A Maturity Model to Promote the Performance of Collaborative Business Processes

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Abstract. Maturity models help organizations to measure the quality of their processes. These models are able to indicate how excellent business processes (BP) can perform and how organizations can reach the expected and higher performance. Maturity models aim at assessing and improving the capabilities, i.e., skills or competences, of business processes. However, finding the most appropriate maturity model is not an easy task especially for practitioners in manufacturing industry. Hence, the purpose of this paper is to critically propose a maturity model for the Collaborative Business Process (CBP) in a Service Oriented Architecture (SOA). We observed in the literature a lack of the evolution maturity over the time and its impact on the business process performance.

Keywords: Maturity, Collaborative Business Processes, Performance, Execution traces.

1. Introduction

Organizations face many challenges (globalization, higher competitiveness, customers' needs, growing IT possibilities, etc.). These challenges lead organizations to perform better, and thus to establish mature and excellent business processes. One of the most vital aspects for organizations is to determine the level of maturity of their implemented business processes. Their maturity analysis is important for business permanence, improvement and sustainability of all organizations. A maturity model helps organizations to assess strengths and weaknesses of their business processes and make improvements. Indeed, it is useful for organizations in term of understanding their current level of maturity process and to draw a map for future development of their processes. The maturity is considered as a key factor for the evaluation of the business process. The aim of this study is to propose a maturity model of collaborative business process and to analyze the impact of the evolution of the maturity on the performance level. In [1], the authors considered that the maturity is a structured collection of elements that describe the characteristics of effective processes at different stages of development. It also suggests points of demarcation between stages and methods of transitioning from one stage to another. The assessment of process maturity is to evaluate organization's strength and weakness and to enable organization to know which level the organization stays in [2].

Variety of standards and frameworks has been introduced in the literature to define, manage, assure, control and improve the maturity of processes. A maturity model consists of a sequence of maturity levels for a class of objects. It represents an anticipated, desired, or typical evolution path of these objects shaped as discrete stages [3]. In [4], authors demonstrated that the maturity models describe and determine the state of perfection or completeness (maturity) of certain capabilities.

Several works discuss the basic concepts of maturity models and give clear definitions of the 'maturity model'. According to [5], Maturity models describe the development of an entity during the time. This entity can be anything of interest: a human being, an organizational function, etc. In [6], a maturity model can be defined like a structured collection of elements that describe the characteristics of effective processes at different stages of development. It also proposes points of demarcation between stages and methods of transitioning from one stage to another.

Maturity models describe and determine the state of perfection or completeness (maturity) of certain capabilities. The application of this concept is not limited to any particular domain. The progress in maturity can either be seen as defined evolution path (lifecycle perspective) or potential or desired improvements (potential performance perspective) [7].

Crosby proposed a quality management process maturity grid, which categorized best practices using five maturity stages and six measurement categories [8]. In the same context, Nolan was interested on the maturation of data processing by defining six stages of growth (Initiation, Contagion, Control, Integration, Data administration, Maturity) that have to be achieved until maturity is reached [9]. The *Capability Maturity Model Integration* (CMMI) model was developed by Software Engineering Institute (SEI) [21]. It presents a framework that is based on best practices for developing or improving processes and services that meet the business goals of an organization.

A Business Process Maturity Models (BPMMs) assesse and improve a business process throughout its lifecycle by focusing on the necessary capabilities to perform [10]. Moreover, BPMMs aim to gradually increase business process performance [15]. In [11], the authors presented 150 available models addressing one or more components of BPM. Some models do not encompass all facets of BPM that are critical to progression. Others models are relevant to the management of a specific process and not to the management of all process. BPMMs present a sequence of maturity levels and a step-by-step roadmap with goals and best practices to reach each consecutive maturity level [12]. For example, the OMG models focused on the business process optimization. For that, they considered five levels 'initial', 'managed', 'standardized, 'predictable' and 'innovating' [13]. Other BPMMs prefer emphasizing business process integration, such as McCormack and Johnson's levels of 'ad hoc', 'defined', 'linked' and 'integrated' [14].

The rest of the paper is organized as follows: Section 2 focuses on the research gap in the maturity model of BP. In section 3, we first present our general framework for evaluating the performance of CBPs, and then we describe our maturity model for CBP. In section 4, we illustrate how our proposed model is instantiated using a real case study. Finally, section 5 concludes the paper and gives some perspectives.

