PROCESS MODELING QUALITY:
A FRAMEWORK AND RESEARCH AGENDA

Jan Mendling[1], Jan Recker[2], and Hajo A. Reijers[3]

[2] Institut für Wirtschaftsinformatik
Humboldt-Universität zu Berlin
jan.mendling@wiwi.hu-berlin.de

[2] Faculty of Science & Technology
Queensland University of Technology
j.recker@qut.edu.au

[3] School of Industrial Engineering
Eindhoven University of Technology
h.a.reijers@tue.nl

Abstract

Business process modelling is widely practiced within organizations to achieve a variety of purposes, such as documentation or workflow implementation. Only recently insights have begun to appear into the factors that influence the quality of a business process model, e.g., with respect to its error-proneness or understandability. Still lacking is an understanding of how such insights can be organized in a way to systematically describe the process modelling landscape. This paper suggests a framework that identifies quality factors and their effects. These factors relate to (i) the modelling process, (ii) the process model as an artefact, (iii) the application process, (iv) the modelling infrastructure and (v) project support. In the short run, this framework is thought to be helpful to inform researchers with an interest in this field about existing gaps of knowledge. Ultimately, the framework is to provide specific guidance for process modellers towards creating better models.

Keywords: Business Process Modelling, Conceptual Framework, Quality Aspects.

1 Introduction

The last decade has produced a wave of popular publications on the power of process orientation (e.g., Davenport & Short, 1990; Hammer, 1990). In this view, organizational performance improvement is best achieved by gaining a thorough understanding of all the actions taken in a process: from the first interaction with a customer until the final delivery of a product or service to that customer. By its focus on the actions *across* functional units, process orientation sharply contrasts with the classical Tayloristic approach that mainly focuses on optimization within separate units (sales, purchasing, manufacturing, etc.).

Over the years, empirical evidence has accumulated that process orientation is indeed positively connected to customer satisfaction, the financial performance of organizations, and the *esprit de corps* of employees (Forsberg et al., 1999; McCormack, 2001; Hung, 2006). This has motivated various authors to explore the scales of maturity that organizations display with respect to working in a process-oriented way (Rosemann et al., 2006a; Hammer, 2007).

An effect of the popularity of process orientation that can be noted in organizational practice is that huge efforts are being spent on the creation of *business process models*. For any process-oriented improvement project to become successful – whether its goal is to implement a new process, organizational structure, or IT system – a deep understanding is required of the process as it currently exists. A process model helps to visualize what the important steps are in a process, how they are related to each other, which actors and systems are involved in carrying out the various steps, and at what points communication takes place with customers and external parties. All this is typically captured in a visual way, using icon-like symbols with certain semantics that are connected to each other and which are supported with textual annotations.

This paper is concerned with the quality of such process models. Bandara et al. (2005) have defined this notion as the extent to which all desirable properties of a model are fulfilled to satisfy the needs of the model users in an effective and efficient way. Despite the fact that the empirical study of these authors showed that model quality is one of the most important success factors for process modelling efforts, insights on the critical impact factors on process model quality (and the critical impediments) have only recently begun to emerge. For example, with respect to one aspect of model quality, namely *error-proneness*, Mendling et al. (2008) found that the size of a model is indeed a factor of influence. Conversely, in respect to another aspect typically associated with quality, the *understandability* of a model, Recker & Dreiling (2007) found that model users' knowledge of the exact modelling notation is rather of negligible influence.

Insights like these are important, but stand isolated as yet. What is missing is a framework that is capable of integrating all current insights into a comprehensive view on process model quality. Such a framework, if available, could serve two purposes. First of all, it could inform organizations about the aspects of a modelling ecosystem that influence the quality and, ultimately, success of their modelling initiatives. Also, it could guide researchers in this space towards gaps of knowledge, viz., areas of process model quality that are yet to be explored.

The purpose of this paper is to propose such a framework, building on earlier work and extending it with a comprehensive synthesis of existing literature. From an academic perspective, we seek to provide a research agenda on process model quality. Then, as the insights on process model quality grow, and "blind spots" are increasingly being eliminated, the framework is hoped to become helpful in a practical sense: It should provide guidance to process modellers in creating process models of higher quality. In concrete terms, if a user is interested in improving quality aspect A of a particular model, the framework should provide a guideline B that is translated from the insights gathered from a research stream C.

