A COMPARATIVE ANALYSIS OF BUSINESS PROCESS MODELLING TECHNIQUES

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Abstract

Business process modelling is an increasingly popular research area for both organisations and academia due to its usefulness in facilitating human understanding and communication. Several modelling techniques have been proposed and used to capture the characteristics of business processes. However, available techniques view business processes from different perspectives and have different features and capabilities. Furthermore, to date limited guidelines exist for selecting appropriate modelling techniques based on the characteristics of the problem and its requirements. This paper presents a comparative analysis of some popular business process modelling techniques. The comparative framework is based on five criteria: flexibility, ease of use, understandability, simulation support and scope. The study highlights some of the major paradigmatic differences between the techniques. The proposed framework can serve as the basis for evaluating further modelling techniques and generating selection procedures.

Keywords: Business process modelling, modelling techniques, comparative analysis.

1. Introduction

Business process modelling represents an important part of information systems (IS) development and evolution within organisations. This is primarily due to the need of organisations to be able to readily and flexibly adapt their processes to change induced by both internal and external factors (Morgan, 2007).

One of the main issues in business process modelling is the enormous availability of different techniques for the representation of organisational processes and their requirements (Luo and Tung, 1999). Individual techniques can focus on different facets of process modelling. For example, while Role Activity Diagrams (RAD) emphasise on the interaction between roles in the organisation (Ould, 1995), Data Flow Diagrams (DFD) focus on the flow of data through a system (Shen et al., 2004).

This paper presents a comparative analysis of popular business process modelling techniques. The motivation for this study derives from the *practical* need of information systems stakeholders (among these developers) to understand the pragmatic differences of various modelling techniques and ultimately select the most appropriate for the task at hand. The comparison is based on key criteria that are used to examine each technique individually and subsequently contrast the techniques. The criteria were defined on the basis of those aspects that the business process modelling literature suggests as being important (Kettinger et al. (1997); Luo and Tung (1999); Melao and Pidd (2000); Giaglis (2001); Aguilar-Savén (2004); Carnaghan (2006); Ortiz-Hernández et al. (2007); and Vergidis et al. (2008)). The comparative framework adopts the following five criteria: flexibility, ease of use, understandability, simulation and scope. These comparative criteria will be defined in Section 3. The remainder of this paper is structured as follows. Section 2 provides the necessary background with an overview of related literature. Section 4 presents the comparative analysis framework, and Section 5 presents conclusions and future work.

2. Background

Business process modelling (BPM) produces the conceptual artefacts underpinning the management of organisational processes and their continuous change (Mendling, 2008). Whether such change is dramatic or subtle the effective management of a business' process models is fundamental to keep an organisation efficient and competitive (Morgan, 2007). Therefore, it is necessary to update and revise business processes periodically in order to achieve improved organisational performance enabling the organisation to deliver quality products and services as required by its customers (Jacobson et al., 1995).

Many definitions of business process have been proposed. For example, Hammer and Champy (1993, p. 85) defined business process as "a collection of activities whose final aim is the production of a specific output that is of value to the customer. A business process has a goal and is affected by events occurring in the external world or in other processes". Other definitions provide similar interpretations of the term (for example, see Davenport (1993); Earls (1994); Jacobson et al. (1995); Ould (1995); and Havey (2005)). From an analysis of these definitions it is possible to extract those elements that are commonly and generally accepted by the business modelling community as characterising a business process. These elements include:

- ***Process***: A set of activities, events, etc. that together and cohesively delivers a service and/or a product.
- ***Activity:*** Specific behaviour carried out in an organisation.
- ***Service and Product:*** The observable outcome of value of a process. The traditional distinction between service and product is that the former is intangible while the latter is tangible.
- ***Role:*** The types of actors or agents that take part in processes.

- ***Goal:*** The aim of a process.
- ***Event:*** An occurrence that takes place at a specific point in time and that is capable of inducing some observable behaviour (activity or process).
- ***Rule:*** A constraint defined for any part of the organisation and its processes.

Hence, business process modelling is that activity aimed at the representation of all or some of the above elements in order to produce a cohesive model of the behaviour required to deliver a service and/or product to a customer or another part of the organisation.

Business process modelling techniques can model all or some of the above elements depending on the technique's focus. The focus may depend on various factors such as the paradigm with which the technique was originally conceived or the domain for which it was developed (e.g. software development, systems engineering, etc.). Some techniques may not explicitly model any of the above elements, but instead provide constructs that can be used to implicitly represent them.

As previous comparative analyses demonstrate, a plethora of techniques have been proposed over the years for BPM. Kettinger et al. (1997) analysed a total of 72 techniques and 102 tools in a survey focused on Business Process Re-engineering. Consequently, given the renewed interest in BPM, IS decision-makers are faced with the dilemma of how to model their processes, hence which technique(s) to adopt. The decision can be based on the purpose (or reason) for undertaking BPM.

