Integrated Modelling of Business Process Models and Business Rules: A Research Agenda

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Abstract

Process models are the basis for a wide range of critical activities within an organisation. It is not surprising then that process models, and the act of process modelling, have been the focus of much research over the last two decades. Recent research indicates, however, that common process modelling notations lack sufficient representation for capturing business rules. Although the need for business processes and business rules to be modelled in an integrated manner is well established, the body of knowledge on integrated modelling of the two is limited. In this paper our aim is to review the state of related research and develop a research agenda, based on a systematic review of related literature, to advance research in this field. We present a consolidated view of the benefits of rule and process model integration, together with an overview of current related approaches, and a research agenda going forward.

Keywords

Business Process Modelling, Business Rule Modelling, Integrated Modelling

INTRODUCTION

Organisations invest in understanding and capturing their business operations so they can improve their efficiency and effectiveness, communicate with stakeholders and articulate business requirements, among others. The elicited information is documented, often in the form of business process models, which are graphical representations/abstractions of organisational practice. Modelling of such organisational practice it facilitated by the use of business process modelling languages, which, in turn, can be classified into two categories, *viz.* procedural languages and rule based languages. Each of these types of modelling languages have their strengths and weaknesses. On the one hand, rule based languages are better in expressibility, flexibility, adaptability and dynamism, however the most significant challenge for rule-based languages is complexity and understandability. Rule based modelling languages often have a formal syntax and require significant expertise to use and to understand. They also lack visual representation, which leads to lower understandability. On the other hand, procedural notations have only limited support for flexibility and adaptability, while they are strong in their simplicity and understandability due to their abstract syntax and visualization. Of the two types, procedural modelling appears more popular in practice given its relative simplicity.

Recently, however, researchers have indicated that business rule modelling is not well supported by commonly used process modelling notations (Recker et al. 2011). Empirical findings (Recker et al. 2011) indicate that process designers often have the need to represent business rules in a process model while business process modelling notations fail to provide sufficient symbols to represent business rules. Thus, designers often cannot use business process modelling notations to adequately represent business rules in process models. Such modelling deficiencies also result in process models without all relevant operational constraints, which in turn lead to misleading guidance and non-compliant process execution. The interpretation of such incomplete models

can lead to breaches of expected operational practice, poor decision-making and less effective process outcomes. Moreover, the hidden information is sometimes vague since it is not represented explicitly or even missing thus it is not possible to achieve a holistic understanding, nor it is possible to have a shared understanding of system requirements between designers and developers. The incomplete system requirements will lead to incomplete system implementation in which business processes might be executed without necessary constraints and monitoring mechanisms and thus, might cause high costs due to operational and compliance risks.

Before we discuss integrated modelling we first clarify what we mean by 'integration'. On an abstract level, integration is the act of combining things into an integral whole. Integrated modelling is the process of representing all aspects of a business object in an integral way. In related literature, researchers use "combination" (Mickevičiūtė and Butleris 2013) and "join" (Habich et al. 2010) as synonyms for integration of process modelling and rule modelling. Thus, in the context of process and rule representation, integrated modelling is the representation of both procedural aspects as well as rules that relate to a process. While the focus in this paper is for integration at the conceptual level, it should be noted that it is common practice in organizations to integrate processes and rules at the application level. For example, between rule engines, business process management systems or process engines and other enterprise system software. However, without integration at model level as guidance, integration at the system level is often: 1) Ad-hoc: different platform vendors, different software components leading to different implementations. Traditionally, each organization has its own ad-hoc method of integration and the system quality varies since there is no standard or best practice in system level process integration. Some small organizations don't have the capacity to hire engineers to integrate their systems, however, the need for an integrated implementation cannot be overlooked. 2) Incomplete: the implementation is fragmented and applicable rules are not recognized and captured where needed. For example, if business rules are not fully incorporated into business process models then tasks in business processes may be executed without some essential constraints, which could be legally obligatory.

