

Integrating a Decision Tree Perspective at the Operational Level of BPM+

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Decision trees are among the best-known decision-making techniques and have been used extensively for both data analysis and predictive modeling. BPM+ is a novel process modeling approach that helps represent business process models in a consistent and structured way to meet different stakeholders' process representation needs. This paper reports on the outcomes of an ontological analysis of the potential use of decision-tree representations as a new BPM+ perspective for the operational level of abstraction. This new perspective effectively demonstrates how a specialized/operational BPM stakeholder perspective can be used to improve the existing organizational business process model repository

Keywords: Operational level of abstraction, business process modeling, business process management, BPM+, ontological analyses, decision tree

1. INTRODUCTION

Business process modeling (BPM) is used to accurately represent and optimize organizational processes [14] [12]. BPM also allows organizations to conceptually clarify details about their activities and roles, and to gain insight into complex aspects of organizational processes. This results in clearer communication of their processes between relevant stakeholders, both internally and externally, therefore, it has been reported that using BPM improves the productivity of teams [2]. Every organization would like to use a process representation and modeling notation that is easily understood and relevant for each employee. A modeling notation is the graphical representation used to illustrate a process model [12][26]. Consequently, organizations continue to experiment with new BPM notations and tools to fit their evolving needs [2][7]. Concurrently, different vendors are promote their own notations and tools. BPM researchers observe [13][5][2] that BPM notations proposed are growing in com-

plexity in their attempt to satisfy the many different modeling perspectives required by different stakeholders involved in a typical organization (e.g. managers, engineers, technicians). Even with these advances, it is still reported that BPM projects have difficulty representing the processes according to these different needed and specialized perspectives [9]. In addition, it has been experimentally confirmed that simple modeling notations tend to be more successful as they increase the comprehension and use of processes even for users that have little previous experience with process model notations [15].

We reported, in previous research results [20] [17], that the proposed BPM+ process modeling approach helps in providing modeling concepts that can address this issue. Especially because BPM+ includes the notion of multiple levels of abstraction (MLA) in order to represent process information that addresses the concerns of different types of stakeholders. BPM+ was originally designed to include three levels of abstraction: 1) strategic; 2) tactical; and 3) operational. The first two levels of abstraction have been the subject of many publications in

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the past [16][20][21]. This paper focuses on the third level of abstraction, the operational level of processes. The intention of this level of abstraction is to represent process models according to operational staff perspectives so it better fits their needs.

To assess the completeness of a modeling notation, a theoretical representational analysis model was proposed by Wand and Weber [32]. This model evaluates and assesses the representational capabilities of real world constructs in modeling notations. It is now widely known as the Bunge-Wand-Weber (BWW) model. This model is based on an ontology initially proposed by Bunge and used for understanding the process of information system development [32]. The BWW representation model allows for representational analyses of all types of information systems [17]. To use it, it is necessary to select a set of constructs from its content that is relevant to the business domain under study [29].

We know that decision making is part of the daily essential processes required for effective operations, particularly in science, engineering, economy and management [31][34][22]. Decision trees are often used to represent complex decision-making processes. A decision tree is a diagram displaying the potential outcomes from a series of choices [31]. Decision trees have contributed significantly to decision making in many different fields, such as critical thinking, machine learning, management science, computer science, and chemical science [31][23]. The graphical representation of decisions has also been widely used for both exploratory data analysis and predictive modeling applications for over three decades [23]. In turn, decision trees assist the user in making a well-informed decision. This graphical representation provides a compact and systematic documentation of the decision process [28]. A reported issue, in decision-making, is the inability to identify and consider the implications of all the possible options [22]. However, well-designed decision trees should address this concern, ensuring that all alternatives are considered. For its appeal, decision trees are considered an interesting notation that should be offered at the operational level of BPM+.

This research paper proposes how to assess the representational capabilities of decision tree representations to be used as a specialized representation perspective at the operational level of a business process. The following questions will be addressed throughout this paper: 1) What are the main decision tree concepts? 2) What relevant BWW ontological constructs fit with the concepts found in a decision tree representation? 3) How adequately could decision tree concepts be represented by business process modeling languages?