2. Research gaps

Maturity Models address a lot of areas, such as project, interoperability [17] [18], Product Lifecycle Management [16], knowledge, business process [14], etc. Hence, Business Process Maturity is an emerging research field. Certainly, the maturity is important dimension for the assessment of business process. However, there are not existing researches on the business process maturity models analyzing the evolution of the maturity and its impact on the business process performance. Many researches treat this issue but they don't link the role of the maturity and the quality of business process performance. In fact, there is no clear link between the maturity and the performance. The main research questions include: What is the relationship between the maturity and the performance? Does achieving each level of maturity allow an incremental and lasting improvement in performance? Does a decrease in performance imply definitely a decrease in maturity and/or vice versa?

To overcome this gap, our study presents a conceptual framework based on CMMI levels to evaluate the maturity of collaborative business process over the time. We choose the model CMMI because this latter presents guideline for developing and improving processes that meet the business objectives of an organization. This model offers an efficient framework for appraising and evaluating the process organization. Our proposed maturity model is able to monitor the evolution of the maturity in order to anticipate deviations and achieve the business performance.

In the next section, we discuss our assessment approach for the collaborative business process that aims to analyze the performance trajectory of business process regarding the business performance level over the time.

3. Proposed Framework

The following section elaborates our assessment architecture for the collaborative Business process. In the sub-section, we explain our evaluation method based on tracking the collaborative process execution traces to assess the business process performance in the SOA environment. A knowledge repository based on ontological model is presented in order to structure the semantics of business process performance.

3.1 Assessment approach for collaborative Process in Service Oriented Architectures

The performance of an enterprise can be analyzed with top-down method and evaluated with the bottom-up method, and the lower-level performance includes or reflects the higher in principle. In this context, we created our assessment collaborative business process approach containing two models (top-down and bottom-up) in order to correlate two performance levels (illustrated in Fig 1). The first model is based on some Key Performance Indictors (KPI). These indicators are related to Business specifications and collaborative objective to evaluate the business performance. Companies use the KPI to calibrate the collaboration between them. The measurement interval of these KPIs is so long such as year, etc. The second model is composed of a set of technical indicators (TI). The TIs are linked to the business process execution and they are measured at the run time. This second performance level is aggregated from TI to the business level. Then, we aim to correlate between the behaviors of the execution of collaborative business process and the evolution of the business indicators. Our main objective is to estimate the performance trajectory of business process regarding the business performance level. At the applicative side, it is important to measure and evaluate the quality of deployed processes. At this level, we characterize applicative tasks through two sets of technical indicators, discussed in Table1:

- Functional Indicators: related to the running environment of each applicative task. It’s about quantitative indicators characterizing input/output data, assigned organization role, the implementation type of the task (i.e., service task, user task, script task, etc.) and duration. Some indicators, like implementation type, input/output and role, are used and don’t have impact on the performance in order to define the applicative task.
- Non-functional Indicators: related to the run-time aspects of Business Process those are defined from the instance data collected from the environment of execution (BPM, SOA, ERP System). This type of indicators helps to evaluate the evolution of different performance criteria, such as maturity, availability, risk, interoperability over the time.

Due to our aggregation model, these functional and non-functional indicators will be calculated at the functional level and the business level using business rules and ponderation. We create at the applicative level a reference analysis framework that will exploit data collected from the business process execution environment (SOA/BPM) given from IT infrastructure. In this reference, we identified our functional and non-functional indicators. After that, we assume the following composition rules:

- The applicative level is composed of a set of *applicative tasks*,
- The functional level is composed of a set of *functions*,
- The business level is composed of a set of *business activities*,
- Each *applicative task* is a sub-class of a *functional task*,
- Each *functional task* is a sub-class of *a business task*.
- There is no consolidation between two Functional and Non-Functional indicators.

