Detection of Process Antipatterns: A BPEL Perspective

Francis Palma*†, Naouel Moha†, Yann-Gaël Guéhéneuc*
*Ptidej Team, DGIGL, École Polytechnique de Montréal, Canada
{francis.palma, yann-gael.gueheneuc}@polymtl.ca
†Département d'informatique, Université du Québec à Montréal, Canada
moha.naouel@uqam.ca

***Abstract*—With the increasing significance of the service-oriented paradigm for implementing business solutions, assessing and analyzing such solutions also becomes an essential task to ensure and improve their quality of design. One way to develop such solutions, a.k.a., Service-Based systems (SBSs) is to generate BPEL (Business Process Execution Language) processes via orchestrating Web services. Development of large business processes (BPs) involves design decisions. Improper and wrong design decisions in software engineering are commonly known as *antipatterns*, *i.e.*, poor solutions that might affect the quality of design. The detection of antipatterns is thus important to ensure and improve the quality of BPs. However, although BP antipatterns have been defined in the literature, no effort was given to detect such antipatterns within BPEL processes. With the aim of improving the design and quality of BPEL processes, we propose the first rule-based approach to specify and detect BP antipatterns. We specify 7 BP antipatterns from the literature and perform the detection for 4 of them in an initial experiment with 3 BPEL processes.**

***Keywords*-Business processes; Antipatterns; Service-based systems; Specification; Detection; Design;**

I. INTRODUCTION

Service Oriented Architecture (SOA) [1], as an architectural trend, is increasingly growing and widely adopted by practitioners because it allows low-cost and flexible development by composing services, *i.e.*, software units that are autonomous, reusable, platform-independent, and are easily accessible over the Internet.

Any systems as well as Service-Based Systems (SBSs) may involve some antipatterns. SBSs are often evolved, *i.e.*, are modified or added new functionalities. This evolution may hinder the design and quality of service (QoS) of SBSs, and thus may introduce 'antipatterns'. An antipattern in a process generally captures common design errors [2], which causes a poor design resulting bad QoS.

SOA business solutions might also contain antipatterns while realizing the processes. The Business Process Modeling Notation (BPMN, [3]) is widely used for process modeling and provides the base for modeling control-flow, data-flow, and resource allocation. As for the Business Process Execution Language (BPEL, [4]), it provides an executable transformation of BPMN to the developers and is currently a *de facto* standard for Web services orchestration.

The automatic detection of business process (BP) antipatterns is an important task to assess the design and QoS of SBSs, *i.e.*, BPEL processes. However, no efforts have been given to detect BP antipatterns in BPEL processes. Our goal is to assess the design and QoS of BPEL processes. To achieve this goal, we propose an approach to specify BP antipatterns and detect them automatically in BPEL processes.

In the past years, several catalogs of BP antipatterns [2], [5], [6], [7] and analysis techniques [8], [9], [10] to discover those antipatterns have been proposed. Indeed, most of these catalogs and techniques focus on BPMN models.

There are some conceptual differences between BPEL and BPMN. BPEL processes define all its semantic details whereas the BPMN models do not. Moreover, the transition from notational (*i.e., graphical*) to scripted (*i.e., executional*) is very often prone to be broken and certain semantic ambiguities. Very often this may cause the loss of various design decisions [11]. There are approaches focusing on detecting antipatterns in BPMN models at the early design phase. But there is no approach for the similar detection in BPEL processes which are at the later phase in the development cycle, and involves higher risk of introducing brokenly implemented design decisions due to semantic gaps between BPMN and BPEL. Therefore, in this paper we focus on BPEL processes rather than BPMN models due to several rationales:

- Firstly, antipatterns in BPMN artifacts already got much attention in the literature;
- Secondly, BPEL processes are more *off-the-shelf* executable entities with more detailed operational semantics, and thus may facilitate both the early design-time and run-time investigation of structural and behavioral properties of processes; and,
- Finally, BPEL is designed for the execution of the models. While the business analysts create the models, and the developers implement the technology, there may arise some translation, adaptation, and–or implementation fault-occurrences. Even, analysts may take some wrong design decisions that may eventually be transferred to the executable processes.

