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TM4BPPMN: Recasting BPMN to Low-Level of Abstraction

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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.

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This put forward the difficulty of detailing control flow related to information systems without reaching the complexity issue. To that end, we propose an approach for breaking-down BPMN high abstraction to low-level, in order to maintain the BPMN facility in representing BPs, using Thinging Machine techniques. is a very young diagrammatic language that ca be combined with different modelling languages. TM will be detailed in following sections.

Therefore, this paper is organied as follows: Section 2 provides the required background knowledge. The first sub-section illustrates different BPMN extensions and their related gaps. The second sub-section defines Thinging Machine static and dynamic mechanisms. Section 3 introduces our BPMN extension, its structure, and components. In Section 4, a concrete case study is depicted to simulate the proposed approach. The case study is about a cross-organisational business process. Section 5 summarises the paper and introduces future research.

II. THEORETICAL BACKGROUND

This section presents theoretical background of this paper. Indeed, we will present existing BPMN extension and their limitations. Also, we will identify the Thinging Machine mechanism and its merits to be used.

A. BPMN Basics

BPMN defines a Business Process Diagram (BPD), which is based on a flowcharting technique tailored for creating graphical models of business process operations. A Business Process Model, then, is a network of graphical objects, which are activities (i.e., work) and the flow controls that define their order of performance (Chis & Ghiran, 2022; Lapeña *et. al.,* 2022; Strutzenberger *et al.,* 2021).

A BPD is made up of a set of graphical elements. These elements enable the easy development of simple diagrams that will look familiar to most business analysts (e.g., a flowchart diagram). The elements were chosen to be distinguishable from each other and to utilise shapes that are familiar to most modelers. For example, activities are rectangles and decisions are diamonds. It should be emphasised that one of the drivers for the development of BPMN is to create a simple mechanism for creating business process models, while at the same time being able to handle the complexity inherent to business processes. The approach taken to handle these two conflicting requirements was to organise 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 they 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 (Bocciarelli, 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

Thinging 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.

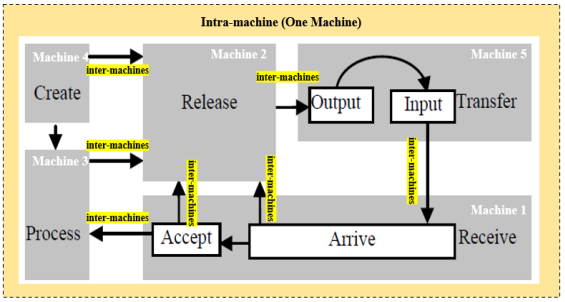


Figure 1. Thinging Machine overview (static and dynamic representations)

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_componemts 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.