Accordingly, while we sense an increasing argument in literature for business process and business rule integration, we observe a gap in the body of knowledge whereby the benefits, current approaches and maturity of existing research have not been consolidated and is thus not well understood. We thus see an opportunity to provide an overview of business process and business rule integration research and present a research agenda to further this field.

The remainder of this paper is structured as follows. In the next section we introduce the methodology employed to conduct a structured review of related literature, including a brief quantitative analysis of the research landscape since 1990. We then we present a consolidation of motivations and benefits from process model and rule integration. We then provide a discussion of the core integration methods reported in literature. Finally, we identify the gaps in current research and discuss requirements for integrated process and rule modelling, and conclude the paper.

METHODOLOGY

To ensure that we have a complete set of related literature, our review is based on three sources of papers, *viz*. core Information Systems and Computer Science journals and conferences, papers indexed by the Web of Science, and backward/forward citation searches of the identified papers.

Our first and main source is a comprehensive set of journals and conferences. To ensure broad coverage of the research topic, we select well-regarded Information Systems and Computer Science academic publication outlets. The selection is based on journal and conference rankings (see www.aisnet.org and www.core.edu.au) and summarized in Table 1.

Table 1. Data set of 1990-2014 publications

Type	**Acronym**	**Totals**
Conferences	ACIS, AMCIS, CAiSE, ECIS, ER, HICSS, ICIQ, ICIS, IFIP, IRMA, IS Foundations, PACIS, BPM, WIDM, WISE, CIKM, SIGIR	20,580
Journals	BPMJ, CAIS, EJIS, I&M, ISF, ISJ (Black-well), ISJ (Sarasota), JAIS, ISR, MISQ, MISQ Executive, TKDE, DKE, CACM, DSS, TOIS	14,115

We keep our perspective broad through the consideration of both conference and journal publications so as to include preliminary research, which may not yet be at a sufficiently mature stage to be published in a journal. We focused on almost 25 years of conference and journal publications (1990-2013)[1]. Our data set consists of 34,695 articles.

[1] Collections vary depending on the span of the conference and journal.

Given the large volume of papers considered, we set out to develop a full text search strategy before commencing analysis. Each article was inspected and prepared (with OCR) for a full text search. The articles were then subjected to the creation of a full-text index generated using Adobe Acrobat 10. The index was used to identify articles relevant to integrated modelling. To identify the appropriate search terms, we scanned a selection of articles to identify synonyms of 'integration' and included them in the search. We use a combined binary full text search using the search term of: "((business process) and (business rule)) and model and (integrate or combine or extend or link or merge or translate or map or complete or full or enrich)". Thus, any article that contains the term "business process", "business rule", "model", and any of the words that are related with integration will be included in the search result. We used a stemming search, so that "integrating", "integration", "integrated", for instance, are all regarded as "integrate". The search resulted in 617 matching articles. In the second phase of the analysis, we narrowed the set of papers to those that had a focus on process and rule integration (rather than incidental mentions). We regarded a paper as sufficiently focused on process and rule integration if the keyword "business process" and "business rule" (including their variants) occurred 3 times or more within the body of the text. This process resulted in 124 unique papers. Once this set of unique articles was obtained, we started the process of eliminating irrelevant papers through a manual filtering process. Papers were evaluated for relevance based on their abstract. If relevance was still not clear, further investigation of the body of the paper was conducted. The last step reduced our set of relevant papers to 22.

While our first source represents a very large data set, we concede that it may not contain all related research. Research on process and rule integration would be predominantly targeted at IS and CS publication outlets but may focus on other publication outlets in the discipline or, indeed, may be published in the context of other domains. Accordingly, we used the Web of Science (electronic version of the Social Sciences Citation Index) full database using the same search terms. Our search was based on the title, keywords, and abstract the Web of Science full database, and identified 764 matching articles. A manual filtering procedure was carried out again to exclude unrelated articles and 46 articles were selected. Then the same manual filtering process of filtering each paper was performed to eliminate unrelated papers. We then used Zotero[2] to detect duplicates between the 46 papers and the 22 papers identified in the first data source. This process eliminated 13 papers from 46, leaving us with 33 additional papers from the second data set.

