monetary value is exchanged between two parties. Each of these processes is accompanied by an *information process*, which represents the flow of data, i.e. the data/information perspective in the company's information systems that is caused by the relevant logistics and financial processes (MUEHLEN, 2002).

Organizational processes are rarely homogeneous entities that are performed by individuals in their entirety (MUEHLEN, 2002, p. 54). Usually, different parties are involved in a process. Process participants communicate by exchanging messages (*communication process*) (GEURTS, 2004), (MUEHLEN, 2002). Basically, a message exchange involves two parties: a sender or producer (sends a message) and a receiver or consumer (receives a message).

In this context, zur Muehlen has classified messages as unidirectional or bi-directional. Unidirectional messages are used either by a sender to request the execution of an activity from a receiver (also called a *unidirectional performative message or communication*) (cf. Figure 6.2, n.1), or by a receiver to notify a sender (*notification message*) (cf. Figure 6.2, n.2). Bi-directional messages form a request/respond pair (cf. Figure 6.2, n.3), where a sender asks a receiver to perform an activity and the receiver answers the sender (also called *bi-directional performative message or communication*), or they form a solicit/respond pair (cf. Figure 6.2, n.4), where a receiver asks the sender for information which is supplied subsequently (*informative message*).

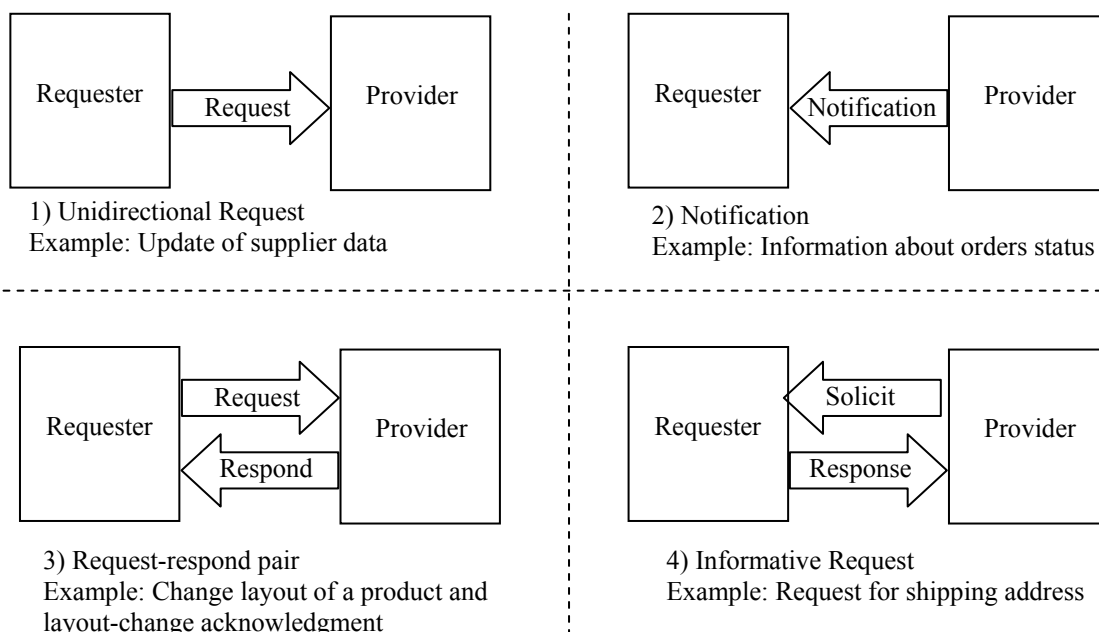


Figure 6.2: Interactions types (MUEHLEN, 2002, p. 153)

In Flores (1998) a similar approach is presented concerning fundamental linguistic actions (e.g., request, promise). *Request* means that someone gets another one to perform an action. This request is semantically similar with the unidirectional performative message. On the other hand, when someone agrees in performing an action he/she *promises* actions to someone who had requested it. This scenario matches the bi-directional performative message.

In the context of this thesis, the activities of an information process correspond to *messages* that implement the organization's flow of data instigated by both logistic and financial processes. For example, in an *approval process* the activity concerning a *document review request* generates a bi-directional performative message (a sender requests a receiver to perform an activity).

It is important to emphasize that either application processes or information processes can be related to a *decision process* i.e., a cognitive process of selecting a course of activities from among multiple alternatives (WfMC, 1999), (AALST, 2003a). In case of an application process it refers to a decision-making action such as the approving or rejecting in an approval process. In an information process the decision occurs in terms of workflow routing.

## 6.2 Classification of Workflow Patterns

This Section presents the processes described above organized into three different categories of patterns (cf. Figure 6.3). The classification was based on specific characteristics of the processes (e.g., dependency of either application domain or organizational structure aspects)

1. *Organizational –based Workflow Patterns*. This category refers to those patterns that are related to one or more organizational structure aspects. Examples of respective patterns are *document approval* and *question-answering* (cf. Chapter 4).
2. *Application Domain –based Workflow Patterns*. This category includes patterns that are related to a specific application domain. Both *financial pattern* (cf. financial process) and *logistic pattern* (cf. logistic process) are examples of this category of patterns.
3. *Recurrent Business Functions –based Workflow Patterns*. This category comprises patterns related to general recurrent functions, i.e., any kind of business or workflow process may contain the patterns of this category independently of the application domain. Examples of corresponding patterns are these: *unidirectional* and the *bi-directional performative pattern*, *information pattern*, *notification pattern* (cf. communication process) and *decision pattern* (cf. decision process).

Figure 6.3 represents through an hierarchy the workflow patterns inherent to the categories presented above. The Figure shows that such patterns are related to different levels of abstraction. Furthermore, it shows that some of the patterns are specializations of other patterns. For example, logistic and financial patterns are related to the application domain level. On the other hand, both approval and question-answering patterns are specializations of the bi-directional performative pattern. Such patterns are based on specific organizational structure aspects. For example, the kind of approval is determined based on the level of centralization on decision making existent in the org. units where the approval process is executed.

On the other hand, the informative pattern is a specialization of the bi-directional performative pattern. It differs from the bi-directional patterns because of the kind of activity being requested, i.e., an information request. Similar, the notification is a specialization of the unidirectional performative pattern because after the notification activity starts its execution the workflow continues with the next activity in the process.



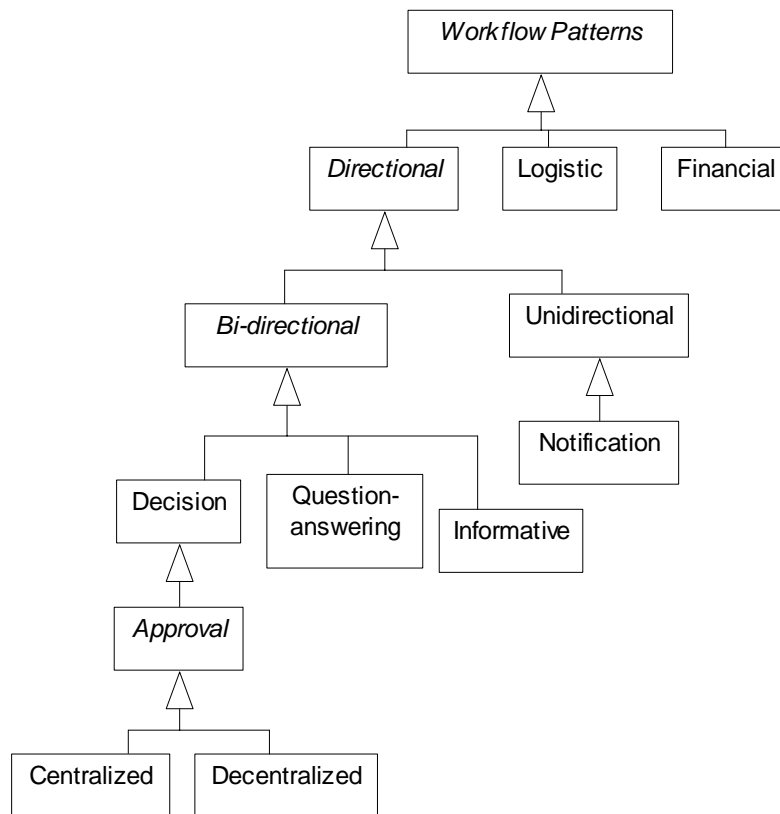


Figure 6.3: Relation between the workflow patterns

### 6.3 Examples of Workflow Patterns

This Chapter presents the set of patterns introduced in Section 6.2 represented as block activity patterns. Since the patterns representation may require input/output parameters and the block activity concept does not support parameters (i.e., parameters are defined in the surrounding workflow definition), the transaction perspective of the serialization theory was applied to overcome this limitation (BERNSTEIN, 1987). An input parameter is represented as a database read operation of *one-time-only* readable information. Similarly, an output parameter is represented in the block as a database write operation of *one-time-only* writable information.

The following Sections describe the patterns. Thereby each pattern is represented in terms of an UML Activity Diagram (using the UML 2.0 notation). Figures 6.5 to 6.15 should be read according to the legend presented in Figure 6.4. The Visual Paradigm for the UML Community Edition based on UML 2.0 was used as an editing tool to design the patterns.

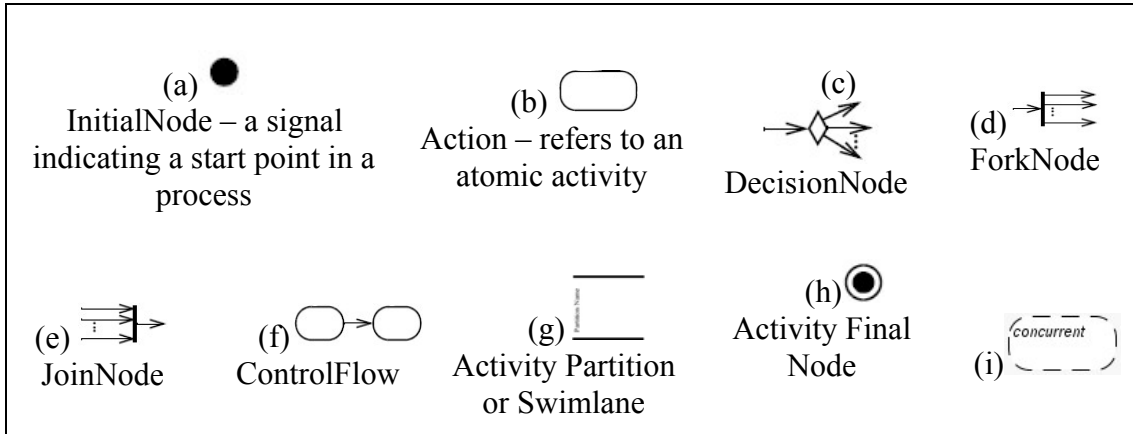


Figure 6.4: Activity diagram with action from UML 2.0

The patterns presented in this section were mainly derived from a literature study about organizational structure aspects (e.g., centralization on decision-making, direct supervision of work) and business (sub-)process types.

### 6.3.1 Document Approval Pattern

As introduced in Chapter 4, a document approval process constitutes a set of agreements (one or more) whereas each agreement is performed by one organizational role. The approval process is completed when all organizational roles have finished their revisions or one of these roles does not agree with the document content. Figure 6.3 brings the approval pattern as workflow block activity.

As illustrated in Figure 6.5, an organizational role *reviewer* performs a document review either resulting in an approval or disapproval. The document review activity is performed multiple times in parallel or in sequence (in this case the process Figure 6.5 brings would not include the concurrent region covering the flow from Prepare work item until the result of the decision) according to the number of organizational roles specified or until a disapproval occurs. Generally, the number of organizational roles is connected to the level of centralization with respect to decision-making.

