TM4BPPMN: Recasting BPMN to Low-Level of Abstraction

Zineb Lamghari∗

Faculty of Sciences, LRIT associated unit to CNRST (URAC 29), Rabat IT Center Rabat, Morocco

Business process modelling languages are a very prominent mechanism to understand companies’ business processes. This mechanism allows managers to communicate and transversal information through a semantic flow for business process improvement. Examples of Business Process modelling languages are Unified Modeling Language (UML) or Business Process Modeling Notation (BPMN). UML presents alternative views to model company’s functionalities. While, BPMN still have a very abstracted level to model Business Processes. In this context, there are many BPMN extensions to break down its high-level of abstraction. However, most of existing BPMN extensions model a significant increase in business process complexity that deviate it from its crucial objective. This put forward the difficulty of detailing control flow related to information systems without reaching complexity. To that end, we propose our TM4BPMN extension for breaking-down BPMN high abstraction to low-level, to maintain BPMN facility in representing BPs, using Thinging Machine (TM) techniques.

Keywords: Thinging Machine; Business Process Improvement; BPMN extension; TM4BPMN

I. INTRODUCTION

Business Process models are used to visualise, describe, prescribe, and explain the behaviour of processes of an organisation for a wide range of objectives such as: communication among stakeholders, process improvement, process management, process automation, and process execution support. Concrete examples are the comparison of the "as-is" and the "to-be" process, documentation for complying with regulatory requirements such as ISO 9001 (Lamghari et al., 2019), and the analysis of performance related problems such as bottlenecks and inefficiencies.

Depending on the goal of the event logs analysis and on the analyst’s personal taste, several ways of process visualisation can be used. Many different process modelling notations have been proposed. The most common are Business Process Modeling Notation (BPMN), event-driven process chains (Scheer, 1992) and flow charts (Zimoch et al., 2017). In the literature, each notation has different properties, which make it applicable in a certain setting. All notations can be transferred to BPMN as the most expressive modelling language (Polyvyanyy et al., 2014; Polato et al., 2014; Oulsnam G, 1987; Polyvyanyy et al., 2010).

BPMN provides a graphical notation to describe business processes, which is both intuitive and powerful (it is able to represent complex process structure). It is possible to map a BPMN diagram to an execution language, BPEL (Business Process Execution Language).

The main components of a BPMN diagram are events, activities, and gateway. Beyond the components just described, there are also other entities that can appear in a BPMN diagram, such as artifacts (e.g., annotations, data objects) and swimlanes.

Recently the usage and acceptance of BPMN increased for business process design, more and more extensions to BPMN elements are proposed to cover the need for modelling processes from different domains. In this context, there are many proposed extensions (Chergui & Benslimane, 2018; Chiu Wang, 2015; Salles, 2018). However, most of available BPMN extensions model a significant increase in business process complexity that deviate it from its crucial objective.

*Corresponding author’s e-mail: zineb_lamghari2@um5.ac.ma
This paper is organised as follows: Section 2 presents the required background knowledge. The first subsection illustrates different BPMN extensions and their related gaps. The second subsection defines the graphical aspects of the notation into specific categories. This provides a small set of notation categories so that the reader of a BPD can easily recognise the basic types of elements and understand the diagram. Within the basic categories of elements, additional variation and information can be added to support the requirements for complexity without dramatically changing the basic look-and-feel of the diagram. The four basic categories of elements are:

- Flow Objects: Event, Activity and Gateway
- Connecting Objects: Sequence Flow, Message Flow and Association
- Swimlanes: Pool and Lane
- Artifacts: Data Object, Group and Annotation

### B. BPMN Extensions

This sub-section presents a literature review that we conducted in order to determine the current state of the art of BPMN extensions. We examined these scientific publications according to the BPMN extension objective. Indeed, we put forward BPMN limitations.

