A literature review on business process modelling: new frontiers of reusability

Laden Aldin*, Sergio de Cesare*

*Department of Information Systems and Computing, Brunel University, Uxbridge, UK

First published on: 07 April 2011

To cite this Article Aldin, Laden and de Cesare, Sergio(2011) 'A literature review on business process modelling: new frontiers of reusability', Enterprise Information Systems, First published on: 07 April 2011 (iFirst)

To link to this Article DOI: 10.1080/17517575.2011.557443
URL: http://dx.doi.org/10.1080/17517575.2011.557443

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.informaworld.com/terms-and-conditions-of-access.pdf

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.
A literature review on business process modelling: new frontiers of reusability

Laden Aldin† and Sergio de Cesare*

Department of Information Systems and Computing, Brunel University, Uxbridge UB8 3PH, UK

(Received 29 April 2010; final version received 20 January 2011)

Business process modelling (BPM) has become fundamental for modern enterprises due to the increasing rate of organisational change. As a consequence, business processes need to be continuously (re-)designed as well as subsequently aligned with the corresponding enterprise information systems. One major problem associated with the design of business processes is reusability. Reuse of business process models has the potential of increasing the efficiency and effectiveness of BPM. This article critically surveys the existing literature on the problem of BPM reusability and more specifically on that State-of-the-Art research that can provide or suggest the ‘elements’ required for the development of a methodology aimed at discovering reusable conceptual artefacts in the form of patterns. The article initially clarifies the definitions of business process and business process model; then, it sets out to explore the previous research conducted in areas that have an impact on reusability in BPM. The article concludes by distilling directions for future research towards the development of a patterns-based approach to BPM; an approach that brings together the contributions made by the research community in the areas of process mining and discovery, declarative approaches and ontologies.

Keywords: literature review; business processes; patterns; ontologies and information systems

1. Introduction

The effective design and execution of business processes are becoming increasingly important to modern business organisations. The need for an organisation to continuously redesign its business processes on a regular basis, as a way of aligning its operational practices with its changing business requirements, has been recognised for decades (Ackoff 1962). It is essential that business process changes are understood and represented systematically and their impact clearly defined (Morgan 2007). To reach such an understanding, there is a need to create business process models (Lindsay et al. 2003). These models represent current or future desired organisational behaviour in order to achieve various purposes including, for example, the control and monitoring of process execution. The growing extent to which business process modelling (BPM) occurs nowadays requires that such an activity be carried out systematically. This helps not only in increasing efficiency and...
productivity of process design but also in ensuring consistency and thoroughness of the models themselves (Aguilar-Savén 2004).

In recent years, ontologies have been suggested as a means to develop more systematic, yet flexible, approaches to business process design (Hepp et al. 2005, Lin and Strasunskas 2005, Hepp and Roman 2007). Ontology is a formalised conceptual model of a real world domain, which explicitly represents the semantics underlying that domain. This level of semantic accuracy is recognised as useful (or even essential) to providing the basis for producing generalised and reusable models of organisational behaviour. Further claimed benefits of ontology-based BPM also include improved model distribution, integration and interoperability (Thomas and Fellmann 2009).

The adoption of ontologies addresses a fundamental problem, i.e. the lack of explicit and systematic reuse of previously developed models. Being able to reuse previously modelled behaviour can have a beneficial impact on the quality and efficiency of the overall information systems development (ISD) process (Eriksson and Penker 2000, Caetano et al. 2005). In related disciplines, like software engineering, patterns have emerged as a widely accepted architectural mechanism for reusing solutions that in the past have proven effective for certain classes of problems and in specific contexts. In BPM, the use of patterns has been quite limited. Apart from a few sporadic attempts proposed by the literature (Eriksson and Penker 2000, Malone et al. 2003, van der Aalst et al. 2003), pattern-based BPM is not commonplace. Its widespread use could however produce various benefits to the enterprise and its information systems. Generally, speaking a reusable business process patterns-based approach could produce a reduction in the effort required to produce process models and their subsequent translation into software designs of enterprise applications. This benefit would be coupled with the acquired advantage of facilitating staff training in BPM as well as staff familiarisation with the organisation’s more general procedures. In fact, adequate knowledge of generalised patterns of business processes would provide BPM staff the opportunity to be more readily capable of identifying common behavioural themes even in the presence of newly designed processes (Zlatkin and Kaschek 2005). In addition, reusability of business process models is likely to help reduce the development time and increase process quality of the models themselves as well as their mapping into information system requirements. Business process reuse could be significantly simplified, if an easy to use and extensible reuse environment were available (Kaschek et al. 1998, Calabrese et al. 2006). As an antecedent to the use of generalised models, it is necessary to discover or mine recurring patterns in the first place and represent them appropriately. As it will be discussed in the remainder of the article, research previously carried out in the areas of process mining and declarative process modelling can provide the foundational elements and suggestions in achieving systematic business process discovery and more accurate representations of organisational behaviour.

This article reviews the literature related to specific research topics of business process model reuse that can assist both practitioners and academics to develop more effective and systematic approaches to BPM. The review identifies four particular types of modelling solutions (patterns, process discovery, declarative approaches and ontologies) and suggests that they can be adopted in conjunction due to some of their intrinsic similarities and/or complementarities. Given that BPM research is not always aligned with the needs of the industry, as highlighted by
Indulska et al. (2009a), this review is also relevant in suggesting how some of the State-of-the-Art research in BPM reuse can help practitioners to more effectively model their organisational processes.

