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An Extension of BPMN Meta-model for Evaluation of Business Processes

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Abstract – **Business process modeling is used for better understanding and communication of company's processes. Mostly, business process modeling is discussed from the information system development perspective. Execution of a business process involves various factors (costs and time) which are important and should be represented in business process models. Controlling of business units uses post execution analysis for detection of failures for improvement. The process models conceived for information system development are not sufficient for post execution analysis. This paper focuses on the challenges of business process modeling in the post execution context. We provide a meta model for evaluation of a business process and discuss BPMN in this context. We also extend existing BPMN meta model for performance analysis of business processes. The proposed extensions are presented with the help of an example.**

Keywords – **BPMN extensions, business process analysis, business process modeling, business process improvement.**

I. INTRODUCTION

Different phases of process management (from initial setting to optimization) require different models [1], [18], [21]. Phalp and Shepperd distinguish two types of the usage of business process models [20]. On the one side software development is in focus, whereas on the other side, restructuring of business processes is the priority. Different models and views are required for restructuring and analysis of business processes [1]. In the UML, there already exist different types of diagrams to focus on the software development process.

For improvement of business processes, evaluation is a necessary step. This is due to the reason that evaluation provides different measurements that indicate whether company goals are successfully achieved or not. These measurements also indicate where deficiencies exist in business processes. Business analysts try to overcome these identified deficiencies in order to improve business processes and interaction of involved elements.

Most of the modeling languages are designed for the development of information systems [16]. However, using these modeling languages for analyses of business processes is not appropriate, specifically after execution, as these models are not designed for this purpose as discussed in [14].

Availability of analytical data and records of business objects in business process execution enable us to analyze processes more carefully. Process mining techniques [26] provide excellent opportunities to extract knowledge from business process executions. Process mining fits between the business process models and business executions. Most of the

research in process mining is focused on alignment of information technology and business processes. It also provides different statistics for analyses. Limited research is carried out to represent process knowledge through business process models for improvement [14], [16]. Currently, information is represented as key performance indicators (KPIs) or represented using different approaches of visualizations (e.g., pie charts or histograms) which is too abstract and does not provide process details to business analysts. Business process modeling has to be further investigated for adequate representation of business processes, especially after execution for analysis and improvement.

We discuss a business process lifecycle to explain different phases from a post execution analysis and improvement perspective in Section II. Evaluation of business processes and post execution analysis are further discussed in Section III where we provide a meta model for evaluation and state the need for a modeling language. In this paper, we extend our earlier work [15], [17] with meta model level investigation of business process and business process modeling notation (BPMN). We discuss the proposed extensions of BPMN in Section IV and explain them with the help of a manufacturing example in Section V. In Section VI, we discuss the related work in this field followed by Section VII which summarizes our paper and provides an outlook as well.

II. BUSINESS PROCESS LIFECYCLE

Business process lifecycle starts with the *analysis phase* where existing operations of an enterprise are investigated. In this phase, analysts make different interviews with employees and prepare an AS-IS (actual) process model. This process model is used to understand and communicate on the current working of an enterprise with stakeholders. This AS-IS model also contains details about enterprise organizational structure with respect to operations performed. The resulted AS-IS process model of the analysis phase is investigated for possible changes in case of change management or for deficiencies in case of improvement. The analysis phase is also a starting point for continuous process improvement.

In the *design phase*, the findings of the analysis phase are considered and a TO-BE (target) model is prepared. This TO-BE model attempts to improve the existing situation or accommodate the new changes. In this phase, domain experts define how business processes should be carried out, like what are inputs, outputs, rules, and actions in processes. In this phase, new target values are also defined for different business objects to achieve desired goals (efficiency and effectiveness).

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Validation of business processes (simulation) can also be carried out before implementation. In business process reengineering, the business situation is also analyzed (analysis phase) but it is not of the main focus. The main focus for business process reengineering is the design phase where different changes are made to improve the operations of an enterprise.

In the *implementation phase*, a target design model is tried to be realized in an enterprise with different technical and organizational details (like deployment, reorganization of organizational structure, and allocation of resources). Different supporting systems are also used for efficiency and realization of target concept, like information systems. The implementation phase of business processes with information technology (IT) can have similar phases of business process lifecycle because business needs and requirements have to be mapped into IT services to provide IT support.