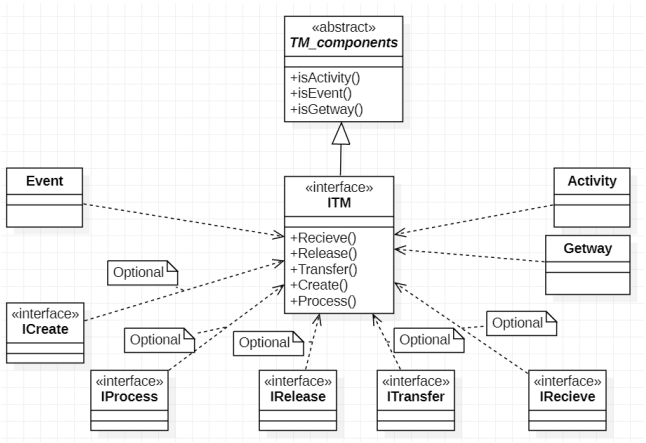
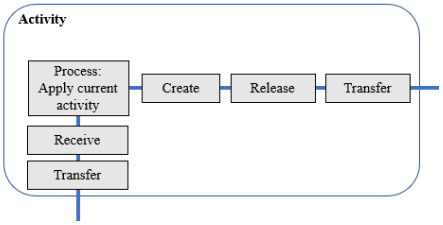
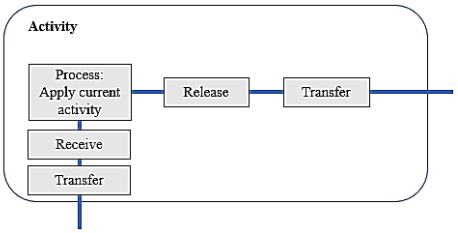
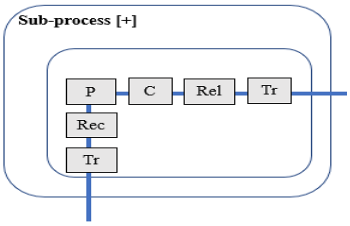
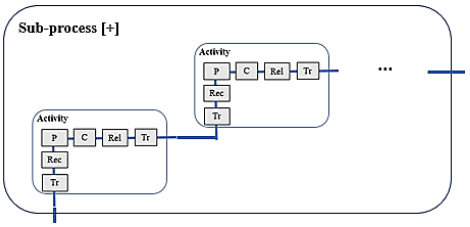
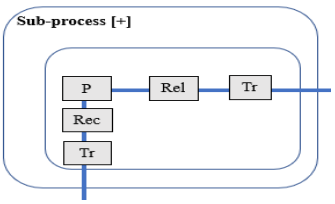
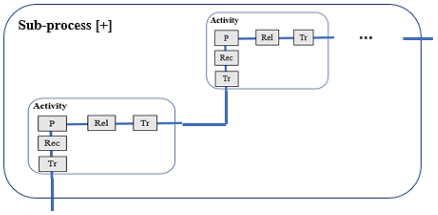
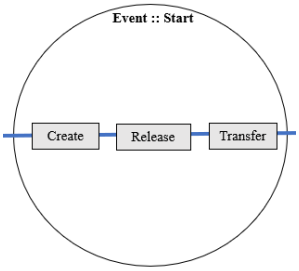
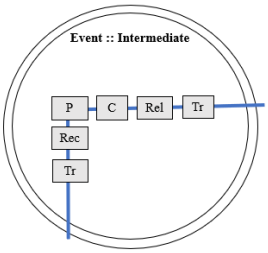
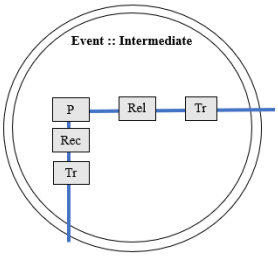


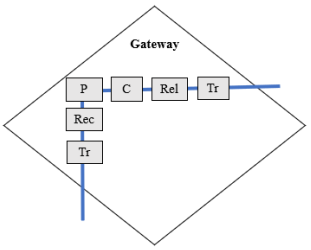
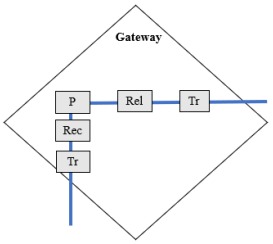
Figure 2. TM4BPMN meta-model

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.

Table 1. TM4BPMN components

BPMN components	**TM4BPMN components (high-level of abstraction)** **C: Create - P: Process – Rel: Release – T: Transfer – R: Receive**	
Activity (all kind)	Resulting new thing: 	Maintain the same thing: 
Sub-process (all kind)	One Activity (Resulting new thing):  Different Activities (Resulting new thing): 	One Activity (Maintaining the same thing):  Different Activities (Maintaining the same thing): 
Event (start-intermediate)	Start (Resulting new thing): 	Intermediate (Maintaining the same thing):  Intermediate (Maintaining the same thing): 

Gateway (all kind)	Resulting New thing: 	Maintain the same thing: 

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.

