Empirical Evaluation of BPMN Extension Language

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Abstract: Business process modelling is essential for knowledge management and business process improvement. Primarily, business process modelling is investigated for communication between stakeholders and information system development. On the other hand, business process performance analysis and its representation are less investigated. Moreover, different visualization techniques present the data perspective, not the process perspective. As a result, enterprises find it challenging to decide where to start and what changes should be made for improvement. This paper evaluates a BPMN extension for business process performance representation. We evaluate different modelling patterns empirically using a case study in a company.

1 INTRODUCTION

Global socio-economic changes and technological developments bring new opportunities and threats for enterprises. Different mergers, standardization initiatives and best practices are common in this competitive environment (Bider and Lodhi, 2020). Process understanding and its evaluation are crucial steps for process standardization and improvement in enterprises (Reijers, 2021). For this purpose, business process modelling is widely used for the graphical representation of processes and communication between different stakeholders.

In enterprises, different silo systems exist that support fragmented parts of business processes. In practice, the communication between silos is not seamless and hinders the smooth execution of business processes. Different other applications, interfaces and macros are used to fulfil this task. The situation is more challenging in larger organizations at the manufacturing level, where process chains are lengthy, and most of the processes are executed manually as discussed in (Lodhi et al., 2018). Different customized applications support these processes. As a result, enterprises find it challenging to decide where to start and what changes should be implemented for improvement. Complexity in a business process is due to various factors like inter-dependencies between activities, stakeholders, involved elements, attributes, and applications.

Business process models can be annotated with performance information which can be used to identify deficiencies. In practice, annotation-based models are used; however, they are not designed for this purpose and do not sufficiently support the post-execution analysis and improvement of business processes (del Río-Ortega et al., 2019). Therefore, the gap will occur when existing models are used for evaluation and improvement, as these models will not provide complete details. Therefore, there is a need to fulfil this gap and offer process models for business process improvement (evaluation and analysis).

Performance evaluation with business process model is undermined research area. Our goal is to address this challenge and focus on the relationship between evaluation of business processes and their representation at the process level. For this purpose, we proposed the modelling constructs for performance evaluation by extending BPMN modelling language. Furthermore, we evaluate the proposed extension empirically in a company. Finally, we discuss the limitation of our case study and the results in this paper's discussion part. At the end, we conclude our paper and provide the outlook of the research.

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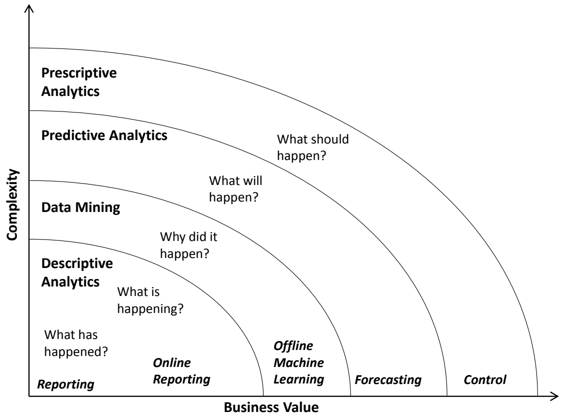

Figure 1: Business Analytics with Value.

2 BUSINESS PERFORMANCE ANALYSIS

Different information systems play an essential role in business process execution, like ERP (enterprise resource planning) systems and MES (manufacturing execution system) (Lodhi et al., 2018). These systems record the interaction between humans, business objects (materials), and organisational elements (machines) and also store other data (like process/product quality during their execution. Information systems has undergone various research disciplines like information system development (requirement engineering, software engineering, graphical models), data management (data modelling, data storage, warehouse systems), and then later for knowledge management (like data mining, knowledge documentation).

Evaluation of business processes is vital for the analysis and improvement of an organisation. Information systems provide excellent means to record and extract performance details. They provide quantitative (like operating time, overall cost) and qualitative (like first pass yield, satisfaction of customers and employees) aspects of the process. These evaluation attempt to answer business questions as shown in Figure 1. Here, the focus is on two types of analytics such as descriptive and predictive analytics, often known as business intelligence technologies. Figure 1 is adopted from (Davenport and Harris, 2007; Eckerson, 2007; Lustig et al., 2010). However, mere data perspective is not enough for operational improvements in the business.

