STREAMLINING PROCESSES FOR DIGITALIZATION

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ABSTRACT

New trends and technological developments bring opportunities and threats for enterprises at the same time. Organizations which do not adapt their strategies have to fight for their survival. Information Technology plays vital role in this evolution. Enterprises still need a seamless process from idea initiation till its implementation and improvement. The gap exists between the research and its application in an enterprise. Organization need to streamline their processes for Digitalization. In this paper, we provide an analytical framework for analysis and improvement of business processes. We also propose an analytical process modelling language to support the framework and to identify the deficiencies in processes. We also provide constructs and patterns of our proposed modeling language which are independent of a specific modeling language. The analytical business process modeling language is further explained with the help of a case study and demonstrated by extending an existing modeling language.

KEYWORDS

Business Process Modeling, Performance Representation, Business Process Analysis, Analytical Framework, Improvement

1. INTRODUCTION

The business world is competitive and fierce competition exists between companies due to globalization, emerging technologies, and digitalization. Even small companies with niche characteristics give competition to well-established companies and have a reach to wider international markets. A research in 2014 indicated that in the span of 14 years (since 2000), 52% of companies in the Fortune 500 have disappeared from the list (either gone bankrupt, been acquired or ceased to exists) (Wang, 2014). Only 12% companies (60 in total) still in Fortune 500 list since 1955 as analyzed in (The American Enterprise Institute, 2017). Old products are replaced by new products and services (e.g. camera films with digital cameras).

In the past three decades, significant technological development has been made and reached to wider society. This has not only increased the competition between companies, but also raised the expectation of customers. Therefore, enterprises seek new ways to provide innovative and quality services to satisfy customer’s needs. Different enterprises attract and involve customers with digital experiences. These new ways also paved the way for new business models to generate more revenue and serve different customer segments.

There are different levels of developments and their implementations in organizations with respect to time as discussed in (Khan & Turowski, 2016b). At universities and research institutes, significant developments have been made in research. These developments are industrialized or applied in organizations after a certain period of time (3-6 years approximately) on enterprise level. For example, the term ”Internet of Things” coined in 1999 by (Ashton, 1999) and ”Cyber-Phyiscal System” in 2006 in (Lee, 2008). At manufacturing level, these developments come after a long time, as technology remain at the time of machine purchase and lasts as long as it works. This relation is shown in the Figure **Error! Reference source not found.**. A company which uses the latest technology at all levels coupled with business model is guarantee for its success (Khan & Turowski, 2016a).

In order to respond to the changes in the business world with existing infrastructure, enterprises continuously try to streamline their organizational structure and operations. This is carried out through effective design and analysis of operations. It requires understanding of operations and its performance evaluation. Evaluation is considered as first step for improvement.

It is quite challenging for analysts to understand the existing infrastructure, performance, and deficiencies of an enterprise. In this paper, we provide an analytical framework which help to understand the processes and their performance. After such analysis, organizations can be able to find out the possible deficiencies in processes and will be able to take steps for its improvement. We also propose the constructs of analytical modelling language which can be used to extend the existing modeling languages for performance analysis purpose.

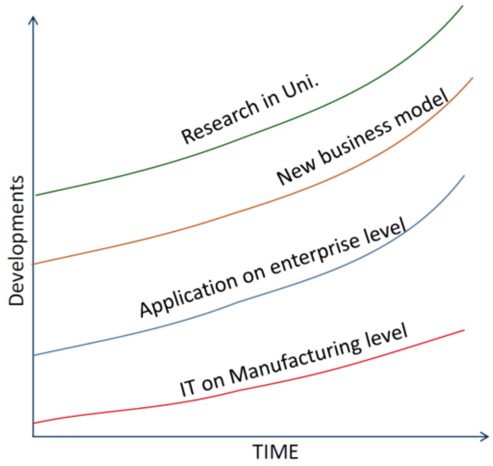

Figure 1. Research & its Implementation (adopted from (Khan & Turowski, 2016b))

The structure of this paper is as follows: In Section II, we discuss the business context and challenges for organizations. This helps the reader to understand the challenges in this domain. In Section III, we provide an analytical framework for analysis of business processes followed by Section IV where we propose the Analytical Business Process Modeling Language to support our framework by discussing our proposed modeling language with its patterns. In Section V, we explain the proposed modeling language with the help of a case study using business process modeling notations (BPMN). In Section VI, we summarize our paper and provides an outlook.

