A Method of Model Transformation in MDA Approach from E3value Model to BPMN2 Diagrams in CIM Level

Nassim Kharmoum, Soumia Ziti, Yassine Rhazali, and Omary Fouzia

Abstract—**The model transformation has become a big defiance in the Model-Driven Architecture (MDA) approach. For that, the Object Management Group (OMG) aims at defining a normative framework for this approach by proposing three abstraction levels; CIM (the higher level), PIM (the average level) and PSM (the lower level). In this paper, we focus on the construction of the CIM level, which is considered as an important and most complex level. Our challenge is to produce a consistent CIM level for the e-business information system, by proposing our disciplined model-driven approach based method, transforming the E3value model to BPMN diagrams automatically. Therefore, the E3value model represents the Business Value Model, whereas, the BPMN diagrams express the new version of the Business Process Model and notation diagrams and are represented by the BPMN Conversation diagram, BPMN Choreography diagram, and BPMN Collaboration diagram. For our proposal, the transformation is done automatically using the Atlas Transformation Language (ATL).**

Index Terms—**Model-Driven Engineering, Model Driven Architecture, Computation Independent Model, Model transformation, Automatic transformation, Meta-model, E3value, Business process model and notation, Business Value Model.**

I. Introduction

Nowadays, the model transformation has become a big challenge in the field of the software industry to ensure competitiveness, which is growing in a very exponential manner. To meet this need, the Object Management Group (OMG) has specified and standardized Model-Driven Architecture (MDA) [1] approach for the new software engineering paradigm Model-Driven Engineering (MDE) [2], considering the model as the main entity in the software systems development process [3]. This approach facilitates the development process [4], passing from an abstraction level to another, via the transformation models key. For that, the OMG offers for this approach three abstraction levels, which are CIM, PIM, and PSM.

According to the MDA specification, CIM (Computation Independent Model) is the higher level of abstraction, which presents requirements and business process models, without taking into consideration the technical or the system implementation. Whereas PIM (Platform Independent Model) shows the average level of abstraction; models of this level are platform independent, which means that the models form an abstract design without knowing any implementation or technical details. However, PSM (Platform Specific Model) or what can be called the model of the code is directly related to the platform execution, it determines features following the rules of a particular programming language [5], and is considered as the low level of abstraction.

In this contribution, we will shed more light on the highest abstraction level, which is CIM because we consider it as an important and at the same time the most complex level [6], [7]. On the one hand, there are no defined standards for the CIM modeling level [7], [8]; and on the other hand, each change in this level influences all the other levels PIM and PSM [7], [8], also, the CIM level constitutes the requirements definition, Business Processes modeling, and gives us a systemic view of the future project [6], [9]. Thus, one of our goals is to simplify and structure our proposed CIM level, to model it and facilitate bridging the gap between the different perspectives, such as Business Value and Business Process perspectives [10] in an automatic way.

For this, our contribution and challenge in this work is to propose a disciplined method based on the MDA approach, in order to build a consistent CIM level for e-business information systems [11], which contains as mentioned in [8]; a correct and complete Business Value and Business Process Models, ensure traceability between them [12], and automation of all its transformations. So, The Business Value Model that presents the source model will be represented by the E3value model [13], which is the value-based requirements engineering [13], [14], and presents the notation to model and unify the e-business models from a value point of view, by defining how the economic value is created, exchanged and consumed within a network of actors [11]. In addition to this, the Business Value Model makes models more comprehensible by the following stakeholders; "Business Executives" and "Business Value Analysts". Furthermore, the Business Process Model generated automatically will be presented by the three diagrams of the BPMN [15], [16] the second version, which are BPMN Conversation diagram, BPMN Choreography diagram, and BPMN Collaboration diagram. We chose the BPMN models, seen as they are the business process modeling standard for OMG [15], these diagrams are typically created by "Business Process Analysts" to describe and better understand the related business processes environment that the future system will use [17].

Manuscript received April 04, 2019; revised May 23, 2019.

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So our method will allow stakeholders who do not know about business processes creation to generate their business processes models.

In our method, model transformation is automatically done using ATL (ATLAS Transformation Language) [18]. The ATL is based on the following OMG standards; like MOF (Meta Object Facility) [19], XMI (XML Metadata Interchange) [20] and OCL (Object Constraint Language) [21], which will allow us to accelerate the development of e-Business information systems process by reducing time, effort and therefore decreasing the cost to ensure competitiveness in the software industry.

The rest of the paper is structured as follows. Next section shows the related work using the chosen models in our method. Later, we describe our proposed method, present the source and the target meta-models, and list transformation rules used in our method. After that, we present a case study illustrating our method. Then, we analyze and discuss all the obtained results. Finally, we conclude by specifying our ongoing work.

II. Related Work

This section surveys the various work done over the last decade that uses the chosen models in our method, especially the E3value model presenting the Business Value Model and the BPMN models diagrams forming the Business Process Model, and sheds more light on the construction of the CIM level and its transformations, based on different approaches. Unfortunately, few methods focus on the CIM level construction, based on the Business Process modeling and the requirements definition, but we managed to detect a number of studies done in this regard.

In [7], Bousetta et al. built the CIM level with three views, which are functional, behavioral and static views of the system based on BPM (Business Process Model). Starting by defining the BPM High level, they detailed them to have the BPM Low level. However, the generated PIM level is formed by the following UML models [22]; Class diagram, Domain diagram and Sequence diagram of External Systems behavior.

Li et al. [8] proposed an automatic refinement of a multi CIM level modeling approach, called GSP modeling, based on the step-by-step transformations. Starting with the "Goal model" that will be transformed into "Scenario model" and the resulting model (Scenario model) are transformed to "Process model". This approach used the QVT transformation language [23].

Pijpers et al., in their e3transition approach [17], started with the E3value model that presents the Business Value Models of a value web, to reach the Process Models of the same value web, through the e3transition models.

Using BRs Filtering Method for Transforming Pre-CIM to CIM in MDA Approach is proposed by Addamssiri et al. in [24]. They automatically obtained the CIM level modeled through the BPMN model, from the Pre-CIM level presented by the Semantics of Business Vocabulary and Rules (SBVR) [25], using QVT transformation language.

In [26], Skersys et al. used an algorithm to integrate the Semantics of Business Vocabulary and Rules (SBVR) to the BPMN Business Process Model, in order to reinforce the CIM level.

Besides, enhancement of the Business Modeling Ontology (BMO) [27] proposed by Schuster and Motal [28] in their approach, is about translating the E3value notation into a REA-stereotyped [29] UML class diagram, applying their own mapping rules.

In [30] Fatemi et al. used a graph transformation tool (Groove) [31], to transform the E3value model (business value model) into the Coordination process Model.

A semi-formal transformation of securing business processes is proposed by Rodríguez et al. [32], where they started by a CIM to CIM transformation from the BPMN to Activity diagram UML in order to build the Business Process Secure (BPSec), after that they applied the CIM to PIM transformation to generate both the class diagram and use case diagram.

A New Method for Generating CIM with Business and Requirement Models is proposed by Sharifi and Mohsenzadeh [33] in order to cover both aspects of CIM. They included business model and requirements model using artefacts and concepts of RUP [34] methodology.

Aligning the business services obtained in a business value model with e-services, based on the MDA approach. Is proposed by Zdravkovic and Ilayperuma [35] in order to transform CIM to PIM models. The CIM level based on business value models using REA framework and OeBTO (Open-edi Business Transaction Ontology) [36] to create a service-centric. However, after applying the proposed mapping rules, the PIM level presented by the UML-based system model; producing both the static and behavioral specifications of the e-services.

Kherraf et al. [37] used patterns and archetypes for their transformations method; they constructed their CIM level based on the business process and requirements. The activity diagram and use case diagram presented business processes, while the system requirement contains a detailed activity diagram. However, the PIM level had the class diagram and the components diagram.

De Castro et al. in [38] applied a semi-automatic CIM-to-PIM model transformation for the service-oriented development of information systems. In the CIM level, they modeled the business view using both the BPMN model and the E3vlaue model. Whereas, after the semi-automatic transformation using ATL language, the generated PIM level is structured by the use case diagrams (use case diagram and extended use case diagram) and by the UML activity diagrams (process model Service and Service composition model).

Using a UML profile for modeling data warehouse requirements in CIM level is suggested by El Beggar et al. [39]. They chose to model the initiative view of system requirements based on GoalCases, and the analytical view of the system using SGAP (Strategic Goal Analysis Process) in order to get an SVBR structured English to ensure the definition of the data warehouse requirements for the CIM level, in a semi-automatic way.