The knowledge extracted by descriptive and predictive analytics must be applied in business operations. The prescriptive analytics attempts to find the answer which changes should be carried out to get the desired results, as shown in Figure 1. In order to carry out such changes, users are interested in the performance details of processes in an organisation. These details are necessary in order to identify deficiencies and improve processes. Therefore, a deep understanding of processes is required for improvement purposes (Klimecka-Tatar, 2021). The field focusing on process analysis is known as business process intelligence (van der Aalst, 2016; Grigori et al., 2004). The post-execution analysis of business processes uses the results of the evaluation phase and analyse the performance of business processes in a broader context. In this phase, focus shifts toward process aspects and their performance rather than data perspective as in the evaluation phase.

The knowledge is presented to end-users using different methods and visualisation techniques. Most of the modelling methods address only the needs of information system development purposes. This view is also strengthened by a study (Alotaibi, 2016), where authors review papers over 13 years. The author positions different process modelling tools and techniques only till the execution phase of the business process lifecycle. Therefore, business process modelling has to be investigated for adequate representations of business processes, especially after execution. We address the main research challenge in this paper to provide representational support for business process improvement. The research question (RQ) is stated as follows.

RQ: *How to represent the knowledge and performance of a business process in order to improve them?*

3 MODELLING PATTERNS FOR PERFORMANCE ANALYSIS

We considered the limitation of modelling languages for performance analysis in (Lodhi et al., 2011). We follow the principles of diagram notations defined in (Moody, 2009) to improve the process performance visualization in (Lodhi et al., 2014; Lodhi et al., 2018). To accommodate different requirements, we combine constructs to build models for analysis from different perspectives and call them as patterns. Different allowed combinations are explained here which also define the method of constructing the models in a particular way. Depending on the user's requirements, models are built at different levels of granularity to facilitate the understanding of processes. In the following, we describe these patterns briefly and provide their representation by extending Business Process Model and Notation (BPMN) (OMG, 2014)

Table 1: Pattern and Characteristics.

Evaluation Pattern	Purpose	Constructs
Time Pattern	analyse the performance of resources and activities with respect to time	Swimlanes, activities
Cost Pattern	analyse the performance from the cost perspective like material and resources	Swimlanes, activities, colours
Path Pattern	To understand the activities which will be fruitful	Edges, activities, colours
Colours Pattern	To represent which activities are distinct in a process	Activities, swimlanes, connecting objects
History Pattern	To understand which activities are frequently executed in process	Edges, thickness, activities
Information Pattern	To provide further information along business process models	Gateway with rules, contents

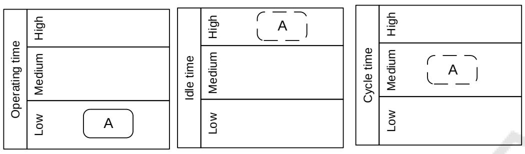

Figure 2: Process Model in the Time Dimension.

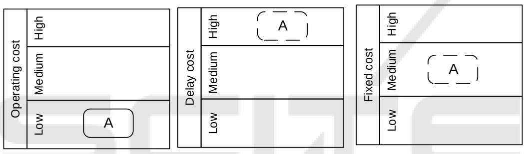

Figure 3: Process Model in Cost Dimension.

(which is a ISO standard (ISO19510, 2013)) as an example modelling language.

3.1 Time Pattern

The time dimension is an essential factor in business process analysis. In this pattern, we focus on representing the process element's performance from time perspective like idle time and operating time. It is interesting to know for process analysis which activities are time intensive or take much time in execution. Different classes can be used for this alignment and categorization. Such alignment can identify the deficiencies in predecessor activities to improve the efficiency of the successor activity. This pattern is shown in Figure 2 using BPMN Swimlanes.

3.2 Cost Pattern

Cost is also a vital factor in business process analysis. This pattern observes the performance of process elements from cost and other related aspects like material and other resources. Like time pattern, process elements can be classified like high cost, medium and low cost. Similarly, process elements can also be grouped or aligned based on the cost incurred by them as shown in Figure 3.