Table 1. The Reference Analysis Framework

Technical Indicators (TI)		Concept details
Functional	Implementation type	-User task: needs to be done by a human actor. -Manual task: is external to the BPM engine, it pass-through Activiti. -Service task: is used to synchronously invoke an external Web service.
	Input	Number of parameters
	Output	Number of parameters

	Role	Internal actor / External actor
	Execution duration	Time between start execution time and end execution time of the task
		Execution duration/average execution duration of the same type of this task
Non-Functional	Status	Task completed (100%) or uncompleted (0%)
	Maturity	level of maturity: using CMMI (initial, managed, defined, quantitatively managed and optimizing)
	Risk	% risk for success = Probability compared to status (completed or not)* Gravity ***For example***: our CBP is composed of 8 parts Gravity: part 1→8 part2→7 part8→1
	Frequency	Number of Calls
	Availability	Number of successful answers (for service task)
	Interoperability	Number of exchanged data/ total number of exchanged data
		% of Applicative task performance

The collaborative business process is composed of several business processes (external or/and internal). In the literature, the concepts of enterprise architecture provide several decompositions of business process viewpoints. We identify in our work 3 abstraction levels which are elaborated by [19] [20]:

- Business level: model created from business perspectives and specifications using the Business Process Model and Notation 2.0 (BPMN). This BPMN representation targets at structuring the business process. We define the objectives and requirements of the company. At this highest level, we want to answer to this question: which basic steps compose the business process?
- Functional level: Further dealing the descriptive business process model with business specifications to ensure the feasibility of the process execution. We want to answer to this question: how to do the business process?
- Applicative level: It investigates where business processes are executed and run. At this level, we can answer to these questions: Where we do that? Wherewith we do that?

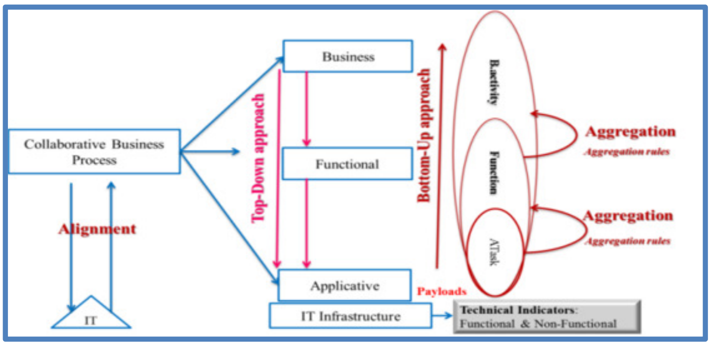

Fig 1. The collaborative business process evaluation framework

In addition, we need to collect and structure the performance knowledge, the measurements and the related analysis in order to correlate it with the frequency dimension and predict business performance degradation. For that, we developed on ontological model (see Fig 2) to better analyze and assess BP performance taking into account the evolution of company events. Our ontological model enriches the semantics of the evaluation BP models. In addition, ontology contains all details about functional and non-functional aspects in order to annotate detected events from the execution of the system and to correlate them to the performance level. Therefore, this ontological model is able to capitalize on assessments of BP and analyzes tendencies in order to anticipate deviations.

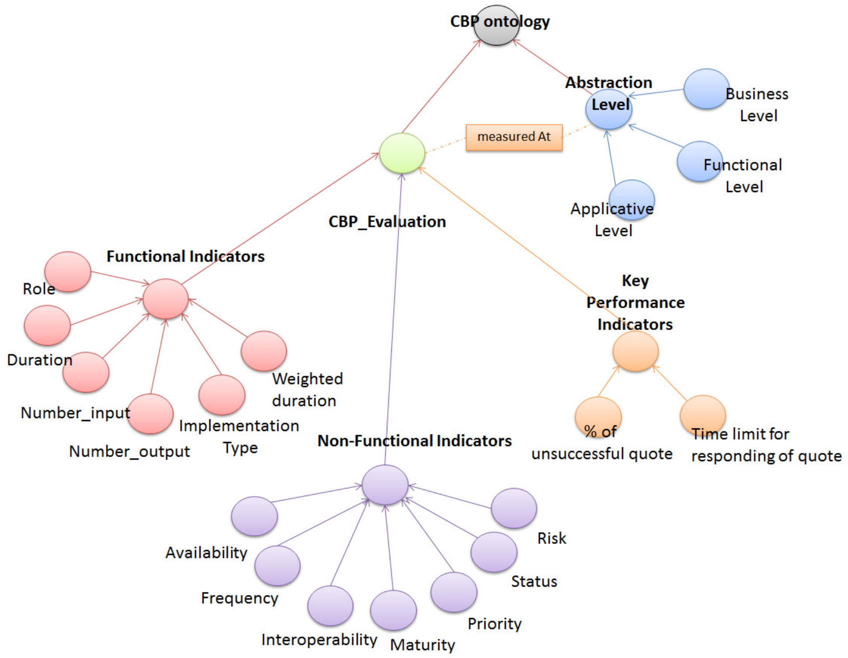

Fig 2. Ontological model for Collaborative Business Process Assessment

3.2 Maturity model based on process lifecycle management

In this section, we present our proposed maturity model for the CBP. The analysis of any process lifecycle allows identifying the following steps:

- Perception: the process has been selected,
- Business specifications: the stage where we answer to the strategic and business objectives,
- Functional specifications: it is the adaptation stage where we define what is possible to implement,
- Implementation of the application: we choose the technology of implementation and execution of the process,
- Test the application: we make sure in this stage that our application is ready to be deployed,
- Deployment: instances of the process are launched and ready to be used by the end users,
- Use: the stage where process is used and runs,
- Test of performance: the stage where the process has been evaluated its performance by using metrics and indicators,
- Detection of deviation: we identify events and degradation in the performance trajectory of the process,
- Alignment Business/IT: the company’s strategy is in harmony with business processes and systems that support them,
- Dissemination: the stage where the process doesn’t answer to any business / or strategic objective and we should freeze it for revision.

- End of lifecycle: process is stopped.

For the specification of a business activity, we defined non-functional indicators at the applicative level (maturity, risk, interoperability, agility, etc.). These indicators can be considered as important criteria for the performance of business processes indicators. In the remainder of this section, we will explain how to measure the maturity of business process and we will analyze its evolution and its impact on the performance of business process.

Maturity Level	***Explanation***	***Potentiality quantification***
Level 1: Initial	No reliable process, no control, general indiscipline	20%
Level 2: Managed	disciplined and modeled process,	40%
Level 3: Defined	Standardized processes, roles and tasks are defined,	60%
Level 4: Quantitatively Managed	Quantified, systematic application of measurement processes	80%
Level 5: Optimizing	continuous improvement, control of change, well managed process	100%

Table 2. Quantification of CMMI Maturity levels

Our CBPs are assessed using the CMMI model (see Table 2): Initial, Repeatable, Defined, Managed and Optimized. For each level, we associate the appropriate ponderation in order to facilitate the calculation of CBP maturity.

In the perspective of defining an assessment model for the maturity of CBP, we aim to propose an analytic process model. The application of this model is expected to supervise the evolution of the Business process maturity over the time and decide about its impact/role on the performance of business process.

The correspondence between process lifecycle stages and CMMI maturity levels is resumed in Table 3. Only the most relevant projections between business process stages and maturity levels are considered. This matrix is able to supervise the evolution of business process maturity during its lifecycle. The objective of this matrix model is to achieve the process optimization and to improve business process throughout its lifecycle. The CMMI is a basic foundational building block for achieving process improvement and ensuring the process optimization.

The process is considered disciplined and managed when its business and functional specifications are identified. Once the functional specifications are defined, the process is able to be executable and used. The knowledge of process performance tends to be more qualitative rather than quantitative up to Maturity Level 3 'define'. In this level, we can obtain measures that provide information about the status of the various implemented processes, but they don't provide the same type of knowledge that exists at Maturity Level 4 'Quantitatively managed'.

In the third level (Define) where the process is deployed and used, several means have been set up in order to supervise the evolution of business process maturity over the time. When the process runs, we are able to assess its performance (the fourth level: Quantitatively managed). The real use of the business process by its end users corresponds to the Maturity level 4. In this level, the organization has collected various types of data on process status and performance. It insists on managing process performance and addressing the main causes and sources of process variation. These causes of process variation can indicate a problem in process performance and may require correction and solution to maintain process performance during its utilization. At Maturity Level 5, organization emphasizes on reducing the common cause of variation and noise and it improves the process performance level.

The business process is considered optimized if:

- The Business Process is stable for a long time. There is no evolution of the means of control and performance.
- On the basis of the BP history during a certain period, a deviation is detected. If the process is not able to answer perfectly to business objectives, the issue of the alignment Business/IT appears. For that, it should be return to the second or the third level of maturity to redefine the specifications or it has to finish the process.