Business process modelling serves multiple purposes. Summarising points from Luo and Tung (1999), Eriksson and Penker (2000), and Caetano et al. (2005), these purposes include:

1. Facilitating a group to share their understanding of the process by using a common process representation, which helps human understanding and communication.
2. Providing the advantage of reuse. If the same business process model can act as the basis for several information systems, it can be reused as the basic input for defining the requirements of each system.
3. Creating suitable information systems that support the business by providing a descriptive model for learning.
4. Supporting process improvement and re-engineering through business process analysis and simulation. BPM will be used for improving the current business by identifying possible ways to make the business more efficient. Normally, the current business is modelled and then re-engineered for enhancement or improvement opportunities.

5. Enabling decision support during process execution, and control.

3. Comparison Criteria

The purposes of BPM listed above lead the way to deriving the five criteria that this study adopts in order to compare seven business process modelling techniques. The five criteria are listed and defined in Table 1.

Criteria	Description
Flexibility	The extent to which it is possible to realise changes in the business process types and instances by modifying only those parts that need to be changed and keeping other parts stable. A business process model is flexible if it is possible to change it without replacing it completely.
Ease of Use	The extent to which the technique can be readily applied by business stakeholders not having specialist knowledge of the technique.
Understandability	The extent to which the technique can be understood by business stakeholders not having specialist knowledge of the technique.
Simulation	The extent to which the technique is capable of dynamically simulating a business process.
Scope	The extent to which the process modelling elements defined in Section 2 are represented by constructs of the technique.

Table 1 Business process modelling criteria descriptions.

Although any technique requires time to master, the criteria 'ease of use' and 'understandability' refer to the time it requires for a business stakeholder to acquire a basic understanding of the diagram(s) underlying the technique. Some of the criteria can overlap or clash in some cases. For example, normally techniques that are 'easy to use' may tend to be 'understandable' as well. On the other hand, techniques that are highly specialised (e.g., for simulation) may require specialist knowledge in order to be used.

The five criteria will be used in the following section to provide a reasoned overview, discussion and comparison of seven business process modelling techniques. In order to assist the reader, a simple example has been adopted and modelled with each technique in order to provide an understanding of notation and the paradigm underpinning each technique.

Due to limitations of space only seven techniques are compared in this paper. These techniques include: (1) flow charts, (2) petri nets, (3) data flow diagrams, (4) role activity diagrams, (5) business process modelling notation diagrams, (6) business use cases and (7) business object interaction diagrams. The selection was based on: the intention of demonstrating differences in techniques that adopt a similar modelling paradigm (such as (1), (2) and (5)) as well as being able to contrast techniques that adopt different paradigms (such as (5), (6) and (7)).

4. Comparative Analysis

In the subsections that follow a course registration business process is used as a scenario to exemplify the different types of notation as well as the underlying paradigm of each technique.

The course registration scenario refers to the typical enrolment process to courses of an academic institution. Upon request new students receive enrolment instructions and application about the university, while continuing students receive instructions informing them how to re-enrol. The new student sends in an application form containing their personal details and their desired course. After receiving the student application, the enrolment officer checks the academic requirements with academic staff and then informs students of the results (approve or reject). For an approved application the university confirms the enrolment by sending a confirmation letter to the student stating that s/he is registered on the course and provides the student with an identity card.

4.1 Flow Chart

A flow chart is a graphical representation that shows the flow of control throughout a process by providing a step-by-step illustration of what occurs given a specific situation. Although flow charts are renown for modelling control flow in software systems, they also represent nonetheless the most basic type of diagram for communicating business process flows (Aguilar-Savén, 2004). Flow charts are used predominantly in software engineering, but their simplicity and ease of use have enabled managers and business owners to adopt this technique for organisational purposes as well.

- ***Flexibility:*** Flow charts are relatively simple to update; the graphical representation of a process with a flow chart can quickly help identify bottlenecks or inefficiencies where the process can be streamlined or improved (Aguilar-Savén, 2004). Flow charts are quite simple diagrams – in terms of what they model – and they can be considered to be easily modifiable since they are a few modelling elements that the modeller needs to mentally cope with. On the other hand, flow charts do not possess a sophisticated mechanism for modularising or packaging diagrams; hence invoking other processes from flow charts can be problematic.