After citing and overviewing the different work done, we notice for the CIM level creation manner that all the work uses a business process graphical representation, which is recommended by the MDA approach. However, for the requirements definition, some work uses non-graphical representation (e.g., textual representation), and there are other

methods that the requirements definition is no longer figured in their work. Besides, we have some methods that generate its models in a non-automatic way using human language. Other methods generate its models in a semi-automatic way.

So, in this paper, we propose a method that automatically generates models using a business process graphical representation from a model that has requirements graphical representation since most of these studies approaches do not meet our proposal. Moreover, the following section will take a closer look at our proposed method.

III. Our proposal

Our proposal is based on the Model Driven Architecture (MDA) approach, which aims to refine the CIM level (the higher level of abstraction) for e-business information systems, that we can consider it as an important and at the same time the most complex level [6], [7]. Furthermore, the CIM level integrates the requirements definition, Business Processes, as well as the systemic view of the future platform. We stress the fact that our proposal results from our last analytical studies [40]–[42].

Moreover, our method (Figure 1) focuses on the "Business View" by automating the transition from the "Business Value Model" to "Business Process Model" for the e-business information systems. The Business Value Model presents our source model, which is modeled by the E3value model. However, the target Business Process Model is composed of the following BPMN diagrams; Conversation diagram, Choreography diagram, and Collaboration diagram, which are the new diagrams of the OMG standard for the second BPMN version.

The aim is to have a consistent CIM level [11] that contains a correct and complete E3value model and BPMN diagrams and ensure traceability between them [12]. Thus, our objective is to use the models of our method as a base for the system's understanding, and facilitating communication between the following e-business stakeholders; "Business executives", "Business Value Analysts" and "Business Process Analysts". Also, to complete the development process of our e-business information system by generating all other abstraction levels.

To illustrate our proposal according to the MDA approach, Figure 2 presents the transformation process of our method. The first step of our method process is the definition of our source E3value meta-model. Indeed, the model instantiation since this meta-model presents the value aspect of the "Business Model". Then, the second step is to determine the targets BPMN meta-models; which aim to present the higher abstraction level of the "Business Process". The third step is about specifying the constraints during the source model construction. The fourth step aims to determine the set of transformation and mapping rules between the "Business Value" model and the "Business Process" models which are implemented via ATL transformation language. However, all models must be conformed to its meta-models.

A. Source E3value meta-model

The purpose of meta-models creation is to create and generate correct models and to perform automated model transformations [32]. So, this part unveils our proposed E3value meta-model (Figure 3(a)), describing the structure that any source model of our method must conform to.

Our E3value meta-model consists of the following elements that are mostly extracted since [13], [43], [44]; which are proposed by Gordijn et al.:

- «Actor»: an independent economic entity may be a producer or consumer of the proposed economic values. We can distinguish two types of actors «Elementary Actor»: presents an individual actor and «Market Segment»: presents a set of actors that share common properties;
- «Value Object»: is the economic value exchanged by the «Actors» which can be good, service, experience, or money;
- «Value Port»: An actor that provides «Value Objects» via «Port Out» or requests them via «Port In» «Value Objects» to or from other «Actors». The «Port Out» and «Port In» are used to extend «Value Port»;
- «Value interface»: groups several «Value Ports» and showing economic reciprocity;
- «Value Exchange»: connects two «Value Ports» to exchange potential «Value Objects». For our meta-model, the «Value Exchange» can have type «request» or «response»;
- «Value Activity»: presents one or more operational activities that an «Actor» can process in order to yield a profit;
- «Value Transaction»: groups a set of «Value Exchanges» that participate in the same economic transaction;
- «Dependency Element»: various kinds exist, «Element AND» and «Element OR» these two elements accept as behavior: «Join», «Fork» or both «Fork_Join». We also have «Stimulus Element» that can be «Stimulus Start» or «Stimulus End»;
- «Connect Element»: connects all «Dependency Elements» between them or with «Value interface» by specifying the source and target for each «Connect Element»;
- «Comment»: used to add a comment or a note for all the elements mentioned above;
- Finally, to rearrange our E3value meta-model, all elements are grouped in «E3valueModel» which are all of the type «E3valueObject», and all its instances are identified by the «Name» attribute.

So, the source model creation will conform to our E3value meta-model, which describes the manner that economic value is created, exchanged, and consumed in a network of several actors.

B. Target BPMN meta-models

This part unveils our proposed BPMN meta-models (Figure 3(b), Figure 3(c) and Figure 3(d)), describing the structure that any target model of our method must conform to. The BPMN diagrams are generated automatically from the E3value source model, which describes and exchanges internal business procedures in a standard way.

Our BPMN meta-models elements are extracted from [15] which are proposed by OMG.

1) BPMN-Conversation meta-model: The generated diagram conforms to the BPMN-Conversation meta-model (Figure 3(b)), which is introduced in BPMN 2.0, its purpose

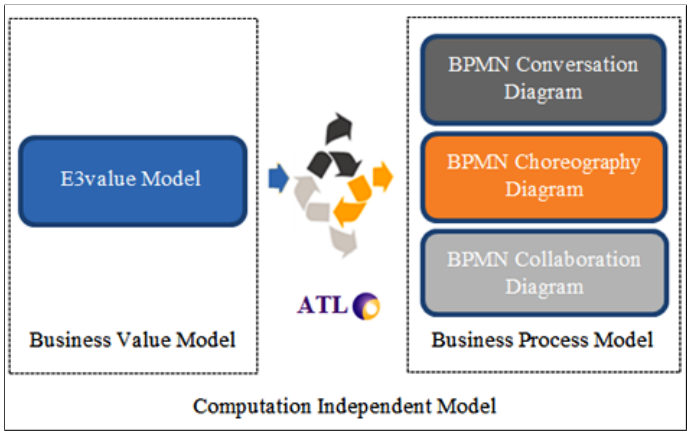

Fig. 1: Our proposed method

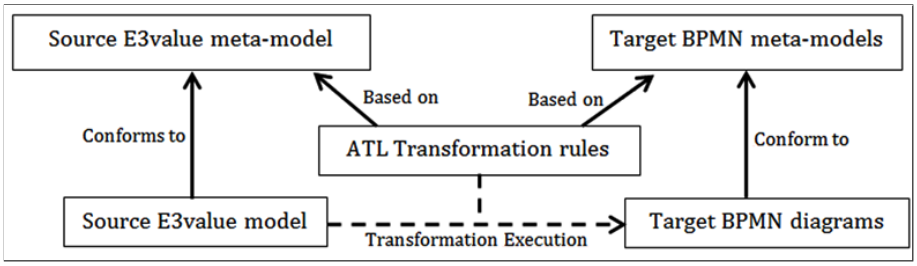

Fig. 2: The Transformation process of our proposed method

is to give an overview of the partners involved in a business model, and its conversations. So, the meta-model consists of the following elements:

- «Participant»: represents a partner entity in a process, such as people, organizations, or devices. It can be a specific partner entity or a set of similar partners based on the attribute «isParticipantMultiplicity»;
- «Conversation»: represent a set of «Messages Flow» exchanged between «Pools» in the BPMN-Collaboration diagram, and it can involve two or more «Participants». We have two sub-elements: «Sub Conversation» used for the devised «Conversations», and «Call Conversation» used for the reused «Conversations»;
- «Annotation»: used to add a note to all the elements mentioned above;
- «Connection»: We have two sub-elements: «Conversation Link» and «Association»;
- «Conversation Link»: used to connect «Conversations» to and from «Participants»;
- «Association»: connects all the objects mentioned above with its «Annotations»;
- Finally, to rearrange our BPMN-Conversation meta-model, all elements are grouped in «Conversation-Model» which are all of the type «ConversationObject», and all its instances are identified by the «Name» attribute.

2) BPMN-Choreography meta-model: The generated Choreography diagram is also new in BPMN 2.0; its goal is to answer the question: how do business model participants exchange messages to coordinate their interactions?