To ensure a comprehensive identification of related papers, we also conducted backward and forward searching of citations, as suggested by (Webster and Watson 2002). In backward searching, the citations for the articles identified in the first two sources were reviewed to discover related cited papers that may be relevant. In forward searching, we used Google scholar to identify articles citing the key articles identified in the first two sources. This process resulted in the identification of an additional 11 papers.

Based on our analysis of the sources described above, we identified 66 related articles. We used NVivo 10 to systematically code the literature. A coding scheme was developed to analyse each contribution. The coding scheme consisted of nodes for 1) integrated modelling motivation/benefits, 2) integration approach, and 3) Type of contributions (conceptual, implementation, evaluation). These nodes are designed to capture the essential parts of each work and to form a systematic overview of the state of research. By coding the motivation/benefits of integrated modelling, we aim to identify consensus on the benefits this research can bring to practice; By coding integration approaches, we aim to identify the status of related research and its main approaches; By coding type of contribution, we aim to understand the progress of research in this field.

MODELLING

As part of our analysis, we were motivated to determine the emergence of research on integrated modelling of business processes and business rules. The breakdown of articles by year of publication is shown in Figure 1.

Our analysis shows increased research activity recorded in 2004 and 2009 respectively. One reason for the increase in 2004 may be the release of Business Process Modelling Notation (BPMN), which is now an international standard for business process modelling. We posit the reason for the second spike in 2009 is the formal release of the Semantics of Business Vocabulary and Business Rules (SBVR) specification. SBVR v1.0 – a business rule modelling standard - was released by the Object Management Group (OMG) in 2008. Following the release of BPMN and SBVR, much research on integrated process and rule modelling has in some way focused on these standards.

We note that Krogstie *et al*. (1991) were the first to motivate and discuss integrated modelling of business processes and business rules. (McBrien and Seltveit 1995) used a process modelling language named PID to couple business process models and business rules. The coupling allows the two languages to be used as complementary languages in conceptual modelling.

[2] Zotero is a reference management software to manage bibliographic data and research materials.

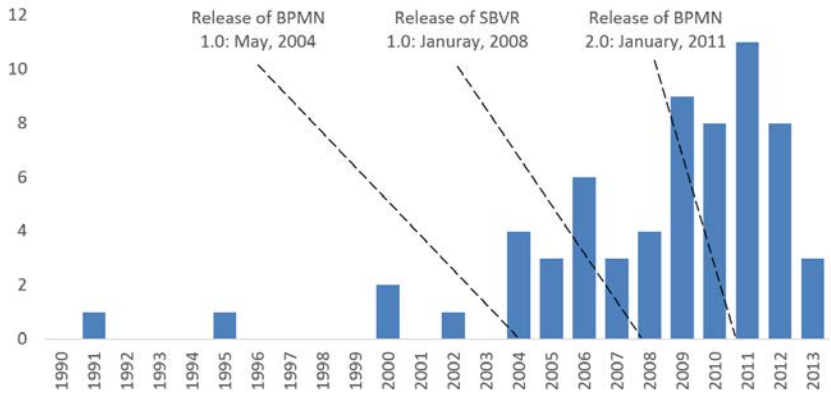

Figure 1: Number of Publications in Each Year

ANALYSIS OF INTEGRATED MODELLING BENEFITS

Using NVivo 10, we performed an analysis of the motivations/benefits of integrated modelling of business processes and business rules. Arguments for integrated modelling in each article were identified and resulted in the identification of five categories, as summarized in Table 2[3]. In the following we provide an overview of each benefit indicated in literature.