- ***Ease of Use:*** Due to the limited set of symbols, flow charts, compared to other techniques, are relatively easy to learn and the technique is relatively easy to use by inexperienced stakeholders (Aguilar-Savén, 2004).
- ***Understandability:*** Given their simplicity, flow charts are frequently used for communication and in discussions between analysts and stakeholders (Giaglis, 2001; Aguilar-Savén, 2004); also the notation is easy to understand because of the clear semantics of the constructs represented. The best way to stay agile when working with flow charts is to keep things simple. The value often is not in the models that have been created, but instead it is in the act of modelling because it helps to think things through.
- ***Simulation:*** There are many commercial simulation tools that adopt flow charts as the underlying technique (for example, iGrafx). Such tools that can be used to build active flow charts, whereby users can construct process models that provide an indication of the appropriate action to perform in order to ultimately execute the model (Damji, 2007).
- ***Scope:*** The modelling elements of a flow chart are start and end, activity, input and output, decision and process (see the example in Figure 1). The terminus symbol is used in flowcharting to designate the beginning and the end. An activity is represented by a rectangle. An arrow connects one activity to another, showing the process flow. A decision (represented by a diamond-shaped symbol) specifies alternative paths based on some boolean expression. Therefore, flow chart can be used as a technique to model processes, and those process steps correspond to the activities of a particular situation, which will support the goal for which this technique aims to represent. On the other hand the technique does not have the means to explicitly represent services, events and rules.

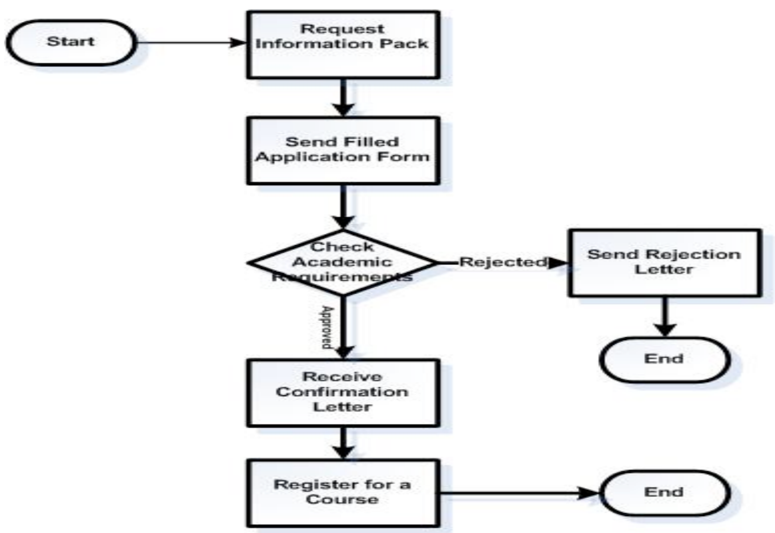

Figure 1. Course Registration scenario modelled in Flow chart.

4.2 Petri Net

A petri net is a mathematical/graphical representation that is appropriate for modelling systems with concurrency. It combines "visual representation using standard notation with an underlying mathematical representation" (Vergidis et al., 2008*)*. Petri nets originate from Carl Adam Petri's doctoral thesis (1962), which introduced a new model of information flow in systems. Nowadays, Petri nets are used for modelling computer software, hardware, control flow and business processes. The technique was developed originally for systems engineering (List and Korherr, 2006).

- ***Flexibility:*** As Petri Nets are both a graphical notation and a precise mathematical notation; it is suitable for the analysis and reengineering of business process models. Petri Nets' mathematical representation makes the analysis and the refinement of BPM easier (Vergidis et al., 2008). Thanks to this formal basis (graphical and mathematical) it is possible to use them to analyse and amend the models of a given process without losing the model identity.
- ***Ease of Use:*** Due to such a small number of modelling elements, Petri Nets have limited explicit expressivity in relation to the elements that constitute a business process. Numbers of extensions have been made to deal with the drawbacks of Petri Nets, but Petri Nets are still considered a non user-oriented technique, which makes it difficult for inexperienced stakeholders to adopt this technique for BPM.
- ***Understandability:*** Petri Nets use very few different types of elements to construct a model which according Desel and Juhas (2001) "is a good basis for an easy understandability of a model and for the learnability of the language". These few elements make it easy to guarantee a rough understanding of any Petri Net model without additional legend. On the other hand, although the underlying logic of the technique is quite intuitive, its application to modelling complex business processes can require a certain level of expertise.
- ***Simulation:*** According to Desel and Juhas (2001) Petri Nets support the construction of simulation models. Petri Nets have been used for transforming static process models into dynamic simulation models. This enables even the inexperienced user to see directly how the processes are executed and what might go wrong when the model is constructed incorrectly. (Gottschalk et al., 2007) There are many simulation applications based on Petri Nets. PNS is an example of such a tool (Shukla and Robbi, 1991).
- ***Scope:*** The graphical and mathematical representation of Petri Nets allows the representation of a process. The flow of activities can be represented with place nodes, transition nodes and arcs connecting places with transitions (see Figure 2 as an example).

