A Systematic Literature Review of Consistency Among Business Process Models

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Abstract. The field of business process modeling has been beset by inter-model consistency problems which are mainly due to the existence of multiple variants of the same business process, for instance when models have been produced by different actors, or through the time by a same (or different) actor(s), as well as the possibility of its modeling from discrete and complementary perspectives (using different lenses).The aim of our research is manifold. First we aim to develop a framework (i) enabling situating new research activities as well as the existing approaches and (ii) targeting to master the inter-model consistency issue. Second, this framework shall offer the capability of handling business process models coherence issue (i) having in mind various modeling goals and targets/products and (ii) having in hand a wide range of problem statements and project situations requiring the use of a large catalogue of business process meta-models. Third, we have the ambition of determining gaps in current research with the aim of suggesting areas for further investigations in the area of inter-models consistency. In order to do so, this paper presents a systematic literature review (SLR) of consistency among business process models, where a total of 982 published papers extracted from the most relevant scientific sources, were considered, of which 41 papers, were ultimately included.

Keywords: Business process models, modeling perspectives, inter-model consistency, systematic literature review

1 Introduction

Business process modeling is chiefly a convergence of two connected modeling disciplines: process modeling [1, 2, 3], which aims at providing "an abstract representation of a process architecture, design or definition" [4] and enterprise modeling, which seeks to provide a full and holistic understanding of the enterprise [5], [70]. Reasons for this convergence might be (i) the key role played by business process (BP) models in both enterprise information systems development [6], and organizational management [7, 8], (ii) the similarity between these disciplines in that both may focus on business processes as subject of investigation by capturing the relevant ones [5], and (iii) both have been beset by inter-model consistency problems.

In the field of process modeling, these problems are mainly due to (a) the existence of multiple models or views, which take part in the information systems engineering [69] and (b) the existence of many variants of BP models, which capture the occurrences of the same BP. The inconsistencies caused by (a) are the root causes of many errors in the resulting software applications [9], while those caused by (b) constitute a serious obstacle "to dynamically switch process execution from one variant to another if required" [10]. The importance of the first family (a) of inter-model consistency problems is reported in a systematic review of UML model consistency

management [11], and a survey on inconsistency management in software engineering [12]. The necessity of dealing with the second family (b) of consistency problems is proved by a large amount of work within this scope.

Similarly, in the field of enterprise modeling, consistency problems are of a great interest to both practitioners and researchers. This interest has emerged from the advent of multi-perspective or multi-view modeling methods where a complex system (e.g., the enterprise architecture, a BP) is captured from different perspectives (views) in order to master its complexity.

Although a SLR [11] and a survey [12] on the inconsistency management of software process models were already carried out and even though software processes are considered as business processes [13, 14], the existing work is mostly related to a particular kind of modeling approaches [15] (mainly object-oriented approaches). This is not the case in BP modeling for which none of the modeling notations is predominant [16] until 2006. This broader extent of the notion of inter-model consistency requires the capability of positioning the great amount of research works in this scope with respect to a reference framework that facilitates identifying the emerging/unresolved problems in the area of inter-model consistency in BP modeling.

Carrying out a Systematic Literature Review (SLR) in this area seems to be appropriate to set up such a framework. In fact a SLR is defined as a means of identifying, evaluating and interpreting all available research relevant to a particular research question or topic area with the aim, amongst others, of providing a framework (background in order to properly position new research activities [17]).

In this paper, we undertake the first SLR for inter-model consistency in the field of BP modeling. We aim at providing a generic framework enabling positioning existing approaches and determining gaps in the current research. The remainder of the paper is structured as follows. Section 2 outlines the key terms and concepts with regard to the topic of inter-model consistency. We describe our methodology in section 3 and present the results and answer our research questions in section 4. We present the framework in section 5. Section 6 concludes the paper.

2 Inter model consistency: Key terms and concepts

Consistency issues have been raised in various domains such as databases, information systems development, enterprise modeling and software engineering. Thereby, manifold are the approaches proposing definitions for concepts in this area. Hence, in order to establish a common understanding of the terminology used in this paper, we start by defining key concepts on which this SLR is grounded.