For the remainder of this paper, we proceed as follows. In the following section we introduce process modelling as the domain of interest of our study and we outline a theoretical framework that informs an understanding of the different facets of quality in process modelling. Next, we describe our framework of factors influencing the establishment of process model quality, and discuss these factors in detail in Section 3. In Section 4, conjectures for research as well as practical guidelines for industry practice are derived from this framework, after which we conclude this paper with a summary of our contributions in Section 5.

2 Background

2.1 Process Modelling

Due to a strengthened interest in a more disciplined approach for managing business processes, many organizations have made significant investments in process modelling initiatives. In turn, this has triggered substantial related research. The recent introduction of legislative frameworks, such as the Sarbanes-Oxley Act for example, further contributed to an interest in business process modelling as a way of capturing and graphically documenting the processes of an organization. Process modelling is widely used within organizations as a method to increase awareness and knowledge of business processes, and to deconstruct organizational complexity (Bandara et al., 2005). It is an approach for describing how businesses conduct their operations and typically includes graphical depictions of at least the activities, events/states, and control flow logic that constitute a business process (Curtis et al., 1992). Additionally, process models may also include information regarding the involved data, organizational/IT resources and potentially other artefacts, such as external stakeholders and performance metrics to name just a few (e.g., Scheer, 2000).

The fundamental focus of most current process modelling approaches, like the industry standard Business Process Modeling Notation (BPMN) (BPMI.org & OMG, 2006), is on the *control flow* of a process (for other modelling paradigms see, for instance, Kavlaki & Loucopoulos, 2006). This means that a typical process model captures the activities of a process and defines the sequence of activities through gateways, events and arcs. *Gateways* represent complex routing constructs, including decision points, concurrency and synchronization. *Events* define how a process reacts to external and internal events, for instance, time-outs or message receipts. *Arcs* capture the partial order of activities, gateways and events. Furthermore, a typical process model includes elements to describe different parties involved in a process via swimlanes, and message exchanges between these parties. Typically, such models also cover elements to represent objects that are created and consumed in the process.

Figure 1 gives the example of a goods receipt process modelled using three popular process modelling notations, namely Workflow nets (e.g., van der Aalst, 1998), Event-driven Process Chains (EPCs) (Scheer, 2000) and BPMN (BPMI.org & OMG, 2006). In all three models, activities are shown as (squared or rounded) rectangles and labelled with texts such as ‘identify delivery’ or ‘inspect quality’. BPMN and EPCs further use annotated events (through circles and hexagons, respectively) that specify certain business events such as the arrival of a message (e.g., a purchase order), that are required to occur for the process to proceed.

As can be seen from Figure 1, different modelling notations tend to emphasize different aspects of processes, such as, for instance, activity sequencing, resource allocation, communications, or organisational responsibilities. In other words, the domain modelled in a Workflow net looks different from the same domain modelled using EPCs or BPMN. From a quality perspective, this situation brings forward significant challenges when seeking to establish a comprehensive and uniform, notation-independent perspective upon process model quality, which abstracts from notation-specific quality aspects. In Section 3 we suggest such a framework.