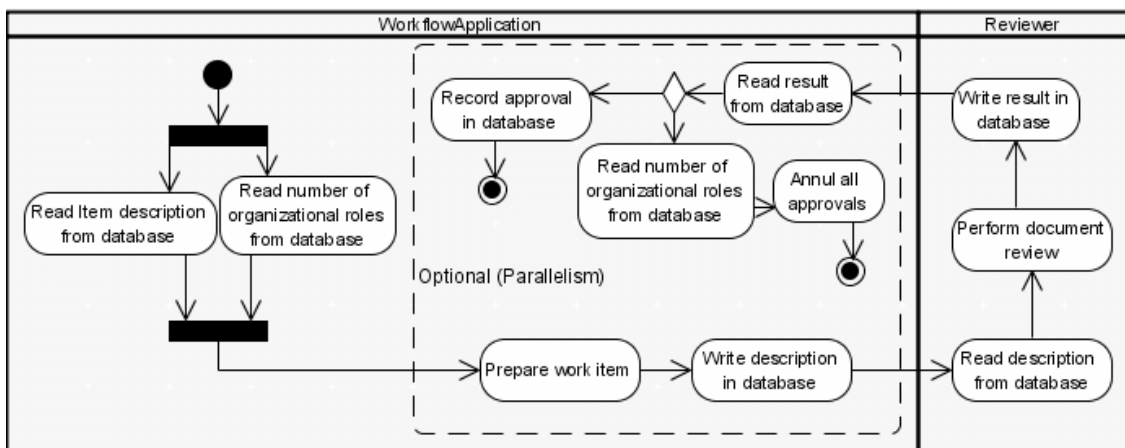


Figure 6.5: Approval pattern

### 6.3.2 Question-Answering Pattern

The Question-Answering pattern was introduced in Chapter 4. While either writing or reviewing a document the performer of such activities may have questions inherent to these activities execution. Such questions are most of the times answered by the author of the document or by a specialist in the question field existent in the organization.

Based on that, Figure 6.6 brings the question-answering pattern as a block activity. The question is reported (by a requestor) for the document author or a specialist who subsequently answers it.

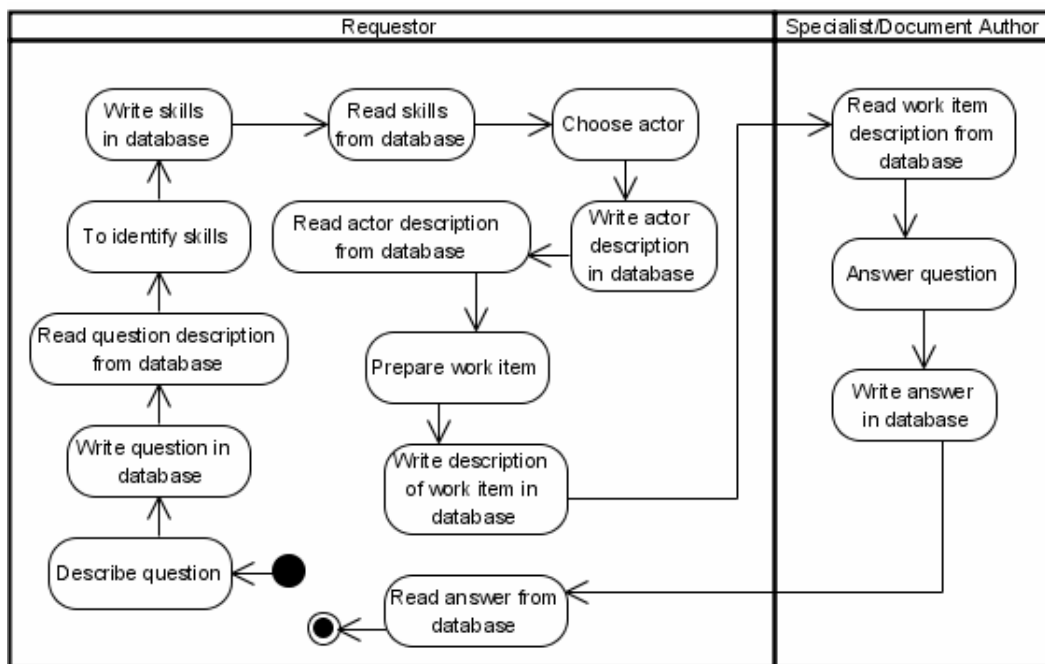


Figure 6.6: Question-answering pattern

### 6.3.3 Logistic Pattern

A logistic process may be related to the manufacturing, buying and selling of products, service provision or transportation of goods. Is out of the scope of this thesis to present detailed patterns for each of these cases, but to illustrate possible generic patterns for logistic activities. At present, the focus is on main data (in terms of message exchanges) these logistic activities can generate. Figure 6.7 shows a conceptual view of the main logistic activities. Based on an order specification, for example, one of several kinds of logistic activities will be executed (e.g., either buy or sell activity).

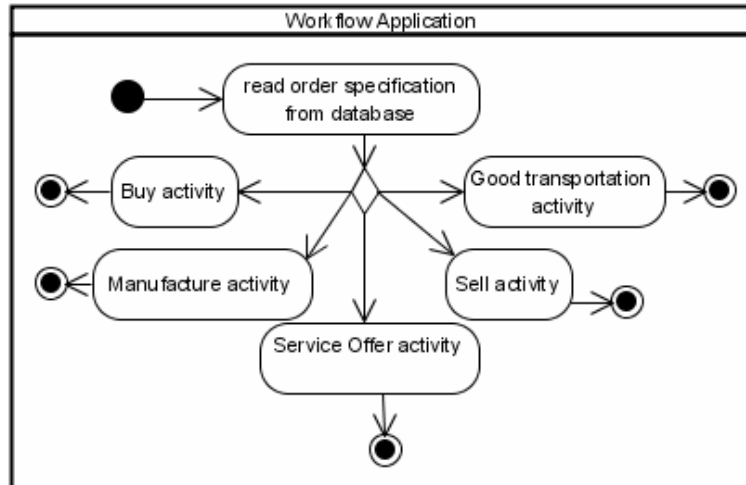


Figure 6.7: Logistic pattern

### 6.3.4 Financial Pattern

This pattern represents a financial process. As shown in Figure 6.8, the financial activity manipulates and, eventually, generates a new monetary value (through special monetary attributes).

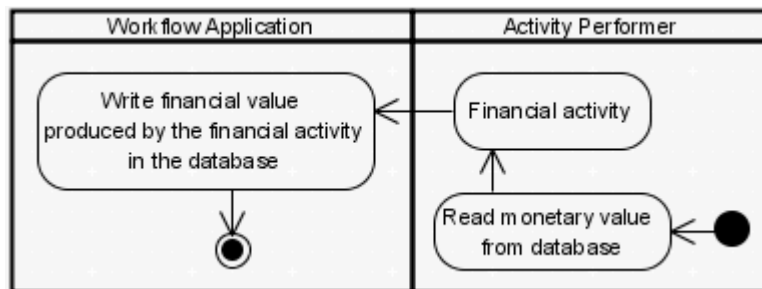


Figure 6.8: Financial pattern

### 6.3.5 Unidirectional Performative Message Pattern

This pattern represents a unidirectional performative message. Figure 6.9, for example, shows the description of an activity execution request. Based on it, a work item is assigned to a receiver (i.e., a specific workflow participant responsible for activity execution; e.g., specified by a user role). After that, the process may continue execution without waiting for a response. Note that the unidirectional performative message does not require a response. Both the write and read activities would be modeled as parameters if allowed by a block activity. As output parameter the activity "Write description of activity execution request in the database" has the *description request*, which is modeled in Figure 6.9 as *write* operation.

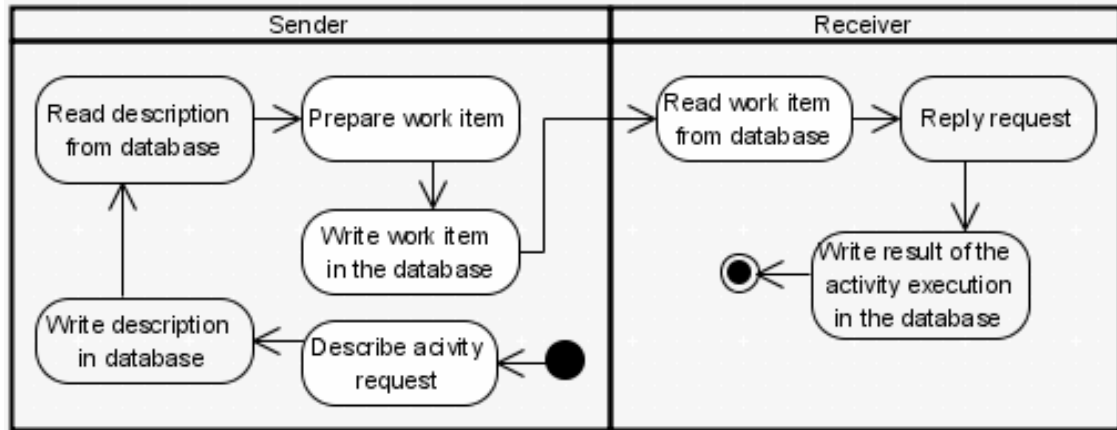


Figure 6.9: Unidirectional performative message pattern

### 6.3.6 Bi-directional Performative Message Pattern

This pattern is based on the bi-directional performative message (cf. Chapter 6). As shown in Figure 6.10, the activity block finishes its execution only after sending a notification about completion of activity execution and recording the result of the execution in the database (AND-Split).

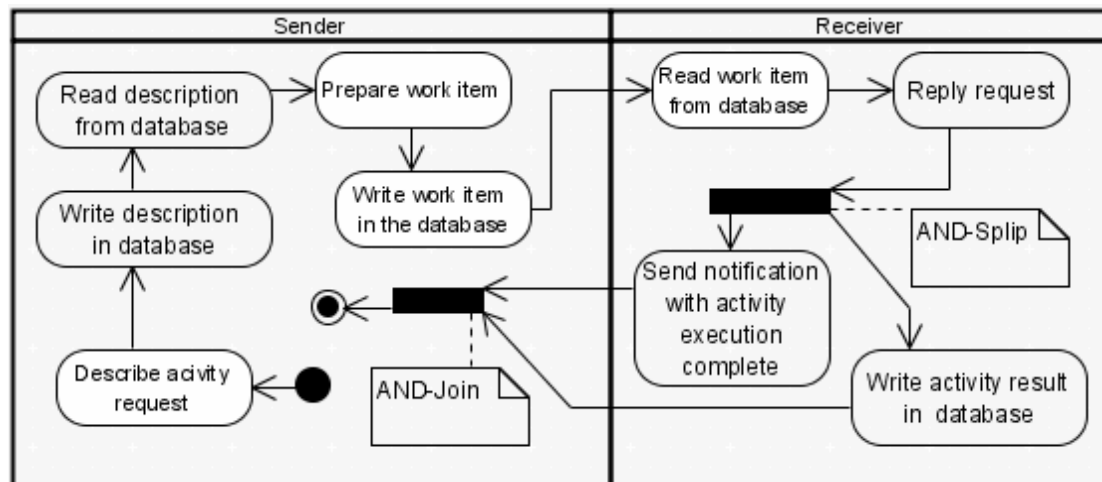


Figure 6.10: Bi-directional performative message pattern

### 6.3.7 Informative Pattern

The informative pattern is based on the informative message (cf. Chapter 6). As illustrated in Figure 6.11, the activity block starts with an information request and finishes when the information required is received. This pattern differs from the bi-directional performative message specially because the workflow waits for a response of the user (e.g., in workflow tools such as Oracle, the user provide information to the system by filling out some field).