After implementation, business processes are executed in order to fulfill requests of customers (internal or external). In the *execution phase*, data about execution of different instances are stored. This is done with the help of information systems in form of log files and tables. The recorded information about execution of a business process is used to evaluate the business process and its involved elements.

In the *evaluation* of business processes, different quantitative measurements are made to evaluate the performance of business objects like processing time, idle time, and different costs. These quantitative measurements are used for qualitative indicators like customer satisfaction and overall quality. In the evaluation phase, actual values are compared with target values in order to measure the performance of involved elements. Therefore, evaluation is used to see whether objectives of an enterprise or improvements are achieved or not. The post execution analysis phase is part of evaluation phase where performances of business objects are analyzed in different perspectives. This post execution analysis is the main focus of our research and we extend business process models for better support for improvement. Extended models help to identify deficiencies in business processes. We will further discuss their difference from the earlier AS-IS model in detail in the next section. The result of the evaluation phase is recommendations from data and modeling perspective.

In the subsequent *analysis phase*, the recommendations from evaluation phase are incorporated with an existing AS-IS model and discussed with employees. The improvements in the existing AS-IS model are made to make it closer to enterprise objectives. In most cases, the effect of improvements takes time to be visible in business processes. Therefore, depending on the kind of changes, a time lag is incorporated to see the effect of improvements and changes [9]. In this way, business process management lifecycle continues to achieve enterprise goals.
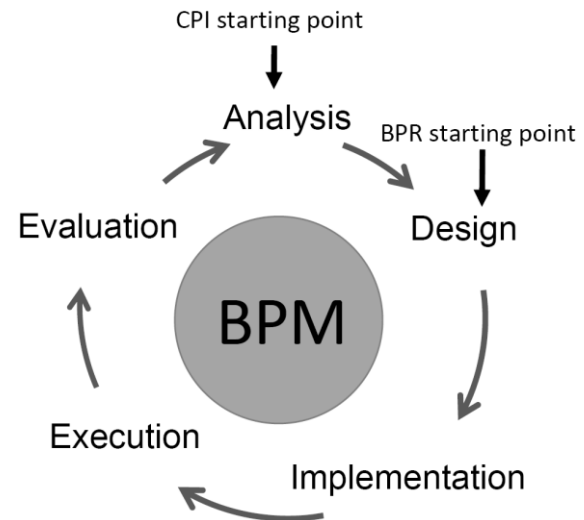

Fig. 1. Business process lifecycle adopted from [9] for the post execution analysis context

III. Evaluation and Post Execution Analysis

Business processes are evaluated in order to determine whether desired objectives are achieved or not. Different parts of processes and business objects are investigated to measure the achievement of overall objective as well as their own performance (business objects and processes). Therefore, depending on the context, different measurements are made which are related to specific instance executions, overall process characteristics, or individual business objects. The collected actual values of related business objects are compared with target values to measure the performance of processes and business objects.

A. Evaluation Meta Model

Evaluation of a business process and its elements can be divided into two categories, quantitative and qualitative indicators. Different techniques provide quantitative and qualitative results about processes and business objects like statistics and process mining [26]. These results are viewed from a different perspective like organizational, control, and operational cf. [14]. Figure 2 shows the classification of evaluation where dotted lines show examples of classes.
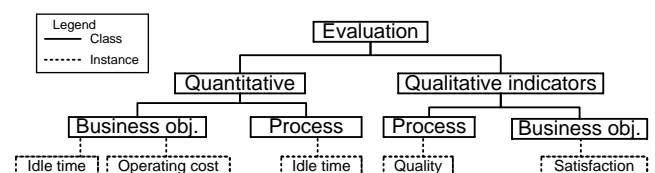

Fig. 2. Classification of evaluation and different examples

Quantitative measurements are direct measurements which are made to evaluate the performance of business object or process. These measurements are made at various levels like for the executive (aggregated in a form of overall profit/loss), managerial level, and operational level. Different methods and KPIs are used at each level, we do not go into details of these

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methods as it is out of scope of this paper. Examples are idle time, operating cost of an organizational resource (employee, machine). Similarly, process performance attribute examples are the number of times the process has been successfully completed. An instance related example is the time taken by a particular instance to complete a process (which includes waiting time before a resource is allocated, material is available for production, or synchronization time).