In the literature, there are two main categories of BPMN extensions. The first category 'Domain-specific BP' is for extensions intended to handle the processes of a particular domain such as healthcare, manufacturing, Internet of Things (IoT), etc. The second category 'BP improvement' contains extensions that aim to business process improvement related issues (expressiveness, complexity, flexibility, variability, etc.). The extensions of the second category can be used in any domain. In this paper, we will focus on the second category especially scientific publications dealing with the complexity issue.

Decker and Puhlmann (2007) describe interaction behaviour between multiple process partners. This allows detailed representations according to different features (sets, correlations, and reference passing). Also, authors develop a new technique that consists of security aspects integration in a business process (Rodriguez & Piattini, 2007). In addition, Zor et al. (2011) treats manufacturing process focusing on manufacturing tasks, parts, and gateways. Further, authors
have been defined specific resource perspective requirements in business process models (Stroppi et al., 2011).

Differently with Arevalo (2016) suggest a new time aspects integration such as temporal dependencies between activities and deadlines within BP models. Moreover, a proposal of treating business process complexity has been treated. This done by providing proposed views of BP models according to specific indicators (Braun & Esswein, 2015). This work completes on qualifying the dynamic allocation of resources to each BP task (Bociarelli, 2017). Besides, Cartelli et al. (2015) propose a new methodology to detail external factors impacts on the process execution under a cost-sensitive perspective. In addition, Carvalho et al. (2018) bring forward an aspect-oriented BP modelling notation to improve the readability and simplicity of BPMN models. Also, De Giacomo, (2015) yields declarative constructs to BPMN. This is done to come up a hybrid process modelling representation.

From another point of view, Laue & Mueller (2016) allow simulation of processes according to different scenarios in order to breaking down BPMN high level of abstraction. Mandal et al. (2017) propose a model to handle events based on explicit subscriptions and buffering techniques. The proposed approach determines probe-oriented features about activities to illustrate more related information (Merino et al., 2016).

Pufahl and Weske (2016) proposed study uses the batch processing into BPMN during the execution of process instances based on the synchronisation technique. In addition, authors define a set of variables to be monitored during BP execution using a machine-understandable manner (Ramos-Merino et al., 2018). Moreover, the work (Salles, 2018) measure non-functional requirements and organisational goals using Business Level Agreements (BLAs). Furthermore, the work discussed by Abouzid & Saidi (2019) proposes a BPMN extension to support process modelling in the manufacturing domain. After the modelling step, authors claims that the complexity of the resulted process increased. Also, a new BPMN extension has been developed (Ribeiro et al., 2021) in order to model inter-organisational processes related to the latest generation of industry 4.0. Also, the complexity of business process is clearly appeared after the implementation of the BPMN extension.

Therefore, the most of available BPMN extensions model presents a significant increase in business process complexity that deviate it from its crucial objective. This put forward the difficulty of detailing control flow related to information systems without reaching the complexity issue.

C. Thininging Machine

Thininging Machine (Terry, 1991) is a very young diagrammatic language that can be combined with different modelling languages as UML (Al-Fedaghi, 2021). It helps managers to have a holistic picture of the company by matching control-flow with different company services, departments, functionalities, responsibilities, etc. Indeed, Thinking machine can be considered as an oriented-reality model due its low-level of abstraction.

Mainly, the TM model considers the world as a complex entity that is divided into things and their functions can be attributed to different machines. Each machine called a Thimac (Terry, 1991). This later can be shown into views static that describes the control flow into machines and dynamic that focuses on actions into and between machines. Indeed, this process can be described by the following actions (see Figure 1):

- **Arrive**: A thing arrives at a machine
- **Accept**: A thing accepted and enters the machine
- **Release**: A thing is currently can be transferred to the next the machine
- **Process**: A thing process results a new thing output
- **Create**: A new thing is created in the machine
- **Transfer**: A thing is input into or output from a machine. This is the direct link between machines.