In this review, the identification of relevant literature generally followed the three criteria suggested by Leedy and Ormrod (2001) and Cooper (1998) (cited by Bandara et al. (2007)). These criteria include:

1. Identification of the domain or the disciplinary area in which the research is conducted. As explained above, business process reusability was the domain under investigation.
2. Identification of the sources or outlets to be targeted in the search for relevant literature for the chosen domain. The sources used in this work were the datasets provided by Springer, ACM, IEEE and Web of Knowledge. Other types of publications were also consulted (e.g. books); these were publications that the authors were already familiar with from their previous research and that were deemed appropriate for the chosen domain.
3. Definition of a search strategy or the selection of appropriate search terms utilised during the article extraction process. The search strategy (and related search terms) went through a process of refinement; from more general terms to more specialised terms. For example, while initially the search conducted was based on ‘business process reuse’, as the papers were gradually sifted it became apparent that there were specific areas of business process management that required a more in depth investigation. It is in this manner that further search terms related to ‘business process discovery’, ‘business process patterns’ and ‘business process ontologies’ were identified.

This literature review is organised as follows. Section 2 provides an overview of BPM with an emphasis on modelling and discovery techniques. Section 3 presents the concept of pattern, how this architectural mechanism has been applied in the related field of software engineering and the extant literature on patterns in the context of business modelling. Section 4 explores ontology in relation to BPM and specifically the different ways in which ontology has been used to evaluate BPM techniques as well as to conceptualise business processes themselves with the aim of enhancing reusability via semantically precise representations. Finally, Section 5 presents the concluding discussion and outlines an agenda for future research.

The broad conclusion envisioned from this literature review is to encourage organisations to reuse their business process models by the use of a methodology that is aimed at discovering process patterns from diverse organisational assets. The general approach envisioned, through a critical analysis of the literature, is one that:

- Adopts a form of process discovery similar to what occurs in the field of science in the discovery of theories and laws of nature. Transposed to the organisational context, this means empirically identifying recurrent behavioural patterns.
- Models business processes and their generalised patterns in a more flexible and less constraining way as opposed to traditional procedural modelling approaches. It is argued here that approaches such as declarative processes and ontological modelling provide the logical and semantic foundation for less
rigid rule-based models in which it is possible to declare and define ‘what’ minimal conditions a business process type must comply with, leaving open the possibility for flexible and emergent variations of the base type.

2. Business process modelling: an overview

2.1. Business processes

Business processes express an organisation’s behaviour, and these processes exist independent of whether they are modelled or not. The traditional functional view of the organisation has now been superseded or integrated by a process view, since processes can more clearly define and relate to the intended goals of the business while cutting across functional boundaries (Malone et al. 2003).

As defined by Hammer and Champy (1993, p. 85), a business process is ‘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’. As with most terms, many other definitions and classifications of business process exist. For example, Aguilar-Savén (2004) distinguish between ‘core’ and ‘supportive’ business processes. A core (or primary) process is initiated from outside an organisation, e.g. the chain of activities that realise the delivery of a product to a customer. A supportive (or secondary) process creates the conditions for the primary process to be carried out. In fact, a business process is not merely a flow of activities; it is also characterised by having a deep and nested structure (Barjis 2007, p. 366). Table 1 summarises five definitions found in the literature and extracts the main concepts emphasised by the respective authors.

The concepts identified in Table 1 represent those elements that the business process community commonly and generally accepts as being fundamental in characterising business processes (Aldin and de Cesare 2009a). Figure 1 provides an example of a business process aimed at arranging a financial agreement with a customer. The example is represented in the business process modelling notation (BPMN) as it contains a set of readily understandable graphical notations for designing processes (Yen 2007, p. 140). This example merely serves the purpose of illustrating how the different elements of a business process contribute to representing the behaviour of an organisation.

Thus, the conceptual elements identified in Table 1 can be defined as follows:

- **Process**: A set of activities, events, etc. that together and cohesively delivers a service and/or a product (e.g. arrange finance).
- **Activity**: Specific behaviour carried out in an organisation (e.g. collect and pass customer details to the accounts department).
- **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 (e.g. providing the customer with the opportunity to apply for finance). According to some authors like Tao and Yang (2008, p. 367), a service instead represents the functionality of the business process. Such definitions of service normally view the concept from a technological perspective rather than a business one.
- **Role**: The types of actors or agents that take part in processes (e.g. front office).
- **Goal**: The aim of a process (e.g. obtaining finance).
• **Event**: An occurrence that takes place at a specific point in time and that is capable of inducing some observable behaviour (activity or process) (e.g. customer request for finance).

• **Rule**: A constraint defined for any part of the organisation and its processes (e.g. only customers with a clear credit check can be considered for a loan).

All of these elements are related to each other and some of these elements like process, activity, event and role are more easily representable and explicit than the rest. In languages like BPMN explicit symbols are provided for representing a process (i.e. an entire diagram), an activity, an event and a role (e.g. partitions or swimlanes). The other elements of a business process are not as explicitly represented in most process modelling notations. Rules can be modelled via the use of a formal or informal ‘rules’ languages. An example of the former is the object-constraint language in UML activity diagrams, while an example of the latter is the use of natural language in textual annotations placed directly on the process model itself.

The concepts of service, product and goal are related to the expected outcome of a business process. While in textual representations of business processes

<table>
<thead>
<tr>
<th>Definitions</th>
<th>Concepts identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>A business process is the set of internal activities performed to serve a customer (Jacobson et al. 1995).</td>
<td>Process, Activities, Serve, Customer</td>
</tr>
<tr>
<td>A business process is a collection of activities that takes one or more kinds of input and creates an 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 (Hammer and Champy 1993).</td>
<td>Process, Activities, Input, Output, Customer, Goal, Event</td>
</tr>
<tr>
<td>A business process is simply a structured set of activities designed to produce a specified output for a particular customer or market. It implies a strong emphasis on how work is done within an organisation, in contrast to a product’s focus on what. A process is thus a specific ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs: a structure for action. (Davenport 1993)</td>
<td>Process, Activities, Input, Output, Customer, Product, Time/place, Rules</td>
</tr>
<tr>
<td>Business process is a lateral or horizontal organisational form that encapsulates the interdependence of tasks, roles, people, departments and functions required to provide a customer with a product or a service. (Earl 1994)</td>
<td>Process, Tasks, (i.e. activities), Roles, Customer, Product, or service</td>
</tr>
<tr>
<td>Business process is a purposeful activity carried out collaboratively by a group, often crossing functional boundaries and invariably driven by outside agents or customers. (Ould 1995)</td>
<td>Process, Activities, Customer, Purposeful (i.e., having an aim)</td>
</tr>
</tbody>
</table>
Figure 1. Example of a business process.
(e.g. business use cases), these concepts tend to be explicitly represented (de Cesare et al. 2003), in diagrammatic models (such as in Figure 1), the outcomes of the process tend to derive from an interpretation of the model itself as well as from the original intention of the modeller.