Table 3. Process lifecycle management maturity

	Initial	**Managed**	**Define**	**Quantitatively managed**	**Optimizing**
Perception	X				
Business specification		X			
Functional specification		X			
Implementation of the application			X		
Test the application			X		
Deployment			X		
Use			X	X	
Test of performance				X	
Detection of deviation				X	X
Alignment Business/IT		X	X		X
Dissemination	X				
End of lifecycle	X				

There are three possible scenarios of track the evolution of the maturity during the business process lifecycle:
- The first scenario “No detected problem”: during a long period, the process runs without problems and deviations.
- The second scenario “Detection deviations & resolution”: When the Business process is evaluated using indicators and metrics, problems and deviations have been detected. There is no alignment Business/IT. For that, the specification must be redefined.
- The third scenario “Detection deviation & no resolution”: When the Business process is evaluated using indicators and metrics, problems and deviations have been detected. The process doesn’t answer to the objectives and needs of the company. The process will be stopped.

There are two types of rules for the identification of the maturity for an applicative task during the time:

- Evolution of the maturity: These rules explain how to move from one maturity level to a higher or lower level.
- Qualification of the state: these rules present how to know the maturity of an applicative task.

These rules are built based on the collected data of execution traces in the applicative level. In addition, we adjust and regulate these rules on the basis of data existing in our ontological model. For the calculation of the maturity of the whole collaborative business process, we proposed the aggregation model (see Figure 3) that is able to evaluate the maturity of process from the Applicative level to the Functional level and then from the Functional level to the Business level.

The aggregation model encompasses all the functional and non-functional indicators, such as maturity, risk, interoperability, etc. This model contains a set of calculation rules in order to evaluate these indicators at the business level and correlate them afterward with business indicators. The calculation rules and the reasoning rules are introduced in the ontological model. The reasoning rules, which is based on the history of evaluation and execution traces, help to estimate the behaviors of the process over the time.

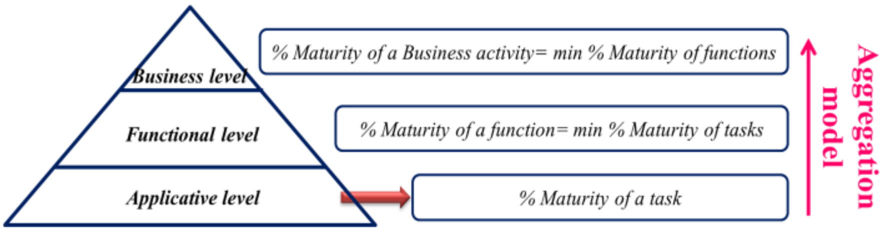

Fig 3. Aggregation model for CBP maturity

4. Case study

To validate this proposed framework approach, we extend an already accepted case study which is a customer relationship management process in APR (Application Plastique du Rhone) company, where the company's goal is to implement the process of creating quote in order to enhance the communication with the customer and save information traceability of quotes. Traceability is necessary for the enterprise in order to facilitate its sustainability.

The BPMN (Business Process Modeling and Notation) modeling language has been used to model the proposed CBP "Create quote". When the customer project is uploaded, sales assistant is notified. She/he checks and validates the customer information. After that, the account manager validates the product and checks raw material needed. The purchase department consults supplier to take idea about the price and the delay of the raw material and needs. Then, when this department receives answers from suppliers, it sends all these answers to the industrial manager to complete the product information and to validate the quote. The final quote containing the price will be communicated with the customer.

The final model of our CBP is modeled with the business process modeling tool Activiti in order to execute it. We collect from the execution traces in order to calculate the Technical Indicators (Functional and Non-Functional). We focus mainly on the maturity and we define maturity rules specific to our CBP 'create quote'. We present in the Figure 4 the qualification of the state rules and in the Figure 5 the evolution of the maturity rules.