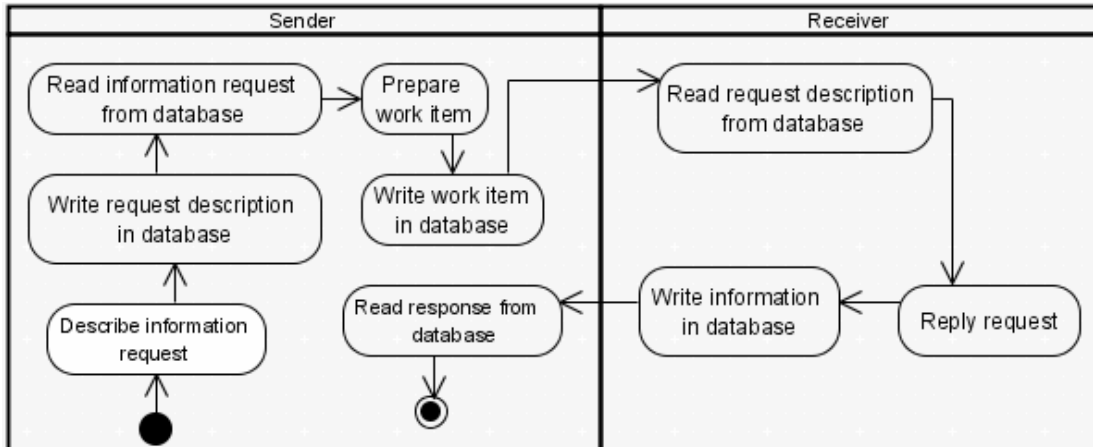


Figure 6.11: Informative pattern

### 6.3.8 Notification Pattern

As shown in Figure 6.12, this pattern is based on the notification message. It comprises a notification activity that either informs about the completion of an activity execution or post news inherent to the respective workflow application (e.g., a notification about the result of an approval process). Regarding the latter case, the sender usually sends a notification informing about the result of an executed activity. Since such a notification informs about the status of an activity execution, it can be considered as part of the bi-directional message (cf. Section 6.1). In the present approach the notification activity is being treated as a self-contained activity; it is assumed that a notification activity status may eventually be sent if requested.

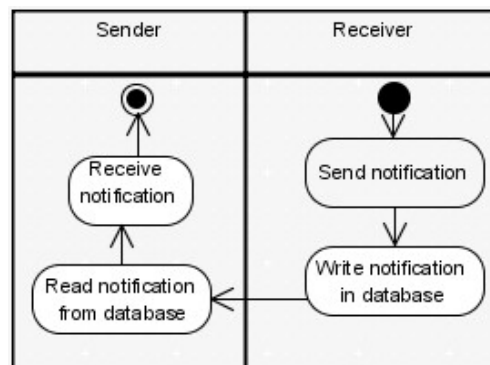


Figure 6.12: Notification pattern

### 6.3.9 Decision Pattern

The decision pattern is similar to the decision control flow as proposed in (AALST, 2003a) (cf. Figure 6.13). However, in this thesis the decision pattern is formed by a bi-directional performative pattern followed by either an XOR-Split or an less frequently OR-Split (refers to Chapter 3 for a definition of these control flows). Based on an activity execution result one or more of several braches will be taken to continue workflow execution.

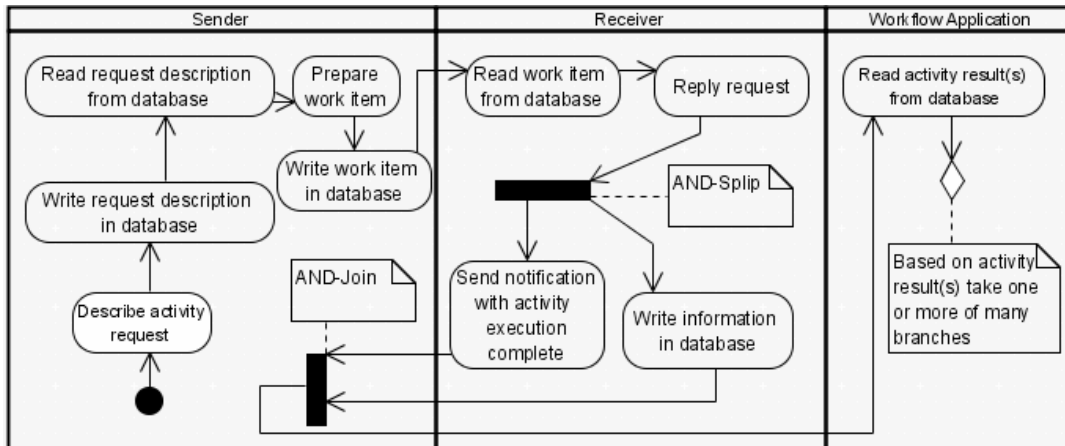


Figure 6.13: Decision pattern

## 6.4 Final Considerations of this Chapter

This Chapter described different kinds of process found in the literature. It also presented a classification of patterns based on these kinds of processes as well as in the patterns described in Chapter 4. In the future, this classification may help to better organize the patterns in a repository of patterns integrated to some existent workflow design tool (e.g., Intalio (INTALIO, 2006), YAWL - Yet Another Workflow Language (AALST, 2005b), EPC - Event-Driven Process Chains (MENDLING, 2006)).

The workflow patterns proposed in this Chapter can be used, for instance, to compare workflow modeling languages with respect to their expressiveness. This conclusion comes from a case study, where simple as well as composed workflow patterns were identified by analyzing workflow processes defined with Oracle Workflow Builder (ORACLE, 2001). In particular, the described patterns were detected in modeling elements of both formalisms, i.e., Oracle Workflow Builder and BPMN (Business Process Execution Language) (OMG, 2006). Rely on (THOM, 2006b) for additional details about this study.

For example, in Oracle Builder an activity is defined as a unit of work that contributes to the accomplishment of a process (ORACLE, 2001). An activity can be a notification, a function, an event, or a process. The present investigation started with the notification activity, which sends a message to a workflow user. The message may simply provide the user with information or request him to take some action. Figure 6.14 illustrates the case when the notification activity comprises the request for a task execution, i.e., a work item is assigned to a workflow participant who must execute it. After completion the requester receives a corresponding notification. According to the patterns described above, the notification activity can be considered as a pattern composed out of two workflow patterns – a *bi-directional performative message* and a *notification* (because of the activity notify sender about execution complete).

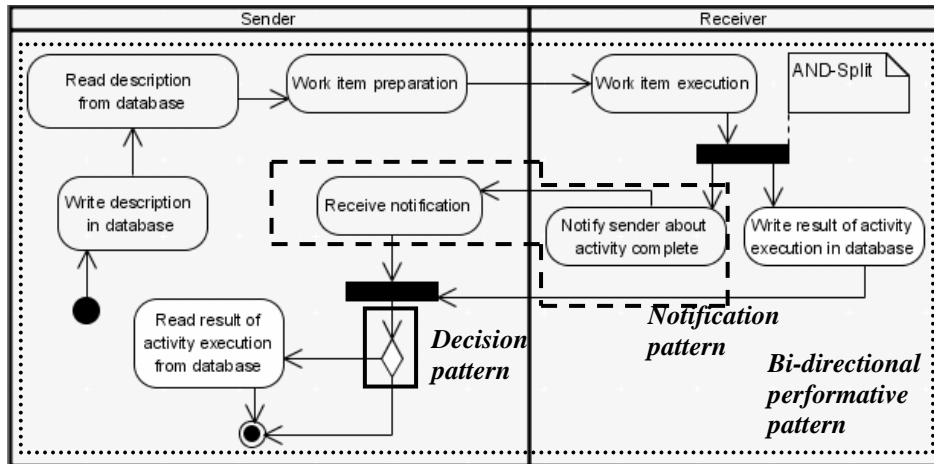


Figure 6.14: Oracle notification activity represented as block activity pattern

Other sample is illustrated in Figure 6.15 where the logic of the end event of BPMN is represented as block activity in UML. End Events may define a *Result* that is a consequence of a Sequence Flow ending. There are multiple types of Results. Figure 6.15 illustrates two kinds of them: (a) generate error code and; (b) send message. The activity choose type of end event for example can be understood as an *application decision* because the user must choose one of several kinds of end events or results to be used in a specific process modeling. Based on this, either an error code must be supplied (Generate error code) or a message needs to be sent reporting the reason for the end event (Send msg).

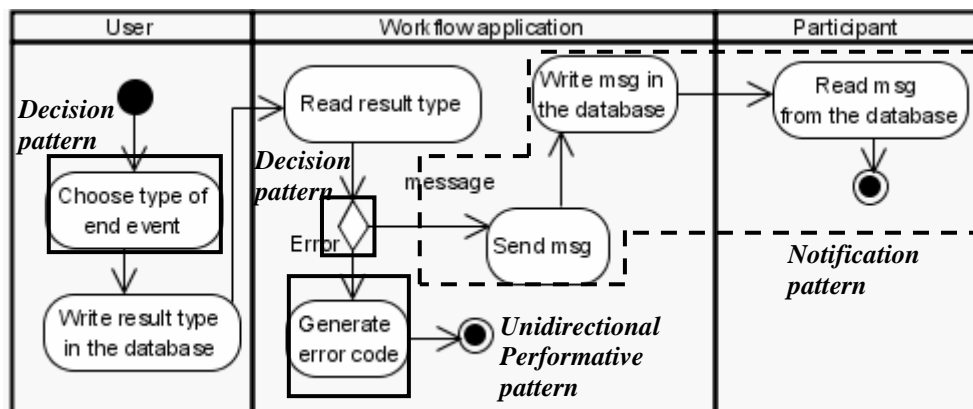


Figure 6.15: BPM End event represented as block activity

In addition to the decision message, Figure 6.15 shows two examples of workflow patterns, the *unidirectional performative message* that in the activity Generate error code and the *notification message* in the Send msg activity.

The next Chapter describes the results of a workflow process mining where 190 workflow were analyzed in order to prove the existence of the workflow patterns. As a result of the workflow process mining, a set of rules that define the patterns and combine them with existent control flow patterns is presented too.



## 7 EVIDENCING THE EXISTENCE OF WORKFLOW PATTERNS THROUGH WORKFLOW PROCESS MINING

As they are executing, workflow systems keep a record of the participants in charge of the activities execution as well as when these activities are executed. Such records are known as *event logs*. Workflow mining through the use of computer software analyses these logs providing a set of structured data. The main goal of the workflow mining is to rediscover the actual workflow process by analyzing information from the event log of a process in execution (AGRAWAL, 1998), (ELLIS, 2006).

With the objective to search the existence of the workflow patterns in workflow processes of real applications 190 workflow processes (WP) were mined. The WP are modeled in the Oracle Builder tool and executed in 13 different organizations related to different application domains. Note that the mining was based on the analyses these workflow processes (models) stand of corresponding instances or logs generated by the execution of them.

Going into more details 11 WP are executed in a large, less-centralized company. Such processes refer to of the total quality management (TQM) of a TQM company. Other 17 are related to the managing of internal activities (e.g., newsletter edition, Feedback of collaborators and work holiday request) of a small Software House. A set of 133 WP are executed in 6 large, highly-centralized organizations. From these, 33 refer to the environmental licensing process of a governmental organization; 63 refer to the managing of internal activities (e.g., Help Desk and both approval of travel request and purchase other) of a Telecom company; 32 refer to the document management (e.g., letters writing and meeting report) of a Financial Marked company and; 5 of them refer to the control of software access rights in a Tobacco company.

For confidential reason information about the organizations where the other 29 WP are executed could not be obtained. However, most of these WP are related to document approval, Help Desk, user service feedback, creation as well as approval of product layout.

In general words, the main results with the mining were:

- a) evidence with high probability that the workflow patterns proposed in this work exist in real workflow processes;
- b) evidence that the set of patterns is both necessary and enough to model all 190 workflow processes analyzed; and

- c) identification of a set of rules that not only define specific workflow patterns but also show how they are combined with existent control flow patterns (e.g., sequence, XOR-Split).

The remaining of this Chapter is organized as follows: Section 7.1 describes the method of mining used. Section 7.2 discusses general results of the workflow process mining. Section 7.3 presents a set of rules that define specific workflow patterns and combine them with existent control flow patterns. Section 7.4 discusses the completeness of the workflow patterns for the business and workflow process modeling.

## 7.1 Method of Workflow Process Mining Used

Given a set of transactions, where each transaction is a set of items, an *association rule* is an expression  $A$  (antecedent)  $\Rightarrow C$  (consequent), where  $A$  and  $C$  are sets of items. The intuitive meaning of such a rule is that transactions in the database, which contain the items in  $A$  tend to contain the items in  $C$  too. An example of such a rule might be that 98% of customers that purchase tires and auto accessories also buy some automotive services; here 98% is called the *confidence* (CF) of the rule. The *support* (S) of the rule  $A \Rightarrow C$  is the probability of transactions that contain both  $A$  and  $C$  (AGRAWAL, 2006).