To answer these questions, we present a case-study where selected constructs of the BWW representation model are used to evaluate the completeness of modeling notations and their ability to represent decision trees. For experimental and demonstration reasons, two modeling notations have been selected by our research team for this case-study: BPMN [24] and Qualigram [3].

This paper is organized as follows: Section 2 provides an overview of the BPM+ process modeling approach and especially its operational level of abstraction; section 3 presents a summary of the concepts concerning the modeling notations selected for this case study; section 4 introduces the BWW model and how it can be used to evaluate the representational capability of modeling notations. Section 5 presents the research method-

ology followed by the case study, section 6 presents the BWW representation analysis of decision trees and its results; and finally, section 7 provides a brief summary of the contributions and limitations of this research and outlines future work in the BPM+ research program.

2. BPM+ AND ITS LEVELS OF ABSTRACTION

2.1 BPM+ approach

BPM+ was originally designed to provide a process architecture that allows process models to be represented differently for various stakeholder perspectives. BPM+ adopts the concepts of multiple levels of abstractions (MLA) inspired from Anthony's process categories for organizational planning and control [1]. This can be useful as 1) previous BPM notations, such as Qualigram, have successfully implemented layered processes using Anthony's model [8] (also named Anthony's triangle); 2) the ISO9001 recommendation for documenting business processes proposes that organizations should document their quality management system using a process architecture comprising three levels as proposed by Anthony's model; and 3) Anthony's model has been used successfully as a basis for the classification of processes in many organizations in the past [19][18].

We think that using this layered architecture of business processes, at multiple levels of abstraction, could contribute to a consistent representation of business process models to be used, shared, and understood easily by various groups of stakeholders [19]. Anthony model proposes three levels of abstraction - strategic (level 1), tactical (level 2), and operational (level 3).



Figure 1 BPM+ levels of abstraction adapted from Anthony's triangle [8]

These concepts are reused as the recommended organizational process architecture in BPM+. Each abstraction level represents a set of particular details that interest a particular audience. The strategic level describes the core processes, goals and policies of an organization. The audience interested by this perspective is mainly upper management. The tactical level describes who does what. It describes the roles, activities and resources used for a process. The audience interested by this perspective is middle management as well as operational staff that execute a process. It is especially useful as it describes how activities pass from one role to another by transitioning across the organizational silos of an organization (see Figure 2).

As can be seen in Figure 2, the last level of abstraction, at the operational level, typically represents the execution of atomic

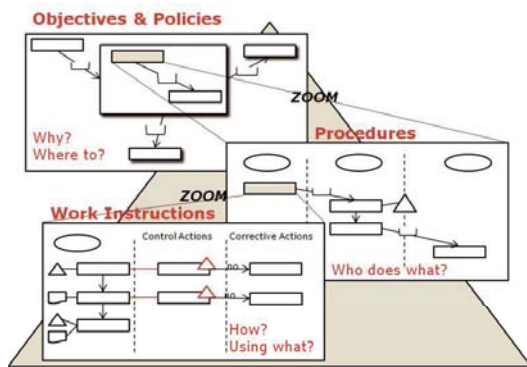


Figure 2 Qualigram notation 3 levels of abstraction adapted from Berger et al. [3]

tasks, describing specific activities of the organization that could be documented in a detailed set of work instructions. The purpose of this perspective is to detail the work instructions for a specific operational role, see Figure 2.

2.2 Operational level of abstraction

For the remainder of this paper, we will focus only on the operational level of abstraction. At the lowest level of abstraction, all the detailed activities that are to be executed by an individual are modeled. At this level of detail, the steps of the work instructions can be documented.