To summarise these fundamental process elements, a business process is triggered by an initiating event that is followed by a sequence of activities and events that are carried out by (or are within the responsibility of) people or organisational units assuming specific roles. The activities and events are carried out in accordance with predefined rules. Altogether, a business process is aimed at achieving a goal that involves the delivery of a product or service.

Since organisations face challenges such as increasing competition, expanding markets and rise of customer expectations (Millet et al. 2009, p. 393), their underlying processes are continuously affected by changes occurring in the environment (e.g. market, society, etc.) of which they are part (Havey 2005) and must improve their business processes to meet these challenges. To do so, they must strive to be agile and responsive (Xu et al. 2008, p. 611). Examples of large-scale factors affecting businesses in recent years include globalisation, deregulation, the growing pace of innovation, the increasing education and affluence of people and new technologies. However, whether these changes are dramatic or subtle, BPM is employed to keep a business efficient and competitive (Morgan 2007). It is worth mentioning that not only have organisations changed but also that the way in which people view business processes has evolved. According to Ould (2006), business processes have gone through three waves of changes:

1. In the first wave, processes are thought of as a ‘way of doing things’ and very rarely they would be mentioned in policy and procedure manuals. Those processes were usually presented using flowcharts in order to achieve a better understanding and to make small-scale improvements to them.

2. In the second wave, the information perspective of processes prevailed. This was naturally determined by developers’ tendency to focus on information requirements and use these as the basis for creating business processes, rather than designing the processes and subsequently making the information systems conform to them. In this wave, business processes were often preferred to be re-engineered to best practice and costing huge sums of money. Thus, processes were only regarded and used as a means to reinforce information.

3. Currently, there is a third wave, which is directed towards business process management’s recent technology. In this wave, business processes are the deterministic factors about how information should be manipulated and what information needs to be stored. There is more emphasis now placed on business processes than on information. Organisations can therefore change the operational methods of their businesses. Today, organisations think more distinctively about processes and how they can be executed, modified and monitored even in real-time via business management systems, so as to enable fast and cost-effective process execution (Tan et al. 2008, p. 745). In fact, as more and more processes become automated, customers become increasingly interested in managing process execution (Tan et al. 2008, p. 745). These latest trends require suitable methods to identify, analyse, model, design, implement, evaluate and use processes. It can be concluded
that the main aim of business process management systems is to enact models of business processes. This is primarily due to the need of organisations to be able to more readily and flexibly adapt their processes to change, induced by both internal and external factors (Morgan 2007), so as to achieve better organisational performance. It can be observed that current management practices are based mainly on process management (Santos et al. 2007).

Thus, in the current third wave organisations have matured in their perception and use of business processes. Processes are increasingly becoming the primary design artefact adopted to both conceptualise and engineer the organisation. Consequently, business process design would require more systematic methods, tools and techniques with which process engineers can achieve the more demanding requirements expected by BPM in this third wave. As it will be argued, process reusability represents an approach that may cope with these increased demands.

2.2. Business process models

Models in essence are a means for explicating, agreeing and managing information in a well-defined and structured manner (Ludewig 2003). Without a model, it would become very difficult to manage vast amounts of information in a coherent manner and come to any form of common understanding. Moreover, the capability to store information means that models often provide a rich means of managing documentation concerns, by preserving the information for future referencing and possible reuse for other purposes. According to Bandara et al. (2007), ‘process modelling occurs before the background of an organisationally and information technology-supported setting in which process models are created to fulfil multiple purposes’. Models of business processes can be understood as simplified, abstract representations of business processes. Curtis et al. (1992, p. 67) defined business process model as ‘an abstract description of an actual or proposed business process that represents selected business process elements that are considered important to the purpose of the model and which can be enacted by a human or machine’.

Workflow models are closely related to business process models. A workflow can be defined as ‘the automation of a business process in whole or in part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules’ (Hollingsworth 1995, p. 6). While a workflow model represents an automated process, a business process model may include both manual and automated activities. As with (procedural) business processes, workflows consist of a number of tasks that need to be carried out and a set of conditions that determine the order of the tasks (Xu et al. 2009).

One of the most important elements of a business model is the definition of the business processes that will operate within the organisations (Morgan 2002). A business model is an abstraction of how a business functions, while a business process model is a type of business model that focuses on an organisation’s behaviour. The details to include in a business model differ according to the perspective of the model creator leading to slightly different viewpoints of the goals and visions of the business, including its efficiency and the various elements that are acting in concert within the business. Business models provide ‘a simplified view of the business structure that will act as the basis for communication, improvements or
innovations and define the information systems requirements that are necessary to support the business’ (Eriksson and Penker 2000).