3.3 Path Pattern (Time-cost Dimension)

The time-cost analysis is helpful in deciding which activities should be further investigated. The activities together create a path of process execution which may not be that efficient or beneficial for an organization. In the case of different possible paths, a path can be defined as a best practice which contributes to the organizational goals with limited expenses (in terms of time and costs). This path can be distinguished from other paths using different techniques (like size and colour as shown in Figure 6). Similarly, difficult paths (incurring costs and problems) can also be distinguished from the other paths. The time and cost dimensions in this pattern are just an example of some dimensions influencing the path pattern; it can also be different from other dimensions as well like the organizational dimension and quality dimension which define the success of business process executions.

3.4 Colour Pattern

Colours have a significant cognitive effect on perception and analysis. For example, red colour is noticed quickly by users. The classes can be codified into colours to distinguish the performance of process elements in process executions. Different colours indicate the effect of the business objects, like green for optimal cost, yellow for high cost, and red for a very high cost. A legend is necessary for such representations as a reference.

In this pattern, swimlanes can also be coloured as shown in Figure 4. Different activities can also be coloured based on their performance to highlight as represented in Figure 5. Similarly, the paths can also

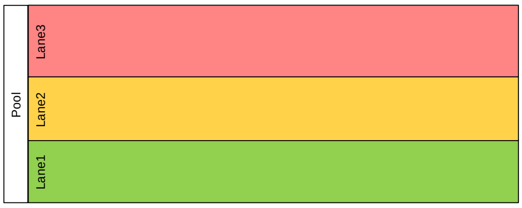

Figure 4: Swimlanes in Colour.

be coloured as discussed in the previous section.

3.5 History Pattern

History pattern represents which process elements are interesting from a statistical point of view in process execution. For example, elements are often executed and which path is taken in most process executions. This pattern can be represented in modelling languages using specific constructs (like shape and size) or represented as additional information.

3.6 Information Pattern

Different decisions are made in process executions. These decisions are implicitly represented in program logic or explicitly stated in the documentation. Information pattern provides performance-related or decision related data as text on a process model. Process states, conditions and rules about process control, and different statistical measures can be added to a process model when we use this pattern. In process execution, the explicit representation will help users to understand the rationale behind these decisions. For example, BPMN artefacts or text boxes can describe the condition near the control elements.

The proposed patterns, their elements, and meanings are summarized in Table 1. In these patterns, different other attributes of the dimensions can be added and correspondingly represented using our proposed modelling language and its cognitive aspects (like colour, shape, and size). This extension serves not only for evaluation and improvement purposes but also for knowledge management purposes like training new employees and knowledge transfer.

4 EMPIRICAL EVALUATION USING CASE STUDY

This paper presents the empirical evaluation of our proposed modelling language. Furthermore, in this empirical study, we also assess the understandability aspects of the proposed extension, i.e. how well it is perceived and understood by the users. In such evaluations, feedback from the participants is collected over the presented content. In this case study, we follow certain aspects of the Quality Framework as defined in ISO/IEC 25010:2011 (ISO2011, 2011) (last reviewed and confirmed in 2017, based on older version ISO/IEC 9126 (ISO2001, 2001)), such as functional suitability (functional appropriateness), usability (learnability) and maintainability (analyzability). We take them as evaluation criteria and ask participants for feedback from these perspectives. Although such empirical evaluations provide valuable insights, however, they are time-consuming.

4.1 Questionnaire Design

We considered a real-world simple production process for the questionnaire and presented it to the participants via a web link (Questionnaire Link, 2022). The questionnaire design is divided into four parts. In the first part of the questionnaire, general information is collected. The second part of the questionnaire focuses on participants' professional experience.

The third part of our questionnaire is the central part introducing a simple organizational process. This part describes the production scenario of product manufacturing in an organization using the BPMN. Here, the focus is to compare two methods for analysis and improvement of a business process. The first method uses traditional graphical charts, whereas the second method is a short demonstration of our proposed extensions of BPMN representation) as presented in Section 3. In this Section, we ask five main questions, each focusing on a particular pattern and its comparison to the traditional approach. To get feedback from the participants, we applied a four-level Likert scale (Joshi et al., 2015), ranging from very dissatisfied (score 1) to very satisfied (score 4).