2. BUSINESS CONTEXT, DRIVERS AND CHALLENGES FOR ORGANIZATION

Customers' demands are fulfilled by enterprises which do business for several reasons like satisfying stakeholders (executives, employees, and customers), monetary gain, or increase in reputation (Lodhi et al., 2011b). To maintain the competitive position in the market, enterprises provide new products and services. This trend of competitiveness triggers other enterprises to provide better services in order to keep or strengthen their position in the market.

Vision is developed by its stakeholders followed by the strategy to fulfill it, whereas business model plays a vital role for the implementation of the strategy. Business processes (BP) are defined to carry out the operations of an enterprise. We refer this as a business perspective and represented in the Figure 2(on left side). Different aspects have to be investigated on the business level due to digitalization such as business models (and business patterns), business process management practices and their impact on supporting information technology.

Business processes are executed by organizational resources. During the execution of business processes data is generated and used for its processing. The execution of processes is supported by different applications and managed by technological entities. This is referred as an enterprise architecture perspective and represented in the middle of the Figure 2. Enterprise Architecture is renowned field of the research. The information and communication technology (ICT) is a critical enabler in digitalization. Often a holistic view of relevant processes, data, applications, and technological infrastructure is missing in the organizations. This is due to the fact that sometimes processes are complex and long which includes automated and manual process steps.

On the right side of the Figure 2, automation perspective is shown. This shows how different technological systems interact with each other during the industrial operations. On Enterprise level, orders are received and planned for manufacturing. Manufacturing Execution System (MES) monitors and controls the execution of orders supported by Supervisory control and data acquisition (SCADA) and programmable logic controller (PLC) components. On the lowest level, actuators perform actions on the raw material and turn it into the products. Different sensors are used to collect the data during this process like quality attributes, machines and environmental conditions. Business perspective is disciplined by an enterprise architecture and operated by industrial automation on wider scale. The relationship between these perspectives is shown in Figure 2.

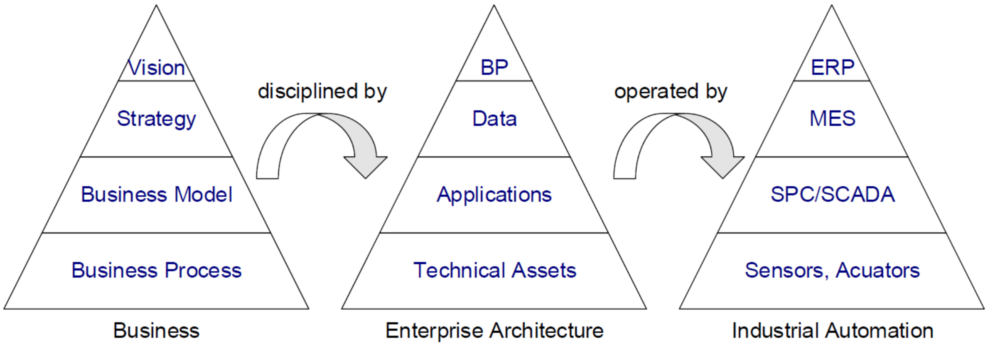

Figure 2. Relationship between Management Perspectives of an Enterprise

3. AN ANALYTICAL FRAMEWORK

In enterprises, different silo systems exist which can be applications and their databases. In reality, the communication between silos is not seamless. Different other applications, interfaces and macros are used to fulfill this task. The situation is more challenging in bigger organizations at manufacturing level where process chains are lengthy and majority of the processes are executed manually supported by different customized applications on old systems. Enterprises find it difficult to decide from where to start and what changes should be carried out for improvement. Complexity in business process is due to various factors like inter-dependencies between activities, stakeholders, involved elements, their attributes, and applications. Research in business process improvement needs to address these complexity issues and provide support to decide which action should be taken for business process improvement.

In order to provide the required support for business process improvement, a complete framework for analysis is required to be specified. This framework should address issues like data collection from silos, its integration, computation with business rules, and representation in business process models. We also need clear directions like defining steps for improvement, and mechanism to carry out the changes. An abstract picture of the overall framework is shown in the Fig. 3.

Enterprise data warehouse systems, extract the data from different legacy systems and applications and then integrate with each other. This data is also combined with Manufacturing Execution System logs which registers different events (like business object ”received”, ”processed”, ”successfully completed”) during the process execution. Different application log files are also collected from the systems.