Business process models represent the main conceptual artefacts (e.g. processes, activities, events, roles, rules, etc.), underpinning the management of organisational processes and their continuous change (Mendling 2008). It is through process models that it is possible to begin to systematically update and revise business processes periodically in order to achieve improved organisational performance and enable the organisation to deliver quality products and services as required by its customers (Jacobson et al. 1995). BPM serves multiple purposes. Summarising purposes of BPM extracted from Eriksson and Penker (2000), Caetano et al. (2005) and Luo and Tung (1999) as well as considering the perceived benefits of BPM as investigated by Indulska et al. (2009b), it can be said that BPM helps to achieve the following:

1. Supporting process improvement and re-engineering through business process analysis and simulation. BPM can 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.
2. Facilitating a group to share their understanding of the process by using a common process representation that helps human understanding and communication. This would be facilitated, for example, by adopting and agreeing a well-defined set of business process concepts among multiple stakeholders.
3. Creating suitable information systems that support the business by providing a descriptive model for learning.
4. Enabling decision support during process execution and control.
5. 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. It is worth stating that the final purpose (and benefit) of reuse is instrumental towards achieving the previous four purposes.

Process modelling could be used for the analysis of an existing business process or to create new process models by modifying existing models rather than recreating them from scratch (Lin 2008). In practice, it is commonly recognised that there are significant amounts of similarities in business domains (Wu et al. 2009). Thus, the modelling expert may encounter similar modelling scenarios many times in their entire career and such experience would be of great value to the organisation if documented (Havey 2005). Recording such experience is the initial step towards discovering common patterns of reusable behaviour. Another term used to denote such commonalities is process model fragment (Lin 2008). In this context, a fragment is a part of a business process model designed and managed to be reusable. Generally, reuse of pre-existing model fragments can facilitate and speed-up the construction of a new model. For their reuse advantages, process fragments and patterns are increasingly attracting the interest of both researchers and vendors. Since businesses change over the years, there arises a need to keep existing business process models up-to-date and to synchronise or translate them into patterns. To facilitate these scenarios, techniques for discovering business process patterns from
existing organisational assets (e.g. people, workflow systems, documentation, legacy systems, models, data, etc.) are required.

2.3. **New trends in process discovery and representation**

2.3.1. **Process mining**

There are some research efforts by the BPM community, which have looked at process discovery by mining the control flow of process models. Process discovery is aimed at correctly summarising an event log and describing how processes have actually taken place. The first articles on process mining appeared in 1996 when Cook and Wolf (1996) started mining process models from event logs in the context of software engineering. They called it ‘process discovery’. Process mining in the business sense was first introduced in 1998 by Agrawal et al. (1998) and they called it workflow mining. Since then many groups have focused on mining process models (Schimm 2000, van der Aalst et al. 2003, 2004, Greco et al. 2005, van Dongen and van der Aalst 2005). Process mining is ‘the automated acquisition of process models from the event logs of information systems such as ERP, role-based access control and workflow management (WFM) systems’ (van der Aalst and van Dongen 2002, van der Aalst et al. 2005, van der Aalst et al. 2007). Event logs contain information about the occurrence of business events and who performed a particular activity in the context of a particular business process involving some particular business information at a particular time. However, van Dongen (2007) highlights that process mining may perform poorly for the following reasons:

1. For event logs taken from computer systems used in an organisation, it is not clear which properties are satisfied. It is impossible to say whether such a log shows all possible interleaving of two activities, since that implies knowledge about the process, which the logs do not have, ‘the more dynamic a process is, the less knowledge you typically possess’ (van Dongen 2007, p. 255).

2. Event logs typically record information at a rather low level while people talk about processes at a very high level. According to van Dongen (2007), there is no given way to link the low-level activities to the high level activities, since interviews provide a subjective, qualitative source of information, whereas event logs are an objective and quantitative source of information. Associated with this general problem is the more specific challenge, mentioned by Mendling et al. (2008), to find state information in event logs.

3. Goedertier et al. (2008) state that event logs rarely exhibit complete behaviour, because of the presence of noise. Thus, incomplete event logs can invalidate the ability to produce the correct underlying process model. van der Aalst et al. (2007) affirm that process mining is particularly useful in the context of human centric processes that are supported, but not fully controlled by computer systems.

2.3.2. **Imperative vs. declarative approaches**

Currently, BPM languages and models are procedural (or imperative) in nature. A business process model is procedural when it contains explicit prescriptive information about how processes should proceed, but only implicitly keeps track of why these design choices have been made (Goedertier and Vanthienen 2007a). When modelling business processes procedurally, modellers inevitably make a
number of modelling assumptions that are not present in the earlier specified requirements. Procedural process models are represented with procedural languages such as workflow nets, the business process execution language (BPEL), the BPMN and UML activity diagrams. The procedural approach is dominant within the context of contemporary workflow technology (Pesic and van der Aalst 2006), because it focuses on the control-flow perspective of business processes.

Such an approach requires specifying all execution alternatives explicitly in the process model. It specifies exactly the ‘how’ of procedures by tracking ‘how things have to be done’ (van der Aalst and Pesic 2006). The fact that the procedural approach requires all execution alternatives to be explicitly specified in the model causes some problems with respect to flexibility of WfM systems. This has several consequences (Pesic 2008):

(1) Procedural models with multiple execution alternatives tend to be large and complex, which makes it difficult to understand and maintain these models.
(2) In a procedural approach, all execution alternatives must be anticipated in advance.
(3) Explicitly specifying the procedure in the model can result in over-specifying the process.

Declarative modelling uses rules at its core since business rules allow for a more flexible description of business processes and workflows (Iacob and Jonkers 2009). The modeller makes assertions about the business organisation and such assertions must hold true and validated against during model execution. The declarative nature of business rules provides several benefits including unambiguous representation, explicit declaration, rapid adaptation and promotion of reuse (Morgan 2002). For example, Graml et al. (2008) proposed a pragmatic approach for combining business processes and business rules. Their research proposes business rule-enabled process modelling patterns to overcome the problem of adaptability. The aim is to extract the business logic contained in process models and encode such logic into business rules. The business rules, and with them the extracted business logic, can thus be more easily modified during the run-time of a business process instance.