Table 2. Overview of Integrated Modelling Benefits

Benefit	**# of Refs**	**Example References**
Process Flexibility, Dynamism and Adaption	23	(Di Bona et al. 2011; Boukhebouze et al. 2009; Zhao et al. 2010)
Completeness	15	(McBrien and Seltveit 1995; Meng et al. 2002; Nalepa 2007)
Improved Governance, Risk and Compliance	8	(Cheng et al. 2011; Ly et al. 2011; Sadiq et al. 2007)
Understandability & Communication	9	(Rabova 2009; Skersys, Tutkute, Butleris, et al. 2012)
Interoperability and Cooperation	5	(Bae et al. 2004; Meng et al. 2002; Xiao and Su 2012)

Process Flexibility, Dynamism and Adaption

The dynamic environment of organizations makes business processes subject to frequent change (Boukhebouze et al. 2009). In practice, business process models and business rules are either kept in separated repositories, which make review and assessment a difficult task, or mixed together, which decreases the configurability and flexibility of processes (Zhao et al. 2010). Prior research has indicated that integration of business process models and business rules can improve the flexibility of business processes (Di Bona et al. 2011). The lack of comprehensive representation for business rules makes business process modelling notations problematic for modelling complex business logics and hard to meet the frequent change business requirements. Thus the flexibility, adaptability and dynamism of business processes, which are emerging requirements for enterprise information systems, are difficult to achieve (Boukhebouze et al. 2009).

Completeness

Business process modelling and business rule modelling are two common aspects in the conceptual modelling of information systems (McBrien and Seltveit 1995). “Integration between business processes and business rules is necessary for applications which not only hold numerous business knowledge or policies but also need the intercommunication among some distributed and heterogeneous components” (Meng et al. 2002). A basic requirement of a model is its completeness in representing the real world. A complete process model represents all key aspects of a business process and thus is a high quality business process model (Nalepa 2007), which cannot be achieved without integrating all business rules into business process models.

[3] Not all references are shown due to page limitations. A table of benefits with all relevant references is available from authors on request.

Improved Governance, Risk and Compliance

Compliance means that business processes are in accordance with a prescribed set of norms (Sadiq et al. 2007). Compliance requirements are interpreted and transformed into rules to ensure the operation of the organization aligns with requirements. Organisations struggle to establish a consistent view of their policies and operating procedures in the heavily regulated business world (Cheng et al. 2011). The separation of process models and business rules further complicates the development of a consistent view of policies and operating procedures and thus increases the risk of non-compliant activities and the difficulty of showing compliant process design (Cheng et al. 2011). Processes need to comply with business rules to ensure error-free at the modelling level (Ly et al. 2012). Without integration of business rules and process models, it is possible for the user to act based on the model only, not realizing that additional constraints exist.

Understandability and Communication

Business rules constitute an entire body of knowledge and have not been adequately addressed in business process modelling notations (Rabova 2009). Typically, business rules are buried in the program code or in database structures (Rabova 2009). The gap between business process modelling and specification of business rules may lead to misunderstandings while reading and interpreting business models, as well as communication issues (Skersys, Tutkute, and Butleris 2012). Some of these issues can be resolved by the integration of business process models and business rules (Skersys, Tutkute, Butleris, et al. 2012).

Interoperability and Cooperation

The increase in strategic alliances and e-Business generally compels organizations to be involved in business processes of other organizations (Bae et al. 2004). Business process sharing is a common need in cooperated organizations (Xiao and Su 2012). However, the separation of processes and rules make communication between organizations difficult because the process models used for communication do not represent all information about relevant business activities. Integrated and complete information should be provided in the business process model for inter-organizational communication and collaboration. Integration of business process models and business rules is further identified as a need for the intercommunication between distributed and heterogeneous components (Meng et al. 2002).

ANALYSIS OF INTEGRATED APPROACHES

We also conducted an analysis to determine the main types of approaches for integrated business process and rule modelling. Our analysis has identified four main approaches, as summarized in Table 3[4].