Monsalve et al. [16] have noted that the operational level of abstraction is very challenging. This is due to the multiplicity of the operational representation of processes that could be required to fulfill the specific needs of operational stakeholders. At the operational level of organizations, there are many different types of specialists that execute steps of a procedure, for example: software engineers, nurses, machine operators, security specialists, chemists, etc. These operational stakeholders have numerous, and often preferred ways of representing their operational process. As an example, the process representation used by a software engineer may need representing formal requirements and methods using software class diagrams and data model representations. Another example could be the process representation required in a security procedure, to comply with external regulations, to show to show auto-control activities and corrective actions when a problem occurs [16] (“Incident handling instructions” in Figure 3).

In summary, we can see that the graphical representation of operational activities and the atomic tasks that compose them could result in very specialized graphical representations to suit each stakeholder need. We think that modeling concepts at the operational level should allow for fulfilling these different needs. These different process models should have common modeling concepts such as: actions: tasks; entities: roles (i.e., internal actors); information (relationships or dependencies): relationships between tasks; tools: physical tools (e.g., computers, software tools, machinery), and documents (i.e., documents that are used or produced by the activity). This is what is research project will explain.

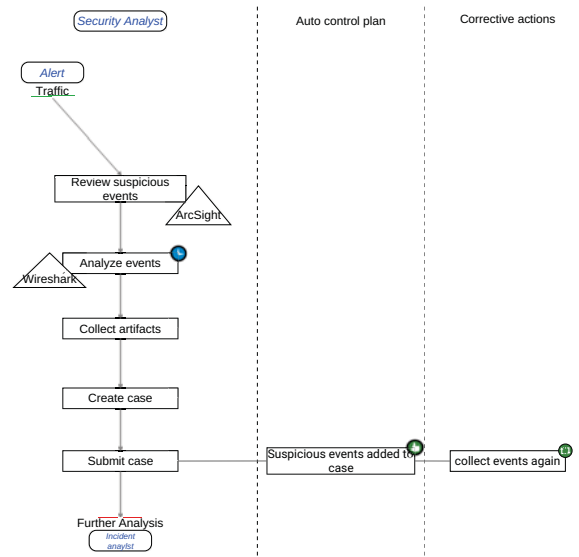


Figure 3 Qualigram’s notation of the operational level for an incident handling process

3. MODELING NOTATIONS

The next section summarizes the concepts of the two existing process-modeling notations selected to experiment with these concepts.

3.1 Business Process model and notation (BPMN)

The Business Process Management Initiative (BPMI) released BPMN in 2004, which was adopted by the Object Management Group (OMG) in 2006, and is now a standard of the OMG [25]. BPMN’s main goal is to provide a graphical notation that is comprehensible for all business users [25]. In addition, specifying business processes in a Business Process Diagram (BPD) based on a flowcharting technique very similar to activity diagrams from the Unified Modeling [25] is another important objective fulfilled by BPMN.

BPMN is a rich modeling notation which includes constructs for the representation of various types of control flow and events. Rosemann et al. [30] presented a study of how the various BPM notations have evolved to become more expressive over time. Their results show that BPMN is the most appropriate to represent business processes among all the studied BPM notations [30]. Furthermore, according to a 2016 survey [7], BPMN continues to intrigue users in the process modeling standards domain.

3.2 Qualigram

The Qualigram notation is a management-centric BPM notation, which facilitates documentation and communication of business processes [3]. Qualigram is based on structuring business processes using three modeling levels (see Figure 2). The highest level of abstraction (i.e., strategic level) uses a notation to

describe the high-level business processes of an organization. It typically represents the context and the strategic aspects of the organization including policies to be implemented, objectives to be reached and the interactions between the various objectives identified at a high level. The goal of this level is to represent the business processes from the point of view of organizational strategy. It is often referred to as the meta-processes of an organization.

The intermediate level of abstraction (i.e. tactical level) models the organizational procedures of the actions to be performed and the roles that perform those actions, in addition to the information they are to exchange and the tools they are to use. This level documents who does what in the organization. Finally, the lowest level of abstraction (i.e., operational) represents the work instructions, aiming to represent how an operational stakeholder in the organization performs a specific activity.