Without a doubt, the generated diagram conforms to the BPMN- Choreography meta-model (Figure 3(c)). So, the meta-model consists of the following elements:

- «Choreography»: presents a processing unit to exchange information between «Participants»;
- «Gateway»: control the orchestration flow in a business process. A «Gateway» can be «Inclusive», «Exclusive», «Parallel», «Event-Based», or «Complex», also, it can have the following behaviors: «Fork», «Join», or both the «Fork_Join»;
- «Participant»: is defined as the BPMN-Conversation meta-model «Participant», we add the attribute «isInitiatingParticipant» to mention that the participant initials «Choreography» Activity;
- «Event»: describes an action that happens during the process execution. It can be «Start», «End» or «Intermediate», and every «Event» type has a marker that expresses its behavior. We add «Type» attribute for «Intermediate Event» to differentiate between catch and throw «Events»;
- «Message»: represents the communication contents between «Participants»;
- «Annotation»: is defined as the BPMN-Conversation meta-model «Annotation»;
- «Connection»: We have two sub-elements: «Sequence Flow» and «Association»;
- «Sequence Flow»: used to connect «Choreography Objects»;
- «Association»: is defined as the BPMN-Conversation meta-model «Connection»;
- Finally, to rearrange our BPMN-Choreography meta-model, all elements are grouped in «Choreography-Model» which are all of the type «ChoreographyObject», and all its instances are identified by the «Name» attribute.

3) BPMN-Collaboration meta-model: The obtained Collaboration diagram presents a higher level of process abstraction, and it focuses on the interactions between all business

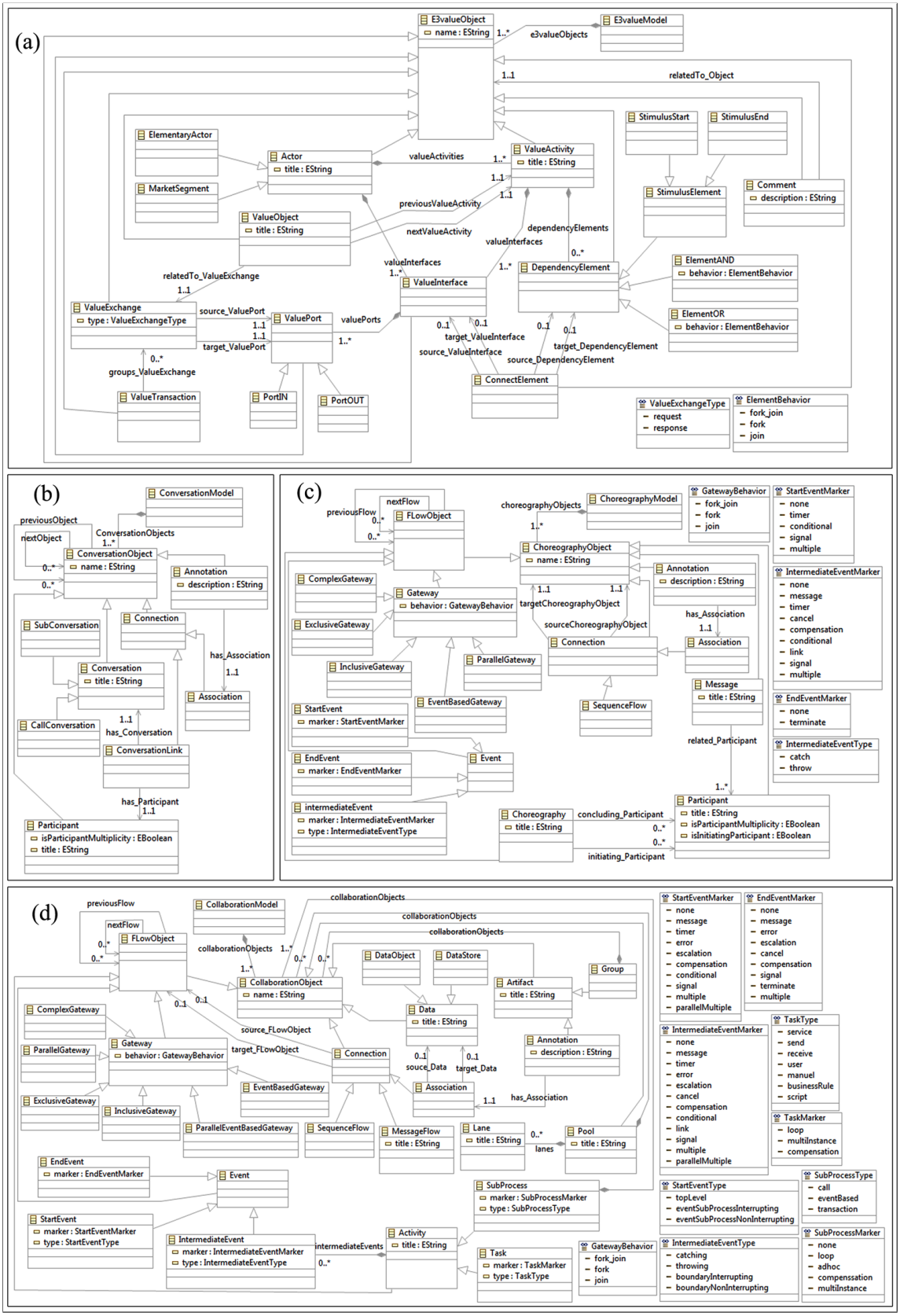

Fig. 3: Our meta-models: (a) E3value meta-model, (b) BPMN-Conversation meta-model, (c) BPMN-Choreography meta-model, (d) BPMN-Collaboration meta-model

processes models elements.

The present BPMN-Collaboration meta-model (Figure 3(d)), describes the set of elements, composing the collaboration diagram. So, the meta-model consists of the following elements:

- «Flow Object»: are «Activities», «Gateways», and «Events», which are the main elements to define the business process behavior;
- «Activity»: is a unit of work performed during the process execution, that has a clearly defined beginning and end, maybe atomic «Task» or «Sub Process», and this «Activity» may have multiple «Types» and «Markers» explaining its behaviors;
- «Gateway»: is defined as the BPMN- Conversation meta-model «Gateway», the specific in this meta-model is that a «Gateway» can also be a «Parallel Event-Based»;
- «Event»: is defined as the BPMN- Conversation meta-model «Event», but here we have more «Markers», and we can also specify the «Start Events» type;
- «Pool»: is the «Participants» graphical representation in a collaboration diagram;
- «Lane»: is a sub-partition within a «Pool» in the collaboration diagram;
- «Data»: can be «Data Object» that models data in the process flow, or «Data Store» that allows «Activities» to retrieve or update its stored information;
- «Artifact»: used to cover additional information in a process, we can have «Groups» and «Annotations»;
- «Group»: group elements in a business process diagram to mention that they have some common characteristics;
- «Annotation»: is defined as the BPMN-Conversation meta-model «Annotation»;
- «Connection»: We have three sub-elements: «Sequence Flow», «Message Flow» and «Association»;
- «Sequence Flow»: used to connect «Collaboration Objects» in the same «Pool»;
- «Message Flow»: used to connect «Collaboration Objects» indifferent «Pools»;
- «Association»: connects all the objects mentioned above with its «Annotations» and with its «Data»;
- Finally, to rearrange our BPMN-Collaboration meta-model, all elements are grouped in «collaboration-Model» which are all of the type «CollaborationObject», and all its instances are identified by the «Name» attribute.

C. Source E3value model construction rules

For our proposed method, the only constraint to create a correct source model (E3value model) is to respect its meta-model that is previously explained and presented in Figure 3(a).

D. Transformation rules

In order to bridge the gap between the e-business perspectives automatically, this part lists the E3value model transformation rules toward the three BPMN diagrams based on its meta-models.

Moreover, after presenting all E3value and BPMN models elements, and after analyzing some chaining guidelines from Business to Process Models [45]; we found compatibility between these models elements even though they present different perspectives. So, for more details; Figure 4(a), Figure 5(a) and Figure 6(a) show graphically a set of transformation rules proposed in our method via simple diagrams, while, Figure 4(b), Figure 5(b) and Figure 6(b) show the set of transformation rules via ATL transformation language.

So, the continuation of this part details the transformation rules of each generated BPMN diagram.

1) From E3value model to BPMN-Conversation diagram: Figure 4(a) presents Graphical transformation rules and Figure 4(b) shows the ATL transformation rules; from E3value model to BPMN-Conversation diagram in order to generate all conversations involved in a business model and their partners. In this figure, we have four transformation rules:

- Rule 1: presents the transformation from «Actor» to «Participant»; the «Actor» can be «Elementary Actor» or «Market Segment». The «Participant» has the same «name» and «title» as «Actor». Also, we call helper function «isActorMultiplicity()» to fix the «Participant» «isParticipantMultiplicity» attribute (if «Actor» is a «Market Segment» the «isActorMultiplicity()» value will be «true», else it will be «false»);
- Rule 2: allows transforming the «Value Object» response that relates «Actors», to «Conversation» And «Conversation Links». In this case, we generate one «Conversation» that has the same «name» and «title» as «Value Object», and two «Conversation Links», which we call «previous conversation link» and «next conversation link» for each selected «Value Object», that have in addition to the «name» attributes «has_Conversation» (presents the current «Conversation») and «has_Participant» (presents the previous «Participant» for the «previous conversation link» and presents the next «Participant» for the «next conversation link»);
- Rule 3: transforms «Comment» to «Annotation» and «Association». The generated «Annotation» has the same «name» and «description» as «Comment», while the generated «Association» has the attributes «previous object» (presents the current «Annotation») and «next object» (presents the «Comment» related object);
- Rule 4: generates the «Conversation Model» from «E3value Model». The generated model groups all Figure 4(b) generated elements, in our case we have: «Participant», «Conversation», «Conversation Links», «Annotation» and «Association».