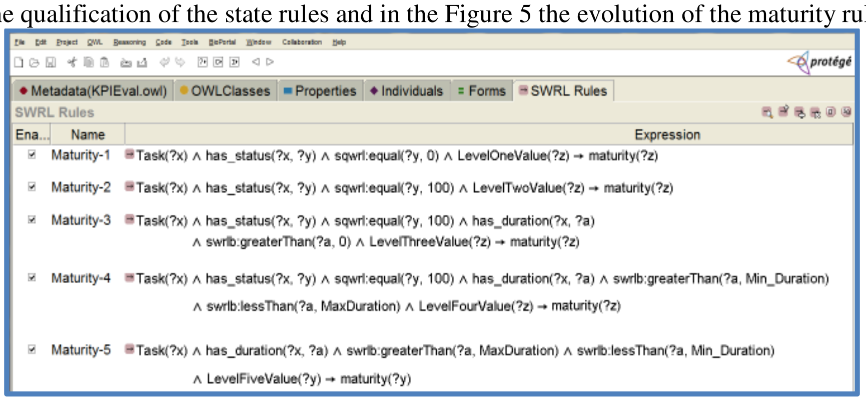

Fig 4. Qualification of the state rules

We can illustrate two scenarios of performance results at business level:

-First scenario presents the maturity at defined level: when the process is just designed with BPMN. The actors, roles and tasks are defined. We have the capacity to control the evolution of maturity in time. This scenario corresponds to the level of business process learning and for that we define a set of learning rules (For example if..then).

-Second scenario presents with maturity at quantitatively managed: when the application is running and we able to assess using the KPI and TI. Indeed, using historical trace and analysis on a specific interval, we can analyze the behavior of BP and detect deviations.

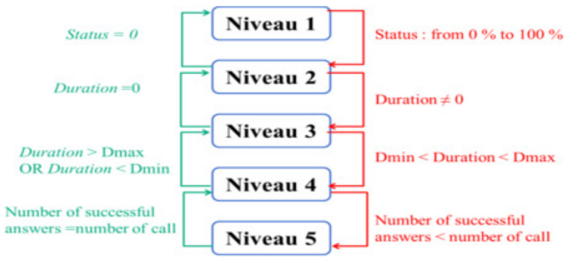

Fig 5. Evolution of the maturity rules

Our proposed maturity model is able to define the Performance of APR Company. In fact, this model allows to mitigate and to anticipate deviations. It lets to improve and optimize the collaborative business performance. The first results obtained from our assessment methodology show that we can bring closer the maturity with the performance concatenated at the business level. Indeed**,** the company APR aims to assess many KPI in order to calibrate the collaboration with its stakeholders (customers and suppliers). The non-satisfaction of one of this stakeholder is related to the facility provided by APR. In the framework of FITMAN project, we designed and analyzed its collaborative business processes to accelerate this collaboration. For that, we implement these CBPs in a system (application) and we evaluate then the performance of this system using our proposed assessment approach in order to accelerate the collaboration at the application (execution) point of view. This methodology helps to evaluate the evolution of different performance criteria over the time, such as the maturity. Using our proposed approach, we can measure the maturity of business processes from execution traces due to the aggregation model. The maturity is a key dimension for the technical performance evaluation. In addition, the ontological model, containing all events and deviations (performance evaluation at the technical level and aggregated at the functional and business level) is able to correlate between the behaviors of the business process execution and the evolution of business performance indicators selected by APR. The first results obtained from our methodology are encouraging. Therefore, the experiments will be conducted on others different collaborative business processes in order to enhance our outcomes in the future.

5. Conclusion and perspectives

In this paper, we proposed performance assessment architecture and maturity model for the collaborative business processes. The process analytic model identifies the process lifecycle stages as well as the CMMI maturity level and the correspondences between them in order to analyze the evolution of the maturity on the time. The metric model measures the performance level at each applicative task from execution traces using several technical indicators, such as *Maturity*. The technical indicators are aggregated at the business level and correlated with the business indicators in order to estimate the deviation and events of collaborative business processes.

Using our proposed approach and our maturity model, we can measure the maturity of business processes from execution traces due to the aggregation model. The first results obtained from our assessment methodology show that we can bring closer the maturity with the performance concatenated at the business level. Accordingly, this proposal is able to improve and optimize the collaborative business performance. In addition, it enables to mitigate and to anticipate deviations. Therefore, the maturity is an important key dimension for the technical performance evaluation.

Our future work concerns the analysis of all proposed technical indicators (risk, interoperability, etc.) and their associations to processes' events. By more tracking data, we aim to refine further the learning processes in order to monitor the evolution of the business process and to anticipate deviations. As a result, we expect to propose an efficient decision making model based on the historic of KPI and the analysis of execution traces at the applicative level.

ACKNOWLEDGMENT

This work was funded by the European projects FITMAN (FP7-604674) and EASY-IMP (FP7-609078).

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