Different techniques related with process mining (van der Aalst & Weijters, 2004) attempt to solve the issues related with data collection (Khan et al., 2010, Ingvaldsen and Gulla, 2008) and its conversion (van Dongen & van der Aalst, 2005, Günther & van der Aalst, 2006). Similarly in (zur Muehlen, 2008), author proposes a data format for recording business events. This BPAF (Business Process Analytics Format) helps in correlating and aggregating business events from different systems to one location. In (Grigori et al., 2004), authors store data from logs into a data warehouse for different analysis. Therefore, data is collected from log files of information system and converted into a suitable format for analysis (this data is sometimes referred as process trace data).

Afterwards, several techniques (like process mining algorithms (Rozinat & van der Aalst, 2006, van der Aalst, 2005, van der Aalst et al., 2005) and business process intelligence (Grigori et al., 2004)) are applied on process trace data to extract knowledge. Application usage mining (Kassem & Rautenstrauch, 2005) techniques analyze user's behavior with applications and attempt to improve the interaction between applications, humans and their working. Similarly, other techniques can also be applied like balance scorecards and other process metrics.

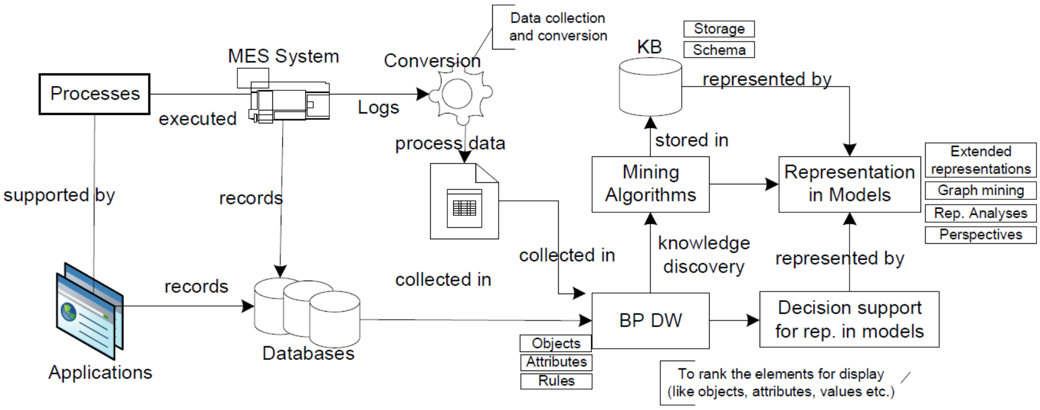

Figure 3. Framework for Business Process Improvement and Analysis

A knowledge base is also required to store the gathered information and knowledge from analysis techniques. Several issues are needed to be further investigated like what would be the schema design or format for storage? How the knowledge will be reflected as a company's best practices or used in enterprise operations?

The extracted knowledge and information are represented in a graphical form for intuitive understanding. For this purpose, depending on the stakeholders, certain information is filtered or provided with more details (context). Therefore, a decision support system is required which will rank the knowledge for representation with context to stakeholders. This is also very important to reduce the cognitive load of users in graphical business process models while representing performance details and other knowledge.

Graphical representation of extracted knowledge and process trace data also provide an opportunity to apply different methods like graph mining (Lodhi et al., 2010). Similarly, extended business process models help analysts to understand processes and identify deficiencies in business processes. We discuss the extended representation and benefits in the following section.

4. ANALYTICAL BUSINESS PROCESS MODELING LANGUAGE

Different stakeholders are involved in enterprises at different levels. In (Lodhi et al., 2011a), we discuss different stakeholders and their participation in business process elements. The performance is usually evaluated in form of quantitative measurements which help to indicate about quality. Business processes and its elements are evaluated in different dimensions like time, cost, and quality. In order to achieve the real benefits of evaluation of all important dimensions, their attributes should be part of the evaluation for a particular product, process, or employee.

We design analytical business process modeling language (ABPML) by performing a thorough analysis of business process performance analysis requirements (Lodhi et al., 2014, Lodhi et al., 2010), existing modeling language (Lodhi et al., 2011b), and different analytical tools (like ProM (van der Aalst et al., 2009, Ingvaldsen et al., 2005)). We do not only include the best of breed features, but also include some innovative features which provide help in analyzing business processes and identifying deficiencies. Therefore, the problem/solution search space is well investigated and considered in designing the new modeling language.