Table 3. Overview of Integration Approaches

Integration Approach	# of References	Indicative (selected) References
Extending and Merging	18	(Agrawal 2011; Milanovic and Gasevic 2009)
Embedding	6	(Kluza et al. 2012; Nalepa et al. 2013; Sapkota and van Sinderen 2010)
Annotation	6	(Cheng et al. 2011; Governatori and Shek 2012; Habich et al. 2010)
Transformation	4	(Cheng et al. 2011; Mejia Bernal et al. 2010)

Extending and Merging

Extending and merging are natural approaches to enrich the representational power of a language. The difference between extending and merging is that the former creates new elements whilst the latter only combines existing meta-elements from other languages. Extending and merging can be used in both procedural or rule based modelling approaches.

For example, using rule based extension, Agrawal (2011) developed an integrated modelling language called Semantics of Business Process Vocabulary and Process Rules (SBPVR). This language is based on the SBVR rule modelling specification. SBPVR divides knowledge of business processes into three parts: process concept types, process fact types and process rules. Process concept types and fact types represent structure of processes and process rules provide guidance over the structure and flow of processes. A more common way compared with rule based extending or merging is to create new integrated modelling languages from procedural languages. For example, Milanović (2009) extended BPMN with the addition of rule representation in the form

[4] Not all references are shown due to page limitations. A table of approaches with all relevant references is available from authors on request.

of a rule gateway. These efforts resulted in rBPMN (Rule Based Process Modelling Notation), which is considered to be the most powerful language in terms of its representation capacity (Prezel et al. 2010).

Embedding

Embedding means encapsulating a model element of a language into a specific unit in the host language. For example, rules can be embedded in process meta-elements in BPMN. One benefit of embedding is its simplicity of representation. The embedded object can be collapsed to keep the whole figure neat and clean.

Using the embedding approach, Nalepa *et al*. (2013) proposed an architecture in which rules that apply in the same context as a process model are grouped into a single task element in the process model. Such a rule task is modelled by a formally defined Decision Table. (Kluza et al. 2012) proposed an integrated framework based on BPMN and the XTT (Extended Tabular Tree) rule framework. The advantage of this type of approach is the visualization of rules and, thus, the potential improvement in understandability. However, the weakness is the limited power of representation. Both Tabular Trees and Decision Tables are not user friendly and can only represent limited types of business rules. Sapkota and van Sinderen (2010) embedded rules into decision points in BPMN processes models. Their method adopted Event Condition Action (ECA) rules, which is a general form of rule representation. The integrated framework used decision points, decision expressions and decision services. A key advantage of this work is that the rule artefacts and process artefacts are stored in separate repositories to maintain consistency of shared rules between processes, while the related artefacts are retrieved from repositories and shown in an integrated model on the user interface when needed.

Annotation

Annotation is the use of additional textual elements to represent other aspects which are beyond the representation capacity of the selected language. The textual elements are typically attached to other notations to represent extra information.

(Habich et al. 2010) enriched BPMN process models with SBVR annotations. They transform rules into Object Constraint Language (OCL), which are in the form of BPMN annotations. (Cheng et al. 2011) also use an annotation approach with BPMN and SBVR. The approach parses a BPMN model and related SBVR rules to identify which activities in the BPMN model have related SBVR rules defined. Once these are identified, the BPMN model is annotated with the SBVR rule. Detailed algorithms are provided in the latter research. (Governatori and Shek 2012) developed a business process compliance checker (BPCC). They used formal contract logic (FCL) to represent rules and the rules are joined with process models in the form of annotations. The annotations are attached to the tasks of the processes, and can be used to record the data, resources and other information related to the single tasks in a business process.

Transformation

Transformation aims to convert one type of modelling language into another. For example, a transformation from procedure based language to rule based language.

(Cheng et al. 2011) proposed a transformation method between BPMN and SBVR constructs. An equivalence relationship is established between the two notations, using the XML Process Definition Language (XPDL) as the intermediate format to bridge the two notations. (Malik and Bajwa 2013) proposed an automated approach to translate BPMN models to SBVR based representation. They translated BPMN notations (events, connectors, gateways, swimming lanes, etc.) and process dependencies into SBVR specification.