2) From E3value model to BPMN-Choreography diagram: Figure 5(a) presents Graphical transformation rules and Figure 5(b) shows the ATL transformation rules; from E3value model to BPMN-Choreography diagram in order to show the exchanged messages between participants to coordinate its interactions. In this figure we have four transformation rules:

- Rule 5: as ATL Rule1 (Figure 4(b)), this rule allows transforming «Actor» to «Participant», using the same ATL code, but in the choreography context;
- Rule 6: on the one hand, we transform «Value Object» to «Choreography», «Messages» and «Associations». In this case, we generate one «Choreography» (that has the «name» and «title» as «Value Object» with

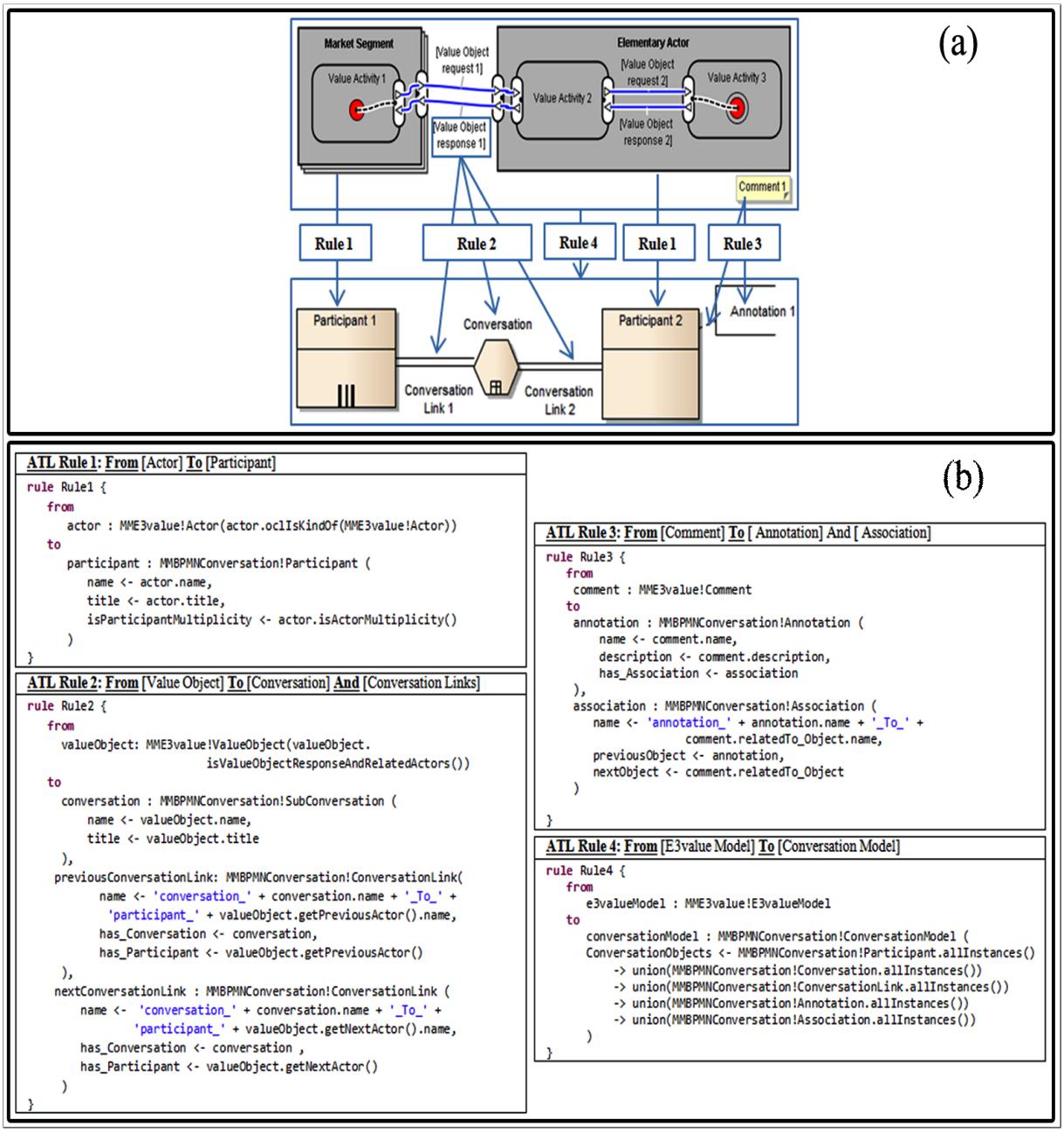

Fig. 4: Transformation rules from E3value model to BPMN-Conversation diagram
(a) Graphical transformation rules, (b) ATL Transformation rules

prefix «treatment», the attribute «initiating_Participant» and «concluding_Participant» are related to the next and previous «Value Object» «Actors»). We also have two «Messages», one is the «Message Request» and the second is «Message Response» (that have both the «name» and «title» of element «Value Object» with prefix «need» for «Message Request», and «give» for «Message Response» and each «Message» is related to a «Participant» with the attribute «related_Participant»). Then we have two «Associations»: «Association Message Request» and «Association Message Response» that associate the current «Choreography» with «Message Request» and «Message Response». In the other hand, according to the «Choreography» status, the following elements: «Start Event», «End Event» and «Gateway» are generated. So, if «Choreography» is not preceded by another «Choreography», we create a new «Start Event», also if «Choreography» does not have a next «Choreography», we generate an «End Event», but if it is followed by more than one element we create a «Gateway»;

- Rule 7: as ATL Rule3 (Figure 4(b)), this rule transforms «Comment» to «Annotation» and «Association». The difference is that the generated «Association» has the attributes «source Choreography Object» (presents the current «Annotation») and «target Choreography Object» (presents the «Comment» related object);
- Rule 8: generates the « Choreography Model» from «E3value Model». The generated model groups all Figure 5(b) generated elements, in our case we have: «Participant», «Choreography», «Messages», «Associations», «Start Event», «End Event», «Gateway», «An-