The concepts of service, goal and role are not explicitly supported, while events are represented by the transitions and rules can be modelled via guard conditions on the transitions themselves.

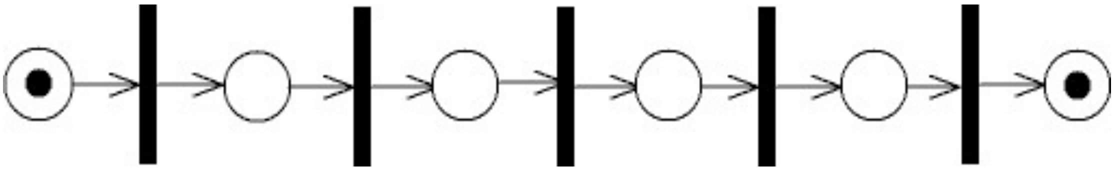

Figure 2. Basic notation of a Petri Net.

4.3 Data flow diagram (DFD)

A DFD is a graphical representation that is appropriate to show system functionality, with its underlying processes and flow of data (as the name suggests) (Lee and Wyner, 2003). It is a well-accepted structured technique to be used for modelling system analysis and design specifications ((Kendall and Kendall, 1995), (Luo and Tung, 1999)). The functional decomposition of DFDs enables multiple levels of representation by creating child diagrams for each activity (Luo and Tung, 1999). DFDs were first used in this field as an approach for studying systems analysis and design in software engineering (List and Korherr, 2006).

- ***Flexibility:*** DFDs can be a powerful technique to be used in the redesign of business processes. The multiple levels of representation (functional decomposition) achieved by creating child diagrams for each activity can facilitate changes and system improvement (Luo and Tung, 1999). Functional decomposition enables each process to be subdivided into subprocesses, which can be further subdivided. Thanks to functional decomposition, child diagrams can modularise the representation of the process hence increasing the level of flexibility of the technique.
- ***Easy of Use:*** DFD is an easy to use technique (Shen et al., 2004), due to the small number of elements required in order to construct a model (Carnaghan, 2007). Also, the expressivity of the modelling elements facilitates the construction of a DFD model for inexperienced users. In that respect, DFDs are comparable to Petri Nets, both consist of small number of notations to construct the BPM, but DFDs differing from Petri Nets in their level of semantic richness.
- ***Understandability:*** DFD is easy to understand both conceptually and in presentation. There are two reasons for this. First, due to the functional decomposition of DFDs, the diagrams can present both more abstract and more detailed representations of the same process, and allowing these representations to relate to one another (Carnaghan, 2007). Second, DFDs are intended to be used for communication and in discussions between

analysts or modellers and users, as they are simple, can be easily understood and comprehend, and are easy to draw, improve and amend ((Aguilar-Savén, 2004), (Damij, 2007)).

- ***Simulation:*** DFD is not a technique that can easily support simulation, but instead a technique for the static modelling of business processes.
- ***Scope:*** DFDs use four basic elements for modelling business processes. These elements are process, data store, terminators and flow to trace and depict the movement of information. The flow shows the movement of information from one point to another. The process is used to show the transformation of data from one state to another. The terminators represent the actors, external to the system being modelled, which interact with the various system processes. The data store represents an information repository. An example is presented in Figure 3. Overall process and activities are represented explicitly, while other elements of Section 2 are at best implicitly supported.

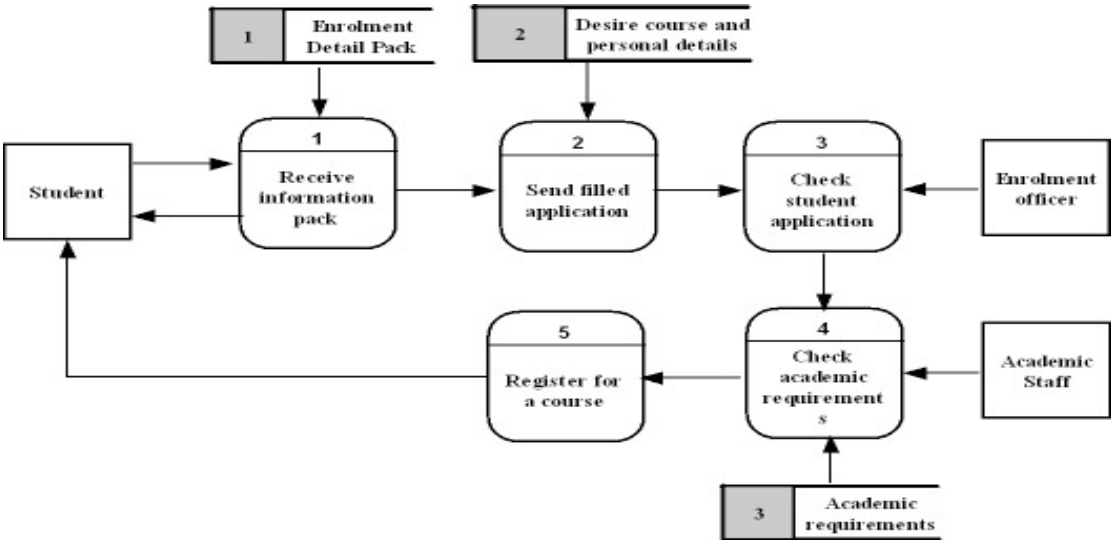

Figure 3. Course Registration scenario modelled in Data Flow Diagram.