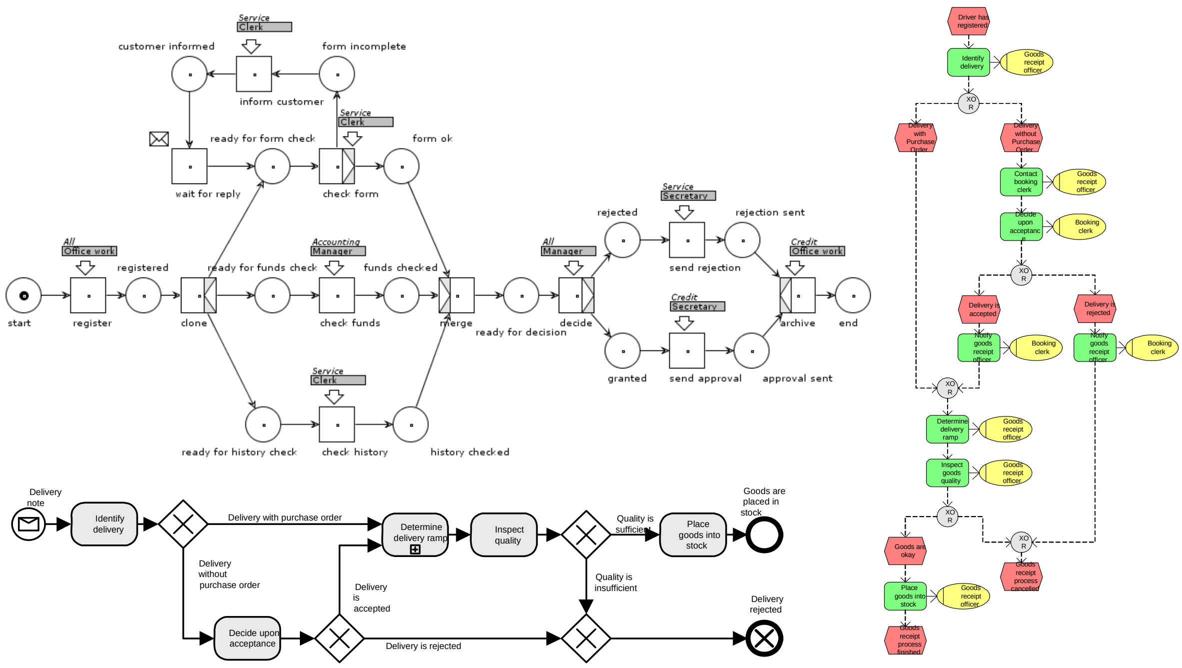

Figure 1: Example process models of a goods receipt process in different modeling notations

2.2 Existing Quality Frameworks

The quality of process models has been of much concern and attention lately. For process management and improvement projects to be successful it is adamant to have as a basis a thorough, complete, comprehensive – and overall *high quality* – process documentation. Surprisingly, however, comprehensive academic contributions to an understanding of process model quality are still scarce, as noted by several authors (Moody, 2005; Nelson et al., 2005; Recker, 2007a). Some works towards a quality framework, however, exist.

Becker et al. (2000) propose a framework containing six Guidelines of Modeling (GOM). The inspiration for GoM comes from the observation that many professional disciplines cherish a commonly shared set of principles to which their work must adhere. GoM is intended to be that set for the process modelling community. The guidelines include the six principles of correctness, clarity, relevance, comparability, economic efficiency, and systematic design. The guideline for clarity postulates, for example, that without a readable, understandable model all other efforts become obsolete (Becker et al., 2000). The aim of GoM is to support the development of organizational modelling conventions for a specific notation or modelling view. While the framework certainly has its practical merits, we note that there has not been any empirical testing of this framework (Bandara et al., 2005), nor have the postulates of the framework itself been based on empirically validated insights into process modelling.

Highly relevant for the topic of this paper is the Semantic Quality (SEQUAL) framework suggested by Krogstie et al. (2006). It builds on semiotic theory and defines several quality aspects based on relationships between a conceptual model, a body of knowledge, a domain, a modelling language, and the activities of learning, taking action, and modelling. SEQUAL denotes an extension to the original conceptual model quality framework proposed by Lindland et al. (1994). Particularly useful is the distinction in this framework between syntactic, semantic, and pragmatic quality aspects of a conceptual model, which have a relevant meaning for process models as well. Yet, the SEQUAL framework is of quite an abstract nature and lacks sufficient operationalization to be directly applicable to practice. Also, we note again that only limited empirical insights have formed the basis of the framework. Finally, the SEQUAL framework's scope is broader in that it addresses conceptual model quality in general, which makes it also less specific to guide process modelling efforts.

A recent proposal for a framework on process model quality is the SIQ framework (Reijers et al., 2009). Similar to the SEQUAL framework, it distinguishes quality dimension on syntactic, semantic, and pragmatic levels, and operationalizes these notions for process models. The framework explicitly distinguishes activities to *retrospectively* safeguard these quality dimensions for concrete models, which are named respectively *verification*, *validation*, and *certification*. It also recognizes some *pro-active* measures to arrive at high-quality process models such that they become syntactically correct, valid, and understandable. However, the SIQ framework focuses more on the quality of the outcome (the model as a product) than on the process of modelling (process quality).