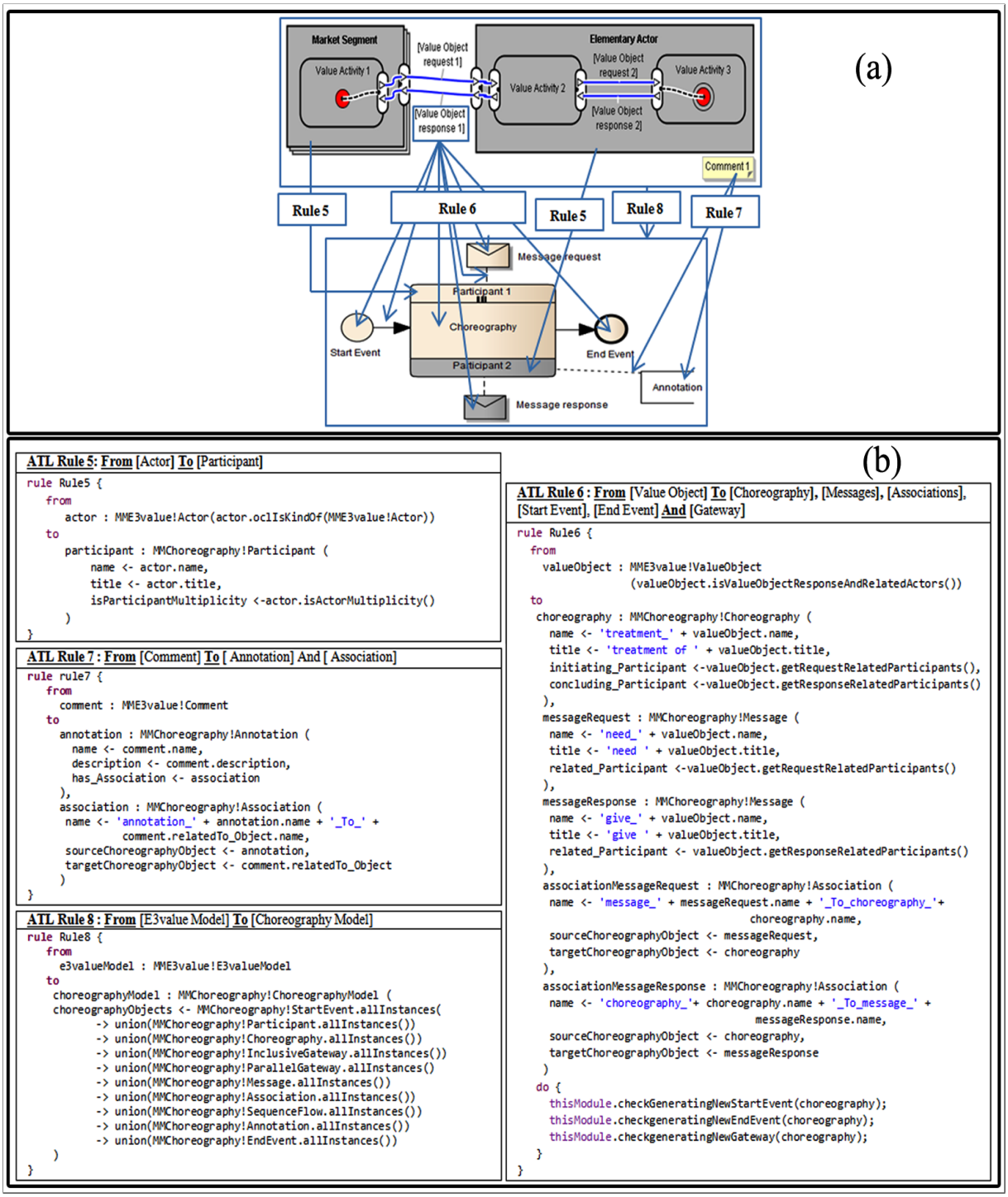

Fig. 5: Transformation rules from E3value model to BPMN-Choreography diagram
(a) Graphical transformation rules, (b) ATL Transformation rules

notation» and «Association».

3) From E3value model to BPMN-Collaboration diagram: Figure 6(a) presents Graphical transformation rules and Figure 6(b) shows the ATL transformation rules; from E3value model to BPMN-Collaboration diagram to generate all interactions between all business processes model elements. In this figure we have nine transformation rules:

- Rule 9: allows transforming «Value Activity» to «Sub-Process» with keeping the same «name» and «title»;
- Rule 10: transforms «Stimulus Start» to «Start Event» with keeping the same «name»;
- Rule 11: transforms «Stimulus End» to «End Event» with keeping the same «name»;
- Rule 12: presents the transformation from «Value Object» that relates «Actors» to «Message Flow». The attributes «source_FLowObject» and «target_FLowObject» are successively linked to the «Value Object» attributes «previousValueActivity» and «nextValueActivity», also the attributes «name» and «title» are constructed based on the attributes «source_FLowObject» and «target_FLowObject»;
- Rule 13: transforms «Value Object» that relates

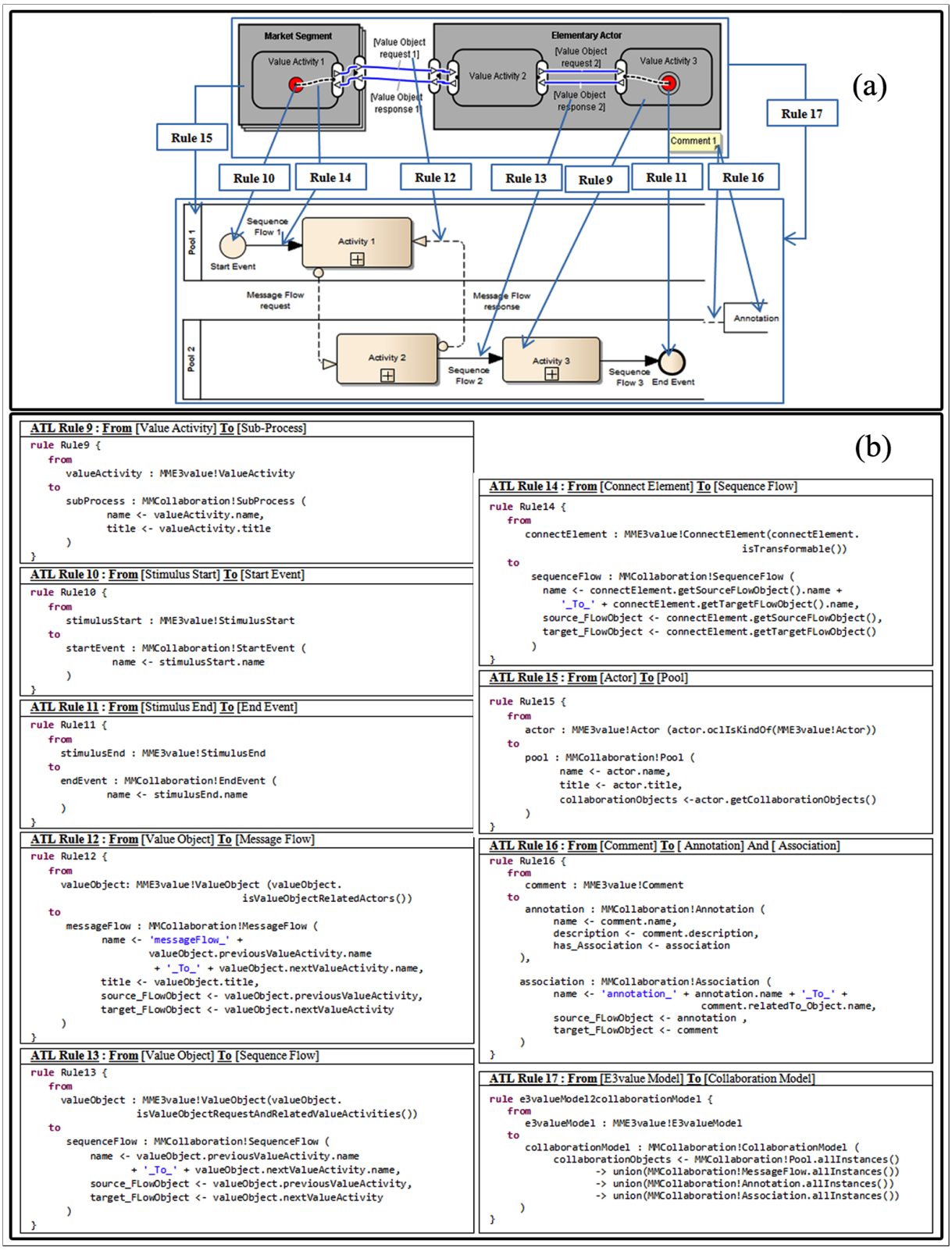

Fig. 6: Transformation rules from E3value model to BPMN- Collaboration diagram
(a) Graphical transformation rules, (b) ATL Transformation rules

«Value Activities» to «Sequence Flow». The attributes «source_FLowObject» and «target_FLowObject» are successively linked to the «Value Object» attributes «previousValueActivity» and «nextValueActivity», also, the attribute «name» is constructed based on the attributes «source_FLowObject» and «target_FLowObject»;

- Rule 14: presents the transformation from «Connect Element» to «Sequence Flow». The attributes «source_FLowObject» and «target_FLowObject» are successively generated via the helper «getSourceFLowObject()» and «getTargetFLowObject()»; the attribute «name» is constructed based on the attributes «source_FLowObject» and «target_FLowObject»;
- Rule 15: presents the transformation from «Actor» to «Pool»; the «Actor» can be «Elementary Actor» or «Market Segment». The «Pool» has the same «name» and «title» of element «Actor». Moreover, the attribute «collaborationObjects» contains all «Pool» sub-elements which are in our case «Sub-Process», «Start Event», «End Event» and «Sequence Flow»;
- Rule 16: as ATL Rule7 (Figure 5(b)), this rule transforms «Comment» to «Annotation» and «Association». The only difference is that the generated «Annotation» and «Association» are in the Collaboration context;
- Rule 17: generates the «Collaboration Model» from «E3value Model». The generated model groups all Figure 6(b) generated elements, in our case we have: «Pool» (with his sub-elements), «Message Flow», «Annotation» and «Association».

IV. Case Study

In this section, we present our theoretical case study with a practical of our «University Library management» case study transformation within «ATL Eclipse plugin», as a standard tool for transformation [46], to evaluate and exemplify the automatic generation of the BPMN models from the E3value model.