4.4 Role activity diagram (RAD)

RADs are a graphical representation of processes in terms of the roles presented within these processes, their component activities and their interactions, together with external events and the logic, which determines what is the sequence of those activities (when and by whom) (Ould, 1995). RADs originate from Martin Ould (1995) by providing a more process-oriented technique. A RAD allows a business process to be modelled diagrammatically through roles, goals, activities, interactions and business rules (Melao and Pidd, 2000). This technique is considered by some to be the most complete to represent most of the features of a process (goals, roles, decisions, etc.) (Miers, 1996).

- ***Flexibility:*** RADs use a notation that represents the actions and the speech acts of a process (Cordes, 2008). The notation enables the representation of the process in terms of: roles, resources, activities, users, states, and the interaction between participants. Roles have attributes to control its behaviour. Both these elements and attributes help managers in visualising the business process so that decisions can be made that lead towards refinement and improvement. In RAD activities are grouped together and carried out by a group, an individual or a system (i.e. some actor or agent). The grouping of activities are called role (Phalp et al, 1998). Roles are depicted as rounded rectangles surrounding activities. Roles enable an analyst to refine and amend the activities without affecting the whole model.
- ***Ease of Use:*** RAD has a set of symbols that are useful in describing processes. The approach provides easy-to-use support that can help stakeholders to maintain the "big picture" of service processes among a wide range of participants. Flexible notation and ease of understanding make role activity diagrams especially useful for large systems with many participants (Cordes, 2008).
- ***Understandability:*** RAD is intuitive to read and understand and presents a detailed graphical view of the process. (Aguilar-Savén, 2004) Therefore, the simple notations used and the expressivity of the model constructed, give RAD credence for communication among many participants and useful for large systems with many participants (Cordes, 2008).
- ***Simulation:*** RAD supports the simulation criterion by enabling detailed inspections of specific parts of the process. This approach is especially useful in the simulation of large system processes (Martinez-Garcia and Warboys, 2001).
- ***Scope:*** The modelling elements of RAD describe the process in terms of roles, resources, activities, users, states, and the interaction between participants. In turn, each role has attributes that govern its behaviour, such as: capabilities and interests (see Figure 4 for an example). The RAD technique is quite effective at representing processes, activities and roles. Service is not supported, while events and rules are implicitly represented.

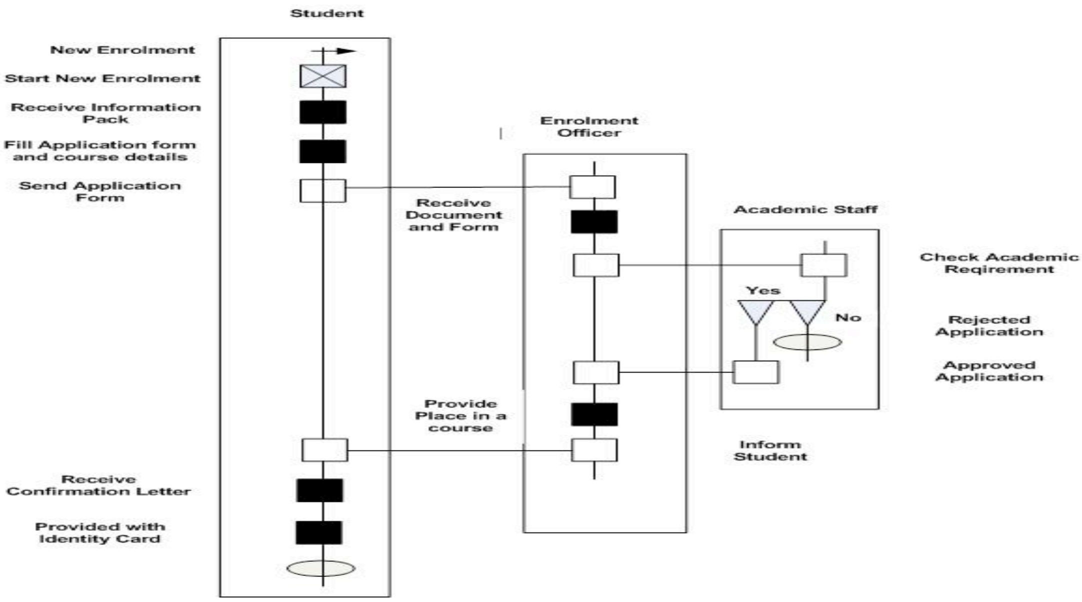

Figure 4. Course Registration scenario modelled in Role Activity Diagram.