All the discussed frameworks have in common that they consider ‘quality’ as a rather static property of modelling artefacts (viz., a product perspective). As we eventually aim at supporting the modelling process itself more effectively, and following the idea of total quality management to establish quality during the *process* rather than examining the properties of a *product* (Powell, 1995), we see a need for a much stronger focus of the quality of modelling as a process that happens in a certain context. We introduce this process focus in the framework we suggest in the following section. In doing so, we refer, and build on, the existing model quality management frameworks above, where applicable.

3 Factors and Effects of Process Model Quality - A Framework

The purpose of this section is to consolidate related research and theoretical considerations into a new framework of factors and effects of process model quality. At the heart of this framework is the *process model* as a design artefact. Factors of its quality relate to the process in which it is created (*modelling process*). Symptoms and effects of its quality materialize in the *application process*. Conduct and outcome of these phases are influenced by the *project support* offered to govern the modelling initiative, as well as by the elements provided in the *modelling infrastructure*. Figure 2 displays the framework, the elements of which we discuss in the following subsections. In our discussion, we will point to, and discuss, related work that has led to the creation of the insights covered by the framework.

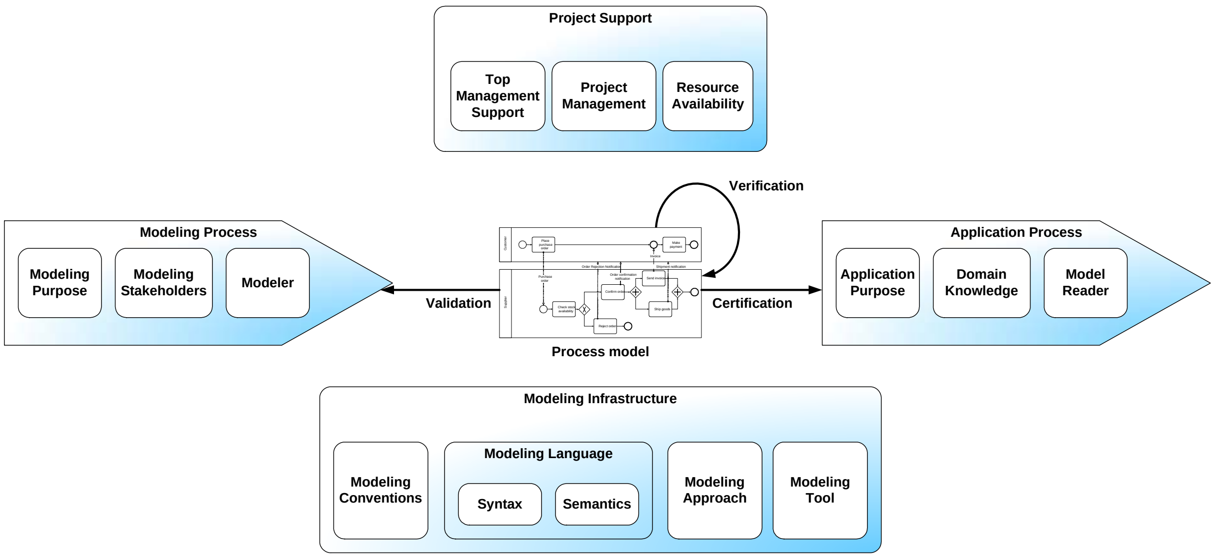

Figure 2. *Overview of the framework*

3.1 Modelling Process

The modelling process has been discussed from a more general perspective in works by Frederiks & Weide (2006) and Hoppenbrouwers et al. (2005). These studies identified as the most essential stakeholder groups in this process the *modelling stakeholders* and the *modeller*. Moreover, Frederiks & Weide (2006) identify a set of competencies these two parties should have. The modeller requires the ability to abstract facts uttered by a stakeholder, to construct a model from it, and to retranslate the model into statements that the stakeholder can verify. These capabilities can be summarized as modelling competence. The modelling stakeholder on the other hand must be able to make statements about his or her work environment in a concise way. We frequently encounter model stakeholders that find it difficult to abstract from particular cases in real-world projects. Van Hee et al. (2006) describe how validation and verification activities can be integrated in the modelling process.