Here, we take the assumption that the analytical data is already available from the analytical framework discussed in previous section and just needs to be represented. The analytical data can be extracted from executional data (process trace data) or database tables.

In design science, a language specification includes constructs, models, method, and instantiation components. Therefore, we address these components for specification of our proposed analytical modeling language. These are correspondingly discussed in the following.

Constructs provide the vocabulary and symbols which are used to represent a problem or a solution (Hevner et al., 2014) or just representing a situation. Constructs are used to represent the tangible or intangible elements of a process. They are used to represent activities, process participants (resources, places), events (communication between elements), gateways (decisions), and other involved objects (materials, orders). Therefore, they are basic building blocks of a graphical model. Semantic defines the meaning of symbols and relationship with each other.

4.1 BPMN as an Example Case Study

We use the basic constructs of Business Process modeling Notations (BPMN) as described in the BPMN [1] standard (BPMI and OMG, 2006). We have select BPMN as it is rigorously defined and has widely accepted as a standard (defined by OMG) for modeling and communicating business processes. It is implemented in different modeling tools and rich in representation. Similarly, various extensions are also proposed in order to suit different business needs. Therefore, adoption of our proposed modeling language will not be a challenge in industry.

For our analytical modeling language, we propose some other constructs as an extension and also define the context in which some of the basic constructs have different semantics (meanings and relations) as compared to BPMN standard. Those constructs are used only in a defined context for performance analysis.

BPMN graphical notations are divided into four basic categories (BPMI and OMG, 2006). These categories are discussed briefly 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 activities and other elements with each other using different arrows which represent messages and associations between them. This core set of elements defines the control flow perspective of processes.

Different modeling elements are grouped through **Swimlanes** which use pools and lanes (BPMI and OMG, 2006). 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 an organizational entity 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 object and guidelines for operations are provided by **artifacts**. These elements consist of data objects, annotations and group constructs.

To accommodate different requirements, we combine constructs to build models for analysis in different perspectives, and call them patterns. Different allowed combinations are explained here which also define the method of constructing the models in the analytical process modeling language. Depending on the user’s requirements, models are built at different level of granularity to facilitate the understanding of processes. We further explain these constructs and their semantics with the help of our proposed patterns.

4.2 Modeling Patterns

Patterns are used to share knowledge and solve problems (Khan et al., 2011). Therefore, in our context, we define patterns as a combination of constructs to analyze the process and its elements in a particular perspective for improvement.

Each pattern intends to analyze performance with a particular focus involving certain dimensions and their attributes. Here, we provide four patterns for visualization of business process performance (with respect to business process modeling language). We consider these four patterns as the most important and frequent in business process analysis.

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[1] http://www.bpmn.org

The analytical data can be used to identify which activities, organizational resources, and involved elements add more value to the enterprise. Based on this information, activities, organizational resources, and involved elements are classified in a particular dimension. The classification of process elements based on performance depends on the metrics used in the enterprise. Overall average values can be used for this classification and threshold values can be set. We recommend that only few classes should be defined for less cognitive loads of models. Enterprises can define their own metrics.

Based on the organizational metrics and values, different colors can be used to indicate the effect of the business objects, 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 as simple as discussed in (Vullers et al., 2007). Once such metrics are defined, then they can be represented using our proposed patterns in our modeling language.

Table 1. Pattern and Characteristics

Patterns	Purpose	Constructs
Time	Analyze the performance of resources and activities with respect to time	Swimlanes, activities
Cost	Analyze the performance from the cost perspective like material and resources	Swimlanes, activities, colors
Path	To understand the activities which will be fruitful	Edges, activities, colors
History	To understand which activities are frequently executed in process	Edges, thickness, activities

4.2.1 Time Pattern

Time pattern focus on representation of process element's performance from time aspect. A few classes and characteristics in this dimension are classified in Table 1 and represented in Section **Error! Reference source not found.** with BPMN. Some examples are idle time and working time.

4.2.2 Cost Pattern

Cost is an important factor in business processes. This pattern observes the performance of process elements from cost and other related aspects involving material and other resources. Different colors can be used to distinguish between high cost and low cost elements of process. Similarly, process elements can also be grouped based on the cost incurred by them.

4.2.3 Path Pattern (Time-Cost Pattern)

The time-cost pattern is helpful to decide at which path the execution will be effective (or beneficial for the organization). In case of different available paths, a path with company best practice can be colored to distinguish it from other options. Similarly, problematic paths (incurring cost and problems) can also be distinguished using colors from the others.