Qualitative indicators are indirect measurements which are made from the quantitative measurements. Quantitative measurements like number of complaints, number of revisions, number of rejections, number of times a particular event occurs help to provide quality indicators. For these indicators certain assumptions are made to define the degree/level of an indicator. Examples are customer satisfaction (satisfied, not satisfied), quality of a process (very good, good, bad), and employee effectiveness. The discussion of quantitative measurements and qualitative indicators is not focus of this paper.

Evaluation of a business process can also be investigated from a structural perspective. In structural perspective, different measurements are made, for instance, which process structures or parts are efficient compared to others. For example, some instance executions are efficient as compared to others because they took a specific process path.

B. Post Execution Analysis

Post execution analysis of business processes is part of the evaluation phase, where results from the above discussed measurements (quantitative and qualitative measurements) are taken to analyze performances from different perspectives such as process, organizational, and operational. The actual process model is built from execution logs (collected process trace data). This process model is compared with the models before execution. In case of discrepancies between plan and target values or behavior (execution order), the deficiencies in business processes are investigated.

In the post execution analysis phase, we focus on performance of business objects and processes by using different metrics. This is different from the analysis phase where we focus on how operations are performed by analyzing execution order and relation of business objects with processes (without performance metrics). In the post execution analysis phase, different analyses are carried out to answer analytical questions and to find out the root causes of deficiencies. Similarly, different methods such as data mining and process mining are applied to improve the existing situation.

Process mining is an analysis technique in which logs of information systems are used for analyses. Process mining technique aims at identifying the quality of process model and adequacy of execution environment [5]. The focus of process mining is on the process structure itself rather than on the data perspective [27]. Currently, the knowledge in post execution analysis is represented at an abstract level using charts and other models. For a better support in business process improvement, knowledge should be represented along the process structure with more details within business process

models. By doing so, models provide further insights to processes and enable analysts to carry out improvements in processes.

Most of the existing process modeling methods are strongly influenced by software development [28], [7]. The process modeling has to be further investigated for process evaluation, analysis, and improvement. The graphical process models developed for information systems development have different focus and details such as transforming business needs in information technology services. For example, abstraction is required for information system development, and certain details are not considered during modeling (like implementation details and execution). On the other hand, for post execution analysis, descriptive models are required and all details are needed to be represented in models for analysis and improvement. Therefore, for post execution analysis within the business process management lifecycle, we need models which have more focus on business domain and also support details from an information technology domain.

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 fulfill this gap and provide models for process analysis and improvement. This representational gap in post execution context and challenges are further explained in [14] where we explain several limitations of modeling languages from different surveys and evaluations in literature.

IV. AN ANALYTICAL MODELING LANGUAGE

In this section, first we describe the basics of business process modeling notation (BPMN). We also state the reasons why we have chosen BPMN over different other modeling languages for our discussion and extension as an analytical modeling language for evaluation and analysis of business processes. We also provide a meta model of BPMN and further extend it for evaluation of business processes. We further discuss the proposed extensions of BPMN model using an example.
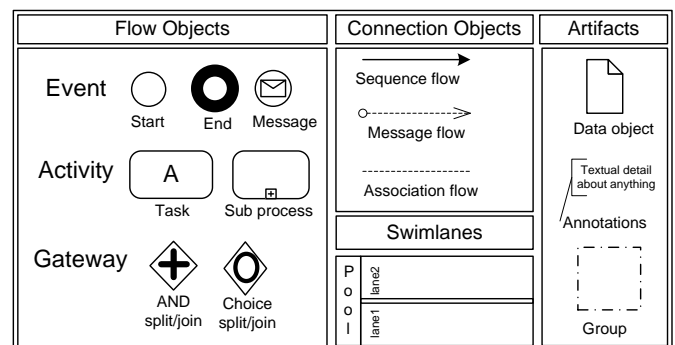

Fig. 3. Main categories of Business Process Modeling Notation and examples of some constructs

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A. Business Process Modeling Notation

The Business Process Modeling Notation (BPMN) [3] is a standard defined by the Object Management Group (OMG) for modeling business processes. BPMN graphical notations are used as a tool for communication between business and technical users. Modeling constructs of BPMN language are transformed into constructs for execution languages such as the Business Process Execution Language (BPEL) [11]. In BPMN specifications, BPMN graphical notations are divided into four basic categories [3]. These categories are shown in Figure 3 and briefly discussed as follow.