In addition to the involved modelling parties, another important driver of the modelling process is the *modelling purpose* (Recker, 2007a). The purpose dictates the perspective and the level of detail of the modelling endeavour (Stachowiak, 1973). In real-world projects, there are different purposes for process modelling, ranging from high-level process documentation to technical workflow implementation. The quality demands for these modelling objectives are quite different: While the models in the first case are created for human readers, the latter are meant to be executed by information systems. Dehnert & van der

Aalst (2004) describe a set of criteria that process models should fulfil for each of these two major purposes.

3.2 The Process Model as an Artefact

The process model is the result of the modelling process. As a design artefact it can be described alongside different dimensions, one of which is *measurement*. Since a process model is essentially a special kind of graph, its structure can be measured. Several process model metrics have been proposed in related work, ranging from simple count metrics to complex ratio measurements like degree of structuredness. Recently, the modularity of a process model has also been shown to be a factor of influence (Reijers & Mendling, 2008). Many of the metrics have been empirically related to model understanding or error-proneness, see Mendling (2008) for an overview.

Beyond that, we can discuss a model from the perspective of three SIQ dimensions (Reijers et al., 2009), i.e. whether it has been verified, validated or certified (as shown in Figure 2). Verification addresses the need to establish a particular *syntactic* quality of a model in relation to various formalized properties and rules. Validation relates to the *semantic* quality of the model , i.e. whether a model makes truthful and accurate statements about the domain it intends to capture. Finally, certification focuses on the *pragmatic* quality of a model, to determine whether a model can actually be understood by people. For the inspection of each of these dimensions, established techniques are available, like verification, simulation, paraphrazation, gaming, etc. (Reijers et al., 2009).

3.3 Application Process

We already mentioned that there is a variety of modelling purposes. It needs to be emphasized that the original modelling purpose can differ from the ultimate *application purpose*. Consider the scenario when business processes are modelled on a conceptual level for documenting the organization, and when these models are later re-used for a workflow implementation. The delta between the quality requirements between modelling and application purpose needs special attention here. Recker (2007a) discusses a variety of model application areas and the notion of ‘fitness for purpose’ as a most essential quality criterion, i.e., the ultimate question of whether a process model as a means is instrumental to achieving some higher-order objective (such as implementing organizational change, retaining knowledge, or designing process-aware information systems).

Furthermore, it is important to consider that process models are not interpreted in isolation by a model reader but against the background of specific *domain knowledge* brought to bear by those reading the models. This fact has been considered in different experiments including those by (Mendling et al., 2007). Similar findings have also been reported in other conceptual modelling domains, see, for instance, (Khatri et al., 2006).

3.4 Modelling Infrastructure

In considering ‘how to’ model business processes, the decision of the type of *language* (or notation) to be used for process modelling is an important consideration (Rosemann et al., 2006b). This decision can be seen as essentially the same problem that software engineers encounter when carrying out analysis or design tasks. One might choose to use structured analysis notations, or object-oriented approaches. One important aspect in the consideration of a particular process modelling language is that different languages have different capabilities for articulating process domains. Different modelling languages tend to emphasize diverse aspects of processes, such as activity sequencing, resource allocation, communications, or organizational responsibilities (Soffer & Wand, 2007).

A wide range of research has been carried out to contrast different process modelling languages, for instance, in terms of their support for workflow technologies (van der Aalst et al., 2003) or representational deficiencies (Rosemann et al., 2006b). These studies clearly highlight that languages differ widely in their capabilities, which in turn, results in notable differences in the quality of the models that can be created with these languages.

Process modelling languages are further often implemented, and used, in a *modelling tool* or even a business process management system. These tools provide extended functionality to support the way languages can be deployed (Recker et al., 2006). For instance, some tools provide model repositories in which models can be stored and linked on different levels of abstraction. Moreover, most tools offer a variety of languages for process modelling, which, in turn, enable users to complement a language with symbols from another technique if they encounter the need to enrich their process models with additional information. Also, advanced tools provide reporting functionality that may include conformance testing, verification or validation of process models produced with that tool, which allows users to ex ante evaluate and establish syntactic and/or semantic quality of their models.

In process modelling practice, modellers often refer in their efforts to a set of conventions, norms or guidelines for the act of process modelling. These so-called *modelling conventions* can be seen as an organization-internal standardization of a process modelling language. Most notably, such conventions, if existent, specify the way a process modelling language is to be put to use for modelling. Two types of impact of the conventions can be differentiated (Recker et al., 2006). First, in some cases, modelling conventions restrict the use of a process modelling language to a reduced set of elements and symbols, which clearly influences the quality of the model produced. Second, in some cases modelling conventions make amendments to the specification of a process modelling language in that they change syntax or semantics of the elements and symbols. Again, such modifications can positively or negatively affect the outcomes of a process modelling process.