4.2.4 History Pattern

History path pattern represents which path is taken in most of the process executions. A thick edge represents that this particular path is taken by most of the cases during execution compared to a thin edge path which represent the opposite.

The proposed patterns, their elements, and meanings are summarized in Table **Error! Reference source not found.**. In the following patterns, different other attributes of the dimensions can be added and correspondingly represented using our proposed modeling language and its cognitive aspects (like colour, shape, and size). The above mentioned patterns are further explained with the help of an case study in Section **Error! Reference source not found.**.

5. CASE STUDY

Instantiation demonstrates the feasibility of a proposed modeling language to solve the problem and its benefit. For this purpose, we take a small example of a real life scenario. This typical purchasing scenario may have different implementations (order of activities and roles) in organizations depending on the size of organization and requirements. For the sake of simplicity, we take if from a very small company which do not have complex processes like big organization.

Consider a typical purchasing scenario where a customer orders a product. Once the order is received, the product is checked in the stock. If the product is available, then it is shipped to the customer. An invoice is also generated and the payment process also starts. If the product is not in stock, then a production order is created for manufacturing the product. In this way, the customer order scenario is completed. Several processes are involved in successfully completing this order-scenario like fulfilling an order request, transfer of payment, manufacturing the product, quality evaluation, and shipping process.

In production, first, the production order is created by a foreman for the required products. Once the production order is created the assignments of resources are made like scheduling of machines and persons for manufacturing. In parallel to this, the raw material is also collected from the store or suppliers. Afterwards, the product is manufactured by workers. On completion of product manufacturing, quality inspector examines the quality of the manufactured product. If the quality of the product is at the desired level, then the shipping process and financial processes are started. Otherwise, the quality of product is brought to the desired level by sub-process “fix quality”. Therefore, the overall order is completed and marked as completed. This production process is shown in Figure 4 using BPMN.

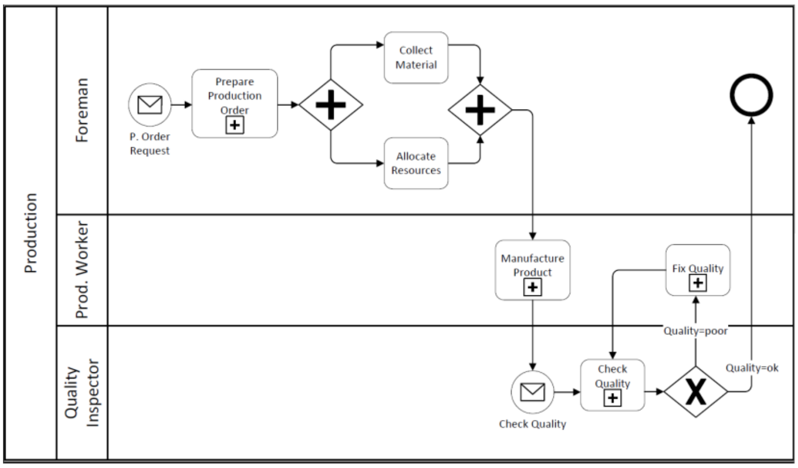

Figure 4. Production process in BPMN

When all these steps are recorded in information systems, we can use this data to analyze the performance of organizational elements and ordering of activities.

The whole process can be analyzed with abstract details like how much time it takes to complete the order. Bar chart like representations are suitable at an abstract level. However, at the managerial level the process can be analyzed with more graphical details that help to identify deficiencies and improve the process. For this detailed representation, we discuss our proposed patterns in the context of this example.

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 the 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 5, where three classes are defined in cost dimension to arrange the process activities and their involved elements.

Similarly, different dimension can also be defined as pools where lanes represent further attributes of these dimensions like in time dimension, Idle time can be defined as an attribute and other classes (like high, medium, and low) align activities for representation. Moreover, different dimensions and their attributes can be combined with one another for further business process analysis.

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.

Similarly, successful paths (or best practices) can be determined by evaluating the performance of processes and its involved elements. The successful paths can be represented by coloring the edges. The frequency of execution on a particular path can be represented by changing the thickness of edges (connecting objects). This corresponds to the history pattern of proposed modeling language.

Based on these extended notations, we represent an extended business process model of our production process in Figure 6. The colors red, yellow, and green represent activities with high, medium, and low cost respectively. In order to avoid confusion, in this figure, we only colored the activities to represent the performance aspects whereas Swimlanes are kept with their classical BPMN semantics (BPMI and OMG, 2006), such as process participants.