Designs defects, *i.e.*, antipatterns must be detected and corrected to improve the design and QoS of SBSs. Therefore, with the goal of detecting BP antipatterns, we propose to: (i) specify BP antipatterns using classical *Rules of Inference* for their detection, (ii) define a concrete approach for the detection of BP antipatterns within BPEL processes, and (iii) perform an experiment with four BP antipatterns using our proposed approach on three example BPEL processes provided by Oracle, FraSCAti[1], and OASIS [4].

This paper is structured as follows. Section II surveys related work on the catalog of BP antipatterns and their analysis and detection in BPMN models. Section III presents our proposed approach, while we show some detection results in Section IV. Finally, Section V concludes the paper and sketches future work.

II. Related Work

Current literature is quite rich with a number of structural and behavioral antipatterns [2], [5], [6], [7] within models, along with some analysis and detection techniques [8], [9], [10], [12], in particular within BPMN models.

For example, Onoda *et al.* [5] first provided a catalog of five deadlock patterns using the concept of reachability and transferability based on the structure of a business process (BP) model. These antipatterns have been detected using the *deadlock detection* algorithm proposed by Maruta *et al.* [8]. Persson *et al.* [6] and Stirna *et al.* [7] provided a list of six patterns and 13 antipatterns related to enterprise modeling mainly focusing on the quality aspects of models. Based on their own practical experiences, the authors identified what mistakes the modelers need to avoid.

Gruhn and Laue [9] also proposed a heuristic-based approach for discovering problems in BP models and suggesting improvements. The authors first translated the models into a set of Prolog facts using simple XSLT transformations. Then, they defined some basic terminologies of BPMN modeling in the form of rules and identified some errors related to soundness and correctness (*e.g.*, deadlock) of the models. Koehler and Vanhatalo [2] described 14 structural antipatterns in IBM WebSphere Business Modeler[2] process models. However, if the antipatterns could be read visually then the localization and correction would become much easier for the modelers. Laue and Awad [12] were able to first visually represent the BP antipatterns. After the detection, the authors visually presented four antipatterns proposed by Onoda *et al.* [5] in BPMN models. Trčka *et al.* [10] formalised nine BP antipatterns using temporal logic that are caused by various data dependencies within the workflows and improper data handling.

From the above discussion, we can highlight the drawbacks of the current literature as follows: (i) antipatterns and approaches to detect them were considered only for BPMN models, whereas the *de facto* language BPEL was not considered at all; (ii) there are no other specifications for BP antipatterns except the one in [10]; (iii) BPMN models are not always executable. Therefore, various runtime quality aspects (*e.g.*, *availability* or *response time* of Web services) were not considered, which can be obtained for the executable BPEL processes; finally, (iv) there is no detection approach for BP antipatterns in BPEL processes until now. We focus on these issues with a viable solution to propose a concrete approach for specifying and detecting antipatterns within executable BPs.

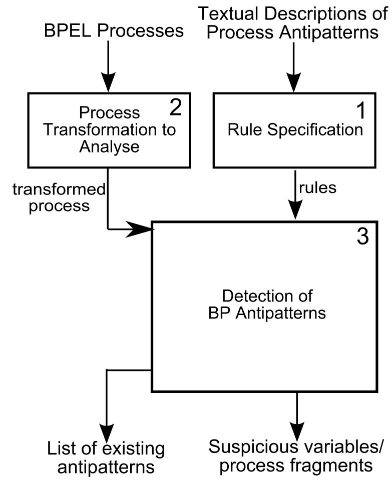


Figure 1. Proposed Detection Approach

III. Approach

With the aim of detecting antipatterns in BPEL processes, we propose an approach as shown in Figure 1 involving three major steps:

Step 1. Rule Specification: This step concerns specifying rules for the detection of BP antipatterns that, later on, will be applied on BPEL processes.