4.5 Business Process Modelling Notation (BPMN)

BPMN is richer in semantic than the other modelling techniques. It presents one type of model called *Business Process Diagram* (*BPD*). BPMN is based on flowcharting techniques specialised for business processes (Havey, 2005). BPMN is a recent addition to the existing set of Business Process Modelling Languages (BPML) and it was developed by the Business Process Management Initiative (BPMI) which released it in 2004.

- ***Flexibility:*** BPMN is a powerful technique to be used in the design of business processes; it is a well-structured technique for modelling the different aspects of processes in an organisation. BPMN allows the representation of extended models for each process. This decomposition enables flexible changes or improvement of any process in the extended model without affecting the original model.
- ***Ease of Use:*** BPMN has been developed with the primary goals of being easy to use and readily understandable by business and technology users. BPMN is particularly rich in having a wide range of different kinds of flow of control and sequences, which make BPMN well defined and as result easy to use approach for inexperience stakeholders. Although BPMN is a complex diagramming technique due to some of its very specialised notation, it is not necessary to know all of the specialised notation in order to create a complete and useful BPMN diagram. Hence both novice and experts can cope.
- ***Understandability:*** A key objective of BPMN is to model business processes in a way that is easily understood by the business end users and analysts. (Zou and Pavlovski, 2008) BPMN provides a notation that is readily understandable by all business users, starting

from the business analysts who create the initial drafts, to the technical developers who are responsible for implementing those processes, and finally, to the business people who will manage and monitor the processes. (White, 2004) BPMN is targeted at users, vendors and service providers that need to communicate business processes in a standard manner.

- ***Simulation:*** BPMN supports the construction of simulation models. Simulation technology can add considerable value to BPMN. Due to the ability provided to test processes and the ability to visualise them before they are implemented, adds considerably to their understanding.
- ***Scope:*** The modelling elements of BPMN are categorised into flow objects, connecting objects, swimlanes and artefacts (see Figure 5 for an example). BPMN supports all of the business process modelling elements listed in Section 2.

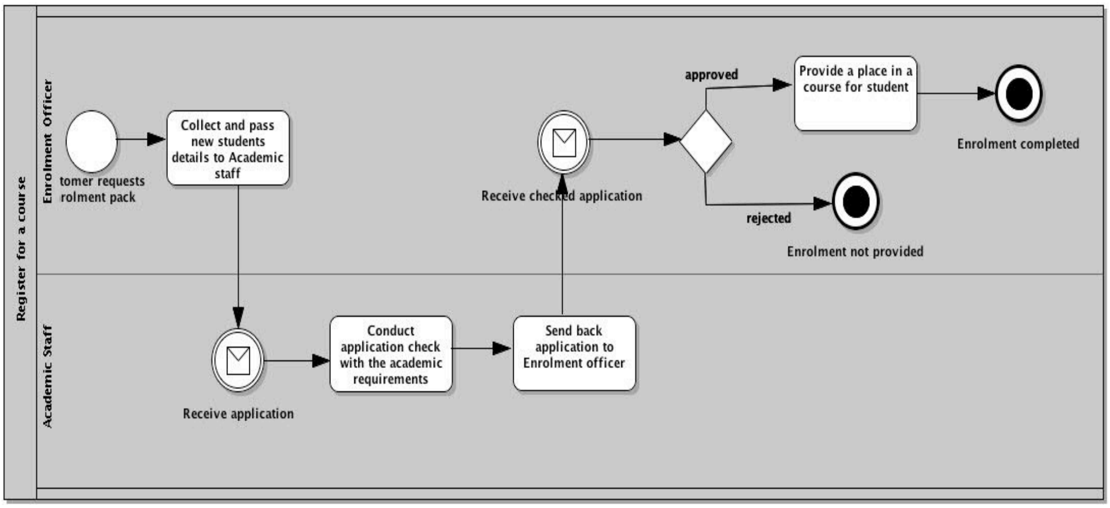

Figure 5.Course Registration scenario modelled in BPMN.

4.6 Business Use Cases

Use case modelling represents a technique that drives most present day object-oriented development methods. In the Unified Process (Jacobson et al., 1999) use cases are employed for both business and software modelling. A use case is "a description of a set of sequence of actions, including variants, that a system performs that yields an observable result of value to a particular actor" (Booch et al., 1999). Consequently, a business use case is the description of organizational behaviour that provides a service to an actor, with the functionality described in terms of a business process (de Cesare et al., 2003). Figure 6 shows an example of a business use case diagram normally used to provide an overview of a set of use cases of a business system or subsystem.