Qualigram is very simple to interpret. Each level of abstraction constructs models based on four concepts with their corresponding graphical forms: 1) action; 2) entity; 3) tool; and 4) information. Variants of the action form are used to illustrate processes, procedures, work instructions, and elementary operations. Roles (internal and external), departmental units, and external entities are represented by the variants of the entity form. The tool form represents any kind of physical equipment or any kind of document produced or used by an action. The information form appears for the input and output flows of information between the various types of elements. Since Qualigram is a simple modeling notation, it is easily understood by most stakeholders in an organization [3].

The main reasons for choosing the Qualigram notation in this that because: 1) it represents a manager's perspective well; 2) it implements the ISO9001 recommendation for describing and structuring processes (e.g., quality management system) using Anthony's model recommendation; and 3) it uses a hierarchy of abstraction levels.

4. BWV MODEL FOR REPRESENTATION THEORY

The Bunge-Wand-Weber representation model (BWV) is a "benchmark for the evaluation of the representational capabilities of modeling standards that form the core of the research method of representational analysis" [6]. The BWV representational model was developed based on an ontology proposed by Bunge [32]. The representation model defines a set of constructs, which describe the structure and behavior of the real world that modeling languages are intended to portray [33][32]. As stated by Wand and Weber, two main situations may be studied when a modeling language is evaluated and analyzed: ontological completeness and ontological clarity [32].

The modeling language is considered complete when at least one ontological construct is represented in the modeling language constructs [32]((a) in Figure 4). Construct overload exists in a modeling language if one modeling language construct represents two or more ontological constructs [32] ((c) in Figure 4).

A modeling language is considered ontologically clear when there is no construct overload, construct redundancy, construct

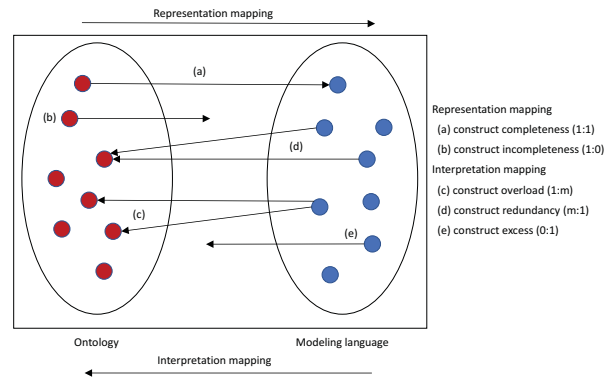


Figure 4 Rules of representational analysis adapted from Wand and Weber [32]

excess, construct deficit or incompleteness. Construct deficit occurs when one or more ontological constructs do not map to any modeling language construct [32] ((b) in Figure 4). Redundancy exists if two or more modeling language constructs represent the same ontological construct [32] ((d) in Figure 4). Construct excess exists when a modeling language construct does not map into any ontological construct [32] ((e) in Figure 4).

The BWV representational model has been used to evaluate and compare many modeling notations such as BPMN [29], Qualigram [10][17], UML [35] and many others. The key constructs of the BWV model can be classified into four clusters: 1) things including properties and types of things; 2) states assumed by things; 3) events and transformations occurring on things; and 4) systems structured around things [27]. In this paper, we use the BWV representation model to assess the capability of modeling languages to represent a decision tree, and thus to define possible constructs that will allow us to design and integrate a new perspective (i.e., decision tree) at the operational level of BPM+.

5. METHODOLOGY FOR PERFORMING REPRESENTATIONAL ANALYSIS

Aside from the choice of the reference ontology for the representational analyses [6], possible shortcomings with the representational analysis process itself have exposed popular reference ontologies to criticism [29]. In order to minimize and address potential shortcomings of the representational analysis, we followed the analytical methodology and recommendations proposed by Green et al. [6]:

1. Perform the representational analyses mappings with the assistance of a modeling language meta-model;
2. Involve two or more researchers in the representational analyses;
3. Conduct various iterations among researchers leading to a consensus of the representational analyses findings.