In order to deal with the problem of flexibility, Pesic and van der Aalst (2006) adopt a declarative approach to enable system users to manoeuvre within the process model or even change the model while working as this is considered to be the most suitable for dynamic process management. This enables organisations to operate effective business processes (Moller 2007). In fact, according to Koehler et al. (2005), declarative approaches have a clear advantage over traditional modelling techniques as this type of approach produces models that ‘can be analysed, reused, and reversed’; adopting a declarative approach helps in defining rules that facilitate, for example, model transformation, specialisation and integration, all of which are essential in process reusability. Also Koehler et al. (2005) believe that the declarative approach can pave the way for future automatic consistency checking of transformation rules as well as bidirectional reconciliation of evolving models.

In Pesic’s thesis (2008), the declarative approach was proposed as a more suitable option for achieving a higher degree of flexibility because it does not require explicit specification of execution alternatives. Instead, a declarative approach allows for the implicit specification of execution alternatives. This approach is based on using activities and constraints for declarative specification of the control-flow perspective
of process models (Pesic 2008). Constraints are rules that should be followed during the execution. Applying a constraint in a business process model would implicitly specify the possible execution alternatives. Thus, everything that does not violate the constraints is allowed. Declarative process models are represented with declarative languages, such as ConDec (van der Aalst and Pesic 2006), that are used to build a wide range of representations: from very strict models, that define the process in detail, to very relaxed models that state only what should be done without specifying how it should be done. ConDec specifies the ‘what’ by starting from all the possibilities and using constraints to approximate the desired behaviour (Pesic 2008).

The declarative approach requires specifying all execution alternatives implicitly in the process model. It specifies exactly ‘what’ should be done without specifying ‘how’ it should be done (Pesic and van der Aalst 2006), because users are driven by the system to produce the required result, while the manner in which the results are produced depends on the preference of users. The fact that the declarative approach requires all execution alternatives to be implicitly specified in the model causes a problem in supervising the flexibility of WfM systems. This assumption has several consequences:

(1) It is unclear whether end users are really capable of adjusting a particular plan to execute a business process when using a declarative approach (Pesic 2008).
(2) There is lack of empirical evidence on how declarative approaches perform in real-world settings (Weber et al. 2009).
(3) It is unclear how well users can cope with the gained flexibility provided by the declarative approach (Pesic and van der Aalst 2006), especially when processes and their context become rather complex. While it might be expected that the declarative approach will be effective to deal with business processes when few constraints are applied, it is not clear whether end users are capable of translating a large number of constraints into effective updates of their initial plans. Since all constraints must be satisfied, one can argue that the sheer number of constraints will obscure from an end user’s view of what proper actions are still available.

The adoption of the declarative approach need not entirely supersede the procedural approach. Notwithstanding the benefits stated above, Sadiq et al. (2005) believe that the combined use of the declarative and procedural approaches would be advantageous, since procedural models are assumed to be easier to understand, while declarative modelling promises a higher degree of flexibility. In their opinion, they represent two sides of the same coin.

Given the flexibility with which declarative modelling approaches are able to represent specific conditions, constraints or rules that classes of business processes must exhibit (or not), these types of models are particularly appropriate to the representation of more generalised models such as patterns. It can be argued that declarative representations can help modellers to both represent and use patterns of generalised behaviour in the sense that it would be possible to state a minimal set of necessary conditions that are required for the application of a certain pattern.

The following section will focus on patterns in information systems development while Section 4 will discuss the major literature in the area of ontologies for BPM, ontologies which can add a high level of semantic accuracy to declarative modelling.
3. Patterns: general concepts

An organisation encounters many problems in its day-to-day operations and in its strategic positioning against other organisations. According to Nelson and Nelson (2003), these problems occur over and over in slightly different forms but with the same fundamental characteristics. A pattern is ‘a core of the solution’ to these common problems (Alexander et al. 1977). The concept of patterns initially originated from the work of the architect Christopher Alexander (Alexander et al. 1977, Alexander 1979). Alexander defined pattern as follows: ‘each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice’ (Alexander et al. 1977, p. x). Therefore, while on one hand a pattern is used to solve problems, on the other hand these problems and their solutions are not unique but may be found and adopted in multiple contexts and situations.

3.1. Patterns in information systems development

Many patterns have been developed and are based on the different phases of the software engineering lifecycle as well as different design paradigms and features (Gzara et al. 2000). These differences result in various levels of suitability and expressive power. In addition, the use of patterns has gained a lot of attention in several facets of information systems development (ranging from business modelling to implementation). Beck and Cunningham (1987) initially introduced patterns in software programming by adopting ideas and principles first described by Alexander et al. (1977) in the field of civil architecture. The pattern concept was developed further and introduced at a design level. Examples of initial design patterns modelled by Coad (1992) included ‘item description’, ‘time association’ and ‘event logging’. Coad et al. (1999, p. 3) later adopted the term archetype to indicate ‘a form from which all classes of the same kind more or less follow’. Design patterns finally became a mainstream architectural technique thanks to Gamma et al. (1995) who systematically compiled a catalogue of over 20 design patterns.

Subsequently, patterns were introduced by Hay (1996) to represent generic data structures typically used to model the information requirements of business organisations. Similarly to Hay, Fowler (1997) defined a set of analysis patterns with the intention of reflecting ‘conceptual structures of business processes rather than actual software implementations’ (p.xv). The works of both Hay and Fowler mainly focused on structural patterns (data/information). Some process patterns can be identified in Fowler, but these represent only a few examples. Furthermore, Fowler’s work tends to be directed towards software designers. As a result, his analysis patterns in many areas commit more to software artefacts rather than to generic business domain structures and behaviour. As suggested by Yang et al. (2005), such analysis patterns seem to be the solutions for reusable problems in software development processes.