The rules are defined based on an  $I$  set, where the elements of  $I$  are the application items.  $A$  and  $C$  must be subsets of  $I$ ,  $A \neq \emptyset$ ;  $C \neq \emptyset$ ; and  $A \cap C = \emptyset$  to assure that for each rule  $A$  and  $C$  are disjoint. The main advantages of associate rules that motivated its use in this thesis are: (a) they are easily understood by humans; (b) they are used to represent empirical associations; (c) through special measures (S and CF) it is possible to evidence the mining completeness (HAN, 2001), (SILVA, 2003).

For each workflow pattern was calculated the  $S$ . In the context of this thesis, the  $S$  means the number of occurrences of each pattern in a set of 190 workflow processes (i.e., the  $I$  set). For those processes including more than one occurrence of the same pattern just one occurrence was considered. The main reason for that is because the support was calculated based on the number of workflow processes and not based on the number of atomic activities. Moreover, in some cases the patterns were identified in partial orders of activities and not in atomic activities. The CF was calculated just for the patterns rules presented in Section 7.3. The following formula was considered to calculate the support:

$$S = \frac{F(A \wedge C)}{T_T};$$

Where:

$F(A \wedge C)$  = frequency of A and C together and

$T_T$  = number of workflow processes

Initially, the workflow patterns were identified with circles and legend in all workflow process analyzed. Figure 7.1 brings an example of this identification (cf. Figure 7.1).

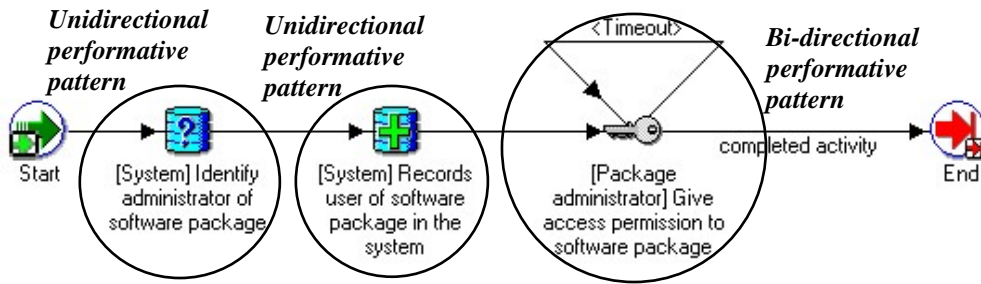


Figure 7.1: Real process that contain the workflow patterns

Afterwards, the number of occurrences of each pattern in all workflow processes was counted. The result was, then, divided by the total number of processes, i.e. 190. Accordingly, the  $(A \wedge C)$  for this calculation corresponds to a specific pattern while  $T_T$  means the set of workflow processes.

The Next Section first presents the frequency (based on of  $S$  value) of each workflow pattern in the set of workflow processes analyzed. Afterwards, it brings a discussion about why specific categories (or specific patterns inherent to them) of patterns were identified in the set of workflow processes with higher probability than others.

## 7.2 Analyzing the Workflow Process Mining Results

This Section presents the probabilistic results of a detailed investigation where 190 workflow processes were mined in order to verify whether the block activities (presented in Chapter 6) could really be considered as patterns with high probability of reuse in business as well as workflow process design.

Figure 7.2 brings the probability of each category of workflow pattern in the set of workflow processes analyzed. The graphic shows that the recurrent business process functions (RBF) –based workflow patterns were identified with high-probability in 75% (i.e. 142 WP) of the WP analyzed. Furthermore, while 60% (i.e. 114) of the WP contain some of the Organization –based workflow patterns, only 8% WP (i.e. 16) contain the Application Domain (AD) –based workflow patterns.

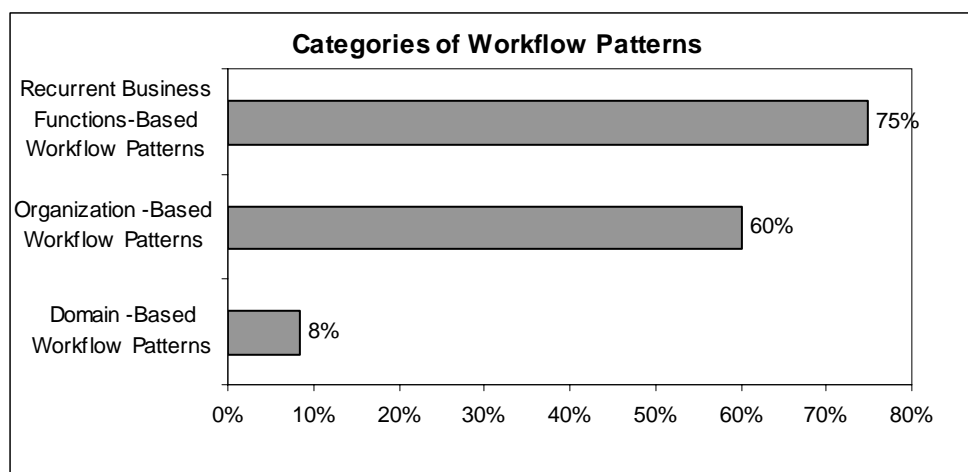


Figure 7.2: Mining results by categories of workflow pattern

The next sections discuss in details the probability (i.e., the support value) of each category of patterns in the set of workflow processes mined. Each Section discusses one specific category based on the probabilistic results presented in Figure 7.1.

### 7.2.1 Frequency of Recurrent Business Functions –Based Workflow Patterns in Real Workflow Processes

This category contains patterns related to the description or modeling of whatever workflow process (e.g., *notification*, *decision*, *informative*, both *unidirectional* and *bi-directional performative patterns*). Such patterns are not dependent on specific application domains or organizational structure aspects. This fact mainly explains why they were identified with high-probability in practically all WP analyzed.

Figure 7.3 graphically illustrates the frequency (based on of  $S$  value) of each pattern of this category based on the set of WP analyzed. The graphic shows that while 142 WP (i.e. 75%) present the *unidirectional performative pattern*, 123 WP (i.e. 65%) contain the *bi-directional performative pattern*. The *notification pattern*, in turn, was identified in 102 WP (i.e. 54%). The graphic also shows that the *decision pattern* was identified in 121 WP (i.e. 64%). The informative pattern was identified in those activities where the user provides some information to the workflow through the fulfillment of some field. Because of that, it was less frequent when comparing with the other workflow patterns.

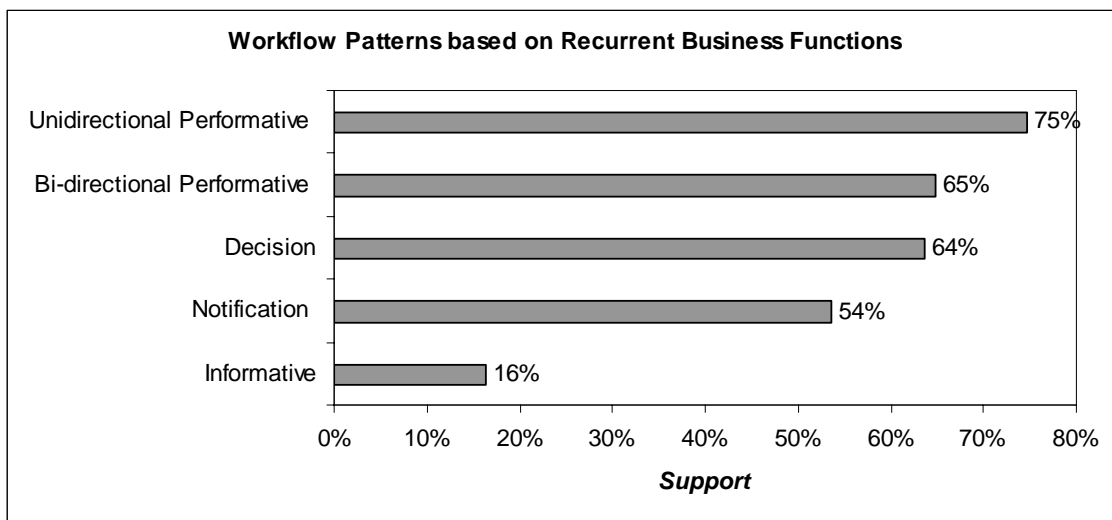


Figure 7.3: Frequency of workflow patterns based on recurrent business functions in real workflow processes

The graphic in Figure 7.4 illustrates the probability of RBF workflow patterns in 32 WP executed in a Financial Market Company. The graphic shows that 97% of the WP contain at least one occurrence of some pattern of this category. This high-probability is justified because most of these WP are general, i.e., non application –domain related. Moreover, as the organization is highly-centralized, the approval pattern was also identified with high-probability.

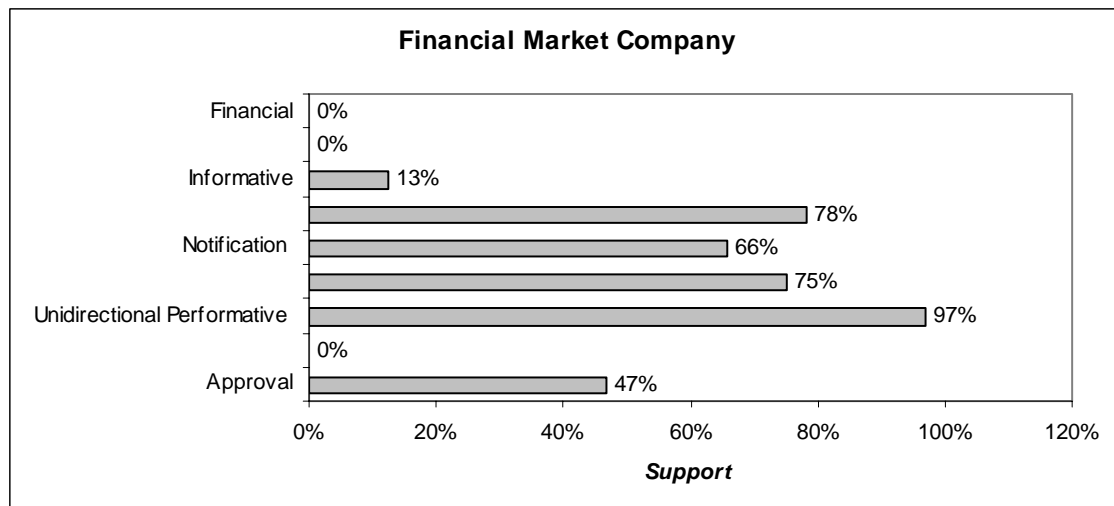


Figure 7.4: Frequency of the recurrent business functions –based workflow patterns in the workflow processes of a Financial Market Company

Figure 7.5 shows a workflow process sample with the purpose of notify reviewers of a document about the canceling of such document. The process is executed in the mentioned Financial Market Company. As shows Figure 7.5, it contains two recurrent business functions -based patterns (notification and decision patterns, respectively).

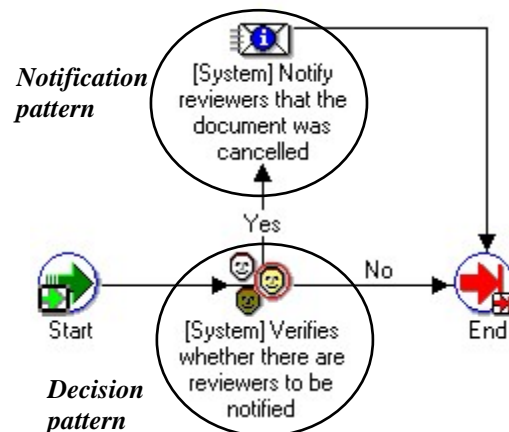


Figure 7.5: A real notification process that contains the recurrent business functions –based workflow patterns

### 7.2.2 Frequency of Organization –Based Workflow Patterns in Real Workflow Processes

This category comprises patterns related to specific organizational structure aspects (e.g., *document approval* and *question-answering patterns*). The *document approval pattern*, in particular, was identified with high-probability in the WP analyzed. Such fact can be justified by the high centralization on decision-making existent in the organizational units where the WP analyzed are executed. Such high centralization implies in the use of approval activities. Besides that, several WP belong to applications related to approval contexts.

Figure 7.6 graphically illustrates the probability of organization –based workflow patterns in the workflow processes analyzed. The *approval pattern* was identified in 114 (i.e. 60%) of the 190 WP analyzed in contrast to the four WP (i.e. 2%) that contain the *question-answering pattern*.