Flow objects consist of activities, involved decision nodes for their order (sequential, parallel, iterations), and events of processes. **Connecting objects** as the name implies are used to connect the activities and other elements with each other using different arrows which represent messages and associations between them. This core set of elements define the control flow perspective of processes.

Different modeling elements are grouped through **Swimlanes** which use pools and lanes [3]. A Pool is used to represent process participants while lanes are used to partition these participants and their activities from one to another. A process participant can either be organizational entities within an organization or different organizations for collaboration in a process. Mostly, organizational perspective is provided by using Swimlanes constructs.

In BPMN, additional information about the process such as involved data objects and guidelines for operations are provided by **artifacts**. These elements consist of data objects, annotations, and group constructs. There are several other modeling constructs in these categories for further specification of a business process. Besides these modeling constructs, different extensions are also possible in BPMN to provide further insights about processes in a BPMN model. An abstract meta model of BPMN is shown in Figure 4.
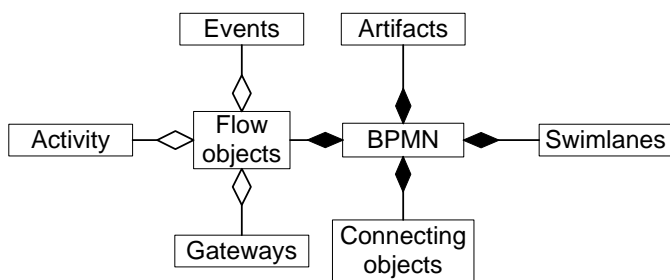

Fig. 4. A meta model of Business Process Modeling Notation.

We deliberately kept this meta model simple and abstract rather than describing different classes and notations in each category. Further details about different kinds of notations can be found in [3].

B. BPMN for Evaluation and Analysis of Business Processes

We selected BPMN as a modeling language for discussion and extension for evaluation and analysis of business processes because BPMN is more expressive as compared with other modeling languages. Another reason for BPMN

selection is that in the scope of its definition the support for XML is already considered [3]. There are already some attempts to transform BPEL into BPMN (cf. [30]). However, sometimes it becomes hard to model the extracted data as things would not be executed in the way they can be modeled.

Different modeling constructs are required to represent involved business objects such as inputs, rules, and performance related information. The existing BPMN notations and meta model do not incorporate the performance details of business processes. BPMN has certain limitations, for example, when Swimlanes (Pools and lanes) are used to represent organizational entities, they just represent organizational roles. They do not provide any information about their performance, skills, workload, and working time. Similarly, data objects involved with activities are represented very abstractly as no information about their structure and their contents (values) is shown in a BPMN model. Some other limitations of BPMN model are also discussed in [22]. Therefore, the BPMN meta model can be extended to include the performance details of business processes and business objects.

Details on data collection, computation, and storage of business objects are out of the scope of this paper. However, in [15], we have already specified an overall framework in this context.
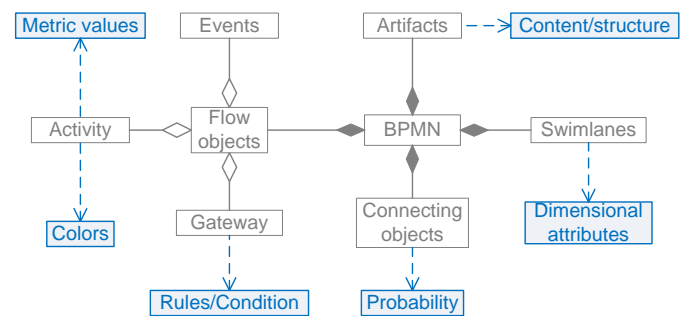

Fig. 5. An extended meta model of Business Process Modeling Notation for evaluation of business process in a graphical way

In Figure 5, we have extended the BPMN meta model for evaluation of business processes. After execution, the computed performance data can be represented with the activities to represent their costs, duration, and other performance details. Similarly, activities can be represented using different colors to show costs and their impacts. Different rules and involved conditions can be represented on decision points to give better understanding about executions. Similarly, connecting objects can be extended with probability of execution for a certain path. Besides representing involved participants, Swimlanes can also be used to classify activities in different dimensions based on time, cost, or quality attributes. Artifacts can provide other statistics and performance data about different objects such as organizational units and events.

We further discuss the proposed usage and extensions of BPMN with the help of an example in the following section.