- Diagram: a graphical representation of real world using a particular modeling language.
- Perspective: refers to the notion of view defined as a representation of a system (e.g. a BP) from the angle of a related set of concerns or aspects [18]. For instance informational, functional, behavioral, organizational, operational and intentional in [71].
- Consistency among models: refers to the fact that the information covered in each model should not contradict each other [19]. For instance, if the concept actor appears in more than one model, its instances in all corresponding models have to be syntactically and semantically equivalent.
- Multi-perspective modeling: refers to the notion of multi-view modeling defined as

the construction of distinct and separate models of the same system in order to model different aspects of it [20]. For instance, in the domain of business processes, multi-perspective modeling allows us to depict the same BP using distinct and complementary representations adopting distinct modeling languages.

- Projective multi-perspective modeling (commonly referred to as projective multi-view modeling): one comprehensive overarching meta-model is given. All perspectives captured by all concerned modeling languages are defined as projections onto this central meta-model [21]. One example of this approach is the UML, which has, in its current version the Meta Object Facility (MOF) as a common meta-model. All UML diagram types (e.g. activity diagrams, sequence diagrams) are specified by projections onto that MOF meta-model.
- Selective multi-perspective modeling (commonly referred to as selective multi-view modeling): no central meta-model is given. Each perspective is captured by a distinct meta-model and the overall system is obtained as synthesis of the information carried out by the different meta-models [21]. Hence, if one concept (e.g. activity) is used in multiple perspectives, the dependencies between them need to be specified manually.
- Horizontal consistency: refers to the consistency between models at the same phase or abstraction level [22]. For instance, the consistency between two BPMN models produced during the analysis phase.
- Vertical consistency: refers to the consistency between models at different development phases or abstraction levels [22]. For example, the consistency between a BPMN analysis model and the associated BPMN implementation model.
- Syntactic consistency: refers to ensure that a model conforms to its abstract syntax specified by its meta-model [23]. For instance, the roles in the actor-role model should appear in the corresponding role-activity model.
- Semantic consistency: refers to the fact that models behavior should be semantically compatible [23]. For example, actors in the actor-role model have to be defined as business objects in the corresponding business objects model.

3 Method applied for the SLR

In order to conduct this study as a SLR, we have relied on the review protocol used in [24], since it was based on the original guidelines as proposed by Kitchenham [25]. Two key concepts are mainly associated with the notion of SLR namely (i) the primary study which refers to an empirical study investigating a specific research question and (ii) the secondary study referring to the study that reviews all the primary studies relating to a specific research issue with the aim of integrating / synthetizing evidence related to that issue [25]. The present study is then categorized as a secondary study and involves the steps cited below.

3.1 Research questions and search process

This SLR raises the research questions listed below resulting from our understanding of the key points after the study of the literature.

RQ1. What can be a source of inconsistency among BP models?

RQ2/RQ3. What type(s) of diagram(s) are being tackled? (i) activity-driven diagrams describing a BP as a sequence of activities, (ii) role-driven ones specifying the roles and the organization related issues involved in the BP and/or (iii) product-driven ones that represent a BP through its products/results (or resources) and their evolution. And how many diagrams have been used?
RQ4/RQ5. On which type of inter-model consistency problem focuses the study? : Horizontal or vertical and what is the nature of the targeted consistency? : Syntactic, semantic or both.
RQ6. What is the main methodological activity [11] on which the consistency management process relies?
RQ7/RQ8. What is the scope of business process models under study? Intra-enterprise or inter-enterprise models and what kinds of multi-perspective modeling are being addressed? Selective or projective multi-perspective modeling.

To perform the manual search process for primary studies, we based on a set of sources that were recommended in [26] as relevant within the research community and that were appropriate for the present study. These sources along with the search fields are presented in Table 1. In the aforementioned sources, we tested with different search string criteria. That which ultimately allowed obtaining the highest number of relevant results was:
("business process model" AND ("consistency" OR "inconsistency"))

Table 1. Selected sources along with research fields

Source	Search field
Google Scholar	Title, abstract and full text
ACM Digital Library	Title, abstract and full text
Science Direct	Title, abstract and full text
SCOPUS Database	Title, abstract and keywords
IEEE Computer Society	Title, abstract and full text

In the search process, we also took into account the synonyms and terms related to each of the three concepts, as shown in Table 2.