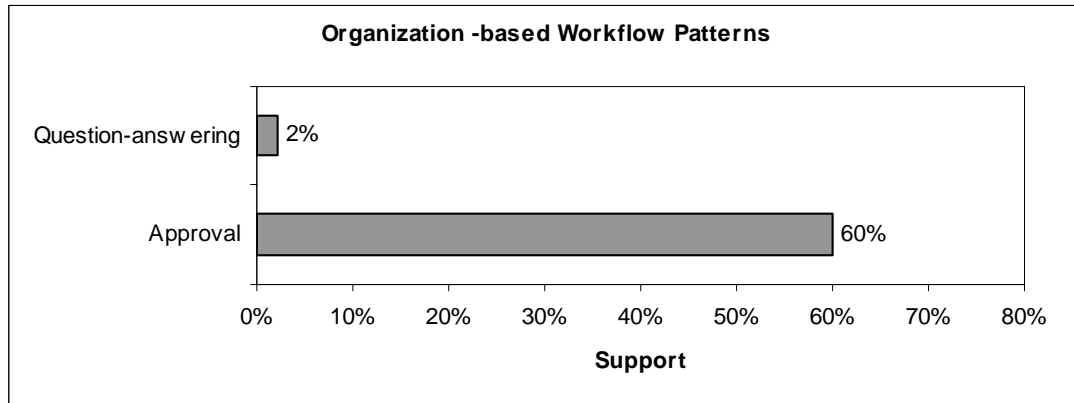


Figure 7.6: Frequency of the organization –based workflow patterns in real workflow processes

Figure 7.7 graphically illustrates the probability of organization –based workflow patterns in a set of 63 WP executed in a highly-centralized Telecom Company. It shows that 63% of the WP, i.e. the majority of them contains at least one occurrence of the approval pattern. As most of the WP from this organization are not related to financial as well as logistic activities these patterns were less frequently identified in this set of workflow processes. On the other hand, as the processes are composed by several recurrent business functions the RBS –based workflow patterns were identified with high-probability.

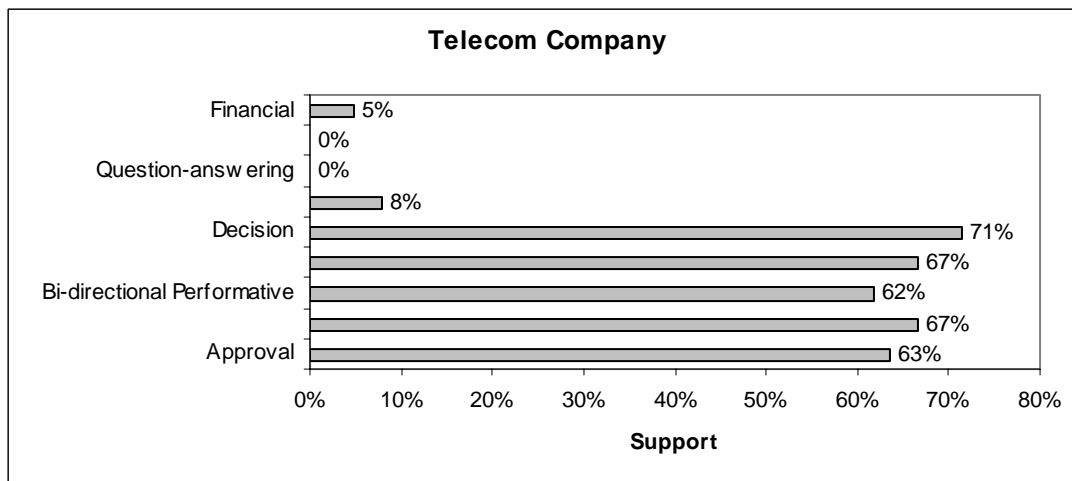


Figure 7.7: Frequency of the organization –based workflow patterns in the workflow processes of a Telecom Services Company

Figure 7.8 depicts a process sample concerning the approval of a purchase order executed in a Telecom Company. In this organization, 40 (i.e. 63%) of the 63 WP analyzed contain at least one occurrence of the *approval pattern*. Moreover, from 32 WP of a Financial Market Company, 15 WP (i.e. 47%) contain the approval pattern. The *question-answering pattern* was less frequently in all the WP analyzed because most of the processes do not include question-answering activities. Only 6% of the 17

WP executed in a Software House presented the pattern. In most of the cases the *doubt*, which may occur in the context of a document writing is solved by the document author.

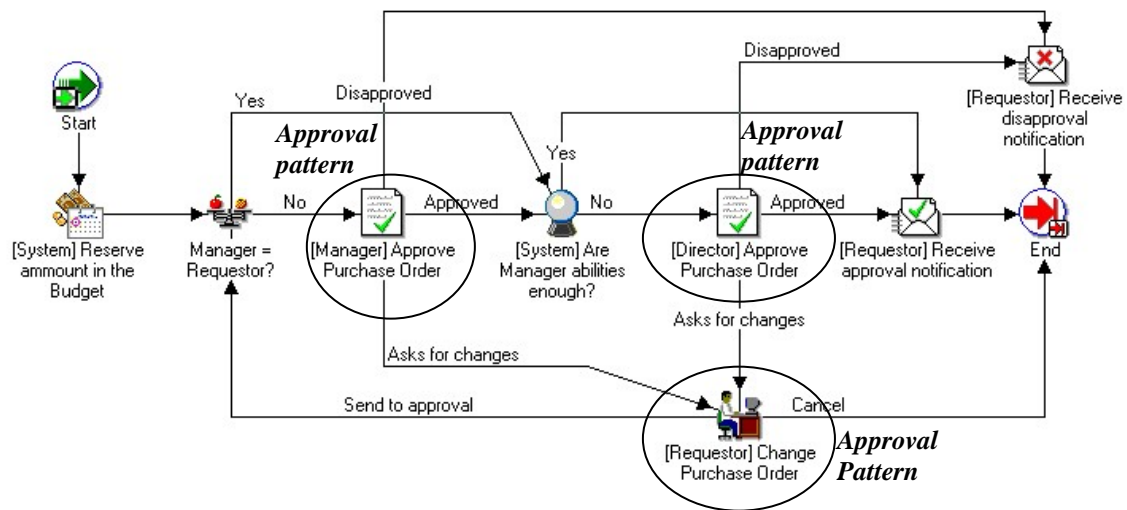


Figure 7.8: A real purchase order process that contains the organization –based workflow patterns

### 7.2.3 Frequency of Application Domain –Based Workflow Patterns in Real Workflow Processes

The patterns of this category are related to specific application domains (e.g., financial and logistic patterns). As the most majority of the WP analyzed do not comprise either logistic or financial activities, the corresponding patterns related to these activities were less frequently.

Figure 7.9 graphically illustrates the probability of *logistic* as well as *financial* patterns in all WP analyzed. It shows that the *financial pattern* was identified in 16 WP (i.e. 8%). Indeed, none of the WP presented the *logistic pattern*.

The *financial pattern* was identified in those activities where some monetary value is used or produced. Going into more details, 5% of the WP executed in the Telecom Company contain the financial pattern (cf. Figure 7.7). The WP where the financial pattern was identified present financial purposes (e.g., management of the organization cash amount). Moreover, 6% of the WP executed in the Software House as well as in the Governmental Organization also contain the *financial pattern*. The *logistic pattern* was not identified in the set of WP analyzed. This can be justified because the WP analyzed are not appropriated to the identification of both financial as well as logistic patterns

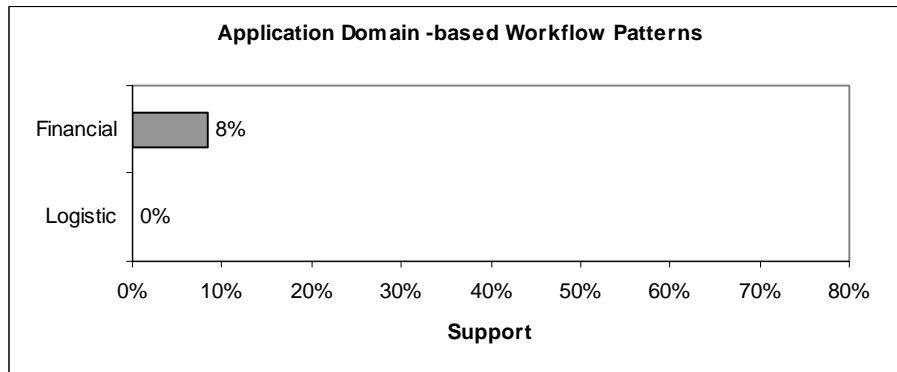


Figure 7.9: Frequency of the application domain –based workflow patterns in real workflow processes

### 7.3 Towards Rules for Defining and Combining Workflow Patterns

As a consequence of the mining process, a set of association rules was identified. The rules not only help to better define specific workflow patterns, but also combine them with existent control flow patterns (cf. Chapter 3). These rules can be useful for building more complex workflows.

The *support* ( $S$ ) as well as the *confidence* ( $CF$ ) were calculated for each of those rules. In this context, the  $S$  means the number of processes containing the items of the rule, i.e., the antecedent ( $A$ ) and the consequent ( $C$ ) together (c.f. the support formula presented in Section 7.1). On the other hand, the  $CF$  of an association rule is the probability of how frequently the rule  $A$  occurs among all the processes containing  $C$ .  $CF$  indicates how reliable a rule is. The higher the value, the more often  $A$  and  $C$  are related to one another. The following formula was applied to calculate the confidence:

$$CF = \frac{F(A \wedge C)}{F(A)}$$

Where:

$F(A \wedge C)$  = frequency of  $A$  and  $C$  together and

$F(A)$  = frequency of  $A$

The association rules that were identified are presented in Extended Backus-Naur Form (EBNF) EBNF is usually used for definition of grammars, so that there is no disagreement or ambiguity (ISO, 1996), (SCOWEN, 1998). Table 7.1 brings the EBNF notation used in this text. The following sections present the rules and bring examples of workflow processes where they occur.



Table 7.1: EBNF notation

---

::=	defining symbol
;	terminator symbol
(*	start comment symbol
*)	end comment symbol
,	concatenate symbol
	option symbol

---

### 7.3.1 Association Rule for the Document Approval Pattern

In this work, 114 workflow processes were analyzed. These processes are related to different approval contexts (e.g., content approval for a newsletter section and the approval of the launching of a new product). 97 of the analyzed approval processes (i.e., more than 85% of the total number of processes) can be defined in terms of a composition of a *bidirectional performative pattern* in a *manual activity* (where the system is the requester and a human is the sender) followed by an *Exclusive Choice (XOR-Split)* control flow pattern (AALST, 2003a). The basic structure of the identified rule is as follow:

R1 ::= *Association Rule for the Document Approval Pattern*

R1.ANTEC ::= *bidirectional performative pattern in a manual activity*

R1.CONSEQ ::= XOR-Split (\* is the following construction \*);

In 85% (S) of the investigated approval processes, the bi-directional performative pattern is present in the context of a manual activity, and has been followed by an XOR control flow pattern. The confidence (CF) of R1 is 78%.

Figure 7.10 depicts an example of an approval process that follows R1. It is a workflow process related to *the setting of a second feedback meeting*. First, a date is defined (Set second feedback). The defined date must then be approved in the subsequent activity (Evaluate second date for the Feedback). This activity matches the *approval pattern*. Based on the activity result or a notification is send (Receive notification about second meeting) or a new date is defined.