Therefore, Figure 7 structures our practical case study in three principal folders; the first for meta-models (with «.ecore» and «.ecore_diagram» extensions), the second for models (has extensions «.xmi») whereas the third folder for transformations (through extensions «.asm» and «.atl»), which presents our transformation rules. For more ergonomics, each folder contains two sub-folders, one for the source (E3value) and the second for targets (BPMN2).

To better position the Figure 7 in our proposed method. This part allows us to link each file in Figure 7 with our created and generated our method parts:

- E3value_metaModel.ecore and E3value_metaModel.ecore_diagram illustrate our E3value source meta-model (Figure 3(a));
- BPMNConversation_metaModel.ecore and BPMNConversation_metaModel.ecore_diagram illustrate our BPMN Conversation target meta-model (Figure 3(b));
- BPMNChoreography_metaModel.ecore and BPMNChoreography_metaModel.ecore_diagram illustrate our BPMN Choreography target meta-model (Figure 3(c));
- BPMNCollaboration_metaModel.ecore and BPMNCollaboration_metaModel.ecore_diagram illustrate our BPMN Collaboration target meta-model (Figure 3(d));

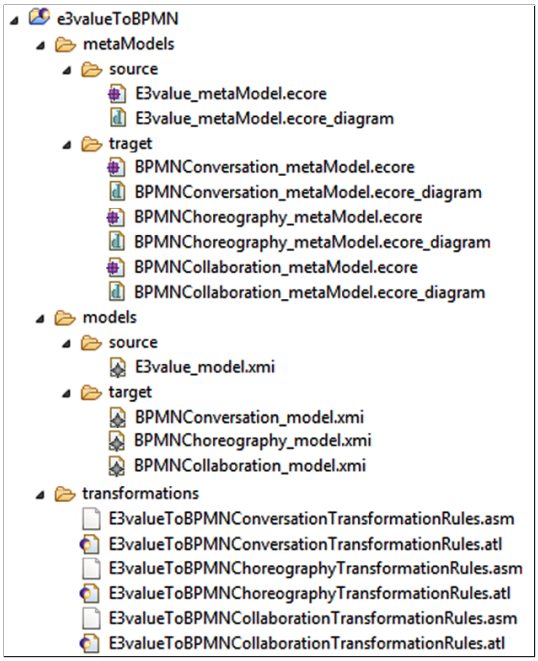

Fig. 7: Our practical case structure

- E3value_model.xmi represents our proposed E3value-source model in XMI format (Figure 8(a)), that we symbolize it graphically in Figure 9(a);
- BPMNConversation_model.xmi represents our generated BPMN Conversation model in XMI formats (Figure 8(b)), that we symbolize it graphically in Figure 9(b);
- BPMNChoreography_model.xmi represents our generated BPMN Choreography model in XMI format (Figure 8(c)), that we symbolize it graphically in Figure 9(c);
- BPMNCollaboration_model.xmi represents our generated BPMN Collaboration model in XMI format (Figure 8(d)), that we symbolize it graphically in Figure 9(d);
- E3valueToBPMNConversationTransformationRules.atl and E3valueTo BPMNConversationTransformationRules.asm present our transformation rules from the E3value model to BPMN Conversation diagram (Figure 4(b)).
- E3valueToBPMNChoreographyTransformationRules.atl and E3valueTo BPMNChoreographyTransformationRules.asm present our transformation rules from the E3value model to BPMN Choreography diagram (Figure 5(b)).
- E3valueToBPMNCollaborationTransformationRules.atl and E3valueToBPMNCollaborationTransformationRules.asm present our transformation rules from the E3value model to BPMN Collaboration diagram (Figure 6(b)).

We propose in our case study a «University Library Management» to illustrate our Business Value Model to Business Process Model transformation method. So, we have four «Actors»: «Library», «Patrons», «Publishing Companies», and «Research Databases». First, «Patrons» can access «Library» resources, such as «Books» and «Online Research Articles», by paying fees for the desired access. From its side, the «Library» is always attentive to the «Patron's» needs; it lends «Books», offers the browse «Research Articles» possibility if the requested document exists, if not, it manages its needs by expressing them to these suppliers who are «Publishing Companies» to offer the requested «Books» and «Research Databases» to give «Databases»

desired access. Moreover, the purchase of each «Book» or «Research Database» access automatically requires fees.

So the rest of the section illustrates the «University Library Management» case study models.

A. Business Value Model proposal

In the source model, we focus on the E3value model presenting the business value model of our case study in XMI format (Figure 8(a)). We focus on the XMI (XML Metadata Interchange) format because it is a standard and trademark from the OMG, also, it allows defining, interchanging, manipulating and integration XML data and objects [47]. In addition to this, we symbolize our XMI model graphically see Figure 9(a).

The «Actors» can identify with «Elementary Actors» like «library» or can be «Market Segments» such as «patrons», «publishing companies», and «research databases». Each «Actor» can have at least one «Value Activity», in our model the «patrons» can «access library resources», the «library» has «lend books», «browsing research articles» and «managing library needs», the «publishing companies» have «sell books», and «research databases» have «sell access to research databases». The «Value Objects» can be a request like «access to books registration fees», «online access to research articles registration fees», «books needs», «research articles needs», «purchasing books fees» and «research databases subscription fees». Furthermore, «Value Objects» can be a response such as «access to books», «online access to research articles», «access to available books», «access to available research articles», «books» and «access to research databases».

For a good Business Value Model understanding, the E3value model exploits «Value Exchange» in order to explain the direction of dependency paths. Those dependency paths connect E3value dependency elements, which can be «Start Stimulus», «End Stimulus», «And-Join», «And-Fork», «Or-Join» or «Or-Fork».

B. Generated Business Process Models

We benefit from the set of transformations previously explained and from the set of previously defined elements that constitute our source and target models. The rest of this part will exemplify all our generated models.

Thus, all targets models are presented by three BMPN diagrams. Figure 8(b) represents the BPMN Conversation diagram in XMI format, that we symbolize it graphically in Figure 9(b). This diagram presents the first transformation result from the E3value source model. However, in this model the «Elementary Actor»: «library» and the following «Market Segments»: «patrons», «publishing companies» and «research databases» are transformed to «Participants», in order to present our partners' entities in the conversation process context. Then, to present messages and conversations between these partners, the «Value objects» that have type responses and connect «Actors» are transformed to «Conversations», so, in our case we have the conversations; «access to book», «online access to research articles», «books» and «access to research databases». Thus, every «Conversation» has two «Conversation Links», in order to link all process partners with its conversations.

Figure 8(c) shows the second E3value transformation result in XMI format, which is the BPMN Choreography diagram that we symbolize it graphically in Figure 9(c). As the first transformation, every «Actor» is converted to a «Participant». However, the following «Choreographies»: «treatment of access to books», «treatment of online access to research articles», «treatment of books» and «treatment of access to research databases» are obtained from «Value Objects», which have responses type and connect E3value actors. Also, each «Choreography» can join multiple initiating and concluding «Participants», for example, the «Choreography»: «treatment of access to books» is connected to «Patrons» as initiating «Participants» and relates to the concluding «Participant» «library». In addition, every «Choreography» can reserve and send «Messages». In our example, the «Choreography»: «treatment of access to books» receives the «need access to books» message from the initiating «Participant»: «patrons» and send the «Message» «give access to the book» to the concluding «Participant»: «library».

This model is triggered by two «Start Events» and bounded by two «End Events». Moreover, the «Choreography Associations» and «Gateways» are used to explain the choreography path and behavior.

The last model in our transformation method is the BPMN Collaboration diagram (Figure 8(d) in XMI format), that we symbolize it graphically in Figure 9(d). The «Actors» are transformed into «Pools»: «patrons», «library», «publishing companies» and «research databases» which are the graphical representation of «Participants» in a collaboration diagram, whereas, the «Value Activities» are transformed to «Sub-Processes» in our diagram we have six «Sub-Processes»: «accessing library resources», «lending books», «browsing research articles», «managing library needs», «selling books» and «selling access to research databases» — knowing that the interaction between those «Sub-processes» is ensured by the «Sequence Flows». The «Start Stimulus» and «End Stimulus» are transformed successively into the «Start Event» and «End event»; in this example, we obtain the «Start Event» in the «patrons» «Pool» in order to trigger our process, whereas, we have the «End Event» in the «Pools» «publishing companies» and «research databases» to show the cases while the process can stop. Then, the «Message Flow» is obtained from the «Value Objects» that connect «Pools» in order to communicate other «Pools» by receiving and sending «Message Flow». E.g. «patrons» «Pool» sends «Messages Flow» «online access to research articles registration fees» and «access to books registration fees» via «Sub-process»: «accessing library resources» to the «Pool»: «library», also «library» request the received «Messages Flow» to «patrons» via «Sub-processes» «lending books» and «browsing research articles». Moreover, «library» sends and receives «Messages Flow» to and from the «Sub-process»: «publishing companies» and «research databases».