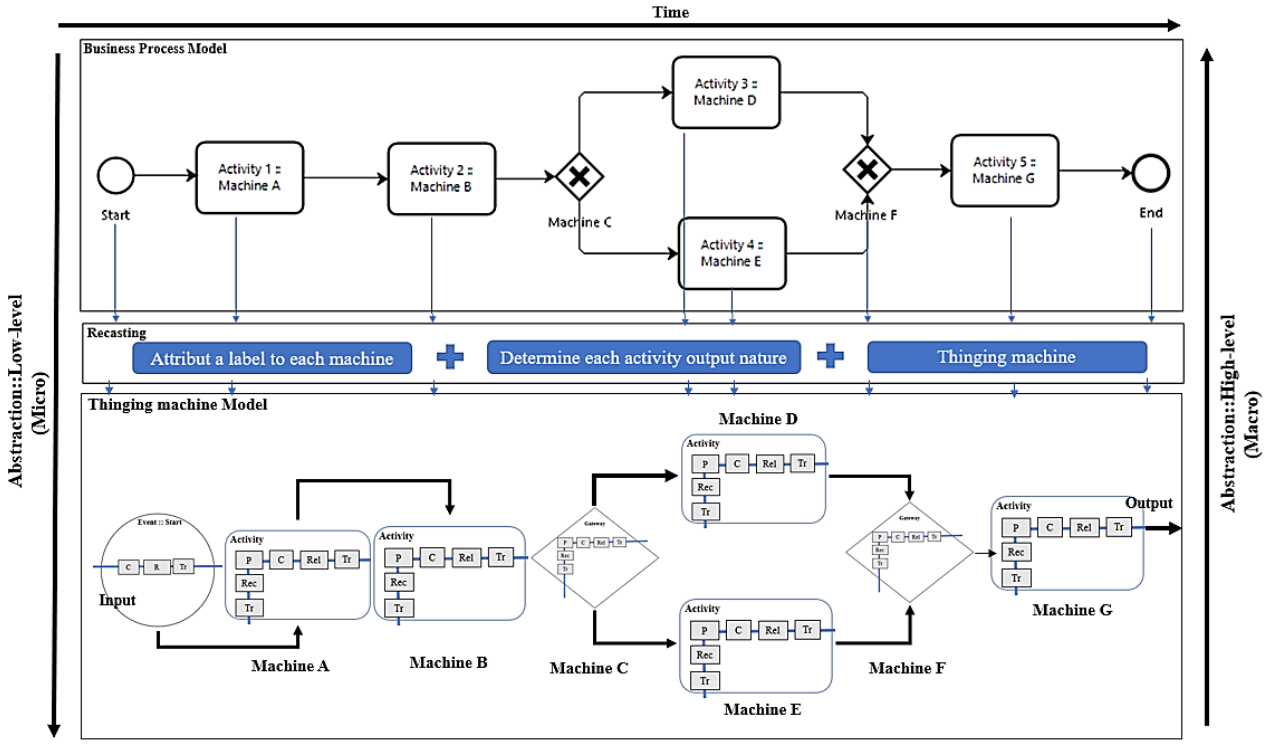


Figure 3. TM4BPMN recasting basic scenario

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.