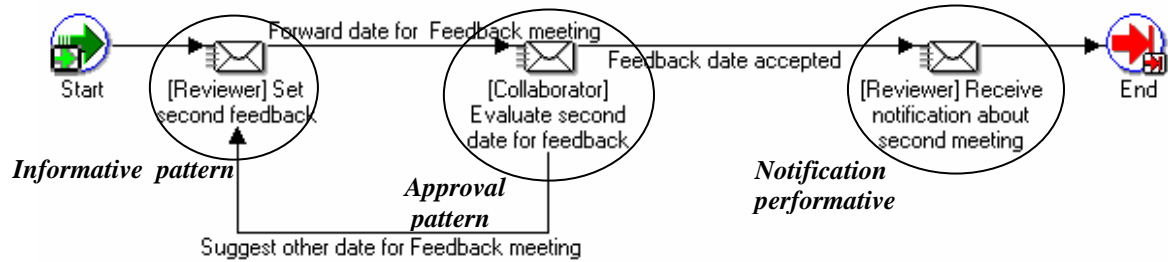


Figure 7.10: A real process that follows the association rule for the document approval pattern

### 7.3.2 Association Rule for the Decision Pattern

In this work, 132 workflow processes were analyzed related to specific selection (one of many options) instead of an evaluation or approval. 121 of the analyzed decision activities (i.e., more than 92% of the total number of processes) can be defined in terms of a composition of a *bidirectional performative pattern* in an *automatic activity* followed by an *Exclusive Choice (XOR-Split)* (AALST, 2003a). The basic construct of the rule is as follow:

R2 ::= Association Rule for the Decision Pattern

R2.ANTEC ::= *bi-directional performative pattern* in *automatic activity* (\*related to a decision construct\*)

R2.CONSEQ ::= XOR-Split (\* is the following construction \*);

In 92% (S) of the investigated decision constructs, the bi-directional performative pattern is present in the context of an automatic activity, and has been followed by an XOR-Split control flow pattern. The confidence (CF) of R2 is 86%.

Figure 7.11 illustrates an order approval process that follows R2. The decision pattern was identified in an activity where the system verifies whether a superior position must participate in an approval process. This scenario matches to the *decision pattern*. The process also includes activities related to both *notification pattern* (Notify approver; Notify reject to the requestor; Notify approval to the requestor) as well as *approval pattern* (Evaluates request).

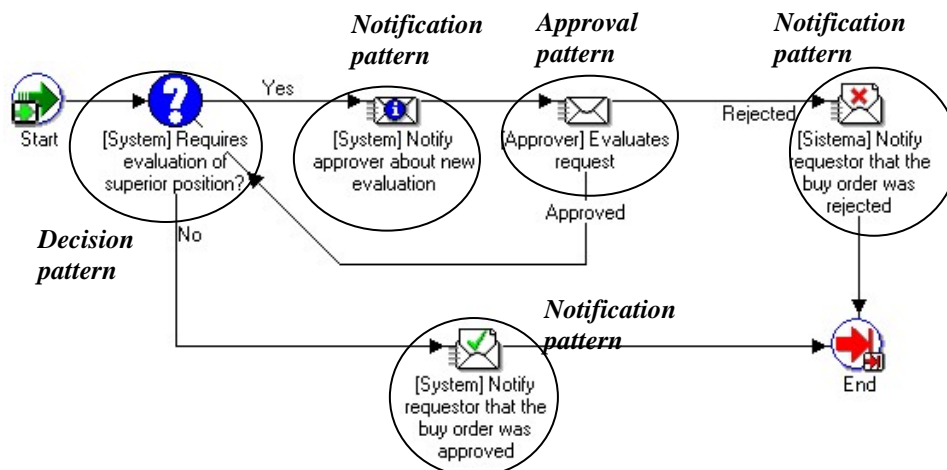


Figure 7.11: A real process that follows the association rule for the decision pattern

### 7.3.3 Association Rule for the Informative Pattern

In this work, 31 workflow processes analyzed contain activities related to information request. All the information request activities can be defined in terms of a *bidirectional performative pattern* in *manual activity* (where the system is the requestor and the user the information provider) followed by a *sequence control flow pattern*.

R3 ::= Association Rule for the Informative Pattern

R3.ANTEC ::= *bi-directional performative pattern* in *manual activity, information request* (\*the activity must contains an information request\*)

R3.CONSEQ ::= Sequence (\* is the following construction \*);

In 100% (S) of the investigated informative request activities, the bi-directional performative pattern is present in the context of a manual activity (where an information is requested), and has been followed by a Sequence control flow pattern. The CF of R2 is 100%.

Figure 7.12 shows an example of a content approval for a newsletter section that follows R3. An organizational role *Staff* sends the section material to an *Editor* who must review it. Depending on the revision result, the process ends or the Editor can ask for changes in the material content. The activity Send material to the Editor matches the *informative pattern* because the user (Editor) must provide information about the newsletter. The next activity approved material or material requires changes matches the *approval pattern*.

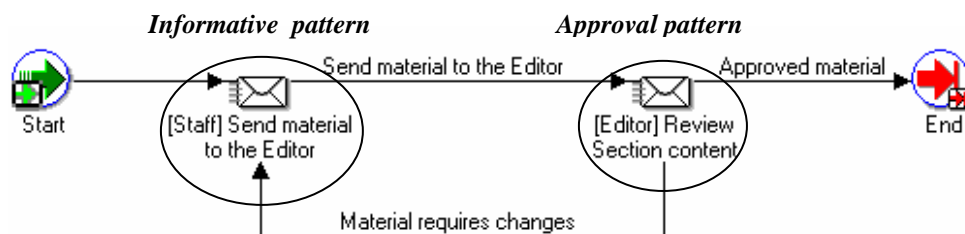


Figure 7.12: A real process that follows the association rule for the informative pattern

### 7.3.4 Association Rule for Notification Pattern

In this work, 102 workflow processes were analyzed. These processes contain activities referring to a notification such as the result of an activity execution, advice or remember. All these activities can be defined in terms of a composition of a *unidirectional performative pattern* in either *manual* or *automatic activity* (where the description of the activity refers to an advice, notification or remember) followed by a sequence control flow pattern.

R4 ::= Association Rule for the Notification Pattern

R4.ANTEC ::= Unidirectional Performative Pattern in manual or automatic activity, [advice | notification | remember] (\*activity description\*)

R4.CONSEQ ::= Sequence (\* is the following construction \*);

In 100% (S) of the investigated notification activities where, the unidirectional performative pattern is present in the context of either a manual or automatic activity, and has been followed by a sequence flow pattern. The CF of R4 is 100%.

Figure 7.13 depicts an example of a process activity that follows R4. The process refers to the maintenance of a supplier data. First, a business team responsible by the maintenance is notified (Send e-mail for reviewer team of business division). This activity reflects the *notification pattern*. Afterwards, the Business team evaluates the request for maintenance of supplier data (Evaluates request for maintenance of supplier data) matching with the *bi-directional performative pattern*.

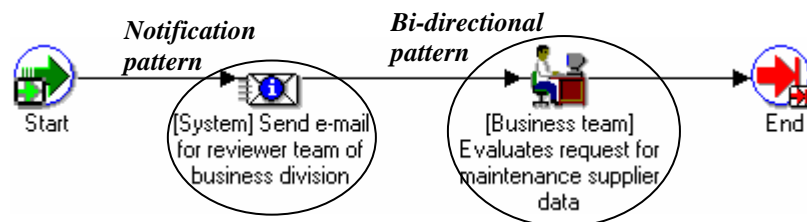


Figure 7.13: A real process that follows the association rule for the notification pattern

### 7.3.5 Association Rule for the Unidirectional Performative Patterns

In this work, 142 workflow processes contain activities related to the *unidirectional performative pattern*. In 141 (i.e. 99%) of these the activities matching to the *unidirectional performative pattern* show some common characteristics. After an activity which covers a task execution request a *sequence flow* has been used. The basic structure of the identified rule is as follow:

R5 ::= Association Rule for the Unidirectional Performative Pattern

R5.ANTEC ::= Unidirectional performative pattern in manual or automatic activity

R5.CONSEQ ::= Sequence (\* is the following construction \*);

In 99% (S) of the investigated processes that contain an activity execution request (where the process continue execution without waiting for a response), the unidirectional performative pattern is present in the context of either a manual or automatic activity, and has been followed by a sequence control flow pattern. The CF of R5 is 99%.

Figure 7.14 brings a process concerning the approval of a new product marketing campaign. The process contains an activity that follows R5. First, an e-mail is send to

the business division informing new requests (Send e-mail to business division informing new requests). Such activity matches the notification pattern. Later, the Business division evaluates the request (Evaluate items waiting for approval). Subsequently, a notification is sent to the administrator informing the evaluation result (Notify administrator about evaluation). Finally, a *unidirectional performative pattern* is identified in the activity Check whether there are new item to be evaluated.

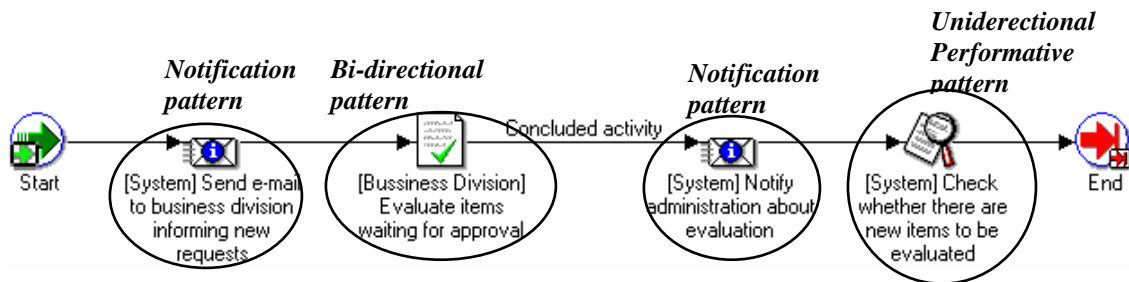


Figure 7.14: A real process that follows the association rule for the unidirectional performative pattern

### 7.3.6 Association Rule for the Bi-directional Performative Pattern

In this work, 123 workflow processes analyzed contain activity execution requests where the process waits for the completion of the activity request execution. Such activities can be defined in terms of a *bi-directional performative pattern in manual or automatic activity* followed by a *sequence control flow pattern*.

$R6 ::= Association Rule for the Bi-directional Performative Pattern$

$R6.ANTEC ::= Bi-directional performative pattern in manual or automatic activity$

$R6.CONSEQ ::= Sequence (* is the following construction *)$ ;

In 100% (S) of the investigated activity execution requests where the process waits for the completion of the activity execution, the bi-directional performative pattern is present in the context of a manual or automatic activity, and has been followed by a sequence control flow pattern. The CF of R6 is 100%.

Figure 7.15 brings a process to give users transaction rights. It contains an example of activity that follows R6. First, the system identifies the transaction Administrator (Identify Administrator of transaction). This activity matches the *unidirectional performative pattern*. Afterwards, the identified Administrator give users right access for specific transactions (Configure rights and give access to other transactions). The process waits, then until the activity completes.

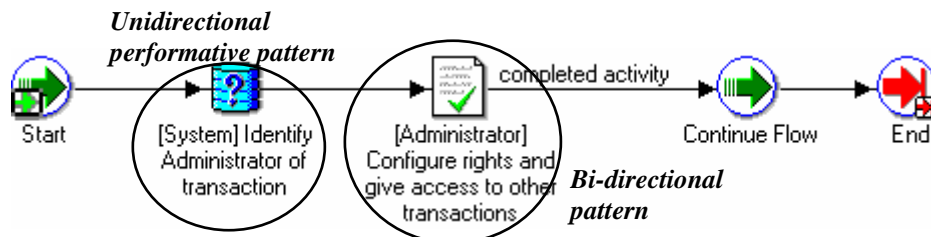


Figure 7.15: A real process that follows the association rule for the bi-directional performative pattern

## 7.4 Discussing the Completeness of Workflow Patterns for Business and Workflow Process Modeling

The main goal of the mining process presented in this text was the measurement of the frequency with which each one of the workflow patterns happens in the set of workflow processes that has been analyzed. This was done in order to verify whether these workflow constructs could really be considered as patterns with high probability of reuse in business as well as workflow process design.

While some patterns were identified only by the analyses of the activity description (e.g., decision, approval and notification patterns), others required a more detailed analyses. For instance, the *informative pattern* was identified in activities where the user provides an information to the system (e.g., by the fulfillment of a field in the context of an activity). In the case of the unidirectional and bi-directional performative pattern, both the activity description and its execution result (i.e., mandatory or not to trigger the next activity in the process) were important to measure how often the pattern occurs. On the other hand, the financial pattern was identified in activities comprising some financial attribute (e.g. Figure 7.16, activity Update Invoice Number as well as Amount sets an internal monetary attribute that is used by the next activity in the process).