The key advantage of transformation based methods is that both the procedural aspect and the business rule aspect of processes can be represented in one language. However it requires a one-to-one mapping between the process modelling and the rule modelling language. Yet, as the language analyses by zur Muehlen *et al*. (2007) show, not all rule constructs can be transformed into process constructs. The transformation definitely will not cover all modelling scenarios. In the literature, process model elements are translated into rule model elements since rule languages can represent broader scope of business objects. However the formal representation increases the difficulties to understand the underlying business objects.

DISCUSSION & RESEARCH AGENDA

Our review indicates that there is consensus in the literature on the benefits that can be achieved by integrating business process and business rule representation. Furthermore, our review of research that presents approaches for said integration indicates several possibilities. It is useful, therefore, to consider the advantages of each type of approach (see Table 4 for a summary). Embedding methods have their strengths in information hiding. Business rules are encapsulated in single business process modelling elements such as activities and tasks thus

the whole business process is simplified. However the relationship between the embedded rules and specific tasks are not clear. Extending and Merging methods borrow notations from other languages or create new notations thus to enrich the power of business rule representation. However, users have to be trained to understand the syntax and semantics of each new notation and to use the notations together. Transformation methods develop algorithms or detailed procedures to translate one language into another, thus existing separated models using different language can be represented in one language which will simplify the integration procedure. However, procedural based languages are translated into rule based languages since less information will be lost in the translation. Thus the integrated business process models are actually represented in rule based languages which are known to be difficult to understand. Annotation methods are easier to design and to understand. It is natural and convenient for designers to use annotations to represent additional information. Since the annotations are attached to tasks and explicitly showed next to the tasks, the constraints are easier to be noticed compared with embedding and transformation methods. However, users often use natural languages rather than formal business rules in annotations which makes it difficult to perform automatic compliance checking and process monitoring.

Table 4. Analysis of strengths and weaknesses

Integration Approach	**Strength**	**Weakness**
Embedding	Information hiding	The relationship between the embedded rules and specific tasks are not clear
Extending and Merging	Represent more constructs	Users have to be trained
Transformation	Parsimony - use of only one existing language	Translation in to rule based languages makes business process modes difficult to understand
Annotation	Easy to design and to understand	The use of natural languages is difficult for automatic compliance checking

To study research gaps and opportunities, we first classify the related work based on the type of contribution offered. We classify papers into four categories, viz. (1) conceptual, (2) method, (3) implementation and (4) evaluation. We note that complete research, in line with Design Science requirements (Hevner et al. 2004), should incorporate conceptual design, detailed methods or algorithms, implementation, and evaluation of the approach. Accordingly, conceptual contributions propose ideas or focus on theory, but no detailed artifact (approach, method or algorithm) is provided. Method papers provide a detailed specification of the developed artifact, method, approach or algorithm, but lack any implementation. Implementation papers offer the method but also extend to implementing prototypes, tools based on the presented method. Evaluation papers report on testing of a particular implemented method or artifact. Table 5 summarises the types of contributions found in literature.

Table 5. Types of Integration Contributions in Literature

Type of contribution	**# of References**
Conceptual	3
Method	17
Implementation	14
Evaluation	8

As seen in Table 5, only 14 publications provide an implementation of artefacts, and only 8 offer evaluation. While conceptual contributions are critical in a developing discipline, there is a need to follow them up with development of innovative and targeted methods, as well as the validation of developed solutions. Thus there is an evident need to pursue this important, well-motivated and challenging area with a consolidated response from the research community. In what follows, we identify the main gaps, and consequently research opportunities, that could be availed to further the body of knowledge in this area in a systematic and targeted way to achieve high impact and meaningful progress. We see several opportunities to advance this body of knowledge, as per our review of the related literature:

First, whereas several benefits and motivations for integrated modelling are discussed in literature, empirical and/or experimental studies that present evidence of the benefits are scarce. Ultimately, business process models are used by experts to represent, design, analyse and improve underlying business practice. Studies are needed that can create knowledge of the impact on ease of use (Davis 1989), understandability and communication capacity of integrated modelling. Some methods or techniques may be very powerful but they may be too complex to learn. For example, automatic translation is powerful but may still need time consuming manual checking and corrections. While some methods like rBPMN can be potentially more acceptable by business users since it is a combination of two popular modeling languages. Moreover, development of tools for

integrating GRC (governance, risk and compliance) rules and process models has been prominent in literature. However, case studies on the adoption of such technology have been scarce, yet such qualitative studies are critical to evaluate and understand related success measures and limits.

Second, theoretical studies are needed to investigate the impact of integrated modelling on the so-called completeness of the model, and the degree to which completeness is enhanced, given that completeness is difficult to categorically define. A prerequisite of model completeness is understanding the representational capacity of various process and rule languages, which is fundamental to integrated modelling solutions. Several research contributions (zur Muehlen et al. 2007; Prezel et al. 2010; Recker et al. 2005) have analysed process modelling and rule modelling notations. However, some notations as introduced in the previous section have not been included in these analyses. Further studies that consider other modelling notations, for example Extended Tabular Tree (Kluza et al. 2012) and Decision Tables (Nalepa et al. 2013) will be useful. Similarly, the use of frameworks based on representational theory such as Bunge-Wand-Weber (BWW) (Weber 1997) to evaluate proposals for integrated modelling will help establish benchmarks and facilitate comparative studies.

Third, business rules and processes change frequently to meet changing requirements stemming from market, regulatory and policy changes. The change of a rule can potentially affect a large number of processes, thus consistency control and atomicity of change operations need to be in place. There are computational challenges in achieving such consistency control, especially for large process repositories, requiring further study. A systematic analysis of change support of each integrated modeling approach (embedding, merging, transformation or annotation) can be an interesting area of study.

Finally, and critically, although integration of business process models and business rules has many potential benefits, researchers need to explore whether all types of business rules should be considered for (conceptual) integration. Some researchers argue, for example, that modelling business processes and business rules together can increase the complexity of business process models and thus reduce the understandability of these models (Mickevičiūtė and Butleris 2013). Moreover, different types of business rules may vary in their suitability for integration into business process models. Thus, the extent and manner in which the integration should be carried out is an important question to explore. Accordingly, there is a need to identify key influencing factors and develop a decision framework for integrated modelling based on the factors.

CONCLUSION

In this paper, we carried out a systematic literature review of integrated modelling of business processes and business rules. The review spans publications since 1990, sourced from three major sources, and then analysed to extract main themes and contributions. Our analysis indicates that the main motivations and expected benefits for integrated modelling include Process Flexibility, Dynamism and Adaption, Completeness of the Models, Improved Governance, Risk and Compliance (GRC), Understandability & Communication and Interoperability and Cooperation. Further the approaches to address integrated modelling can be broadly classified into: Embedding, Extending/Merging, Annotation, and Transformation. A number of insights emerged from the analysis of the literature, which we summarized as key gaps and research opportunities to address integrated modelling in a consolidated way, thus proposing a research agenda paving the way forward in this field.

Our work is not without limitations. Although we conducted an extensive literature search from core Information Systems and Computer Science journals and conferences, as well as papers indexed by the Web of Science, it is possible that relevant papers were missed. We considered papers that contained more than three occurrences of the keywords: “business process” and “business rule” (including their variants). This approach may overlook papers that use other keywords. In addition, our work focused only on a literature review, while another form of analysis might involve a comparison of the representation capacity and ease of use of existing integrated modeling approaches.

Based on our analysis, we argue that a better understanding on the extent of integrated modelling is a fundamental aspect that requires research. In our future work we will investigate the development of a decision framework for integrated modelling within an organizational context in consideration of the various factors that can influence the success of an integrated modelling approach.

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