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V. EXAMPLE

Consider an online purchasing scenario where a customer arrives on a web portal. A customer selects a particular product to purchase. He adds the product into a shopping basket and fulfills the order request form with shipping details. Then, he processes the online payment form. Several other processes are involved in processing this scenario like fulfilling an order request, transfer of a payment, manufacturing the product, and shipping process.

In our scenario, we consider that the ordered product is a replica shirt (German national football team jersey). Customer has an option either to print his own name or select from available star player names. Once the order form is completed, it is sent to the manufacturer/retailer for further processing. On the manufacturer side, the required product is checked in stock. If the required products is not in stock, then a production order is prepared for manufacturing product (assume a ready product is not available for printing).

In manufacturing product scenario, first the raw material (fabric) is collected from the store. Afterwards, it is cut into required shape for further manufacturing. Then certain cut pieces go for printing while the rest of the pieces are stitched according to design. Once printed cut-pieces are available, they are stitched with other parts, and the whole shirt is prepared. Quality inspectors examine the quality of the shirt. The manufacturing process is abstractly shown in Figure 6.

Afterwards, shirts with satisfactory quality are packed for further processing. Products are handed over to a shipping agent, and the customer is notified about shipping. When all these steps are recorded in information systems, we can use this data to analyze the performance of organizational elements, ordering of activities, and other involved objects.
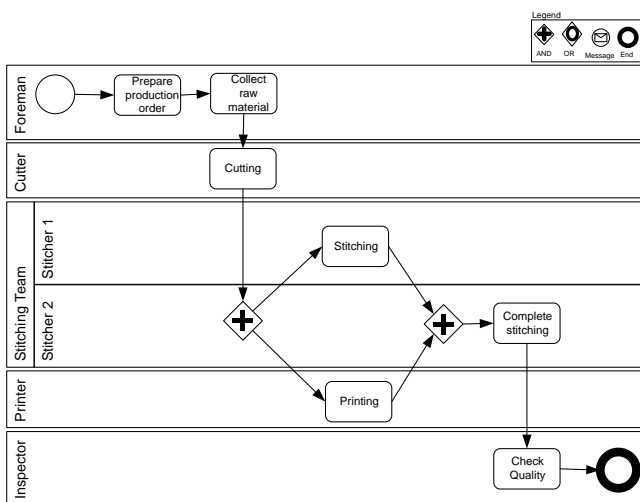

Fig. 6. Process for manufacturing a replica shirt in BPMN model

A. Proposed Usage and Extensions of BPMN

Business process models can be structured differently to represent performance related information. Here, first we propose the usage of different colors to represent the impact of business objects in execution. Afterwards, we discuss the

Swimlanes and other extensions for better understanding and evaluation of processes using BPMN. We also discuss the other proposed extensions of Figure 5.

B. Classification and Colors in Representation

The executional data can be used to specify the usage of which activities, organizational resources, and involved elements adds more value to an enterprise. Based on this information, activities, organization resources, and involved elements are classified based on a particular dimension. This classification depends on metrics used in the enterprise, overall average values can be used for this classification or user defined threshold values. We recommend that only few classes should be defined for less cognitive loads of models.

Based on this information, different colors can be used to indicate the effect of a business object like green for optimal cost, yellow for high cost, and red for very high cost. Similarly, these classes can be represented in other dimensions as well like quality and time. Although, the relation of cost and time is not that simple as discussed in [29].

During execution the values of operational objects (inputs) are changed by involved business objects. The change in values gives us details what operations are already performed and which path is taken. During analysis, different colors can also be used to represent the instance executional history, like which path instance has taken and at which particular stage a certain decision is taken. Similarly, up to which time process path was optimal. For this, such data can also be extracted from information systems logs or operational databases. Colors can also be used to represent the best practices and non-optimal paths.