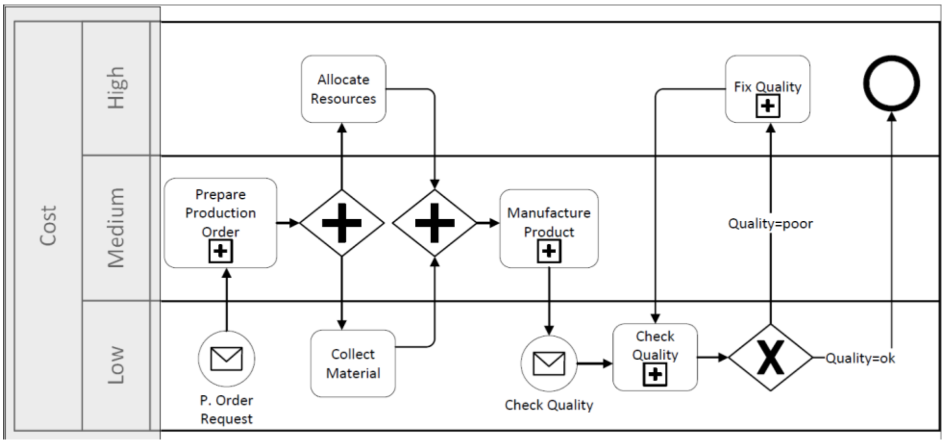

Figure 5. Cost of activities in ABPML

Figure 6, also represents that the quality of production is poor and frequently activity "fix quality" is executed to improve the quality of product. Similarly, it can be further investigated why activity "manufacture product" is consuming extra resources, which may result a representation that product manufactured by certain employee often need quality fixes or often certain paths with loops are executed.

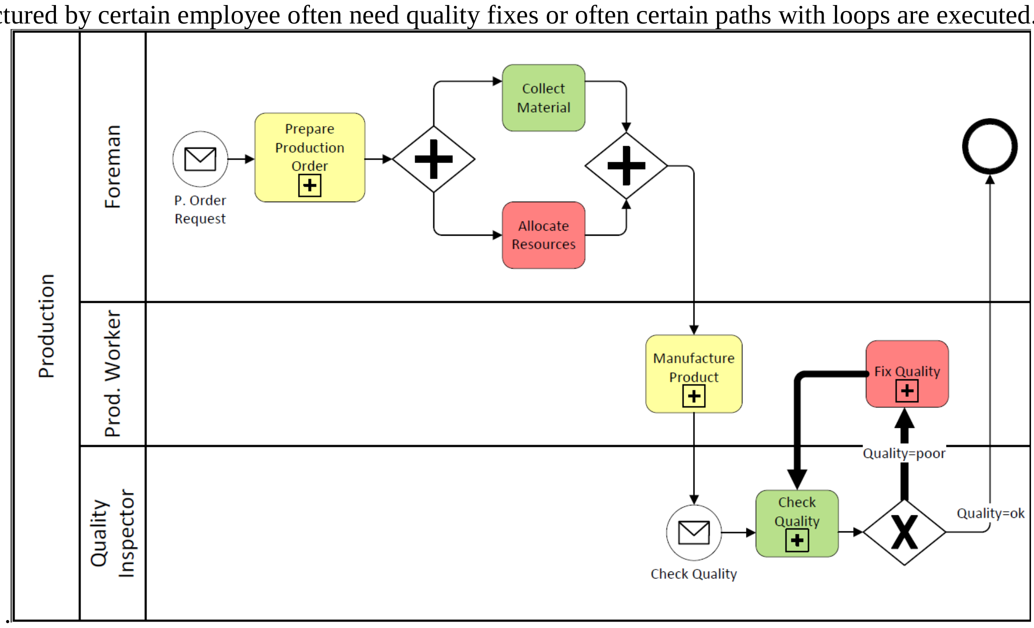

Figure 6. Production process in ABPML

6. SUMMARY AND OUTLOOK

In this paper, we presented a design science artefact (an analytical framework and modeling language) to solve the problem of performance analysis of business processes. We followed the design science guidelines for the specification of the framework. In order to support our analytical framework, we also devise and presented the patterns of proposed modeling language for performance analysis. These patterns are explained with the help of an example using a rigorously defined modeling language (BPMN). The patterns are independent of modeling language and can be used to extend any modeling language.

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