Step 2. Process Transformation to Analyse: In this step, we transform BPEL processes into a more abstract and simplified representation, by filtering some process elements those are not required to apply a certain rule, to ease: (i) the implementation of the rules defined in the previous step and (ii) the further analysis of the processes.

Step 3. Detection of BP Antipatterns: The third step consists in applying the rules defined in *Step 1* on the transformed processes from previous step. This step reports a list of existing antipatterns with the involved process fragments.

The following sections detail each of the previous steps.

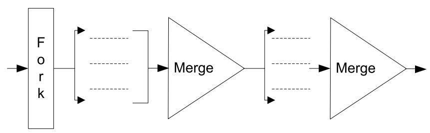
A. Defining Rules for the Detection of BP Antipatterns

As the prerequisite to defining the rules, we carry out a thorough domain analysis of process antipatterns by studying their definitions in the literature, namely [2], [5], [6], [7]. This domain analysis allows us to identify clues, *i.e.*, bad design criteria relevant to each process antipatterns. These identified clues have direct link to different design elements used for specifying BPs, *i.e.*, *gateways*, *decision points*, and–or *loops*. Therefore, the identification of these relevant controllers within antipattern specifications is also an important

[1]http://frascati.ow2.org/

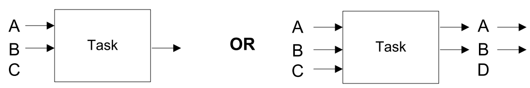
[2]http://www-03.ibm.com/software/products/us/en/modeler-advanced/

RULE: *Lack_Of_Synchronization*
IF: (((COUNT(*Fork*) $\geq$ 1 AND COUNT(*merge*) $\geq$ 1) AND (*Fork* PRECEDE *merge*)) PRECEDE *merge*)
THEN: LACK OF SYNCHRONIZATION



(a) Lack of Synchronization Through Fork-Merge Pairs

RULE: *Dangling Input_And_Output*
IF: ((*InputVar* DEFINED) AND (COUNT(Connection(*InputVar*))=0))
THEN: DANGLING INPUT
IF: ((*OutputVar* DEFINED) AND (COUNT(Connection(*OutputVar*))= 0))
THEN: DANGLING OUTPUT



(b) Dangling Inputs and Outputs

Figure 2. Rules for 'Lack of Synchronization' and 'Dangling Inputs and Outputs' (Fork: *parallel gateway*, Merge: Inclusive Gateway).

task while defining rules. To define the rules, we use the classical *Rules of Inference* that is simple to understand and implement for the developers. In this paper, we mostly focus on BP antipatterns defined in [2] because that paper explains the antipatterns that are mostly found in practice, and are collected from a wide range of process modeling tools including IBM WebSphere Business Modeler, Aris[3], and Adonis[4].

Figure 2 shows the rules for the two common BP antipatterns, *i.e.*, *Lack of Synchronization* and *Dangling Inputs and Outputs* that we define. All process antipatterns in the literature are defined for BPMN models. However, we do a simple mapping between BPMN models and BPEL processes using a well-known and straightforward approach proposed by Weidlich *et al.* [13]. To define rules, we use different logical operators including OR and AND, and different relational operators, including PRECEDE, NOT_PRECEDE, BACKCONNECT, etc., that define relations between process fragments and nodes. For example, *A* PRECEDE *B* means *B* appears after *A*, or *A* BACKCONNECT *B* implies *B* has a *backward* connection to *A* in the process.