Table 2. Other synonyms and terms used in the search process

Concept	Synonym and/or related term
Business process model	process model; process variant; enterprise modeling or enterprise modeling; multi-perspective modeling or multi-perspective modeling; multi-view modeling or multi-view modeling
Inconsistency	inconsistencies: incoherence: incohesion

3.2 Inclusion/exclusion criteria and quality assessment

In this study, peer reviewed papers with the following concerns were included:

- Papers proposing approaches that favor or evaluate consistency between BP models; each included paper raise one of the following questions: how to check consistency between BP models or how to maintain consistency between BP models.
- Papers where the proposed approach was based on the comparison of two or more BP models depicting the same BP, since such comparison is the cornerstone of each

inconsistency management activity. For instance, papers dealing with the verification of similarity between BP models are included.

- Papers dealing with the issue of consistency in the context of multi-perspective modeling with a particular focus on the consistency among BP models or with a wider focus towards enterprise modeling.

Articles with the following concerns were excluded:

- Papers focusing on the issue of compliance defined as "a relationship between two sets of specifications: the specifications for executing a BP and the specifications regulating a business" [27]. Thus only papers where the models in question depict the same BP as subject of modeling have been considered.
- Papers dealing with the topic of inter-model consistency, where the subject under study is the software process. This means that our study is not concerned with the inter-model consistency in the field of software engineering.

We also excluded books, doctoral dissertations and non-English papers focusing on the topic of inter-model consistency.

The activity of assessing the "quality" of primary studies is generally viewed as important mainly in guiding the interpretation of findings and determining the strength of inferences as well as in guiding recommendations for further research [25]. The main criteria on which we based the quality assessment of the primary study were (QA1) "is the inter-model consistency the main purpose of the paper in such a way that the issue is studied in a thorough manner, contextualized and validated?", and (QA2) "is the proposed approach generalizable and to which extent is it applicable in another context?" The questions were scored as follows:

QA1. Y (yes), the inter-model consistency problem was contextualized, a well-defined approach was proposed in order to solve it, and a validation of the approach was provided and supported with a tool; P (Partly), the problem was contextualized, a well-defined approach was proposed, a first manual validation was given, but no support tool was offered; N (No), the approach was defined in a general and a succinct way and no validation was given.

QA2. Y (yes), the proposed solution is likely to be applicable outside of the primary study; P (Partly), the proposed solution needs to be slightly altered to meet other requirement outside of the study; N (No), the proposed solution is not likely to be applicable outside of the study (i.e. it is limited to a narrow context).

The scoring procedure was Y=1; P= 0.5; N=0. In the coordination between the two authors with regard to the stages of the data collection as well as the quality assessment, each author played a particular role. The one applied inclusion and exclusion criteria during data collection, assessed the quality of primary studies and checked manually the excluded papers based on the abstracts and introduction sections. The other checked all included papers and their score. In case of doubt of the former and lack of availability of the latter to perform a deeper verification, we contacted the authors of the paper.

Data collection and data analysis: The data we extracted from each primary study are: (i) the source, where the paper was found.; (i) the data related to the research questions we have raised in section 3.1; (iii) quality evaluation. The data was tabulated in order to put emphasis on the research questions listed in Section 3.1.

4 Results

In this section, we summarize and analyze the results of our SLR. We discuss the answers to our research questions and provide recommendations.

4.1 Search results

Table 3 shows the results of the search procedure respectively before and after applying inclusion and exclusion criteria, along with the selected papers. Before applying the exclusion criterion for eliminating papers that deal with inter-model consistency in the field of software engineering, the number of studies in the first round was very large (982). Applying the aforementioned criterion has considerably decreased this number. This implies that the inter-model consistency is a widely-tackled topic in the field of software engineering. In order to avoid biasing the results of the data analysis, it was essential to ensure that papers appeared in multiple sources were taken into account only once (leading to 982). Also, among the 41 resulting papers the ones describing the same approach were grouped together (leading to 36 as shown in Table 4).

Table 3. Summary of results before and after applying inclusion and exclusion criteria.

	IEEE	Scopus	Google Scholar	ACM	Science Direct	Total
Results before	192	12	678	24	76	982
Results after	9	0	24	2	6	41
Selected papers	[28, 33, 34,38, 47-49, 59,68]	-	[29-32,35-37, 41-46,51,52, 55-58,60,61, 65-67]	[50,53]	[39,40, 54,62-64]	

Thereby, the total number of approaches considered during the data analysis and evinced in Table 4 is 36. The aforesaid Table 4 puts emphasis on the first part of data extracted from each primary study. It includes data related to the source of inconsistency (RQ1), the type (RQ4) and nature (RQ5) of consistency, the type of multi-view modeling (RQ8), the type of diagrams (RQ2), the number of modeling techniques used (RQ3), the scope of BP models (RQ7), and the main activity (purpose) on which the consistency management relies (RQ6). Regarding the latter we identified six fundamental activities in consistency management:

(i) *Detect common concepts* refers to determining the concepts shared between several models;
(ii) *Establish correspondences between elements of models* refers to making correspondence between pairs of elements (mainly activities) between two models;
(iii) *Evaluate consistency between models* refers to checking whether two models are consistent (they do not contradict each other);
(iv) *Generate views dependency model* refers to generating an intermediate model, which captures the common concepts between multi-perspective models;
(v) *Evaluate views dependency model with regard to consistency rules* refers to verifying whether the view dependency model complies with the defined consistency rules;
(vi) *Generate model from another* refers to transforming one model to another.

Table 4. Summary: The first part of extracted data related to the inter-model consistency.

ID	Reference	Inconsistency source (RQ1)	Consistency type (RQ4)	Consistency nature (RQ5)	Type of multi-view modeling (RQ8)	Diagram type (RQ2)	Number of modeling techniques (RQ3)	BP models scope (RQ7)	The main purpose of inconsistency management (RQ6)
S1	Bork et al, [28]	Multi-persp. modeling	Horizontal	Syntactic &Semantic	Projective	DSML	4	Intra-	Generate intermediate model (iv)
S2	Bork et al, [44]	Multi-persp. modeling	Horizontal	Syntactic &Semantic	Projective	DSML	4	Intra-	Detect common concepts (i)
S3	Yan et al, [29]	Multi-persp. modeling	Horizontal	Syntactic &Semantic	Projective	DSML	>1 (unknown)	Inter-	Detect common concepts (i)
S4	Hallerbach et al, [30]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Establish correspondences between models (ii)
S5	Smirnov et al [31]	BP models merging	Vertical	Semantic (behavioral)	-	Activity-	1	Intra-	Generate model from another (vi)
S6	Koliadis [32],[38]	Multi-persp. modeling	Horizontal	Semantic	-	Activity- Role-	2	Intra-	Evaluate intermediate model (v)
S7	Gerth et al, [33]	BP models merging	Vertical	Semantic (behavioral)	-	Activity-	1	Intra-	Generate model from another (vi)
S8	Zemni et al, [34]	BP models merging	Vertical	Semantic (behavioral)	-	Activity-	1	Intra-	Generate model from another (vi)
S9	Pascalau et al, [35]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Generate model from another (vi)
S10	Pascalau et al, [43]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Establish correspondences between models (ii)
S11	Weidlich al, [36],[56],[63]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Generate model from another (vi)
S12	Koschmider et al [37]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Generate model from another (vi)
S13	Milani et al, [39]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Generate model from another (vi)
S14	Dijkman et al [40],[49], [66]	BP models variants	Horizontal	Semantic	-	Activity-	1	Intra-	Establish correspondences between models (ii)
S15	Lu et al, [41]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Evaluate consistency between models (iii)
S16	Rastrepkina et al, [42]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Establish correspondences between models (ii)
S17	Cheng-Leong et al [45]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Generate model from another (vi)

S18	Chen-Burger [46]	Multi-persp. modeling	Horizontal	Syntactic &Semantic	Selective	Activity-Product-	2	Intra-	Evaluate intermediate model (v)
S19	Koehler, [47]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Evaluate consistency between models (iii)
S20	Worzberger et al, [48]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Evaluate consistency between models (iii)
S21	Lu et al, [50]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Establish correspondences between models (ii)
S22	Gulden et al, [51]	Multi-persp. modeling	Horizontal	Syntactic &Semantic	Projective	DSML	3	Intra-	Detect common concepts (i)
S23	Delen et al, [52]	Multi-persp. modeling	Horizontal	Syntactic &Semantic	Projective	unspecified	unspecified	Intra-	Detect common concepts (i)
S24	Leist et al, [53]	Multi-persp. modeling	Horizontal	Syntactic &Semantic	Projective	Activity-	1	Intra-	Detect common concepts (i)
S25	Shunk et al, [54]	Multi-persp. modeling	Horizontal	Syntactic &Semantic	Projective	unspecified	unspecified	Intra-	Detect common concepts (i)
S26	Fang et al, [55]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Evaluate consistency between models (iii)
S27	Koubarakis et al, [57]	Multi-persp. modeling	Horizontal	Syntactic &Semantic	Projective	unspecified	unspecified	Intra-	Evaluate intermediate model (v)
S28	Vanderfeesten et al, [58]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Evaluate consistency between models (iii)
S29	Martens et al, [59]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Generate model from another (vi)
S30	Decker et al, [60]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Evaluate consistency between models (iii)
S31	Fang et al, [61]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Establish correspondences between models (ii)
S32	DeMedeiros et al, [62]	BP models variants	Vertical	Semantic (behavioral)	-	Activity-	1	Intra-	Evaluate consistency between models (iii)
S33	Niemann et al, [64]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Evaluate consistency between models (iii)
S34	Kuster et al, [65]	BP models variants	Vertical	Syntactic &Semantic	-	Activity-	1	Intra-	Evaluate consistency between models (iii)
S35	Van der Aalst et al, [67]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Evaluate consistency between models (iii)
S36	Li et al, [68]	BP models variants	Vertical	Semantic	-	Activity-	1	Intra-	Evaluate consistency between models (iii)