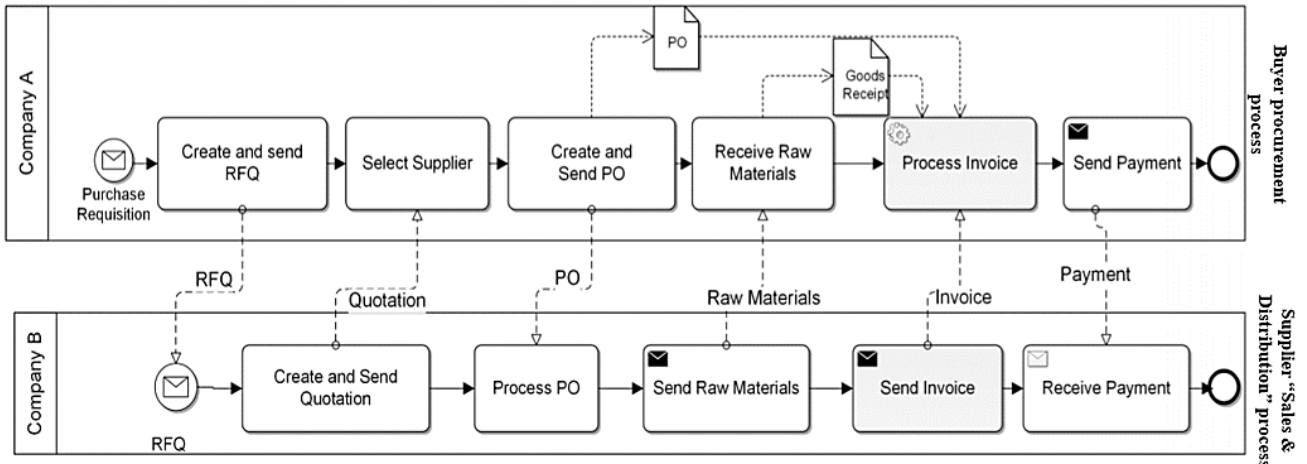


Figure 4. Cross-organisational Business Process (low-level of abstraction)

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 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).

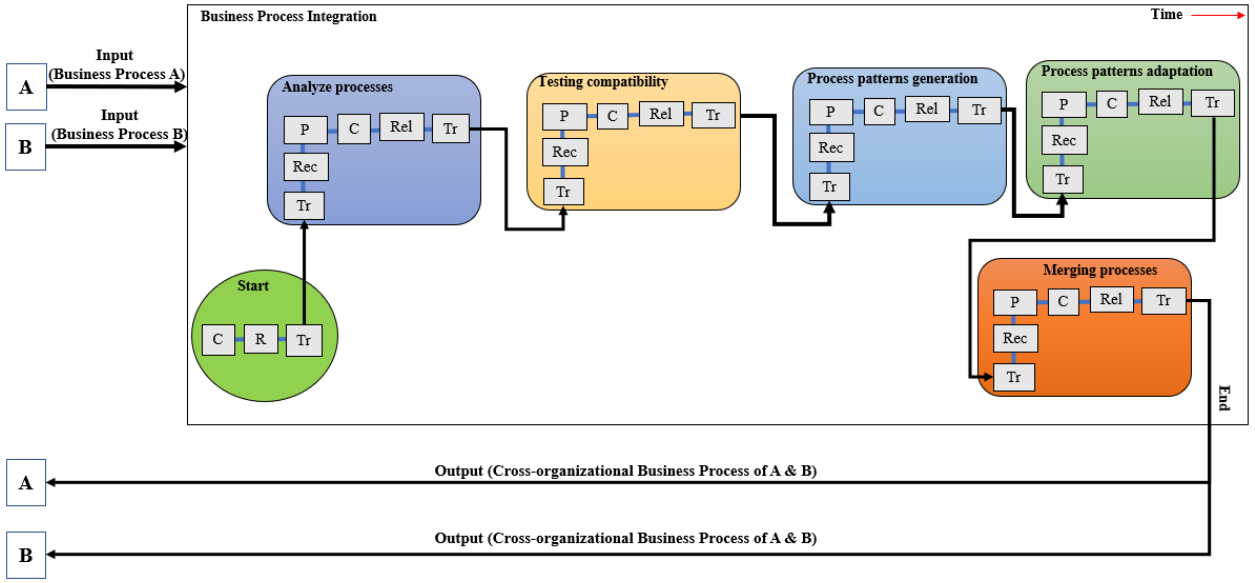


Figure 5. Cross-organisational Business Process using TM4BPMN extension

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

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