We have also taken into consideration four formal rules recommended by Gehlert and Esswein [5] where each ontological analysis activity should comply with:

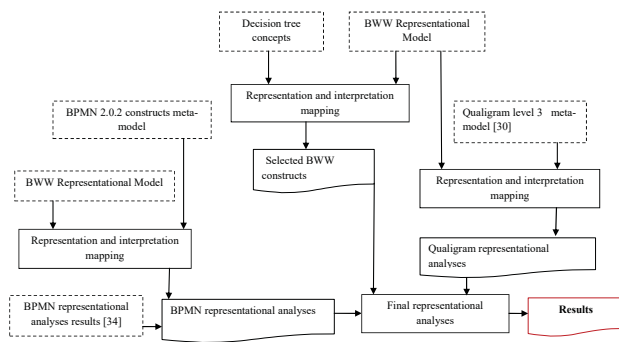


Figure 5 Research Methodology

1. The same set of ontological constructs must be used during all ontological analyses steps;
2. The modeling language version used in the comparison must be stated;
3. The mapping results state if the construct mapping is to be equivalent, similar or different; and,
4. Maintain a criteria of construct similarity and dissimilarity across all analysis.

All of the aforementioned recommendations have been taken into consideration in our research methodology. Two researchers were involved in each representation mapping activity. Once done, it was followed by a consensus as to the final analysis by the entire team of researchers. The BPMN 2.0.2 modeling language meta-model was used for the BPMN representation analyses activity.

The meta-model of the Qualigram modeling language, developed in [10], was also validated with members of the technical staff of the company that developed the Qualigram software (now renamed Pyx4). The analysis methodology was conducted using four steps:

1. An introductory meeting between researchers was conducted and the scope of the research was explained and defined;
2. A representation mapping of ontological constructs, based on selected decision tree concepts, was conducted. The selected BWW constructs represent the most relevant decision tree concepts. We named this step "scoping";
3. The representation mapping of BPMN 2.02 and Qualigram modeling languages was conducted to analyze the capacity of both the BPMN and Qualigram modeling constructs to represent the BWW representation model constructs;
4. The representational mappings of Qualigram and BPMN with the BWW set of constructs produced from the scoping step (Figure 5).

6. REPRESENTATIONAL ANALYSIS OF A DECISION TREE

The representation analysis of a decision tree helps to identify relevant concepts that should be considered when using the de-

cision tree perspective to model a business process at the operational level of abstraction. The first step identifies the set of relevant decision tree concepts that should be taken into consideration when developing a process model. Table 1 shows the concepts selected by the research group based on their relevance when generating a process model.

The relevant concepts associated with a decision tree for analyzing the BWW representation model within the specific span of the decision tree are adopted from the work of [4][11].

Figure 6 shows a general example of a decision tree which describes all possible outcomes and decision points that could occur chronologically with the data security encryption requirements for the Payment Card Industry (PCI).

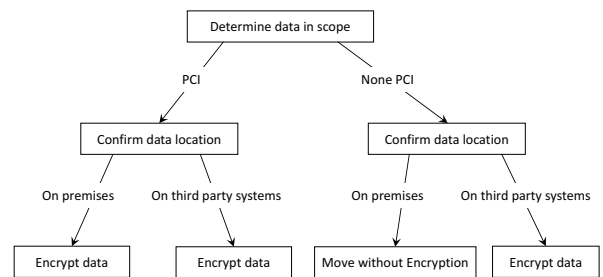


Figure 6 Decision tree describes data encryption

6.1 Decision tree concepts mapping: results and analysis

During this step, we conducted two activities: 1) a representation mapping, in which we mapped the decision tree concepts of Table 1 to the BWW representation model constructs (as depicted in Figure 5); and 2) an interpretation mapping, in which we mapped the BWW representation model constructs to the identified decision tree concepts of Table 1. The outcome of these two mappings results in a subset of concepts, from the BWW representation model, that have been selected based on their capabilities to represent the relevant decision tree concepts of Table 1.