The fourth part of the questionnaire focuses on participant feedback on proposed modelling patterns based on criteria like understandability, support in decision-making, application in other areas and organizational hierarchy level. For this purpose, we again ask five questions as of our proposed patterns, further containing sub-questions from four mentioned criteria to evaluate them from these perspectives (score 1 as strongly disagree to score 4 as strongly agree).

4.2 Conduction of Case Study

In the empirical study, 38 participants from different organizations and domains have participated. We conducted the empirical study in two separate groups by presenting the same questionnaire. The first group

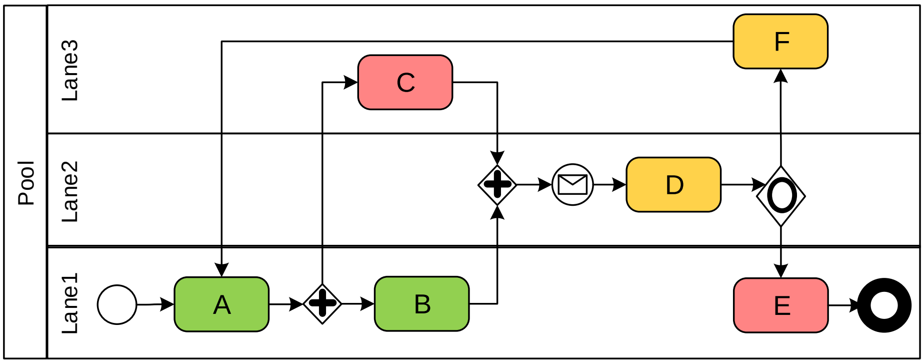

Figure 5: Activities in Colour.

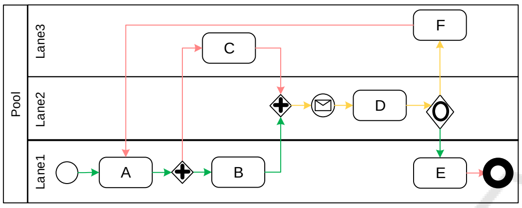

Figure 6: Connecting Objects in Colour.

is from one particular organization (manufacturing company, referred as Case Study 1). Although we asked more than 30 participants in the first group to fill out the questionnaire, only 14 participants provided their feedback. The same questionnaire was asked to the second group (referred as Case Study 2), which was very generic as it was intended for professionals from different companies, academic staff, and students. In this group, 24 participants filled out the questionnaire. In this group, five students participated as well. In (Höst et al., 2000; Svahnberg et al., 2008), authors have shown that students are a proper substitute for professionals in empirical studies as they will be future professionals. For the sake of space constraints in this paper, we discuss only the results of the first case study (i.e. in a company).

4.3 Analysis Method

In order to analyse responses and test our hypothesis, we used Wilcoxon signed-rank test from inferential statistics. Wilcoxon test is used if the experiment participants are low (Gehan, 1965; Hollander et al., 2013), as is the case in our case study. Since we do not have a large set of responses, we use statistical inference to infer the characteristics of different analysts based on the responses we have received in this case study. We want to analyse the scores of participants by comparing the two methods. For this purpose, we made null and alternative hypotheses related to our patterns. Then, based on the participant's feedback, we test our hypothesis.

$H_0^q : \mu \leq \delta$

with the alternative hypothesis

$H_1^q : \mu > \delta$,

where δ describes the *median* in a survey question q.

H0: There is no significant difference between these two approaches (traditional and extended BPMN) from a particular perspective.

H1: There is a significant difference between these two approaches from the a particular perspective.