V. Analysis and Discussion

In this section, we start with the evaluation criteria construction of our proposed method, respecting several approaches and recommendations. After that, we analyze and discuss our proposed method based on an analytical survey

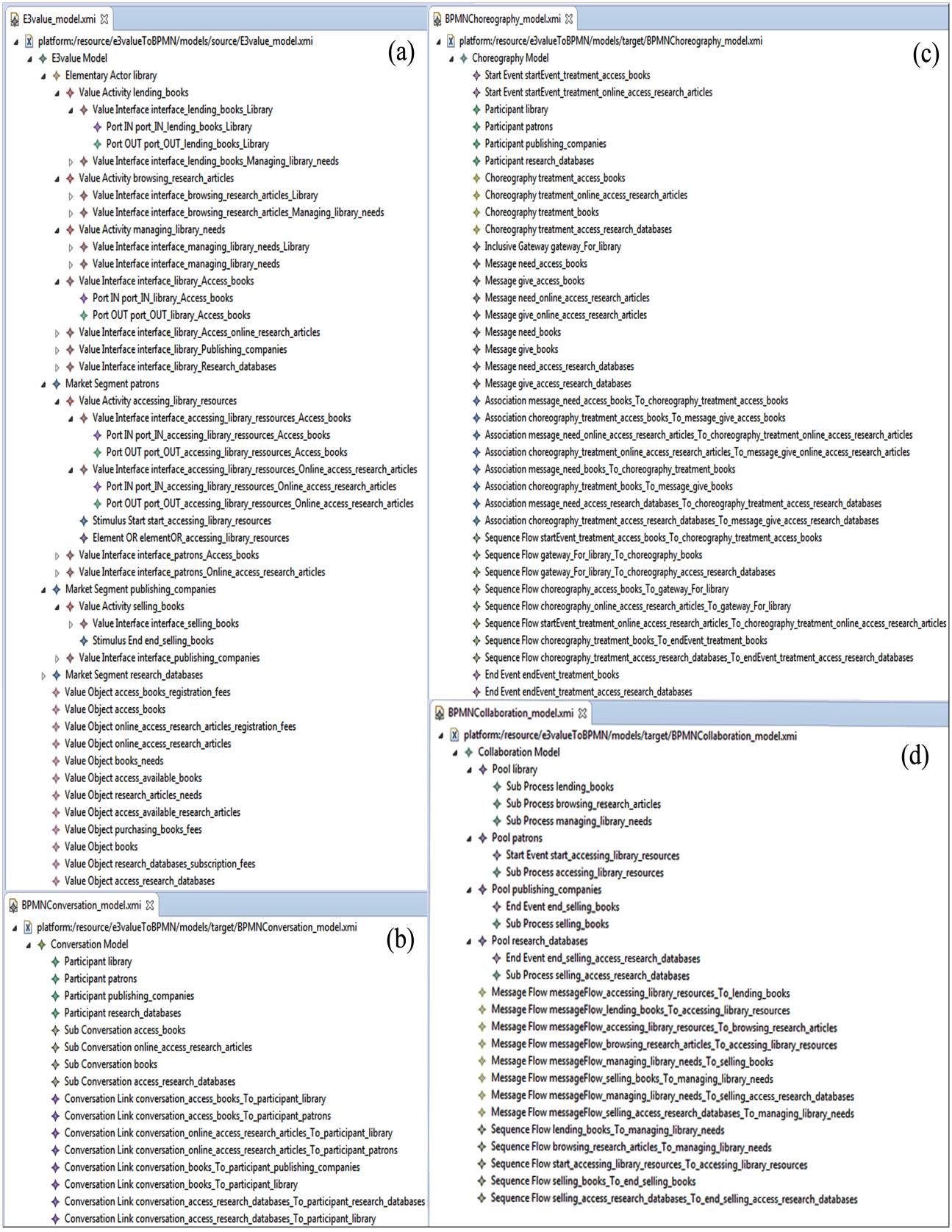

Fig. 8: (a) E3value-source XMI model format, (b) Generated BPMN-Conversation XMI models format, (c) Generated BPMN-Choreography XMI models format, (d) Generated BPMN-Collaboration XMI models format

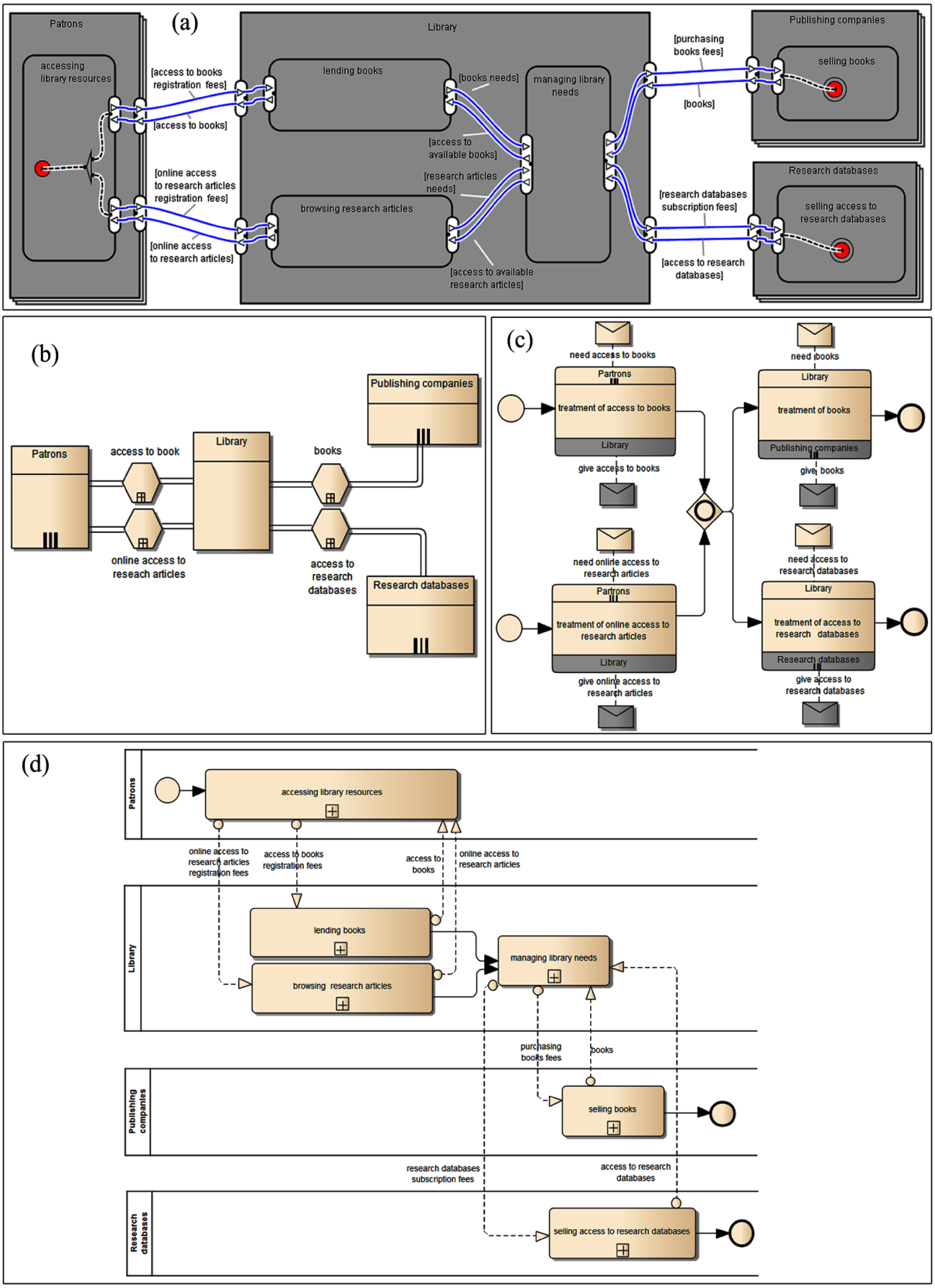

Fig. 9: Our models: (a) E3value-source model, (b) Generated BPMN-Conversation diagram, (c) Generated BPMN-Choreography diagram, (d) Generated BPMN-Collaboration diagram

of all related work studied previously in the second section using the created evaluation criteria.