The representation mapping in Table 2 and the interpretation mapping in Table 3 were obtained using the methodology described in Section 5. From Table 2, we can see that the decision tree concepts of Degree, Path, Height of node, and Height of tree have no BWW representative constructs. A potential reason for this could be that the BWW representation model is incomplete when describing the decision tree concepts. It was observed among the research group that such modeling concepts are not necessary for the model of a decision tree.

As for Table 2, the transformation BWW construct has mapped: root node, child, leaf, internal node, and parent decision tree concepts. The research group agreed that the decision tree concepts' state can be transferred based on interaction level (i.e. leaf and child node can be parent).

Within the same context, lawful transformation represents branches and edges. Any type of interaction or relationship between nodes can be represented either by branch or edge. However, Table 2 shows that edge has also been mapped to coupling and act on BWW constructs.

Table 1 Decision tree concepts

Concepts	Description
Root node	Root node has no incoming edges and zero or more outgoing edges(Top node in the tree)
Child	A node directly connected to another node when moving away from the root
Parent	The converse notion of a child
Siblings	A group of nodes with the same parent
Internal node	A node with at least one child
Branch	The arrows connecting nodes with conditions
Edge	Relationship between nodes
Leaf	A node with no children
Level	The number of edges between the node and the root
Degree	The number of sub trees of a node
Height of node	The number of edges on the longest path between that node and a leaf
Height of tree	The height of its root node
Path	A sequence of nodes and edges connecting a node with a descendant

Table 2 Representation mapping of the BWW representation model based on selected Decision tree concepts.

Concepts	Description
Root node	Transformation (Top node in the tree)
Child	Transformation
Parent	Transformation
Siblings	System decomposition, subsystem
Internal node	Transformation
Branch	Lawful transformation
Edge	Coupling, act on, lawful transformation
Leaf	Transformation
Level	Level structure

Table 2 shows how the siblings have been mapped to System decomposition and subsystem BWW constructs and how the level decision tree concept has been mapped to the level structure BWW construct.

Table 3 shows the BWW representational model constructs that do not map to any decision tree concepts (* indicates the constructs were not mapped).

Based on the mapping results presented in Table 2 and Table 3, we have selected a subset of BWW representation model constructs that are the most applicable for a decision tree perspective. Table 4 describes this subset.

Rosemann et al. [29] suggested that a specialization of ontological constructs of some particular domains, which is called focused ontology, can enhance and simplify the representation analyses process.

6.2 BPMN and Qualigram: mappings and comparisons

As depicted in Figure 5, and from the representation analyses performed in the previous sub-section, only the selected BWW subset summarized in Table 4 has been used for the representa-

Table 3 Interpretation mapping based on selected Decision tree concepts

Concepts	Description
Conceivable state space	*
State law	*
Lawful state space	*
Event	*
Event space	*
Transformation	Child, parent, internal node leaf, root node
Lawful transformation	Edges, branch
Lawful event space	*
History	*
Act on	Edge
Coupling	Edge
System	*
System composition	*
System environment	*
System structure	*
Subsystem	Siblings
System decomposition	Siblings
Level structure	Level
Stable state	*
Unstable state	*
External event	*
Internal event	*
Well-defined event	*
Poorly defined event	*
Class	*
Kind	*

tion analyses with BPMN and the Qualigram notations. In this representation analysis, we evaluated and compared the completeness of BPMN and Qualigram to represent this subset of the BWW representation model constructs selected for the decision tree perspective.

Table 4 Selected subset of BWW representation model constructs.

Cluster	BWW Constructs
Events and transformations occurring on things	Transformation
	Lawful transformation
	Coupling
	Act on
Systems structured around things	Level structure
	System decomposition
	Subsystem

Table 5 Representation mapping of the BWW representation model based on selected Decision tree concepts.