Finally, it is important to distinguish the modelling approach. The modelling result can differ quite significantly depending on whether the models are constructed in modelling sessions and/or using a particular approach for correctness-by-design, truthfulness-by-design, or understandable-by-design. Following a certain compositional approach can result in syntactically correct process models (van Hee et al., 2006), i.e., these models are then correct by design. Models generated by process mining tools, though being truthful by design, are typically more difficult to understand than models constructed by humans (van der Aalst et al., 2007) since reality is often more complex as described by modellers.

3.5 Project Support

Under project support, we subsume those factors that influence process modelling practices and outcomes by making decisions about governance, procedures, roles and responsibilities. Project support is thus concerned with overseeing process modelling initiatives, ensuring commitment and buy-in from relevant management and making required resources available. In this context, Bandara et al. (2006) showed empirically that good *project management*, ongoing *top management support*, and *resource availability* are stand-out factors that significantly contribute to overall success of process modelling initiatives. In light of these observations, we would argue that these factors also contribute to establishing process model quality, based on the following arguments:

First, the utilization of established, standardized and/or best practice approaches to project management allows process modellers to concentrate their efforts on the act of process modelling without being distracted or consumed by surrounding management activities. Thereby, more time and/or resources are available that can be leveraged to process modelling performance, which ultimately improves the quality of the model produced. Second, top management support ensures commitment, relevance, and sponsorship of a process modelling initiative. These factors can contribute to building a sense of motivation, which typically positively affects working engagement, working practices and working performance. All this translates to building better process models. Third, resource availability ensures that all material is made available to the modeller that she requires to build good process models. Such resources include, for instance, access to relevant documentation, availability of relevant primary and secondary process stakeholders for workshops and interviews, scheduling of direct process observations, and procurement of relevant reference models and other guidelines. This material, if available, ensures a thorough requirements elicitation process and the provision of relevant guidance, norms and re-usable practices, all of which contribute to better process models.

4 Implications

4.1 For Practice

We identify a number of benefits from our study for the practitioner community of process modellers and their ecosystems. First, the framework discussion provides guidance to organizations adopting or using process modelling in terms of validated evidence of various factors impacting the quality of modelling initiatives, which will assist them in understanding and anticipating realistic project success estimates. Similarly, the framework gives guidance about the number of factors to be considered when establishing a modelling environment in which modelling stakeholders can work efficiently, effectively and successfully.

We have observed in real-world projects that tool selection and choice of modelling language receive much attention, while other issues are hardly considered. It would not surprise us, however, when modelling conventions and the modelling approach turn out to be much more influential with respect to the quality of the process artefact and, as such, to the application process. Consider the developments within one of our industrial partners, a manufacturing company with a yearly turnover of USD 150 billion. This company is about to adopt the policy to allow for a great variety of modelling techniques to be applied in-house while it simultaneously aims at the standardization of the modelling conventions across its various project teams.

4.2 For Research

In addition to its practical merits, our work serves both as motivation and input to extension of process modelling-related research. Our framework uncovered a number of factors related to process model quality that are "under-researched" at current. For instance, the increased number of application areas for process modelling, and the increasing complexity of process modelling techniques, induces a strong need for organizational policies and guidelines for managing this complexity in process initiatives. Virtually no research exists yet that taps into procedural guidelines (the modelling approach), the requirements of process modelling for different application areas and stakeholder groups (the modelling and application purpose), or the impact of conventions management on process model quality.

Similarly, Recker & Dreiling (2007) concluded that more research is needed on the impact exhibited by the modelling stakeholders (modeller versus model reader) involved in process modelling processes. A great paradox at this stage is that actual affinity with a specific modelling technique did not turn out to be very relevant (Recker & Dreiling, 2007) although training in abstract process modelling concepts (i.e., not specific for any technique) seems to increase the capacity of readers to understand models (Mendling et al., 2007). Deeper insights here could cause a dramatic change in the way we should teach people process modelling.