In this sense, TM presents two main modelling views **static** and **dynamic** (see Figure 1):

1. **Static representation (defining machines)**: this view emphasises the static structure of the system using things and flows.
2. **Dynamic representation (intra-machine and inter-machines movement)**: this view describes the dynamic behaviour of the system such as events. In tm, behaviour explains how things act during events flowing. The chronology of activities can be identified by orchestrating the sequence of these events in their interacting processes. Indeed, an event is a thing that
can be created, processed, released, transferred, and received.

Figure 1. Thinging Machine overview (static and dynamic representations)

III. BUILDING TM4BPMN EXTENSION

Based on the released state of art (section 2), we identified several gaps, and we suggest in this section the TM4BPMN solution as a recommendation to fill the gap of the control-flow complexity.

A. TM4BPMN Structure

A Meta-Object Facility (MOF) meta-model describing the concepts represents the BPMN core structure. Mainly, any proposed extension must not contradict the semantics of any element that is defined in the BPMN specification. Then, the shapes defined in the specification must not be changed, and the shapes of extension elements must not conflict with the shapes defined in the specification. Furthermore, the graphical elements should respect the BOMN facility. It can be easy to understand by any viewer of the process diagram.

Also, the extension elements should have the “look and-feel” of BPMN. Figure 2 shows the extended meta-model. We define different classes and interfaces that must be implemented by the classes of the BPMN v2.0 standard. These classes reflect our BPMN extension “TM4BPMN” for detailing business processes using Thinging Machine mechanisms.

First, we have defined an abstract class that consists of verification functions. These functions help in determining which component will be selected. Then, we have created an interface (ITM) that extends the TM_components class. This one includes all TM actions (Receive, Release, Transfer, Create and Process). This interface can be implemented by BPMN original classes (Activity, Gateway, and Event).

Moreover, our proposed meta-model illustrates optional relations. These relations can redefine the ITM interface functions for more specific treatments.

In Table 1, we present our proposed BPMN extension according to TM actions. Indeed, we observe the following rules:

- Each activity is an isolated machine.
- A gateway is a process intra or between machines (intra-machine flow).
- The control-flow is the direct link between machines (inter-machines flow).
- An intra-control flow describes the high-level of abstraction of each BPMN components.
- Each component can result a new thing or maintain the same thing.
- The start event always results a new thing.
- TM4BPMN components presents a low-level of BPMN abstraction. Therefore, there is no new icons.
- BPMN component receive and send information on the transfer action.
- BPMN component with result must passe by the create action.
- BPMN component maintaining the same result after the process action do not have a create action.
| BPMN components | TM4BPMN components (high-level of abstraction) |
|-----------------|------------------------------------------------|
| **Activity** (all kind) | **Resulting new thing:** |
| | **Maintain the same thing:** |
| | ![Activity diagram](image) |
| | ![Activity diagram](image) |
| **Sub-process** (all kind) | **One Activity (Resulting new thing):** |
| | **One Activity (Maintaining the same thing):** |
| | ![Sub-process diagram](image) |
| | ![Sub-process diagram](image) |
| **Event (start-intermediate)** | **Start (Resulting new thing):** |
| | **Intermediate (Maintaining the same thing):** |
| | ![Event diagram](image) |
| | ![Event diagram](image) |
**B. Modelling with Extends BPMN**

The utility of using BPMN combined with business process improvement methodologies in representing companies’ business, allows to have both an abstracted level of the giving business process model, which can be understood by different viewers and maintain the flow of data between entities and structures. Also, the BPMN merits realise improvements and increase the profitability of the outputs or finished goods.

Figure 3 illustrates a very basic scenario that describes the recasting process of a very high abstracted level of a specific business process to the very low-level abstraction of this business process. In this figure, we made use of our proposed BPMN extensions. The recasting passage operation consists of three activities:

- **Attribute a label to each machine:** labels aim at defining the component currently occupied the recasting passage operation (activity, event or gateway).
- **Determine each activity output nature:** this step aims at defining if the result after executing the current component (new thing emerged or the same thing maintained).
- **Thinging Machine:** this helps in break-down each component with appropriate actions (transfer, receive, process, create, release).
The most observed differences compared to the version without extensions (shown in Figure 3) are the very high level of abstraction matched with each BPMN component. This gives a holistic representation of the process. Beyond, our BPMN extension allow putting much more information into the process model without increasing its complexity, which makes the process more complete.