BWW constructs	Qualigram	BPMN
Transformation	Macro-operation, alternative operation, operation, corrective operation, Self-checking operation	Activity, Task, Collapsed sub process, expanded sub-process, nested sub-process, transaction, Choreography Task, Collapsed Sub-Choreography, Expanded Sub-Choreography
Lawful transformation	Information arrow, up-stream action, down-stream action	Default Flow, exception flow, uncontrolled flow
Coupling	Information arrow, up-stream action, down-stream action	Message flow
Act on	Information arrow, up-stream action,down-stream action	Message flow
Level structure	Macro-operation, alternative operation, operation	Pool, Lane
System composition	Alternative operation, macro-operation, operation	Pool, Lane
System	Alternative operation, macro-operation, operation	Pool, Lane

We present the results of the representation mapping using both BPMN and Qualigram operational level constructs in Table 5. With regards to BPMN, we observed the same representation mapping results as reported by Recker et al. [27] for the subset of the BWW representation model selected for decision tree. Then the new extended constructs of BPMN 2.0.2 were mapped including: choreography Task, collapsed sub-choreography and expanded sub-choreography to the same subset of BWW representation model constructs as shown in Table 5.

Table 5 shows that no incompleteness deficiencies were observed when representing the selected set of BWW representational model constructs. As both the modeling notations experimented offer at least one construct, corresponding BWW representational model constructs are selected to describe concepts related to decision tree perspectives. We can also see that the BWW model constructs transformation and lawful transformation present several redundancies for both modeling languages.

Some potential representational shortcomings based on the situations described in section 4 were observed in the representational analyses of both BPMN and the Qualigram notation. From a clarity perspective, both situations of construct redundancy and overloading are present. The redundant BWW model constructs are: transformation, lawful transformation, coupling, act on, level structure, and system decomposition. Both model-

ing notations used offer construct redundancy for BWW representation model constructs described in Table 5.

For the redundancy of transformation, 9 BPMN constructs mapped to the transformation BWW construct including: collapsed sub-choreography, expanded sub-choreography, and the choreography task. For this reason, it is possible that users could be confused as to which construct is to be used when representing a transformation. The BPMN constructs differ in terms of visualization, however, as reported by Recker et al. [27], no significant semantic differentiation can be stated in terms of their use.

Next, the BWW representation model constructs: level structure, subsystem, and system decomposition mapped to the lane and pool notions of BPMN. Lawful transformation mapped to default flow, exception flow, and uncontrolled flow demonstrating the same results of representation analyses performed by Recker et al. [27].

Lawful transformation, coupling, act on, level structure, system decomposition, and Subsystem BWW model constructs also present redundancies, particularly in the Qualigram notation.

With respect to construct overloading, both BWW model constructs: act on and coupling, mapped to the same BPMN construct, message flow. Level structure, system decomposition, and sub system mapped to the same BPMN constructs- pool and

lane. In this experiment, we did not observe any construct excess or construct deficit.

The Qualigram notation has shown the ability to represent all the selected set of BWW representational model constructs, where construct overloading and construct redundancy are present. In terms of overloading BWW constructs, level structure, subsystem and system decomposition have been mapped to the same set of Qualigram concepts, alternative operation, macro-operation and operation. As well, BWW constructs: act on, coupling and lawful transformation mapped to the equivalent Qualigram constructs, information arrow, up-stream action, and down-stream action. Finally, these results suggest that the BPMN notation offers a higher level of representational clarity for the decision tree perspective representation.

7. CONCLUSION AND FUTURE WORK

In this paper, we have presented a representational analysis to assess the decision tree representation as a new perspective to be added at the operational level of BPM+. BPM+ is a proposed modeling approach that has 3 levels of abstraction and aims at proposing many specialized process model representations to meet the needs of different stakeholders.

Based on the results from the identification and the representational analysis of the concepts of a decision tree perspective obtained using the BWW representational model, BPM users could use familiar concepts of current BPM languages to represent decision trees. The recent extended constructs of BPMN version 2.0.2 were identified and mapped including: choreography task, collapsed sub-choreography and expanded sub-choreography.

Based on this experiment and comparison of the capability of BPMN 2.0.2 with the Qualigram modeling notation to represent decision tree concepts in terms of ontological completeness and clarity, BPMN showed a higher level of representation in terms of clarity. Further applied research is needed where experts could validate these initial findings and evaluate both the BPMN and Qualigram modeling notations abilities to represent decision trees.

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