We will use the Wilcoxon signed-rank test as it is used to compare two sets of scores that came from the same participants. This method is more powerful than the sign test as it uses the magnitudes of the differences rather than just their signs. The Formula of Wilcoxon signed-rank method is as follows

$$W = \sum_{i=1}^{N_r} [sgn[x_{2,i} - x_{1,i}) \cdot R_i] \qquad (1)$$

5 RESULTS OF THE CASE STUDY

For the sake of space constraints in this paper, we skip the demographical information of participants and focus on the survey results. We divide the results into two parts. The first is the comparison between the traditional approach and our proposed extension. The second part is the questionnaire results that evaluate the proposed extensions from different perspectives.

5.1 Time Perspective Comparison

From the time perspective, we wanted to test the null and alternative hypothesis as mentioned above. Based on the feedback from the participants, there is a significant difference between these two approaches, as concluded by Wilcoxon signed-rank test as mentioned

Table 2: Case Study 1: Descriptive and Inferential Statistics of Two Methods.

Patterns & Values	**W+**	**W-**	**W (n)**	**p-value**	**H0**	**H1**	**Average Rating Trad.**	**Average Rating ABPML**
Time	4.5	73.5	13 (12)	0.0068	0	1	2.42	3.5
Cost	36	9	5 (9)	0.11	1	0	3	2.5
Time-Cost (Colour)	3.5	74.5	13 (12)	0.005	0	1	2.29	3.43
Rule	4	62	10 (11)	0.01	0	1	2.21	3.14
History	18	18	3 (8)	1	1	0	2,71	2,71

in Table 2. This is also confirmed by the descriptive statistics method where an average rating of ABPML is 3.5, which is above than satisfied level. In contrast, the traditional method got an average score of 2.42.

5.2 Cost Perspective Comparison

From the cost perspective, participants responded with mixed feedback on these methods. The feedback is also shown in Table 2. Based on Wilcoxon signed-rank method, there is no significant difference between these two approaches. However, based on the descriptive statistics, it can be seen that most of the participants showed satisfactory behaviour towards the traditional approach. The results show that the average score of the traditional method is more than the ABPML. We will discuss these results further in Section 6 of this paper.

5.3 Time-cost Perspective Comparison

In this pattern, we combine different KPIs and represent them in colours. The feedback from the participants and their corresponding Wilcoxon signed-rank test is shown in Table 2. Since our test statistics is less than the critical value, we can reject the null hypothesis; that is, there is a significant difference between these two approaches. It is also supported by p value that is less than 0.05.

5.4 Rule Perspective Comparison

From the rule perspective, the participants' feedback and their corresponding Wilcoxon signed-rank test is shown in Table 2. Since our test statistic is less than the critical value, therefore, we reject the null hypothesis. This is also supported by the p-value. Based on this feedback, we can conclude that there is a significant difference between these two approaches and end-users like the explicit representation of rules.

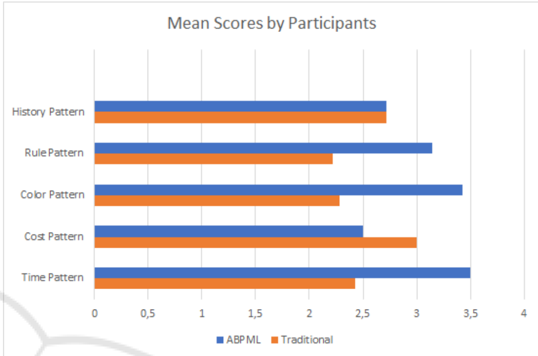

Figure 7: Case Study: Mean Scores of Two Methods.

5.5 History Perspective Comparison

Representing history in ABPML also got mixed responses like cost perspective, where participants showed almost the same feedback. The Wilcoxon signed-rank method and its result for the history pattern is shown in Table 2.

The positive and negative signed-ranks got identical scores, and our test statistic is not less than the critical value; therefore, we accept null hypothesis.

The overall summary of patterns with Wilcoxon scores and their hypothesis is already summarized in Table 2. The mean score of each pattern with respect to traditional and proposed approaches is shown in Figure 7. The coding of values with their categorical score was discussed in Section 4.1, where we mentioned the score 1 as very dissatisfied and the score 4 as very satisfied.

5.6 Feedback over Patterns

The fourth part of the questionnaire evaluates patterns from the participants' viewpoint. We evaluate the patterns based on four criteria: understandability, support for decision-making (for correct and timely decisions), ability to apply in different domains or areas, and support at different managerial levels (like aggregating values on different levels).