- ***Flexibility:*** Business use cases (BUC) are predominantly textual descriptions of organisational processes delivering a service to an actor. This characteristic can have positive effects on flexibility given that the narrative can be easily modified, but this can be offset by the ambiguities and inconsistencies that derive from the use of natural language in modelling processes. From the perspective of modularity, BUCs model processes based on a precise criterion, i.e. "observable result of value to a particular actor". Based on this criterion only processes that deliver such an observable result (which can be considered a service) can be modeled as use cases. The criterion (called previously 'actor perception' (de Cesare et al., 2003)) defines a clear boundary. Moreover, use cases can invoke one another with two types of relationship: 'include' and 'extend' depending on whether the invoked use case is mandatory or optional.
- ***Ease of Use:*** Since BUCs are predominantly textual narratives of business processes, the development of a BUC can be learned fairly quickly as long as the modeller is aware of the fundamental principle that BUCs are based upon as stated above. Furthermore, textual narratives can be coupled with any graphical representation of choice.
- ***Understandability:*** Business use cases are fairly straightforward to read even by the non-expert due to their development in natural language.
- ***Simulation:*** Business use cases do not directly support simulation.
- ***Scope:*** The textual description of a BUC normally includes properties such as: name, goal, preconditions, triggering event, basic and alternate flows of the process and postconditions. BUCs support all of the business process modelling elements listed in Section 2. As described by de Cesare et al. (2003), BUCs model services and the processes delivering such services.

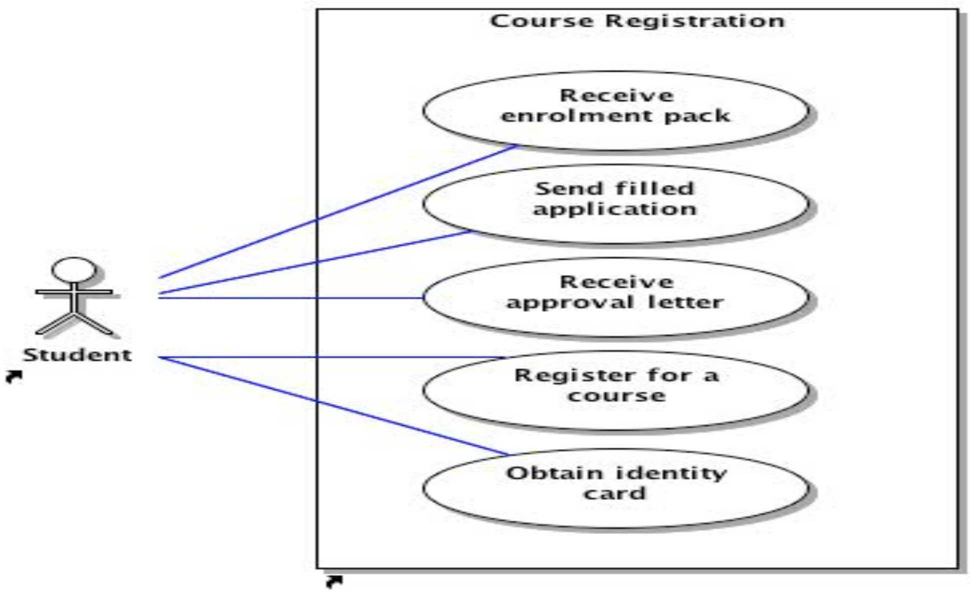

Figure 6. Course Registration scenario modelled in Business use case diagram.

4.7 Business Object Interaction Diagram

Although object-orientation is a paradigm conceived for and widely applied in software engineering, there have been some attempts to introduce this paradigm into the area of business modelling (Jacobson, 1995) and, in fact, the Unified Process (Booch et al., 1999) does include among its business modelling techniques object interaction diagrams to provide an object-oriented perspective to business use cases. In the current version of the Unified Modelling Language (UML) two types of interaction diagrams are included: communication and sequence diagrams. Figure 7 provides an example of a sequence diagram.