IV. CASE STUDY: CROSS-ORGANISATIONAL BUSINESS PROCESS

In this section, we present a case study to approve the applicability of our proposed BPMN extension. The case study treats a cross-organisational Business Process. This business process type still has more difficulties in terms of representation and interoperability between different concerned organisations.

This example shows the business process of two companies A and B. The first concerns the procurement process from company A and the Sales and Distribution (S&D) process from company B. Both companies want to provide a cross-organisational business process by collaborating their processes. This required linking these two processes and crossing out all boundaries of both companies.

As illustrated in Figure 4, the BPMN model, the procurement process activates when it receives a purchase requisition. The process then transmits a request for quotation (RFQ) to proposed suppliers who, in turn, prepare quotations and redirect them back to the company. After receiving quotations, company A selects a supplier, creates a purchase order (PO), and sends it back to that supplier. Once the products are received, a goods receipt is generated, and the payment is made. The S&D process of company B starts by receiving an RFQ from a purchaser. company B then prepares a quotation and sends it back to the purchaser. After receiving the PO, company B fulfils the order and delivers it to its clients. Once the products are delivered, an invoice is generated. The process ends once the payment is received. Last, Figure 4 shows the resulting BPMN model of the cross-organisational process after merging the procurement process of company A and the S&D process of company B. Obviously, this new process has significant interoperability between A and B business processes. This interoperability is highly abstracted and that makes a hidden collaboration (not clear). In this sense, will use our TM4BPMN proposed extension.

![Figure 4](image-url)

**Figure 4. Cross-organisational Business Process (low-level of abstraction)**

Our goal is to describe deeply the process of modelling cross-organisation processes that accurately reflect their way of doing things from a collection of private process models. To this end, we propose the business process illustrated in Figure 5.

![Figure 5](image-url)

**Figure 5** presents an example of modelling cross-organisational process. We describe a merging business process using Thinging Machine techniques, to integrate company A process and company B process. From the high-level of abstraction, this process contains four activities. The process starts by analysing received processes from
companies A and B (Activity: Analyse processes). Then, we test compatibility (Activity: testing compatibility) between these processes to generate in the following activity main patterns (Activity: Process patterns generation). These patterns can be adapted according to companies’ business objectives (Activity: Process patterns adaptation). Finally, resulted processes are emerged (Activity: Merging processes) and one cross-organisational BP is transferred to each company (see Figure 5).

In this example, we supposed that each activity results a new thing. In this sense, we proceed through the following action:

Transfer ➔ Receive ➔ Process ➔ Create ➔ Release ➔ Transfer

However, the flow of actions can be changed according to the intra-machine flow (TM4BPMN components). Indeed, the flow of actions can be alternated between release and create. Therefore, proposed TM4BPMN components are not a generic structure that do not take into consideration excepted behaviours. Thus, TN4BPMN still admits appropriate intra-machine scenarios.

From the high-level of abstraction, TM4BPMN recasts an activity to one specific machine. Each machine is a set of actions. They clearly describe the intra-machine (the same activity) and inter-machines (different machines) actions. Time can be attributed through these actions flow (see Figure 5). To that end, we begin the recasting process by attributing labels to the business process components and determining the output nature. In this context, attributes help maintaining each component basics functionality, and the output nature describe explicitly the flow of actions that must be selected (new things or maintain same things).

![Figure 5. Cross-organisational Business Process using TM4BPMN extension](image)

**V. CONCLUSION**

In this paper, we have proposed a new BPMN extension for breaking-down its high-level of abstraction to a very expressive low-level BP representation, in order to maintain BPMN facility in representing BPs, using Thinging Machine techniques.