The time pattern is rated very high in all mentioned criteria compared to all other patterns. All participants agreed that it was easy to understand. Similarly, more than 90% of participants agreed that it helps in decision-making and flexibility to apply in different domains. On its usage at different levels, participants were divided as 65% of participants agreed that it can be used at different managerial levels; however, at the same time, 35% disagreed with that perspective.

The cost pattern also got more than 90% of agreement on the understandability perspective. Regarding decision-making support, 78% of participants were satisfied with that perspective. However, more than 50% of participants disagreed with its ability to apply in different areas and its usage at different managerial levels (precisely 71% of participants). We will discuss their feedback and reasons later in Section 6 of this paper.

The time-cost pattern with colour representation is also appreciated by the participants as all participants agreed on its understandability perspective (57% with strongly agreed feedback). More than 90% of participants agreed on its ability for decision-making (50% with strongly agreed feedback). In addition, 78% of participants agreed upon its ability to apply in different domains. However, 57% of participants disagreed on its ability to apply at different managerial levels.

The rule perspective also received similar feedback as the time-cost pattern where all participants agreed the perspective of understandability. Similarly, more than 90% agreed on its ability for decision-making, however, only 42% strongly agreed. The feedback of 71% of participants favoured its applicability in different areas, whereas 28% of participants disagreed. More than 60% of participants disagreed with its applicability at different managerial levels as underlying rules and regulations will be complex in representation.

From the understandability point of view, all participants agreed on the history pattern as it is easy to understand. More than 78% of participants favoured its support in decision-making, whereas 21% disagreed in this perspective. We received mixed responses in other criteria as well. For example, 57% of participants agreed, while the same percentage have disagreed on its applicability in different domains at managerial levels.

6 DISCUSSION

The case study was carried out in a company where participants had experience with different evaluation techniques and production environments. We have received feedback from different participants not only about the method but also about the questionnaire. In addition, some feedback was related to questions and the terms, such as their definitions and the method used. We discuss the results and the feedback in the following.

The time pattern received the most positive feedback compared to other patterns, as can be seen from the Wilcoxon scores and mean value. Aligning activities in time dimension based on their KPIs make the analysis easier, especially in understanding the relationship with other activities. Other methods like Pareto charts and Gantt charts can also be used for this purpose. However, these representations do not show the relation of activities with one another. This provides us with the first justification of the limitation of existing methods and representational benefits of our proposed extension for analysis and improvement of a business process.

Regarding cost pattern, no statistically significant difference could be observed by the feedback of participants, as shown in the results. The cost pattern receives the highest dissatisfaction scores of our proposed patterns. Since the response data "points towards" the positive influence of the traditional method, it means that participants are comparatively satisfied with traditional analysis methods from a cost perspective. This raises the question of whether there is no impact on the proposed pattern at all or if there can be another way to explain the missing impact. To this end, a detailed look at the scenario example and feedback from a few participants provide a plausible explanation: Cost is always related to some values with activities. In our questionnaire, it is related to some categories like low, high, and medium. However, it was not mentioned about the definition of categories and their thresholds. Whereas in a traditional method, it can be quantified and analyse each activity accordingly.

Similarly, one feedback was that production process activities are too broad in their abstraction. These activities can be further specified and their corresponding cost can be assigned. Once they are at the detail level with cost, then the proposed cost pattern can show a better advantage over the traditional method. However, abstraction and specification of activities can also be related to the evaluation of patterns themselves, where it is least rated that the pattern can be applied on different managerial levels. Therefore, a further demonstration of cost and hierarchy levels is required.

After the time pattern, most positive feedback is received to the colour pattern. Colour is an important

Table 3: Case Study 1: Evaluation of Patterns under Quality Criteria.