More recently, the process communities have taken a similar approach by identifying and codifying its own set of common problems. In business modelling, Eriksson and Penker (2000) developed a set of business patterns, which came closer to a generic representation of organisational structures and processes. These include
resource and rule patterns, goal patterns and process patterns. Although these patterns like the previous (Fowler and Hay) are ultimately aimed towards the facilitation of realising software artefacts that will help to effectively and efficiently develop and ‘run’ information systems, Eriksson and Penker’s business patterns are modelled and described from a perspective that is closer to that of the enterprise rather than the software developer. Another form of business modelling patterns are those proposed by Malone et al. (1993, 2003). The MIT process handbook project started in 1991 with the aim to establish an online library for sharing knowledge about business processes. The business processes in the library are organised hierarchically to facilitate easy process design alternatives. The hierarchy builds on an inheritance relationship between verbs that refer to the represented business activity. There is a list of eight generic verbs including create, modify, preserve, destroy, combine, separate, decide and manage. These business process patterns provide a systematic means of (re-) designing new processes by finding a richer structured repository of process knowledge through describing, analysing and redesigning a wide variety of organisational processes.

Within the business domain, there are examples of more specialised patterns like the Resources Events Agents (REA) framework (Geerts and McCarthy 2002). REA is a domain ontology specialised for the enterprise context. Its main area of application was initially accounting information systems, but REA has now become more widely used for the conceptualisation of enterprises in the more general sense. REA has also been used as the foundation for more specialised and reusable pattern-based frameworks. One of these is represented by READY (Dynamic REA) (Batra and Sin 2008). READY focuses on revealing typical interaction scenarios in accounting applications. The READY model (Batra and Sin 2008) represents predictable activities such as search, select, create transaction, add line items, review transaction and commit transaction. These generic patterns can be found in key revenue, expenditure and conversion accounting cycles. By providing patterns of dynamic behaviour of accounting scenarios, the READY model has been shown to be a valid and useful extension of the REA model (Batra and Sin 2008).

There has also been an increased interest in business process patterns specifically in the form of workflows. Russell et al. (2004) introduced a number of workflow resource patterns aimed at capturing the various ways in which resources are represented and utilised in workflows. Popova and Sharpanskykh (2008) stated that these patterns provide an aggregated view on resource allocation that includes authority-related aspects and the characteristics of roles. This greater interest is primarily due to the emergence of the service-oriented paradigm in which workflows are composed by orchestrating or choreographing web services due to their platform-agnostic nature and ease of integration (Rosenberg et al. 2008). van der Aalst et al. (2000) produced a set of so called workflow patterns. Workflow patterns proposed by van der Aalst are referred to as ‘Process Four’ or P4lists and describe 20 patterns specific to processes. However P4 catalogues a comprehensive account of patterns for processes of ‘control flow’. This initiative started by systematically evaluating features of WfM systems and assessing the suitability of their underlying workflow languages. However, as Thom et al. (2007a,b) justly point out, these workflow patterns are relevant towards the implementation of WfM systems rather than identifying business activities that a modeller can consider repeatedly in different process models. In fact, the workflow patterns (van der Aalst et al. 2003)
are patterns of reusable control structures (for example, sequence, choice and parallelism) rather than patterns of reusable business processes subject to automation. As such these patterns do not resolve the problems of domain reuse in modelling organisational processes. Consequently new types of business process patterns are required for reusing organisational process models (Aldin et al. 2009b,c).

3.2. Limitations in existing patterns

It can be seen from the background investigation that existing patterns provide limited support to resolving the problems of domain reuse in modelling organisational processes. Although, more and more researchers and practitioners recognise the importance of reusability in BPM (di Dio 2007), little consensus has been reached as to what the essential ingredients of business process patterns should be. Therefore, the need arises to provide patterns that support the reuse of BPM, as patterns offer the potential of providing a viable solution for promoting reusability of recurrent generalised models.

An additional limitation is that, none of the previous work provides guidelines to modellers as to how these patterns can be discovered. Most of the patterns community mentioned earlier agrees that patterns are developed out of the practical experience of real projects by stating, for example that ‘patterns reflect lessons learned over a period of time’ (Kaisler 2005, p. 45). During that process, someone creates and documents a solution for a certain problem. In similar situations, this person refers to the solution that had been documented before and adds new experiences. This may lead to a standard way of approaching a certain problem and therefore constitutes the definition of a pattern. Thus, each pattern captures the experience of an individual in solving a particular type of problem.

In reality, with every new project, analysts create new models without referencing what has already been done in previous projects. So, providing systematic support towards the discovery and reusability of patterns in BPM can help resolve this problem. In addition, writing good patterns is very difficult, because patterns are not only providing facts (like a reference manual or user’s guide), but are also telling a story which captures the experience patterns are trying to convey. A pattern should add value and help its users to comprehend existing models, customise models to fit user needs and help to construct new models.

A conceptual technology that has gained popularity recently and that can play a useful role in the systematic discovery as well as the precise representation and management of business process patterns is ontology. Ontologies have the potential of improving the quality of the produced patterns and of the modelling process itself due to the fact that ontologies are aimed at providing semantically accurate representations of real world domains.

4. Ontologies in business process modelling

Ontology is a term that originates from a branch of philosophy known as metaphysics. Here ontology is defined as ‘the science of what is, of the kinds and structures of objects, properties, events, processes and relations in every area of reality’ (Smith 2003, p. iii). Ontology is about understanding what things actually exist in the world and how they are related.
More recently, however, the concept of ontology has been expanded as well as specialised in the fields of computer science and artificial intelligence. In these disciplines, ontology is recognised as an ‘explicit specification of a conceptualisation’ (Gruber 1993, p. 5). Gruber defines specification of a conceptualisation as ‘the objects, concepts and other entities that are assumed to exist in some area of interest and the relationship between them’ (Gruber 1995, p. 1). As a result, a number of domain ontologies have been created over the last decade, such as the Enterprise Ontology (Dietz 2006) and TOVE (Fox and Gruninger 1994) for enterprise modelling and the REA ontology in the field of accounting (Geerts and McCarthy 2002). In addition to domain ontologies, there are foundational ontologies such as DOLCE, task ontologies such as the Web Services Modelling Ontology and application ontologies such as those that describe a specific application domain such as retail banking.