A. Evaluation criteria

The evaluation criteria deal with horizontal transformation which is the transformation between models in the same abstraction level [48]; in our case we have CIM to CIM transformation. Furthermore, based on OMG recommendations [1] additional to those following work [46], [49]–[52]; we can deduce that a consistent CIM level should meet three criteria:

- CIM Criterion 1: CIM Coverage of Business Process: CIM level is considered as a glossary of business process definitions [6];
- CIM Criterion 2: CIM Coverage of Requirements: CIM level is considered as a glossary of requirements definitions [6];
- CIM Criterion 3: CIM Coverage of the graphical representation of the Business Process and Requirements (MDA approach we consider that all as a model [3].

We can also conclude that the transformation of this level respects four criteria:

- Transformation Criterion 1: transformation automation: is one of the key concepts in MDA [1], [53];
- Transformation Criterion 2: correctness of transformation rules: is the conformity of the generated model to its meta-model specification. [48], [54], [55];
- Transformation Criterion 3: completeness of transformation rules: is the corresponding of each element of the source model to an element of the target model [53], [54];
- Transformation Criterion 4: meta-models based transformation (is one of the key concepts in MDA [1], [53].

Besides, another deduction is that the evaluation approaches may also have other criteria:

- Evaluation approaches Criterion 1: Existence of an assessment methodology, which can be a theoretical case study or a practical transformation through a supporting transformation tool [56].

B. Analysis

The result of the evaluation criteria analysis is presented in Figure 10. The figure line present studied papers, while the columns show the deduced criteria.

1) CIM criteria: We start with the coverage of the Business Process criterion, we have as a result that all the methods are based on the graphical representation of this criterion, which is recommended by the OMG. Besides, we find that BPMN diagram is the most used model, and is used by approaches [7], [8], [24], [26], [32], [38] and our proposal. We also have the uses of UML activity diagram by [17], [32] and [35], plus the presence of the REA model in [28] and [35]. Supplementary to this, we find that the following models are rarely used like OeBTO (Open-edi Business Transaction Ontology) in [35], Coordination process Model in [30] which is a variant of the BPMN model and SGAP (Strategic Goal Analysis Process) in [39].

We find that some approaches do not focus on the requirements for the construction of its models like [32] and [35]. But we can discover as in our proposal that most of the studied methods use E3value model since [17], [28], [30] and [38]. We also have the uses of UML Use Case diagram by [7], [33] and [35]. Additionally, some papers like [24] and [26] do not respect the graphical representation of the requirement, but it is based on the requirements as text using the SBVR standard.

2) Transformations criteria: For the transformation criterion, in some papers there is discussion about the use of meta-models like our approach which are [8], [24], [28], [32], [35], [38] and [39]. However, most methods transform models using non-automatic way for transformation; for example, they base their work on human language like [7], [17], [28], [30], [33], [35], [35] and [38], or developing an algorithm as [26]; that makes the transformation more complex. But few papers that use an automatic way like using transformation language; QVT for [8] and [24], and the ATL our proposed method where transformations are made easier and rules are completely defined. Other papers combine between the automatic and non-automatic transformation way; which is called semi-automatic transformation like [32] and [39].

3) Evaluation approaches Criterion: All approaches are based on a case study to evaluate their proposal. However, we rely only on three papers [8], [32] and [39] with our method that use a practical case with «Eclipse», which is a standard tool for supporting transformation [36].

C. Discussion

After the analysis of the studied methods, we conclude that the paper [8] respects our evaluation criteria. The authors create their CIM level using BPMN diagram as Business Process model and relying on Goal model-GRL and Scenario model-UCM for modeling requirements. They start by defining Goal model-GRL and it transformed into Scenario model-UCM after that the resulting model transformed to BPMN process diagram, using the meta-models and QVT transformation rules. Resultantly, they focus on several models and transformations in order to achieve one single model.

Our proposal validates all evaluation criteria. Besides, our method is the unique work starting with one simple model which is E3value model (drawing requirements with graphical representation) in order to generate three business process models automatically for the OMG standard, which give several views of the business process. Also, the executions of our transformations rules are complete and correct: complete because most elements in the source model match the destination models, and correct because the generated BPMN diagrams are conformed to its meta-model; forasmuch these diagrams are generated automatically using ATL Transformation language.

Besides, we respect two distinct perspectives of the e-business information system development [11], which are the “the value viewpoint” via the E3value model, and the “the process viewpoint” with the three diagrams of the BMPM.

Finally, using our method for e-business systems will allow getting a consistent CIM-based level that contains correct and complete models and ensures traceability between them. Thus, we can use the models of our method as a base for the system’s understanding, and facilitating communication between the following e-business stakeholders; “Business executives”, “Business Value Analysts” and “Business Process

High abstraction level coverage											
Studied papers	Business Process			Requirements coverage			Transformation			Assessment Methodology	
	Coverage	Graphical representation	Representation	Coverage	Graphical representation	Representation	Coverage Meta-models	Type	Representation	Theoretical	Practical
Bousetta et al. [7]	Yes	Yes	BPMN process diagram (High & Low Levels)	Yes	Yes	UML Use Case diagram.		Human language		Case study	
Li et al. [8]	Yes	Yes	BPMN process diagram	Yes	Yes	Goal model-GRL & Scenario model-UCM	Yes	Automatic (Transformation language)	QVT	Case study	Standard tool
Pijpers and Gordijn [17]	Yes	Yes	UML activity diagram (High & Low Levels)	Yes	Yes	E3value models & E3transition models		Human language		Case study	
Addamssiri et al. [24]	Yes	Yes	BPMN process diagram	Yes		SBVR	Yes	Automatic (Transformation language)	QVT	Case study	
Skersys et al. [26]	Yes	Yes	BPMN process diagram	Yes		SBVR		Algorithm		Case study	
Schuster and Motal [28]	Yes	Yes	REA model	Yes	Yes	E3value model	Yes	Human language		Case study	
Fatemi et al. [30]	Yes	Yes	Coordination process Model	Yes	Yes	E3value model		Human language		Case study	
Rodríguez et al. [32]	Yes	Yes	BPMN-BPD & BPSec & UML Activity diagram.				Yes	Semi-Automatic (Transformation language & Human language)	QVT	Case study	Standard tool
Sharifi and Mohsenzadeh [33]	Yes	Yes	Business Use Case Model & Business Analysis Model	Yes	Yes	UML Use Case diagram		Human language		Case study	
Zdravkovic and Ilayperuma [35]	Yes	Yes	REA model & OeBTO				Yes	Human language		Case study	
Kherraf et al. [37]	Yes	Yes	UML Activity diagram	Yes	Yes	UML Use Case diagram		Human language		Case study	
De Castro et al. [38]	Yes	Yes	BPMN process diagram	Yes	Yes	E3value model	Yes	Human language		Case study	
El Beggar et al. [39]	Yes	Yes	SGAP (Strategic Goal Analysis Process)	Yes	Yes	GoalCases & SBVR	Yes	Semi-automatic (Transformation language & Human language)	ATL	Case study	Standard tool
Our proposal	Yes	Yes	BPMN diagrams (Conversation, Choreography & Collaboration)	Yes	Yes	E3value model	Yes	Automatic (Transformation language)	ATL	Case study	Standard tool

Fig. 10: Studied papers Comparison via Evaluation criteria

Analysts" basing on Figure 9. Our proposal will complete the development process of our e-business information system and facilitate the generation of other models for the next levels such as PIM, based on the generated XMI models format (Figure 8). Moreover, our method allows the reduction of time, the effort and therefore, the cost during the development of e-business projects as all transformations are automated.

VI. Conclusion and Future Work

In this paper, we present our disciplined model-driven approach based method, to get richer and consistent CIM level construction, destined for the e-business information systems. We transform automatically via the ATL the Business Value Model that is represented by E3value model to the following BMPN diagrams; BPMN Conversation diagram, BPMN Choreography diagram and BPMN Collaboration diagram, presenting the Business Process Models, which are OMG standard models. For that, we started by establishing the source and the target meta-models. Then, we defined the restrictions during the source model construction. Besides, we revealed the set of transformation rules realized via ATL transformation language. After that, we deal with a case study to illustrate our proposed method. In the end, we analyzed and discussed our method obtained results.

To achieve an enhanced e-business Information System, the generated BPMN diagrams will be considered as the source models of our ongoing work, by proposing a new method generating rich and consistent models in PIM level. And those will eventually be models of the OMG standard.

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