What really surprised us was the fact that all analyzed workflow processes can be defined as a composition of the investigated patterns (see Figure 7.16 for an example). That is, the set of workflow patterns is necessary and sufficient to design all 190 real workflow processes that were subject of the mining effort. In each process, a specific workflow pattern may appear zero or more times combined with other patterns.

This fact can be considered as a very important one which points out to new questions to be investigated as part of a future work. For instance, how much could this set of patterns be helpful if it was to be integrated into a workflow design tool? One could think of an intelligent software module which relies on both a workflow patterns repository and the set of patterns combining rules presented in prior sections in order to help designers to complete their workflow design. On the other hand, the identified combining rules could be applied in the process of translating legacy software applications (e.g., those ones written in COBOL) into workflow based applications with activities that are written in modern programming languages.

Figure 7.16 shows a workflow process sample where all activities match either a workflow pattern or a combination of them.

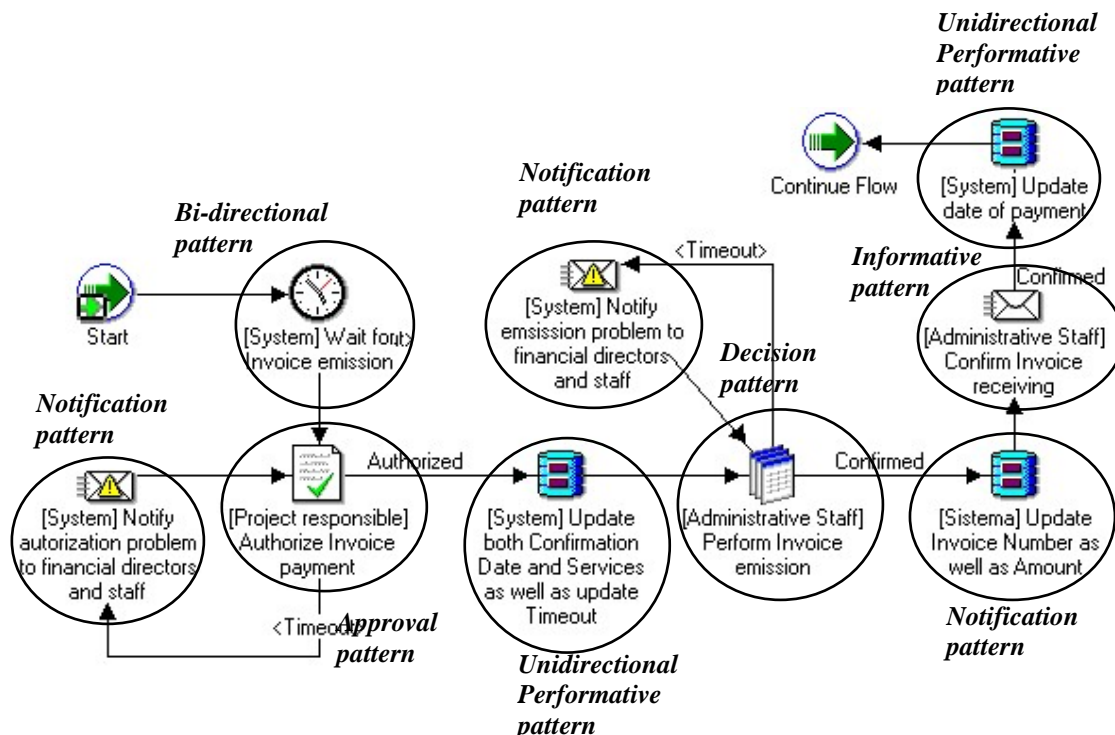


Figure 7.16: A payment process built up exclusively from the combination of workflow patterns

## 7.5 Final Considerations of this Chapter

The analysis of a set of workflow processes, which are related to different application domains and executed in different organizations is crucial in order to achieve satisfactory results. The workflow mined reported in this Chapter showed that more than 50% of the workflow processes which activities matches to the workflow patterns based on business recurrent functions use the same construct even when referring to different application domains. The same occurs with the approval pattern because most of the organizations present high-centralized structures. In contrast, the financial pattern was identified in specific activities comprising monetary values (cf. Figure 7.5). The logistic pattern was not identified in the workflow processes analyzed because the analyzed workflow processes are not related to logistic activities.

The main difficulty concerning the workflow process mining effort was the no availability of a computerized tool, which could (semi)-automatically supports the identification of the workflow patterns in the set of workflow processes analyzed as well as the calculus of both support and confidence values. If existent, such a tool could reduce the mining time and the human effort

One of the most important conclusions of the mining presented in this Chapter is that all workflow processes analyzed can be defined as a combination of workflow patterns. Moreover, it is possible to assume that the patterns are enough to describe a large diversity of business processes or workflow processes in high-level of abstraction.

On the other hand, the rules introduced in this Chapter are useful for a better definition of the workflow patterns. This may help in the extending of some workflow design tool with the patterns. All rules presented high support and confidence, which help to evidence their existence in the set of workflow processes analyzed. The next Chapter presents the conclusions of this work.

## 8 CONCLUSIONS

This thesis showed that though there exists several consolidate (meta) models as well as notations for both business process and workflow processes modeling, none of them achieved broad usage of organizational structure aspects. Most of the existent organizational sub-models use the knowledge about structural aspects only to assign performers to process activities. Moreover, little effort has been devoted to the development of (meta) models supporting the reuse of patterns in the design phase of the workflow project. Although this thesis has not focused on performance measurements, there is a strong possibility that these limitations can threaten both the accuracy and efficiency of the whole workflow project. On one hand, the business as well as workflow processes modeled on the bases of these (meta) models and notations may not be represented as they are really executed in organizations. On the other hand, the reuse advantages that have been proved in several application domains are not being extensively applied in the development of workflow applications.

Focusing on these limitations, this thesis proposed a set of patterns based on organizational structure aspects. Each pattern represents a relationship between one or more aspects of the organization and specific business (sub-)processes. In this context, this thesis also proposed the Transactional Metamodel of Business Process (TMBP). The advantages of TMBP are twofold: First, it comprises an organizational sub-model with support to structure aspects. Second, it provides a high-level specification that supports semi-automatic selection of at least organization –based patterns.

Thinking about implementation aspects based on TMBP, this thesis demonstrated how the BPEL4WS might be used in the description of executable organization –based workflow patterns. The approach presented in this thesis proposes the automatic mapping of TMBP processes to BPEL4WS processes. The mapping is done on the bases of rules, which map UML elements to BPEL4WS constructors.

This thesis has also reviewed different kinds of business processes found in the literature (e.g., logistic process, financial process and information process). As described in the text, logistic as well as financial processes generate data that are implemented by the information process activities of the organization as message exchanges (e.g., unidirectional and bi-directional messages). Based on these kinds of business processes, this thesis proposed a set of workflow patterns represented as workflow patterns. By applying the “block activity” concept to define the patterns, the atomicity property was provided for the patterns. It means that all activities inherent to a specific pattern are completely executed from the beginning to end before the surrounding workflow (outside the activity block) may continue its execution.

In order to evaluate the existence of the workflow patterns in real workflow processes a large study case was performed. A set of 190 workflow processes from



more than 10 different organizations was mined. The mining results had evidenced that there is a high probability that the workflow patterns exist in real workflow processes, i.e., 60% of the analyzed workflow processes include organization-based patterns; 8% include some domain application-based patterns and; 75% include patterns related to recurrent business functions. Moreover, it became clear through the study that the patterns are both necessary and sufficient to design all 190 workflow processes investigated. From this, one can conclude that the detected patterns could be very suitable for defining both business and workflow processes related to different application domains. However, this thesis had not explored whether they can help reducing design efforts (i.e., may increase productivity during design time).

Another important contribution of this thesis is a set of rules, which define the workflow patterns and combine them with existent control flow patterns. During the analysis of the workflow (sub-)processes it was verified that certain patterns can be defined by combining existing ones (e.g., *approval pattern* ::= [*bi-directional performative pattern* + *manual activity*] → *XOR-Split*). In general, most of the patterns are followed by specific kinds of control flow (e.g., *unidirectional performative pattern* → *sequence*).

As reported in the thesis, one of the benefits resulting from the identification of the described patterns and rules is that they can be used to compare expressiveness and completeness of existing workflow modeling languages. Other important use case for the patterns and rules is the automation of reengineering efforts. For example, if the organization structure changes from a highly hierarchical to a flat decision-making structure, patterns of decision-making can be automatically found in the flows and also be substituted by new structures (based on patterns). This reflects how decision-making has to be done from now on.

## 8.1 This thesis resulted in several papers and academic works:

### Bookchapter:

1. THOM, L. H.; IOCHPE, C.; AMARAL, V. L.; VIERO, D. Towards Workflow patterns for Reuse in Workflow Design. In: *Workflow handbook 2006 including business process management* : published in association with the workflow management coalition. Lighthouse Point : Future Strategies, 2006. p. 249-260. (THOM; IOCHPE; AMARAL; VIERO; 2006a).

### Journal Paper (To be submitted)

1. THOM, L.; IOCHPE, C.; REICHERT, M. Workflow Patterns: Towards Definition and Combining Rules. This paper must be submitted to *Data and Knowledge Engineering*.

### Wokshop and Conference Papers:

1. THOM, L. H.; IOCHPE, C. Applying Block Activity Patterns in Workflow Modeling. In: *Proceedings of ICEIS – International Conference on Enterprise Information System, Setúbal, Portugal, 2006*. Pages 457–460. (THOM; IOCHPE, 2006b).

2. THOM, L. H.; IOCHPE, C.; MITSCHANG, B.. Improving Workflow Project Quality Via Business Process Patterns Based on Organizational Structure Aspects. In: Proceeding of GI Workshop XML4BPM - XML Interchange Formats for Business Process Management, Karlsruhe, Germany, 2005. Pages 65–79. (THOM; IOCHPE; MITSCHANG, 2005a).
3. THOM, L. H.; IOCHPE, C; MITSCHANG, B. A Transactional Metamodel For Business Process Modeling With Support To Business Process Patterns. In: IFIP First Academy on the State of Software Theory and Practice - PhD Colloquium, Porto Alegre, Brazil, 2005. (THOM; IOCHPE; MITSCHANG, 2005b).
4. THOM, L. H.; IOCHPE, C; MITSCHANG, B.. TMBP: A Transactional Metamodel for Business Process Modeling Based on Organizational Structure Aspects. In: Forum of the CAiSE – Conference on Advanced Information Systems Engineering, Porto, 2005. Pages 195–200. (THOM; IOCHPE; MITSCHANG, 2005c).
5. THOM, L. H; IOCHPE, C. Integrating a Pattern Catalogue in a Business Process Model. In: Proceedings of ICEIS – International Conference on Enterprise Information Systems, Porto, Portugal, 2004. Pages 651–654. (THOM; IOCHPE, 2004).
6. THOM, L. H.; IOCHPE, C. Identifying Patterns o Workflow Design Relying o Organizational Structure Aspects. In: Proceedings of ICEIS – International Conference On Enterprise Information Systems, Angers, France, 2003. Pages 462-467. (THOM; IOCHPE, 2003).

This thesis has also originated one Undergraduate Final Project and one Master Dissertation.

1. LAU, J. M. Projeto para Implementação de Padrões de Atividade em Ferramentas para Modelagem de Processes de Workflow. Informatics Institute. UFRGS. (Title in English: Project for the Implementation of Block Activity Patterns in Workflow Design Tools). Cirano Iochpe (advisor); Lucinéia H. Thom (co-advisor).
2. CHIAO, C. Um Mecanismo Baseado em Regras de Associação para Auxílio na Escolha de Padrões de Workflow. Informatics Institute. UFRGS. (Defense forecast: 2007). (Title in English: An Association Rule Based Mechanism to Selection Aid Workflow Patterns) Cirano Iochpe (advisor).

## 8.2 Future Trends

This Section describes some open problems that could lead to future research work:

**Improvement of TMBP.** Future work concerning TMBP metamodel can focus on the improvement of the catalogue package. Currently, the catalogue describes the classes (based on the other packages of the metamodel) required during the selection of the best design pattern from a catalogue of patterns (e.g., organization –based workflow patterns) (THOM, 2005a), (THOM, 2005c). In order to support whatever

workflow pattern it is necessary to extend the catalogue with additional classes. One of these classes is a Classifier class to represent the patterns classification introduced in Chapter 6. In addition, the metamodel needs to be validated. To do so, both real business processes and workflow processes must be modeled on the bases of it.