- ***Flexibility:*** With the introduction of 'frames' in UML 2.0 sequence diagrams can be invoked by one another even through parameters, enabling different sequence diagrams to focus on modelling the specific responsibilities of the corresponding use cases that they realise. This achieves a certain level of modularisation and separation of concerns of different organisational behaviour. These characteristics of modularity and focused responsibility are present even at a finer grain level with the objects that form the core elements of an interaction diagram.
- ***Ease of Use:*** Sequence diagrams are seldom applied in business modelling due to the expertise required in mastering object-orientation when modelling business processes at more detailed levels of abstraction.
- ***Understandability:*** Similar consideration can be made for understandability of sequence diagrams. Even in this case some knowledge of object-orientation is required, however given that the objects involved in business process modelling normally concern roles of individuals or groups within an organisation, a novice in the technique would more likely be able to more easily interpret a sequence diagram than produce one.
- ***Simulation:*** Simulation was originally the initial domain of application for objet-orientation with the programming language Simula-67. As a consequence sequence diagrams could theoretically be an ideal diagram type for running simulations of business processes. The reality is that although modern UML CASE tools all have excellent support for modelling sequence diagrams, simulation with this technique is not widely supported. Some of these tools nowadays support simulation via BPMN diagrams (as explained above), which represent processes in a way that is closer to the manner in which business stakeholders view organisational processes.
- ***Scope:*** Since object interaction diagrams are used to realise use cases, the business process modelling elements that are represented with BUCs can be represented with sequence diagrams, but from an object-oriented perspective rather than a process/use case perspective. For example, sequence diagrams do not strictly support the concepts of

process and activity in the same way as BPMN and BUCs do. In object interaction diagrams, processes would map to collaboration (between objects) and activities would map to messages sent between objects.

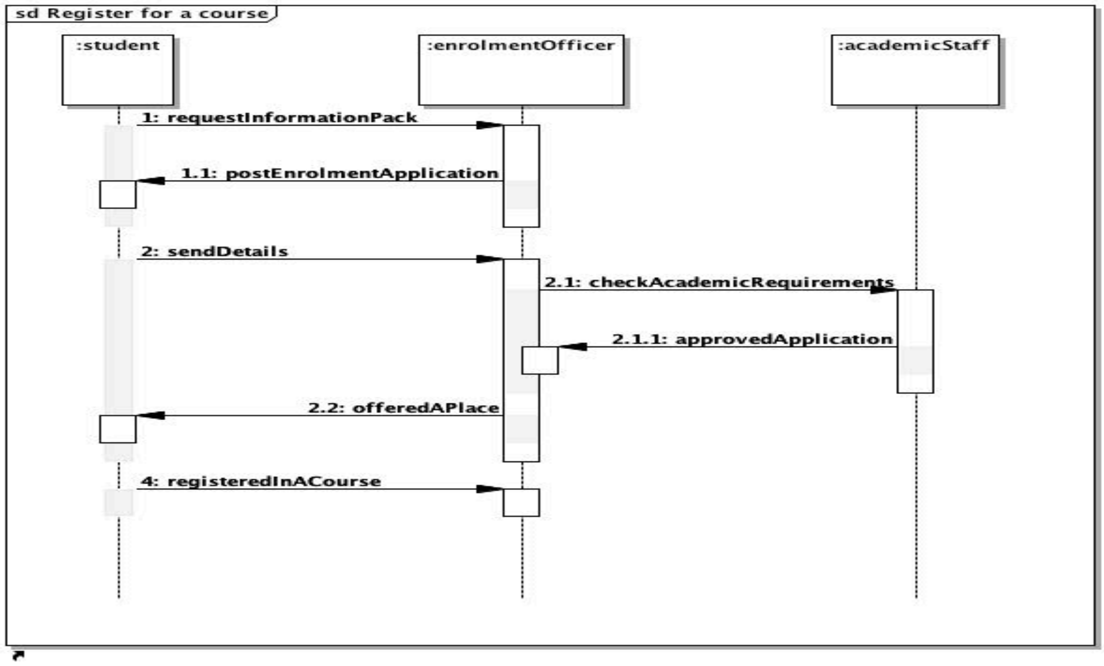

Figure 7. Course Registration scenario modelled in Business Object Interaction Diagram (Sequence Diagram).

5. Conclusion and Future Work

Organisations are constantly evolving. In order to understand and better manage change, organisations develop models of their current and future business processes. Due to the numerous business process modelling techniques that are available, organisations, that seriously introduce business process modelling practices, need to make informed decisions in relation to the representational technique(s) that are eventually adopted; hence, the motivation for this study. In this paper seven business process modelling techniques were compared according to five criteria: flexibility, ease of use, understandability, simulation and scope.

The outcomes of this study are of particular interest to both academia and organisations. Academia should be motivated to examine existing business process modelling techniques in order understand the differences and similarities between them. One area of application for such an evaluation is the possible mapping between business process models represented according to different paradigms. Studies of this kind would contribute to improve our understanding of the role of business modelling in model driven development and, more specifically of computational independent models in the Object Management Group's Model Driven Architecture initiative. Such comparisons and evaluations can also feed into industry in which there is a growing interest for business process modelling especially in relation to the emerging service paradigm to systems development.

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