To approve the applicability of our proposal extension, we have utilised “TM4BPMN” on a cross-organisational BP. We have demonstrated a flow of easiest steps to reach the cross-organisational process representation.

The two main benefits of adopting “TM4BPMN” as a clear business model notation are:

1) The visibility of activities in low-level of abstraction, that allows the identification of problems (e.g., bottlenecks) and areas of potential optimisation and improvement.

2) Grouping the activities in “department” and grouping the persons in “roles”, in order to better define duties, auditing and assessment activities.
As future research, we plan to combine our proposal BPMN extension with distributed systems, to take into consideration “TM4BPMN” for unstructured business processes in the big data context.

VI. ACKNOWLEDGEMENT

This work is supported by the National Center for Scientific and Technical Re-search (CNRST) in Rabat, Morocco.

VII. REFERENCES

Abouzid I & Saidi R 2019, ‘Proposal of BPMN extensions for modelling manufacturing processes’, in the 5th International Conference on Optimization and Applications (ICOA): Proceeding of IEEE, Kenitra, Morocco.

Al-Fedaghi S 2021, ‘TMUML: A Singular TM Model with UML Use Cases and Classes’, arXiv preprint arXiv:2107.00757

Arevalo C, Escalona, MJ, Ramos, I & Domínguez-Munoz, M 2016, ’A metamodel to integrate business processes time perspective in BPMN 2.0’, Information and Software Technology, vol. 77, pp. 17-33.

Bociarelli P, DAmbrogio A, Giglio A & Paglia E 2017, ’A BPMN extension for modeling Cyber-Physical Production-Systems’, The Context of Industry 4.0.

Braun R & Esswein W 2015, ’Towards Multi-Perspective Modeling with BPMN’, Enterprise Engineering Working Conference (EEWC 2015), pp. 67-81.

Cartelli V, Di Modica G & Tomarchio O 2015, ’Extending the BPMN Specification to Support Cost-Centric Simulations of Business Processes’, in the 7th International Joint Conference on Knowledge Discovery, Knowledge Engineering, and Knowledge Management IC3K 2015, November 2015, Lisbon, Portugal.

Carvalho LP, Cappelli C & Santoro FM 2018, ’AO-BPM 2.0: Aspect Oriented Business Process Modeling’, in Teniente E., Weidlich M. (eds) Business Process Management Workshops.

Chergui MEA & Benslimane S M 2018, ‘A Valid BPMN Extension for Supporting Security Requirements Based on Cyber Security Ontology’, in the International Conference on Model and Data Engineering (MEDI), Springer, 219-232, October, Marrakesh, Morocco.

Chis A & Ghiran AM 2022, ‘BPMN Extension for Multi-Protocol DataOrchestration’, in Domain-Specific Conceptual Modeling, Springer, Cham, pp. 639-656.

Chiu HH & Wang MS 2015, ‘Extending Event Elements of Business Process Model for Internet of Things’, IEEE International Conference on Computer and Information Technology, Ubiquitous Computing and Communications, Dependable, Autonomic and Secure Computing, Pervasive Intelligence and Computing, October 2015, Liverpool, UK.

De Giacomo G, Dumas M, Maggi FM & Montali M 2015, ‘Declarative Process Modeling in BPMN’, in the International Conference on Advanced Information Systems Engineering (CAiSE 2015), Advanced Information Systems Engineering.

Decker G & Puhlmann F 2007, ’Extending BPMN for Modeling Complex Choreographies’, in Proceedings of the 15th International Conference on Cooperative Information Systems (CoopIS), Springer.

Laue R & Mueller C 2016, ’The Business Process Simulation Standard (BPSIM): Chances and Limits’, in the 30th European Conference on Modelling and Simulation ECMS, May 2016, Regensburg, Germany.