Patterns	**Understandability**	**Decision Support**	**Scalability**	**Levels**
Time Pattern	3.64	3.5	3.21	2.64
Cost Pattern	3.5	2.86	2.5	2.14
Colour Pattern	3.57	3.43	2.86	2.5
Rules Pattern	3.57	3.36	2.79	2.36
History Pattern	3.64	2.93	2.64	2.36

element in visualizations, as represented in different cock-pit or dashboard charts. Aligning activities in one perspective (roles, time) and representing colours for other dimensions (like cost) is positively rated. Activities can be highlighted with different colours to get attention based on their performance. This is also interesting from an analytical perspective as it is considered one of the limitations of BPMN. Technological development (from a hardware and software perspective) encourages using colours as a standard in business process models (rather than merely black-white representations).

When we traditionally describe rules and conditions, most of the participants are not satisfied. On the other hand, the explicit description of rules in process models for analysis and improvement is appreciated by participants, as discussed in Section 5. Moreover, we provide additional information on model edges, which is a better way to explain why a particular path is taken. However, if models are at an abstract level, then the description of underlying rules and conditions could be challenging.

The history pattern received mixed feedback from the participants, and no significant difference was observed between these two methods. One possible reason for no significant difference is the same as of cost pattern; that is, the process model is too easy and small so that no benefits can be foreseen as communicated by the end-user in feedback. On the other hand, the increased number of activities and complexity can help to present the limitation of traditional methods or the benefits of new proposed patterns. Similarly, a legend can explain the relationship between the thickness of connectors and the frequency of their activities if there are different thickness of arrows that exists in the process.

In Table 3, we summarize the mean score of patterns evaluation of the case study (here 1 is strongly disagree, and 4 as strongly agree as discussed in Section 4.1). These are correspondingly represented in Radar chart in Figure 8. It can be seen that all patterns are suitable for understanding the point of view. Time, colour, and rule patterns are also good for providing decision support. However, time and colour patterns are rated high in application in different areas. In contrast, all patterns have less mean scores to be applied at different managerial levels. The reason is again the same as we discussed in the case of cost and history pattern; that process is too simple in the case study.

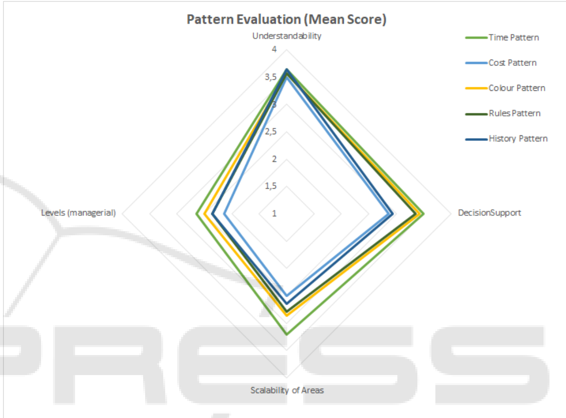

Figure 8: Case Study 1: Mean Scores of Patterns Evaluation.

Our empirical evaluation and its case studies face certain limitations. The example process introduced in the case study was small and simple without involving many activities and different levels. Due to this, the benefits of the proposed modelling language were not apparent in cost and history patterns. A detailed process with more activities and aggregation levels can help to evaluate the proposed modelling language better.

Since most of the patterns are rated well (like time, colour pattern, rule), therefore, it will be adapted as a standard in modelling business process for analysis and improvement with a performance perspective at a certain point.

Before the empirical evaluation, we assumed that traditional methods are insufficient, especially from a time and cost perspective. However, empirical results did not statistically confirm the developed hypothesis. Instead, the results show that most participants favoured the traditional method in cost dimension analysis and history perspective. Similarly, we thought our proposed model extension is very helpful for analysis and improvement; however, the experts see the need for data preparation work and tool support as necessary step for its realization.

7 CONCLUSIONS & OUTLOOK

In this paper, we have propagated the demand for modelling language to analyse and improve the business process. The modelling language is not only necessary for the performance perspective of business processes but also knowledge management. We proposed the extension of the BPMN modelling language for this purpose. We also evaluate the proposed extension on empirical basis. The feedback collected from the experiments will be accommodated in further improvement of the proposed modelling language. We also want to extend the proposed modelling language with other constructs. Similarly, it has to be evaluated in different organization, their processes, and the general public. This will further improve the effectiveness of proposed extension.

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