Lack of Synchronization [2] is an antipattern with the presence of fork-*merge* pair. The fork, *i.e.*, *parallel gateway* triggers output on all of its outgoing branches, while the *merge*, *i.e.*, *inclusive gateway* waits for input on only one of its incoming connections. Further later in the process, another final *merge* may cause synchronization problem because the latter *merge* requires all the input which may not available (see Figure 2(a)), thus a lack of synchronization occurs. *Dangling Inputs and Outputs* [2] is a form of antipattern where inputs and outputs of an activity or gateway

[3]http://www.ariscommunity.com/aris-express
[4]http://www.adonis-community.com/

RULE: *Deadlock_Through_Decision-Join*
IF: ((*Start_Node* PRECEDE *Decision_Node*) PRECEDE *Join*) OR
((*Task* PRECEDE *Exclusive_Gateway*) PRECEDE Task_All_Output_Required)
THEN: DEADLOCK
(a) Deadlocks Through Decision-Join Pairs

RULE: *Cyclic_Deadlock*
IF: (((Join PRECEDE Task) PRECEDE Exclusive_Decision) AND (Exclusive_Decision BACKCONNECT Join)) OR
(((Join PRECEDE Task) PRECEDE *Fork*) AND (*Fork* BACKCONNECT Join))
THEN: CYCLIC DEADLOCK
(b) Cyclic Deadlocks Through Join-Fork and Join-Decision Pairs

RULE: *Cyclic_Lack_of_Synchronization*
IF: ((*Fork* NOT_PRECEDE Join) AND ((*Fork* BACKCONNECT *merge*) OR (*Fork* BACKCONNECT *Inclusive_Decision*)))
THEN: CYCLIC LACK OF SYNCHRONIZATION
(c) Cyclic Lack of Synchronization Through Merge-Fork Pairs

RULE: *Stop-Node_In_Parallel_Branches*
IF: ((*Fork* EXIST) AND (EACH Fork-Branch HAS Stop-Node)) OR
((Inclusive_Branch EXIST) AND (EACH Inclusive-Branch HAS Stop-Node))
THEN: STOP-NODE_IN_PARALLEL_BRANCHES
(d) The Stop Node in Parallel Execution Branches

RULE: *Multiple_Connections*
IF: ((Control-Flow EXIST BETWEEN Tasks) AND (COUNT(Control-Flow) $>$ 1))
OR
((Data-Flow EXIST BETWEEN Tasks) AND (COUNT(Identical_Data-Flow) $>$ 1))
THEN: MULTIPLE CONNECTIONS
(e) Multiple Connections Between Activities

Figure 3. Rules for Five Process Antipatterns (Fork: *parallel gateway*, Merge: Inclusive Gateway).

remain unconnected in the process. Dangling data outputs are produced by a task or subprocess, but never used. In contrast, dangling inputs might cause deadlocks if the input is a data input of a gateway or an activity (see Figure 2(b)). We also specify five other BP antipatterns as shown in Figure 3, and graphically present them in Figure 4.

B. Transforming Business Processes

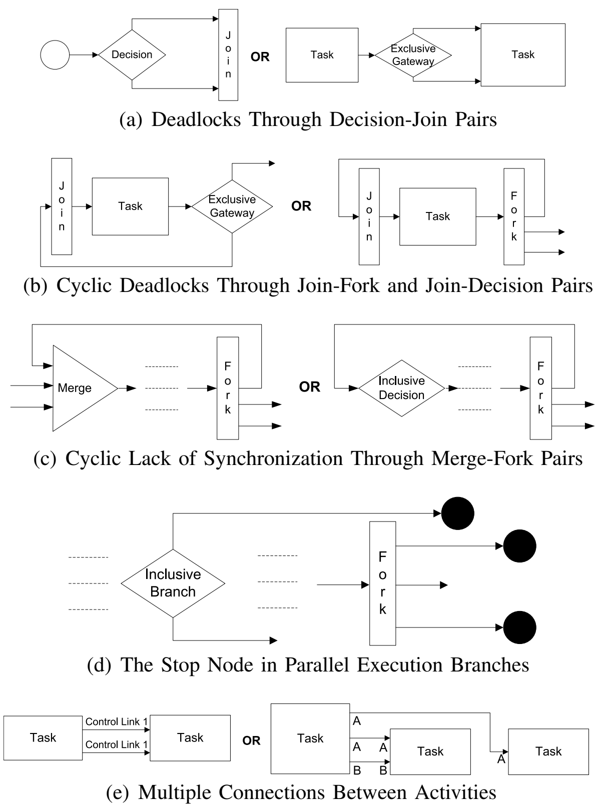
BPs are very complex entities and their complexity increases with their sizes. BPs define a collection of tasks, *i.e.*, Web services and the communication details among them including data handling. For our analysis, we do not require all those details because in this paper we consider only the static analysis of BPEL processes. To filter optional details, while maintaining the process integrity, we generate a simplified model of the original BPEL. We make sure that we retain all the required information to apply our predefined rules. The transformation is done in the following way:

- *From the original BPEL process to a simplified BPEL process:* Figure 5 shows an example how we perform this transformation. We parse and filter all the required details, *i.e.*, all the tasks, input data, output data, and control-flow information, etc., and generate a simplified process (see Figure 5(a)). Furthermore, we generate another process skeleton that can be mapped easily to the rules defined previously (see Figure 5(b)).

Developers can use this latter version of the process for further investigation and analysis, *i.e.*, implementing the executable versions of the rules.

C. Detection of BP Antipatterns

The detection phase follows the specification of the rules and the transformation of BPs. We implement the rules



(a) Deadlocks Through Decision-Join Pairs

(b) Cyclic Deadlocks Through Join-Fork and Join-Decision Pairs

(c) Cyclic Lack of Synchronization Through Merge-Fork Pairs

(d) The Stop Node in Parallel Execution Branches

(e) Multiple Connections Between Activities

Figure 4. Graphical View of Five Process Antipatterns.

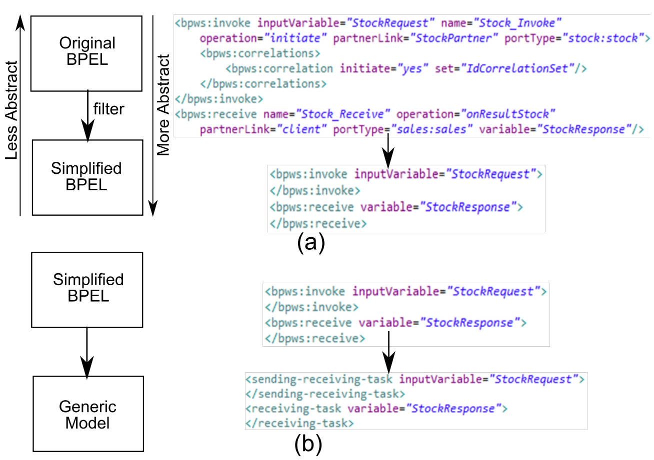


Figure 5. Transform of Business Processes

shown in Figure 3 programmatically using a language like JAVA. We implement the rules in a modularized way, *i.e.*, we implement each side of different logical operators (*e.g.*, `AND`, `OR`) in a rule, and join them afterwards to check the conformance with the defined conditions. Then we apply those code segments on transformed processes to detect BP antipatterns. This process is currently not automatic, however, one of our future goals is to automate this code generation phase.

Business Process	Added I/O Variables	Added Control Flows
TravelProcess	name=`TempAmericanAir` name=`TempDeltaAir`	*merge* gateway with an *assign* task before end node
sales-bpel	name=`notify` name=`subscribe`	-
auctionProcess	*no-changes*	*no-changes*

Table I
CHANGES MADE IN *TravelProcess* AND *sales-bpel* PROCESSES.