C. Swimlanes and Dimensions

In BPMN, Swimlanes (pool and lane) are used to represent process participants and their interaction during execution. We propose to use Swimlanes not only to see participant interaction but also performance of organizational resources and activities. Based on collected data, process participant performance should be computed and their lanes should be colored (like green, yellow, and red). Similarly, activities can also be aligned using Swimlanes based on their computation in a particular dimension and their attributes. Consider Figure 7 where three classes are defined in cost dimension to arrange the activities of processes and their involved elements.
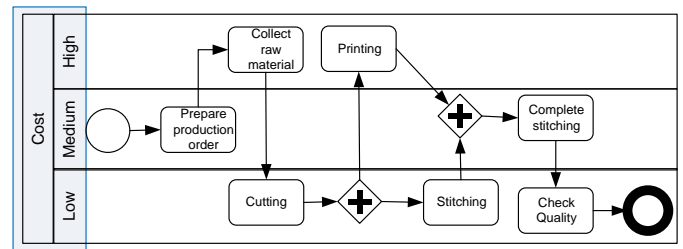

Fig. 7. Process model representation based on different classes of cost

Similarly, different dimension attributes can also be defined as pools where lanes represent further classes of these

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attributes as shown in Figure 8. In Figure 8, activity *collect raw material* is represented in two different attributes of time dimension. This Figure shows that the actual operating time would be very short but with high idle time. For simplicity, we have not shown different other involved activities. Moreover, different dimensions and their attributes can be combined with one another for further business process analysis.
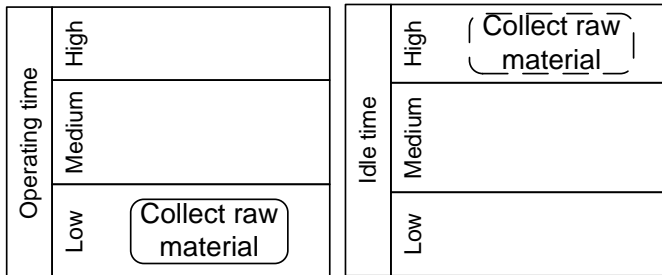

Fig. 8. Process model in time dimension with alignment of activities according to its different attributes

When we represent performance details using Swimlanes in the BPMN model, we can find out which activities are consuming time and taking high costs. Afterwards, these activities can be further investigated to identify their deficiencies for improvement.

D. Other Extensions

In Figure 9, we propose new symbols to represent different operational objects (e.g. physical), organizational resources (if not represented in lanes/pool), and data objects with attributes. These symbols are necessary to provide more understanding of business scenarios and their corresponding process models. Similarly, the values of attributes are very important in case of business rules and conditions. It is due to the fact that values of attributes play a major role in deciding the route of an instance. Similarly predicates on a connecting object or gateway represent involved condition of the flow. Based on these extended notations, we represent an extended business process model of our example in Figure 9. The colors red, yellow, and green represent the business objects with high, medium, and low cost respectively.

VI. Related Work

Most of the research in business process modeling domain is related to the information system, like information system development [2], workflow management [24], simulation of business processes [12], alignment of IT services with business processes [25], or configuration of information systems [8]. The focus of research on business process modeling after execution is limited. The approaches which analyze business processes after execution use same models which are conceptualized for information system development like some process mining [26] tools use Petri nets [24].

A survey on business process analysis for optimization and improvement is provided in [28]. In that survey, the authors categorize different approaches to notational, formal and semi formal categorizing. Their survey indicates the lack of business process modeling languages for post executional phases. However, they do not provide any extensions or examples of modeling languages which we have provided in this paper. The concept of excluding activities at the abstract level and including them at the detailed level is also discussed in [8], [3] whereas in [4], it is discussed at the attribute level. Different views of models are generated based on the environment (role) of execution as discussed in [6], but they only discuss them from the software process perspective. The concept needs to be applied in a business process domain.

In [19], the author presents an approach to transform business process dimensions (time, business rules, and information) into BPMN constructs that could be implemented in a BPMN modeling tool. However, the author does not discuss it from post execution analysis and improvement perspective. Here, we provide different extensions of BPMN for better understanding and representation. There are some other attempts as well where BPMN models are extended in particular dimension like knowledge in [23] or for modeling process goal and their measures [13].

Several business process intelligence cockpits exist which represent performance metrics in different models like histograms, radial graphs, and several other techniques. Similarly, process mining tools (like ProM [27], EVS [10]) also exhibit performance metrics through different graphical models. In ARIS PPM tool, frequent paths are represented by their weight of connecting arrows. However, performance metrics are represented using traditional statistical approaches. Though these KPIs visualization techniques lack the support of business process modeling language to provide overall process perspective for improvement. Similarly, these approaches provide the facilities in one perspective and for other perspectives other techniques have to be used.