Recently, it has been recognised that ontology can guide the development of new information systems by helping analysts and designers choose appropriate processes, rules and software components (Guarino 1998, McBride 2003, Jurisica et al. 2004, Sharman et al. 2007). This has led to a growing interest in the role that ontologies can play in improving the quality of business process models. In a way ontology can be thought of as a declarative approach for modelling entities in a domain of discourse, since it provides a declarative basis that enables reasoning about what information is and is not available to business process occurrences at a given time. Hence, this level of abstraction enables business level BPM facilities to better connect to the technical implementation level for supporting the automated execution of business processes.

Among the literature that investigates ontologies in BPM, at least two groups can be identified. The first group of research adopts ontology as a means to evaluate existing modelling languages and techniques. The second group is more interested in the benefits that ontologies can provide to improve the alignment between business process models and the implemented software technology primarily in the form of Web services.

4.1. Evaluation of modelling techniques via ontologies

Research in this area is aimed at assessing business modelling languages/techniques via an ontological analysis of the underlying notations. Normally, the semantics of the notation is compared against a well-recognised ontology. In most of the works in this area, the Bunge-Wand-Weber (BWW) (Weber 1997) ontology is adopted. The BWW ontology is an extension of an ontology presented by Bunge (1977) and specialised by Wand and Weber (1990) to the field of Information Systems. The BWW model has over the years reached a significant level of maturity, adoption and dissemination with many research projects extensively applying the ontology in the context of the analysis and evaluation of various process modelling techniques. Major works that have applied the BWW ontology for such a purpose include Keen and Lakos (1996), Green and Rosemann (2000), Green and Rosemann (2004) and Recker and Indulska (2007).

Keen and Lakos (1996) determined essential features for process modelling schemes by evaluating six process modelling techniques in a historical sequence while using the BWW representation model. Among the modelling techniques evaluated were: flowcharts, data flow diagrams (DFD), IDEF3 and Petri nets. The evaluation
was restricted to the assessment of the ontological completeness of each technique. From the analysis, the authors concluded that in general the BWW ontology facilitates the interpretation and comparison of process modelling techniques. The authors did not, however, empirically verify their findings on the features of process modelling schemes and in the choice of appropriate modelling constructs.

Green and Rosemann (2000) used the BWW ontology model to analyse event-driven process chains (EPC) and assessed them for both ontological completeness and clarity. Empirical confirmation found shortcomings in the EPC notation with regards to the representation of real world objects and business rules, and in the thorough demarcation of the analysed process.

Green and Rosemann (2004) also extended the use of BWW in the area of enterprise systems interoperability. They focused on BPM languages like ebXML, BPML, BPEL4WS and WSCI. All these standards, which claim to allow for specification of intra- and inter-organisational business processes, were analysed in terms of their ontological completeness. However, this study found that some of these modelling languages provide a wider range of language constructs for specification requirements, while others overlap. At present, their analysis too has not yet been empirically validated.

Recker and Indulska (2007) used the BWW ontology to evaluate the representational capability of Petri nets. The findings of this study shows that Petri nets suffer a number of deficiencies classified as construct deficit, construct redundancy and construct overload in modelling real world domains. Also, this study found that a large number of BWW ontology constructs do not appear to be represented in Petri nets. This implies that Petri net are not able to model various real world concepts that are covered by the BWW constructs. However, it is worth mentioning that according to Recker and Indulska (2007), this study needs to be empirically tested to confirm, which of the proposed Petri nets weaknesses have or do not have effects in the domain of process modelling as the outcome of this study represents just a significant first attempt at the evaluation of Petri nets.

A twofold criticism can be raised for these studies that adopt the BWW to validate modelling languages and techniques. On the one hand, concerns remain on the lack of understandability of the BWW constructs, the problematic application of these constructs to other loosely defined modelling grammars and the limited empirical testing of the implications of the BWW model (Green and Rosemann 2000, Green and Rosemann 2004). In addition, an ontological analysis of a modelling technique requires not only detailed knowledge of the selected ontology and technique, but also a good understanding of the languages in which the ontology and the grammar are specified. On the other hand, the research mentioned above has mostly been of a purely theoretical nature. Most of the evaluations lack empirical verification of the theoretical findings (Recker et al. 2006). Interested readers are encouraged to refer to the use of BWW by Weber (1997), Green and Rosemann (2004), Weber and Zhang (1996) and Green et al. (2001) for a more comprehensive treatment of the ontology.

While the line of research summarised above adopts the BWW ontology as a means to assessing modelling tools (Green and Rosemann 2000), methods (Green 1996) and interoperability standards (Green et al. 2005) (as well as for the selection and introduction of standard software (see Soffer et al. 2001)), another stream of research has applied ontologies as a way of modelling business processes and aligning business systems with the underlying software applications.
4.2. **Ontologies for the alignment of business and software systems**

The potential of adopting ontologies as the foundation to modelling process models has been recognised in the literature for quite a while now (Hepp *et al.* 2005, Lin and Strasunskas 2005, Hepp and Roman 2007). In most cases, the authors try to ontologically create process representations aimed at facilitating the automated processing of procedural models. Most of these works are geared towards a certain language, i.e. they only deal with the semantic annotation of process models represented with the help of a certain language.