IV. EXPERIMENTS AND RESULTS

We show with a small scale experiment the effectiveness of our proposed approach. We performed the experiment with three small BPEL processes: (1) *TravelProcess*, a reference example provided by Oracle, (2) *sales-bpel*, developed by FraSCAti and available in FraSCAti repository, and (3) *auctionProcess*, a reference example in BPEL 2.0 specification [4]. *TravelProcess* is a composite Web service containing three other Web services and seven I/O variables, whereas *sales-bpel* includes two other Web services and four I/O variables. Finally, *auctionProcess* involves three Web services and six I/O variables.

We analyse and specify seven process antipatterns from the literature and we perform detection for four BP antipatterns, namely *Dangling Input and Output*, *Lack of Synchronization*, *Deadlock Through Decision-Join*, and *Stop-Node In Parallel Branches*. Detection for other three BP antipatterns also currently is in progress.

A. Results

After the initial experiment, with our defined rules, we could not detect any antipatterns on *TravelProcess* and *sales-bpel* processes because they are small in size, and indeed, there were no such antipatterns. We also perform the detection for those antipatterns on *auctionProcess* without injecting or changing any variables or nodes. Indeed, we detect *Lack of Synchronization* in *auctionProcess*, *i.e.*, it has two *Forks* and *merge*, and one *Fork* precedes *merge*, then this precedes another *merge*. However, we do not detect any such antipattern in *sales-bpel* as it does not possess any *Forks*, *i.e.*, the *parallel gateway* (see Table II). We then ask a student who is not involved in the experiment and has knowledge on BPEL, to add randomly some I/O data, or to change the original control flow while maintaining the integrity of *TravelProcess* and *sales-bpel* processes. Obviously, we inform the student our goal, *i.e.*, the antipatterns we intend to detect. The main goal of these changes is to inject antipatterns intentionally without biasing the results. The changes made by the student are summarized in Table I.

B. Discussion

With the modified BPs after injecting antipatterns, we again perform the detection and this time we detect the *Dangling Input* and *Lack of Synchronization* antipatterns in two processes as shown in Table II for *TravelProcess* and *sales-bpel*. Namely, in *TravelProcess*, we detect `TempAmericanAir` and `TempDeltaAir` as *Dangling Input*

Process Name	Detected Antipatterns	Process Fragments or Elements
TravelProcess	Dangling Input	TempAmericanAir, TempDeltaAir;
	Lack of Synchronization	1 Forks, 2 Merge, *parallel-gateway* precedes *sequence-flow*, *merge* precedes *assignment*, *merge* precedes *assignment*
auctionProcess	Lack of Synchronization	2 Forks and Merge; [Forks] followed by *merge*, then followed by *merge*
sales-bpel	Dangling Input	notify, subscribe

Table II
DETECTION RESULTS FOR BPEL PROCESSES

(see Table II) because they are declared within the process under its <variables> node but not have been used later. We also detect subscribe and notify as *Dangling Input* in *sales-bpel* process on the same rationale (see Table II).

In *TravelProcess* process, we also detect *Lack of Synchronization* after manually injecting a *merge* in the process (see Table II). According to the rule of *Lack of Synchronization* antipattern (see Figure 2(a)), if one (or more) *parallel gateway* and *merge* exist in the process, providing that the *parallel gateway* PRECEDE a *merge*, and again the combination of those *parallel gateway* and *merge* PRECEDE another *merge* then there is certainly the presence of lack of synchronization. This occurs mainly due to the characteristics of *merge*: *merge* does not wait for inputs on all its incoming links. Therefore, after a *parallel gateway* where tasks may not always finish their jobs at the same time, the *merge* may trigger even with one single input, which is obviously not expected. This causes a lack of synchronization, thus we detect *Lack of Synchronization* antipattern in *TravelProcess* as reported in Table II. However, no occurrences were detected for *Deadlock Through Decision-Join* and *Stop-Node In Parallel Branches* in the processes, and injecting them intentionally might disrupt the integrity of the original processes.