Lamghari Z, Radgui M, Saidi R, & Rahmani MD 2019, ’Defining business process improvement metrics based on BPM life cycle and process mining techniques’, International Journal of Business Process Integration and Management, vol. 9, no. 2, pp. 107-133.

Lapeña R, Pérez F, Pastor Ó, & Cetina C 2022, ’Leveraging execution traces to enhance traceability links recovery in BPMN models, Information and Software Technology’, pp. 146.

Mandal S, Weidlich M & Weske M 2017, ’Events in Business Process Implementation: Early Subscription and Event Buffering’, International Conference on Business Process Management, BPM.

Merino MR, Alvarez Sabucedo LM, Santos Gago JM & Alonso Rorís VM 2016, ’Extending BPMN Model for Improving Expressiveness and Machine-Understandability’, WorldCIST’16 – 4th World Conference on Information Systems and Technologies, in New Advances in Information Systems and Technologies, March 2016, Recife, PE, Brazil.
Oulsnam G 1987, ‘The algorithmic transformation of schemas to structured form’, The Computer Journal, Oxford, vol. 30, no. 1, pp. 43–51.

Polato M et al. 2014, ‘Data-aware remaining time prediction of business process instances’, in the International Joint Conference on Neural Networks (IJCNN).

Polyvyanyy A, Garcia-banuelos L & Dumas M 2010, ‘Structuring acyclic process models’, in the International Conference on Business Process Management, vol. 6336.

Polyvyanyy A et al. 2014, ‘Maximal structuring of acyclic process models’, The Computer Journal, Oxford, vol. 57, no. 1, pp. 12–35.

Rufahl L & Weske M 2016, ‘Enabling Batch Processing in BPMN Processes’, BPM in BPM Demos, Springer, 2016, pp. 28-33.

Ramos-Merino M, Santos-Gago JM, Álvarez-Sabucedo LM, Alonso-Roris VM, & Sanz-Valero J 2018, ‘BPMN-E2: a BPMN extension for an enhanced workflow description’, Software & Systems Modeling.

Ribeiro V, Barata J & Rupino da Cunha P 2021, A BPMN Extension to Model Inter-Organizational Processes in Industry 4.0.

Rodríguez FM & Piattini M 2007, ‘A BPMN Extension for the Modeling of Security Requirements in Business Processes’, in IEICE Transactions on Information and Systems, vol. 90, no. 4, pp. 745-752.

Salles GBM, Fantinato M, Barros VA & Albuquerque JP 2018, ‘Evaluation of the StrAli-BPM approach: strategic alignment with BPM using agreements in different levels’, International Journal of Business Information Systems, vol. 27, no. 4, pp. 433-465.

Scheer IDS 1992, ‘Architecture of Integrated Information Systems’, Business Process Engineering, Springer, Berlin, Heidelberg, pp. 4-16.

Stroppi LJ, Chiotti O & Villarreal PD 2011, ‘ABPMN 2.0 Extension to Define the Resource Perspective of Business Process Models’, CIBSE.

Strutzenberger, DV, Mangler, J & Rinderle-Ma, S 2021, ‘BPMN Extensions for Modeling Continuous Processes’, in International Conference on Advanced Information Systems Engineering, pp. 20-28, Springer, Cham.

Terry W 1991, ‘Thinking Machines: Can There Be? Are We? In The Boundaries of Humanity Humans, Animals, Machines’, eds James J. Sheehan, and Morton Sosna. Berkeley: University of California Press.

Zimoch M, Pryss R, Probst T, Schlee W & Reichert M 2017, ‘Cognitive insights into business process model comprehension: preliminary results for experienced and inexperienced individuals’, in Enterprise, Business-Process and Information Systems Modeling, Lecture Notes in Business Information Processing.

Zor S, Leymann F & Schumm D, ‘A Proposal of BPMN Extensions for the Manufacturing Domain’, in Proceedings of 44th CIRP International Conference on Manufacturing Systems.