**Improvement of TMBP methodology.** This thesis presented a first inside towards a methodology for business process modeling based on TMBP (THOM, 2005b), (THOM, 2005c). The methodology has at least two important characteristics. First, it proposes the modeling of either business processes or workflow processes from the reuse of at least organization –based workflow patterns. Second, it considers the automatic generation of BPEL4WS processes. Future work should focus on the use of TMBP in the development of real workflow applications. By doing that, it will be possible to verify how complete and efficient is the methodology for the workflow project development.

**Storing and query of workflow patterns.** This thesis presented a set of workflow patterns represented through the block activity concept. Each pattern is based on recurrent functions frequently found in business processes. The existence of such patterns was proved through the mining of a large set of workflow processes from different organizations. As presented in chapter 7, the mining results not only proved with high support the patterns existence in the set of analyzed workflow processes but also led to the identification of a set of rules that better defined and combine the patterns with existent control flow patterns. In the future a larger set of workflow (sub-)processes must be analyzed in order to identify not only new patterns but also new rules related to them. Moreover, to develop an extension to some workflow design tool with the set of workflow patterns. Such extension must comprise an intelligent mechanism (based on the pattern rules) to semi-automate the reuse of patterns.

**Performance measurement of workflow patterns reuse.** It is important to verify whether the modeling phase of a workflow project will result in a performance gain through the use of workflow block activities. To do so, it is yet necessary to perform experiments that compare design time with and without a pattern management tool integrated into a workflow design editor.

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## APPENDIX CONTRIBUIÇÕES DA TESE

Organizações atingem seus objetivos através da execução de seus processos de negócio. Tal processo compreende o conjunto de um ou mais procedimentos ou atividades relacionadas, as quais, coletivamente, realizam um objetivo de negócio no contexto de uma estrutura organizacional (Fisher, 2001) e (WfMC, 1999). Neste contexto, um sub-processo de negócio é um processo integrado e controlado por outro processo de negócio.

Processos de negócio têm um papel fundamental na maneira como as organizações são estruturadas. Diversos autores e profissionais concordam que para estruturar uma organização, pelo menos, dois passos devem ser executados. No primeiro passo, os processos de negócio executados na organização devem ser identificados. No segundo passo, com base nos processos identificados, valores específicos são atribuídos para um conjunto de aspectos estruturais, tais como centralização na tomada de decisão e mecanismos de coordenação do trabalho. É importante observar que estes passos não devem ser executados uma única vez. Ou seja, as organizações devem constantemente adaptar e atualizar sua estrutura organizacional conforme os processos que executam (JONES, p.33, 2001).

Organizações modernas apresentam necessidades quanto à automação dos seus processos de negócio devido à complexidade dos mesmos e da necessidade de maior eficiência na execução. A tecnologia de workflow, através da automatização dos processos de negócio executados na organização, proporciona não apenas a redução de custos, tempo, erros e redundância na execução dos processos, mas também maior controle sobre os mesmos, o que leva ao incremento da qualidade dos processos, de seus resultados e da organização como um todo. Devido a estes e outros fatores é crescente o interesse acadêmico e científico pela tecnologia de workflow e pelo gerenciamento de processos de negócio.

Atualmente, diversas entidades incluindo a *Business Process Management Initiative (BPMI)* (OMG, 2005b), (OMG, 2005c), (OMG, 2006), *Workflow Management Coalitions (WfMC)* (HOLLINGSWORTH, 1995), (WfMC, 2005), *Workflow on Intelligent Distributed Database (WIDE)* (GREFEN, 1999), assim como a *Organization for the Advancement of Structured Information Standards (OASIS)* (OASIS, 2006) têm proposto (meta) modelos e notações com o objetivo de auxiliar e aprimorar a etapa de modelagem do projeto de workflow. Contudo, tais (meta) modelos, notações e linguagens apresentam limitações.

Uma das limitações é o uso restrito de padrões com base em aspectos estruturais na fase de modelagem do workflow. A abordagem em (THOM, 2002) mostra que tais aspectos (ex.: centralização na tomada de decisão) estão fortemente relacionados a partes específicas dos (sub-)processos de negócio (ex.: aprovação de documentos). Em

um processo de aprovação, por exemplo, a atividade de aprovação é, na maioria dos casos, recursivamente executada, conforme o nível de centralização da tomada de decisão nas unidades organizacionais, onde é executada. Neste contexto, o conhecimento sobre os aspectos estruturais é fundamental para uma representação fiel dos processos de negócio como estes são, de fato, executados na organização.

Outro problema dos (meta) modelos existentes é o baixo poder de expressão dos seus sub-modelos organizacionais. A maioria destes utiliza o conhecimento dos aspectos estruturais apenas para definir os responsáveis pela execução das atividades inerentes aos processos de negócio e workflow (ex.: (HOLLINGSWORTH, 1995), (GREFEN, 1999, p.39)) Além disso, ainda que existam diversas iniciativas em termos de padrões de workflow (e.g., padrões de controle de fluxo (AALST, 2003a), fluxo de dados (RUSSELL, 2004a), recursos de workflow (RUSSELL, 2004b) e tratamento de exceção (RUSSELL, 2006)), não há um mapeamento consolidado de padrões com base em funções recorrentes em processos de negócio (ex.: solicitação de execução de atividade, aprovação de documentos, notificação) em (meta) modelos e ferramentas de workflow. Uma das principais iniciativas é proposta pela Oracle no escopo da Business Process Execution Language for Web Services (BPEL4WS) (BRADSHAW, 2005).

Neste contexto, processos de negócio (computadorizados) apresentam diversos fragmentos, os quais podem ser entendidos como atividades de bloco com semântica bem definida. É importante observar que, cada fragmento pode ocorrer diversas vezes em uma mesma definição de processo. Durante a execução do processo, por sua vez, diferentes cópias de um mesmo fragmento podem apresentar tanto os mesmos valores de parâmetros como valores diferentes. A figura 1.1 mostra um processo de aprovação de empenho de verbas de uma organização do setor varejista. O processo inclui as seguintes atividades: a) Necessita aprovação complementar; b) Avalia Empenho de Verbas e; c) Avisa Administrador sobre Atraso. Este processo contém fragmentos relacionados a funções recorrentes de processos (ou padrões) tais como *decisão* (atividades a), *aprovação* (atividade b) e *notificação* (atividade c).

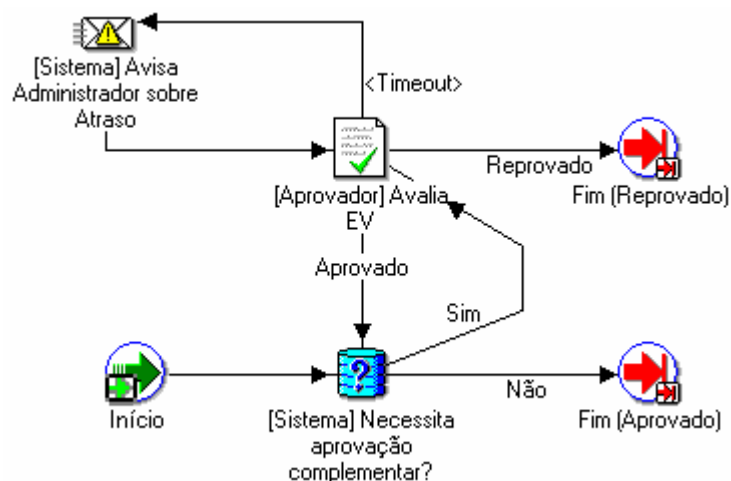


Figura A: Processo de aprovação de empenho de verbas

Embora estes fragmentos possam ser semanticamente caracterizados de maneira precisa, existem poucos estudos relacionando-os com padrões de workflow (BRADSHAW, 2005). Geralmente, eles são redesenhados para todas as aplicações de workflow. Também não foram encontrados estudos pesquisando a existência destes

padrões em aplicações reais de workflow, assim como a necessidade e completude destes para a etapa de modelagem (FLORES, 1988), (MEDINA-MORA, 1992), (MALONE, 2004), (MUEHLEN, 2002), (BRADSHAW, 2005). Além disso, as ferramentas contemporâneas para modelagem de workflow não provêm funcionalidades para definição, consulta e reuso de padrões.

Considerando os problemas descritos acima, esta tese tem como objetivo:

1. investigar padrões com base em aspectos estruturais da organização;
2. desenvolver um metamodelo de processo de negócio com suporte aos aspectos estruturais, assim como, um catálogo de padrões;
3. pesquisar a existência de padrões com base em funções recorrentes em processos de negócio em aplicações reais de workflow.

O Capítulo 1 da tese apresenta em maiores detalhes a motivação que levou à realização deste trabalho, assim como a metodologia adotada para atingir os objetivos descritos acima. O capítulo 2 apresenta o estado da arte em (meta) modelos e notações para modelagem de processos de negócio e processos de workflow, assim como padrões de workflow. Além disso, compara tais (meta)modelos, notações e padrões com a abordagem sendo proposta nesta tese. O capítulo 3 apresenta os conceitos básicos sobre workflow, os quais são utilizados ao longo da tese. No capítulo 4 é proposto um conjunto de padrões com base em aspectos estruturais. O capítulo 5 traz a proposta de um Metamodelo Transacional de Processo de Negócio (MTPN), cuja principal característica é o suporte aos aspectos estruturais e um catálogo de padrões. Neste Capítulo também é proposta uma metodologia para modelagem de processos de negócio e workflow com base no MTPN.

Os principais tipos de processos de negócio existentes na literatura são discutidos no Capítulo 6 da tese. Tais processos e/ou fragmentos destes são frequentemente utilizados em aplicações de workflow. Com base nestes processos e respectivos fragmentos, é proposto um conjunto de padrões de workflow representados como atividades de bloco. Com o objetivo de pesquisar a existência dos padrões de atividade de bloco em processos de workflow de aplicações reais foram minerados 190 processos de workflow modelados na ferramenta Oracle Builder (ORACLE, 2001). Os resultados desta mineração são apresentados, em detalhes, no capítulo 7 da tese. Finalmente, o Capítulo 8 da tese apresenta conclusões e trabalhos futuros.

As principais contribuições desta tese são:

1. Um metamodelo (MTPN) para modelagem de processos de negócio e processos de workflow. O MTPN possibilita a criação de (sub-)processos de negócio, pelo menos a partir do reuso de padrões com base em aspectos estruturais (THOM, 2004), (THOM, 2005b);
2. Uma metodologia com base no MTPN. A metodologia é composta por 3 etapas: 1) definição de processos de negócio com base no MTPN; 2) geração automática dos processos de negócio para processos BPEL4WS. Para esta etapa foram definidas regras de mapeamento e; 3) execução dos processos BPEL4WS em qualquer gerenciador de workflow (THOM, 2005a).
3. Um estudo detalhado sobre tipos de processos de negócio. Com base neste estudo, foi definido um conjunto de padrões representados como atividades de bloco. Cada padrão representa uma função recorrente em processos de negócio.

Tais padrões foram classificados como segue: padrões orientados à organização (ex.: aprovação de documentos, retirada de dúvidas); padrões orientados ao domínio de aplicação (ex.: padrão logístico e financeiro, respectivamente) e; padrões com base em funções recorrentes em processos de negócio (ex: padrão para solicitação de execução de tarefa, solicitação de informação, notificação) (THOM, 2002), (THOM, 2003), (THOM, 2005a), (THOM, 2006a), (THOM, 2006b).

4. Com base na mineração de 190 processos de workflow executados por diferentes organizações foi constatada com alta probabilidade a existência dos padrões de atividade de bloco em processos de workflow reais. Além disso, foi constatado que os padrões são suficientes e necessários para modelar os 190 processos de workflow analisados. Isso demonstra que o conjunto de padrões é adequado para modelar uma variedade significativa de processos de workflow.
5. A mineração também resultou em um conjunto de regras que definem os padrões e mostram como os mesmos se combinam com padrões de controle de fluxo, formando agregações de padrões. Tais regras podem ser úteis para a implementação dos padrões de atividade de bloco em alguma ferramenta de modelagem de workflow.