Finally, the measurement of quality itself is an open venue for further research. For instance, while 'understandability' has already been used on various occasions to pin down the quality of a process model as an artefact, it is an open issue how to properly transfer this psychometric notion to the field of process models. An important distinction between variable types for measuring understanding is between *retention* and *transfer* (Mayer, 2001). Retention is defined as the comprehension of material being presented (viz., the contents of a process model). Transfer, or problem solving, is the ability to use knowledge gained from the material to solve related problems not directly answerable from it (viz., the ability to use the process model for a certain purpose, e.g., to identify opportunities for process improvement, to analyze process performance, to develop process-based systems etc.). Another issue is to what extent time should be included in process model quality measurement. Presumably, earlier research like the work by Genero et al. (2008) into the understandability of structural data models could serve as a source of inspiration here.

In summation, we suggest the following items as a research agenda for process model quality-related research:

- Pragmatics of process modelling: A wider variety of process modelling purposes exist but it remains to be comprehensively understood what type of quality criteria different application areas (documentation versus organizational change versus workflow engineering versus systems configuration) impose on the act of process modelling. A related challenge would also be to produce process models of high quality that are re-usable across different application areas.
- Process modelling skills: We have still only limited understanding as to what makes a good process modeller, and how process modelling expertise can be instilled in current and future generations of process analysts. Some of the notions that deserve further attentions include modelling experience, process-aware skills, attitude, self-efficacy, vocabulary and structural knowledge, and recognition skills, to name just a few.
- Process modelling governance: Virtually no research exists that taps into governance issues. We know, for instance, that top management support, resource availability and modelling conventions are key to successful modelling projects, but how can these insights be operationalized to guide process modelling? How should modelling conventions and organizational responsibilities be implemented to produce ‘good’ process models? What is the effect of different project management styles on the outcome of process modelling projects?
- Process model quality measurement: The notion of process model quality as “all desirable properties of a model are fulfilled to satisfy the needs of the model users” (Bandara et al., 2005) is yet to be further operationalized. A number of quality criteria exist, e.g., understandability (Mendling et al., 2007; Recker & Dreiling, 2007), fitness for purpose (Recker, 2007a), adoption (Recker, 2007b), correctness (Rinderle et al., 2004), soundness (Verbeek et al., 2007) and so on – it will be important to have a comprehensive framework that differentiates and correlates such measures in a comprehensive measurement instrument.

5 Conclusion

In this paper we synthesized prior research in a framework that displays factors influencing the establishment and measurement of process model quality. We derived the factors based on previous research in this area as well as a review of literature, and our own experience in teaching, analyzing, and applying process modelling. In particular, we identify the process model as an artefact, the modelling and the application process, the modelling infrastructure, and project support as the essential perspectives for discussing quality of process modelling.

Our work builds upon earlier framework on model quality management (e.g., GoM, SEQUAL and SIQ), and extends these *product*-focused frameworks with a *process*-focus, viz., a consideration of the quality factors pertaining to the modelling and application process of process modelling.

We believe that our work has laid the ground for extensive future research into process modelling practices and outcomes. Some of the conjectures we derive from the development of our framework present a call for future research in these areas to guide process modelling in practice (see Section 4.2). Thereby, our work can serve as the conceptual underpinning of future work aiming towards delivering a comprehensive body of knowledge in an important yet under-researched domain of conceptual modelling.

It is worth reflecting that research efforts in the process modelling domain so far typically adopt a design science paradigm (Hevner et al., 2004), in which the emphasis is on the development and evaluation of artefacts (e.g., modelling formalisms, algorithms, patterns, etc.). To us, it seems paramount to extend the process modelling research domain with theories and methods from behavioural science. We call for an increased use of relevant theories and empirical research methods, a call articulated before by Moody (2005) and others (e.g., Rosemann, 2008). Such future research could, for instance, consider (i) metrics and methodologies from empirical software engineering, such as applied by Vanderfeesten et al. (2008) and Genero et al. (2008), and (ii) cognitive theories, such as multimedia learning (Mayer, 2001) and the cognitive dimensions framework (Green & Petre, 1996). This extension is a necessity if we want to gain a better foundation for ongoing design-oriented research on process modelling on the one hand, and to create a much bigger impact on the practice of process modelling on the other hand. Formulated loosely: We really have enough modelling techniques, we now want to understand how to use them well.

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