VII. Summary & Outlook

In this paper, we discussed business process lifecycle from the post execution analysis perspective. We provided a meta model for evaluation of business processes and discussed existing modeling languages for performance. We also provided the meta model of BPMN and extended this meta model with other elements for business process evaluation. We used a manufacturing example to explain the proposed usage and extensions of BPMN for analysis and improvement of business processes.

In future, a tool support for generating such extended models from information system logs files will be provided. Application of the proposed analytical modeling language in industrial case studies is also planned.
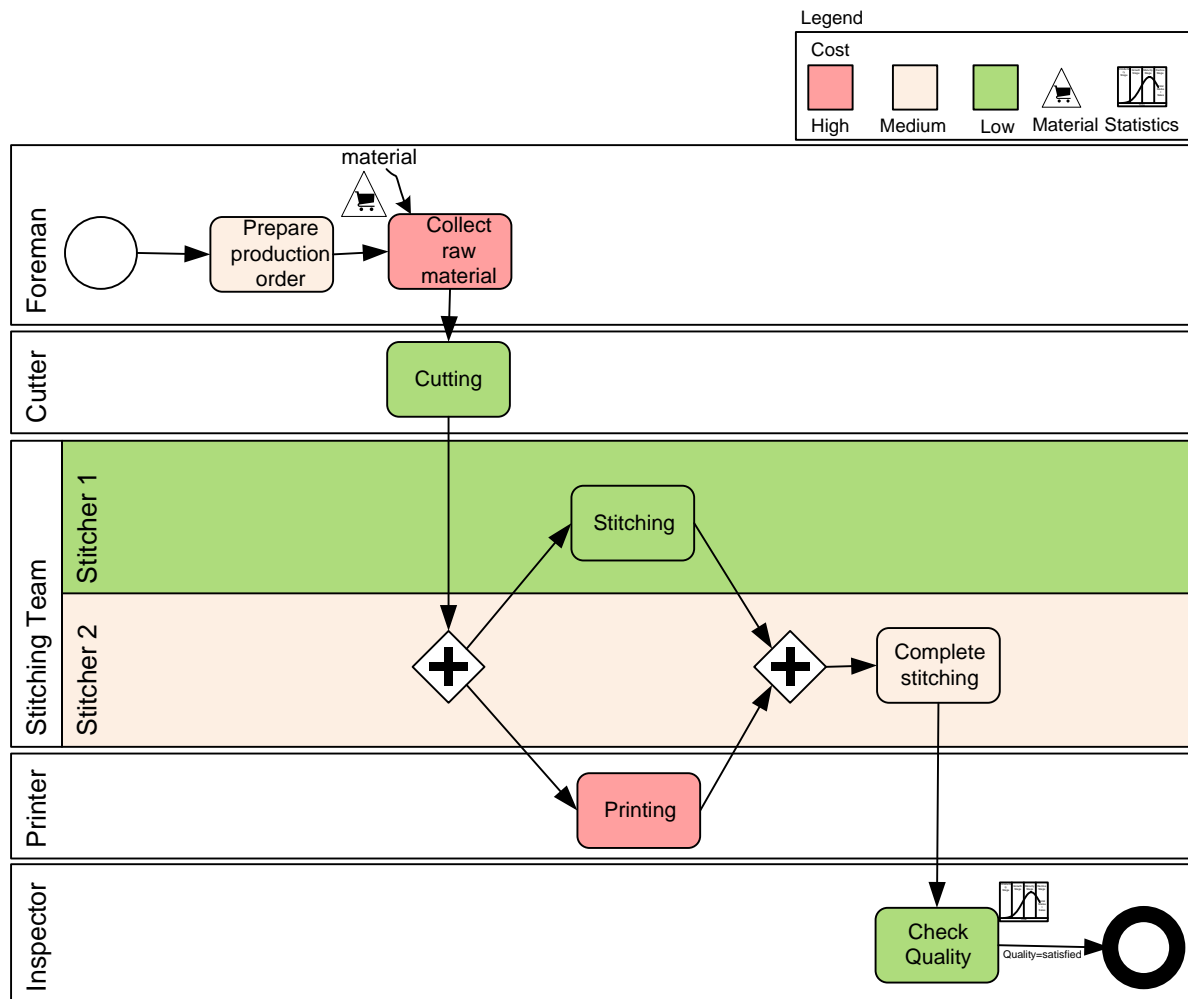
Fig. 9. Performance based extended BPMN model with involved business objects

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