DSML: Domain specific modeling language

4.2 Quality evaluation of primary studies

We assessed the studies for quality based on the two quality assessment questions defined in the section 3.2. The score for each study is shown in Table 5.

Table 5. Summary: Quality evaluation of studies.

Study	QA1	QA2	Total score	Study	QA1	QA2	Total score
S1	Y	Y	2	S19	P	N	0.5
S2	P	Y	1.5	S20	Y	P	1.5
S3	P	P	1	S21	P	N	0.5
S4	P	P	1	S22	P	N	0.5
S5	P	P	1	S23	P	N	0.5
S6	P	P	1	S24	P	N	0.5
S7	P	P	1	S25	P	Y	1.5
S8	P	Y	1.5	S26	Y	P	1.5
S9	P	P	1	S27	P	N	0,5
S10	Y	P	1.5	S28	Y	P	1.5
S11	Y	Y	2	S29	Y	P	1.5
S12	P	P	1	S30	P	Y	1.5
S13	P	P	1	S31	Y	P	1.5
S14	P	Y	1.5	S32	P	Y	1.5
S15	Y	P	1.5	S33	P	P	1
S16	P	P	1	S34	P	P	1
S17	P	N	0.5	S35	P	Y	1.5
S18	Y	P	1.5	S36	Y	P	1.5

4.3 Analysis of results and discussion

The column named "Inconsistency source" in the above Table 4, along with Fig. 1 reveal that mainly three sources (the multi-perspective modeling, the existence of many BP models variants depicting the same BP, and the merging of BP models) prompted researchers to deal with the issue of inter-model consistency.

Fig. 1 shows that the BP models variants as source of inconsistency is tackled by 64% of the studies (23 of 36), whereas the other sources are somehow overlooked. When focusing on this source in relation with the columns named respectively "Consistency type" and "Number of modeling techniques", a strong dependency can be deduced between them as shown in Table 6.

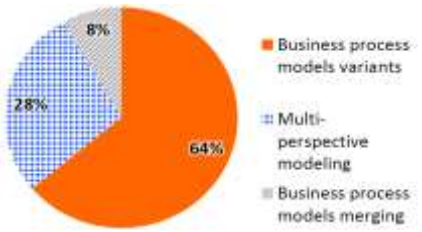

Fig. 1. Sources of inconsistencies addressed in literature

Table 6 reveals on one side that consistency problems caused by the existence of many variants of BP models are mainly vertical consistency problems (95.7%), whereas those arising from the multi-perspective modeling as inconsistency source refer usually to horizontal consistency problems (100%). On the other side, all primary studies dealing with consistency across BP models variants rely on one single modeling technique, whereas often more than one technique are (90% of studies) used when the cause of

inconsistency between models is the multi-perspective modeling.

Similarly, the nature of consistency can be strongly linked to the inconsistency source. Table 7 puts forward this link.

Table 6. Consistency type and number of techniques in relation with inconsistency source.

Inconsistency source	Consistency type		Number of modeling techniques	
	Horizontal	Vertical	=1	>1
BP models variants	4.3% (1 of 23)	95.7% (22 of 23)	100% (23 of 23)	0%
BP models merging	0% (0 of 3)	100% (3 of 3)	100% (3 of 3)	0%
Multi-perspective modeling	100% (10 of 10)	0% (0 of 10)	10% (1 of 10)	90% (9 of 10)

Table 7. Consistency nature in relation with the inconsistency source.