Semantics Utilised for Process Management within and between Enterprises (SUPER) is an European Union funded project (http://www.ip-super.org/) in which the consortium’s aim was to develop innovative approaches for business process management using Semantic Web standards (Hepp and Roman 2007). With the aim of bridging the gap between businesses and the IT world, the project sought to enable at least semi-automation of the business process management lifecycle using Semantic Web and Semantic Web services technologies (Wetzstein *et al.* 2007). The SUPER ontology is aimed at providing an extensive conceptualisation of the BPM domain, ranging from process modelling to the definition of business strategies. This is done by providing a set of constructs to generate semantic business process models via the application of ontologies to describe enterprise models and business processes in general. The project also demonstrates the potential benefits of the application of ontologies for companies. In the context of the SUPER project, in order to formally represent business process knowledge, several ontologies for different languages such as BPMN, BPEL, EPC, Petri nets, etc. are proposed to cover not only behavioural aspects, but also organisational, functional or data perspectives.

Brockmans *et al.* (2006) proposed an approach for semantic alignment by modelling business processes using Petri nets and then providing a presentation of Petri nets in an ontology language like the Web Ontology Language in order to semantically enrich the business process models. The Petri net notation was presented as an ontology; however, this work only provides semantic annotations without understanding the underlying meaning of the process models.

In Thomas and Fellmann (2006), a proposal to annotate EPCs with semantics (sEPC) is presented. This proposal includes four instances of ontologies named business ontology, business process concepts, sEPC model and the underlying EPC model. From the analysis, the authors concluded that, further research is needed regarding suitable ontologies and tools for the annotation of process models. Therefore, a prototype for a sEPC repository is currently being planned that will provide interfaces or plug-ins for well-established modelling tools. The authors did not, however, empirically verify their findings on how well the mapping of EPC notation with ontology.

The main limitation of this line of research is that the ontologies produced provide semantic annotations for BPM languages without describing and presenting the knowledge of the domain presented (Hepp and Roman 2007). Most of these works are designed towards presenting a certain language, i.e. they only deal with the semantic annotation of process models represented with the help of a certain modelling language (Thomas and Fellmann 2009). An additional limitation of SUPER is that it considers the business process models as a given, which affects the requirements engineering methodologies to acquire correctly semantically annotated business process models (Decreus and Poels 2009).
In reality, there are other ontologies aside from those mentioned earlier, but there is no generally accepted ontology (Wand et al. 1995). A different ontology may employ different concepts and constructs, which can lead to different outcomes. Despite this, the vision is that ontologies can contribute towards improving the adaptability (flexibility and agility) of business change and consequently improve alignment between requirements of the organisation and its enterprise software systems (see Hepp and Roman 2007).

5. Discussion and conclusion

In this article, the literature on BPM was reviewed with an emphasis on new lines of research in BPM that can contribute towards promoting the reusability of business process models as well as rendering BPM more systematic yet flexible enough to cope with continuous change; hence, as suggested by Neill and Sohal (1999, p. 572), the discussion moves from ‘from cost and quality to flexibility and responsiveness’. These new lines of research include patterns for BPM, process discovery, declarative modelling and ontologies.

As BPM becomes more extensively adopted in organisations, the need for more efficient and effective methods and techniques to process modelling becomes greater. While traditionally process models were mainly created from scratch where and when required, with the increase in the rate of change that modern organisations undergo, the focus now lies on producing quality process designs more rapidly and better aligned with an enterprise’s information system. Previous research has already started addressing this challenge and suggested some novel approaches to the problem. While most of the research to date does not provide a complete solution, as the limitations mentioned in the previous sections highlight, various elements of all approaches surveyed have together the potential to produce a viable solution to the problem.

The solution that is envisioned here is the proposal of a methodology aimed at discovering process patterns from diverse organisational assets and capable of modelling such patterns in a way that facilitates their reuse in the design or redesign of organisational processes. The literature surveyed in this article and the themes that can be drawn from it contribute towards the definition and development of a methodology for systematically discovering and using generalised patterns of business processes. A generic and initial framework aimed at underpinning such a methodology has been suggested by Aldin et al. (2009b,c).

Business process patterns are essentially models representing general organisational behaviour. This means that when identifying patterns, it is necessary to undergo a process of discovery not dissimilar to the process of scientific discovery. While the latter results in the formulation of laws or theories that help us understand the physical universe, business process pattern discovery allows us to understand common ‘chunks’ of organisational behaviour that can be specialised and instantiated when required. As Section 2.3.1 highlighted, current research is limited to the discovery of processes from event logs. This is useful but insufficient for a systematic discovery of process patterns. In fact, as previously observed, event logs often provide very limited data as well as incomplete information. Although process mining in itself may not be sufficient as it stands, it must be noted that the core idea and principles underlying this technique should be transposed so as to
identify ways in which process patterns can be discovered from other organisational assets such as people, documentation, legacy systems and so on.

If process patterns are to be flexibly applied, then it may be necessary that such patterns not be rigidly encoded, as procedural process models tend to be, i.e. with rigid execution paths and outcomes. Declarative models may provide the foundation for constraint-based patterns that provide support for foreseen and unforeseen process flows in which variants of a typical class of business process may emerge. Such models would be based on both logical as well as graphical types of representations of business processes. The former is typically the type of representation envisioned by the Semantic Web community in the representation of ontologies.

Since the business process patterns must be reused, their representations must be as clear and unequivocal as possible. This implies semantic precision or correspondence between a model and the real world system it represents. Ontologies are semantic models and tend to represent real world systems, so that there is a one-to-one mapping between the symbols in the model and the real world things that those symbols represent. In order to discover process patterns, an ontology of business processes is required. This ontology would drive the interpretation of organisational data during process mining and discovery. Moreover, the elements of the discovered patterns would be individually classified according to the classes defined in the business process ontology. The contribution of projects like SUPER (Hepp and Roman 2007) provide contributions to this specific problem.

The ontological patterns discovered must be continuously evaluated as new data emerges. This implies adopting ontology evaluation approaches similar to those used by Green and Rosemann (2004). Although BWW may not be the optimal ontology to base the evaluation on, the research surveyed above provides indications as to what a general ontology evaluation framework should provide.

References