C. Threats to Validity

The main threat to the validity of our results involves *external validity*, *i.e.*, the possibility to generalize our approach to other large BPs. Indeed, the availability of large and existing BPs is a real limit for this research. As the future work, we plan to run the experiment on other BPEL processes. Also, the subjective nature of defining rules is a threat to *construct validity*. We try to minimize this threat by defining rules based on a thorough literature review.

V. CONCLUSION AND FUTURE WORK

Business processes, in particular, BPEL processes are the key standard to orchestrate Web services for building composite services. While designing, BPEL processes may possess antipatterns. Thus, the detection of process antipatterns is important to ensure and improve the quality of design of business processes (BPs). In this paper, we presented an approach, for the detection of BP antipatterns. We also defined rules for seven BP antipatterns from the literature to ease their detection. We applied our approach with four BP antipatterns on three example BPEL processes.

As the future work, we intend to fully automate the approach with more detected process antipatterns. Furthermore, we intend to perform experiments on other large and complex BPs. In this paper, we analyzed the BPs statically, *i.e.*, without executing them. One of our future goals is to analyze the processes dynamically, *i.e.*, executing them, to acquire run-time properties.

VI. ACKNOWLEDGMENT

This work is supported by the NSERC Discovery Grant.

REFERENCES

[1] T. Erl, *Service-Oriented Architecture: Concepts, Technology, and Design*. Prentice Hall PTR, August 2005.

[2] J. Koehler and J. Vanhatalo, "Process Anti-Patterns: How to Avoid the Common Traps of Business Process Modeling," *IBM WebSphere Developer Technical Journal*, February 2007.

[3] "OMG: Business Process Modeling Notation (BPMN) version 1.2," Tech. Rep., January 2009.

[4] A. Alves and et al., "Web Services Business Process Execution Language Version 2.0," Tech. Rep., 2007.

[5] S. Onoda, Y. Ikkai, T. Kobayashi, and N. Komoda, "Definition of Deadlock Patterns for Business Processes Workflow Models." Washington, USA: IEEE Computer Society, 1999.

[6] A. Persson and J. Stirna, "How to Transfer a Knowledge Management Approach to an Organization - A Set of Patterns and Anti-patterns," ser. PAKM '06. Berlin, Heidelberg: Springer-Verlag, 2006, pp. 243–252.

[7] J. Stirna and A. Persson, "Anti-patterns as a Means of Focusing on Critical Quality Aspects in Enterprise Modeling," in *Enterprise, Business-Process and Information Systems Modeling*. Springer Berlin Heidelberg, 2009, vol. 29, pp. 407–418.

[8] T. Maruta, S. Onoda, Y. Ikkai, T. Kobayashi, and N. Komoda, "A Deadlock Detection Algorithm for Business Processes Workflow Models," in *IEEE International Conference on Systems, Man, and Cybernetics, Vol 1*, October 1998.

[9] V. Gruhn and R. Laue, "A Heuristic Method for Detecting Problems in Business Process Models," *Business Process Management Journal*, vol. 16, pp. 806–821, September 2010.

[10] N. Trčka, W. M. van der Aalst, and N. Sidorova, "Data-Flow Anti-patterns: Discovering Data-Flow Errors in Workflows," ser. CAMISE '09. Berlin, Heidelberg: Springer-Verlag, 2009, pp. 425–439.

[11] J. C. Recker and J. Mendling, "On the Translation Between BPMN and BPEL: Conceptual Mismatch Between Process Modeling Languages." Namur University Press, 2006, pp. 521–532.

[12] R. Laue and A. Awad, "Visualization of Business Process Modeling Anti Patterns," in *Proceedings of the 1st International Workshop on Visual Formalisms for Patterns*, vol. 25, 2010.

[13] M. Weidlich, G. Decker, A. Grokopf, and M. Weske, "BPEL to BPMN: The Myth of a Straight-Forward Mapping," in *Proceedings of the OTM 2008 Confederated International Conferences, CoopIS, DOA, GADA, IS, and ODBASE*. Berlin: Springer-Verlag, 2008, pp. 265–282.