Inconsistency source	Consistency nature		
	Syntactic	Semantic	Both
BP models merging	0%	100% (3 of 3)	0%
BP models variants	0%	95,7% (22 of 23)	4,3% (1 of 23)
Multi-perspective modeling	0%	10% (1 of 10)	90% (9 of 10)

Furthermore, the three approaches (S5, S7 and S8) seeking to tackle the consistency when merging two fragments of BP models chiefly target consistency of a semantic nature as depicted in Table 7. This refers to consistency problems related to behavioral aspects of a BP like the exclusiveness of a pair of activity (i.e. the execution logic such as AND, OR, XOR) or their order of potential occurrence. Fig. 2 and Fig. 3 summarize the relation between the six fundamental activities in inconsistency management, and the three sources of inconsistency.

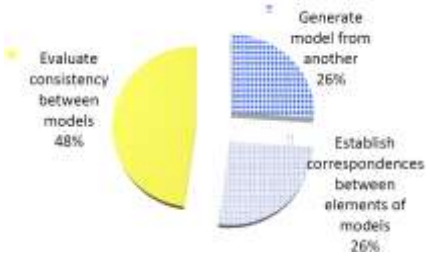

Fig. 2. Activities in inconsistency management when inconsistency source is *BP models variants*

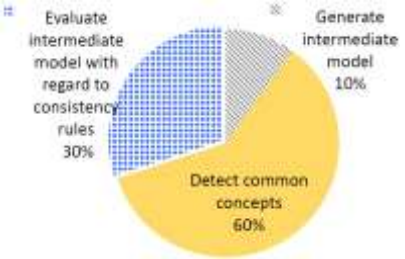

Fig. 3. Activities in inconsistency management when inconsistency source is *Multi-perspective modeling*

Fig. 2 highlights that the most common activity (48%) in the literature with respect to the inter-model consistency is its evaluation, known as *consistency checking* between two or more BP models variants. Fig. 3 shows that managing inconsistency in case of multi-perspective modeling consists mainly in detecting common concepts among multiple views (60%). Evaluating an intermediate model with regard to consistency rules (30%) is also referred as *consistency checking* in the literature. We also observed that only few concepts are shared between the models when they depict the same system from complementary perspectives. Hence, a partial dependency exists between the BP models. An inter-model consistency problem occurs when a partial or a total (strong) dependency exists between BP models. The former happens in case of multi-perspective modeling,

whereas the latter appears when many variants of the same BP exist. The source of inconsistency among BP models seems to be the cornerstone of each attempt for categorizing research works dealing with the inter-model consistency issue.

In the following, we attempt to answer the research questions set in section 3.1.

RQ1: We identified three sources of inconsistency among BP models (see Fig. 1). The majority of approaches focus on the variants of the same BP model (64%). During our analysis of multi-perspective modeling approaches (28%), we noted that among the 10 primary studies, only one, S27, has focused on the BP as a subject of modeling, i.e. according to multiple perspectives. Unfortunately, the proposed solution is not applicable outside of this primary study (QA2=N, see Table 5). Four others (S1, S2, S3, S6) analyze the enterprise as a whole, offering the BP models among the multiple perspectives. Finally, the five latters (S18, S22, S23, S24, S25) offer multiple perspectives in enterprise modeling, excluding BP models. Hence, it will be promising to overcome the lack of approaches dealing with the consistency among multi-perspective BP models.

RQ2/RQ3: The majority of approaches presented (75%) focused in the activity-driven diagrams, where a BP is modeled as a sequence of activities by using a single modeling technique. This does not allow capturing all facets of a BP in a comprehensive manner. The need to resorting to different types of diagrams emerges, especially for modeling knowledge intensive BPs. Thereby, mastering the consistency between BP models produced using a variety of modeling techniques becomes essential to guarantee a complete and coherent picture of a BP.

RQ4/RQ5: Only 30.6% of the studied approaches handle the horizontal consistency. The percentage of approaches seeking for both syntactic and semantic consistency among BP models is limited to 27, 8% (10 of 36). These results reveal the need for enhancing the other approaches by similar capabilities, when the causes of the inconsistencies call for such capabilities.

RQ6: The most recurrent activity in consistency management applied to BP models variants (Fig. 2) is the evaluation of consistency between models (48%), also called consistency checking. Hence, it will be beneficial if the inconsistencies between models can be prevented (i.e. managing inconsistencies in early steps of modeling) rather than corrected (i.e. managing inconsistencies at late steps of exploitation).

RQ7/RQ8: 97.2% of approaches focus on BP models within the same enterprise. 80% of approaches dealing with the consistency issues in the context of multi-perspective modeling are concerned with a projective type, and hence with a particular enterprise modeling method. It may seem obvious that approaches aiming to master the consistency between inter-enterprise BP models, which often implies heterogonous modeling techniques, are still lacking.

5 Towards categorizing approaches related to inter-model consistency: A reference framework

In the light of the results of the SLR and their analysis summarized in the above section 4, the inconsistency source is considered as the basic factor on which we can rely in order to categorize the approaches dealing with the consistency among BP

models. For each class of approaches, related to a particular source of inconsistency amongst the three sources (the variants of BP models, the multi-perspective modeling and the merging of BP models), we consider in turn other factors which may characterize approaches placed in the same class.

Fig. 4. A Framework towards categorizing approaches focusing on inter-model consistency

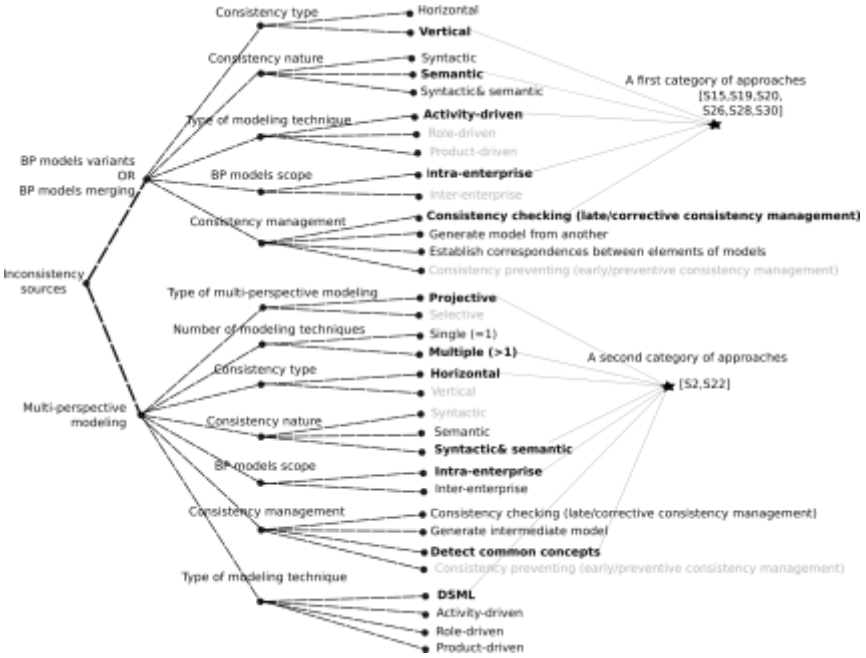

Fig. 4 shows the proposed framework in the form of a tree. We aim that each research work dealing with the issue of consistency among BP models takes place in this framework (which is a first attempt and is candidate to evolution). Values in bold are the most common ones in the literature regarding the corresponding characteristics. The less common values among the studied approaches are shown in gray; together with the values in simple black, they suggest us research challenges. In Fig. 4, we also illustrated the use of this framework, by *requesting* the approaches offering the indicated values for the *search parameters (shown with the gray lines)*.

6 Conclusion

A problem of inter-model consistency can occur when a partial or strong dependency exists between BP models. A partial dependency arises when few concepts are shared between models; this is the case for multi-perspective modeling. A total dependency occurs when it is possible to establish correspondences between all elements involved in the models. Therefore, challenges related to the decomposition (vertical coherence) or the similarity issues between BP models might be also considered as consistency issues.

In this paper, we presented the results gained from undertaking a SLR on consistency

among BP models with the aim of proposing a framework that facilitates (i) categorizing the plethora of existing approaches and (ii) providing directions for promising new research activities with regard to this topic. We considered a total of 982 papers and extracted from the most relevant scientific sources, of which 41 papers were ultimately analyzed in depth by referring to the Kitchenham's guidelines. The results mainly showed that a special attention must be given to the consistency between multi-perspective BP models, where a lack of approaches has been noticed. The results also revealed that the majority of the existing approaches tackle the consistency checking and thus handle the detected inconsistencies between models (i.e. late/corrective consistency management) rather than preventing them (i.e. early/preventive consistency management). The latter seems to be a promising line of research.

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