Extrinsic Dependencies in Business Process Management Systems

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Abstract: The demand for supporting the flexibility in business processes has been increasing due to dynamic business environments and technological progress. That led to the challenge of designing business processes so as to take context changes into consideration. A context refers to any circumstance of a process and includes factors which impact process execution steps. To overcome this challenge and better fit business processes to customers expectations, this paper conceptualizes contextual factors relevant to the business process description. It defines a model that explains how the relevant contextual factors could be identified and computed in a structured way. To verify the applicability of the identified approach, a prototype is set up for running the experiments. It examines the approach with real information in different real-life scenarios.

1 INTRODUCTION

Over the last two decades, business process management (BPM) has been considered as an essential approach to achieve high performance of organizations and improve customer satisfaction (Dumas et al., 2013) (Weske, 2012). BPM is a comprehensive approach designed to achieve business objectives by managing end-to-end processes in a structured way (Hammer, 2010). Modelling business processes properly is an essential step for the BPM lifecycle. The traditional modelling approach relies on describing processes by five fundamental perspectives (Jablonski and Bussler, 1996): the functional perspective (what are the process steps?), the data perspective (what data consumed or produced?), the operational perspective (which tools are used?), the organizational perspective (who is performing the process?), and the behavioral perspective (when should activities be performed?). This approach meets the expectations in a given context (Saidani and Nurcan, 2007). However, during the last decade, companies have increasingly been confronted with flexibility challenges like adjusting their business processes to changing circumstances to best meet customer's expectations. The main reasons for that are (Saidani and Nurcan, 2007): *(i)* rapidly changing business environments; *(ii)* companies have been increasingly running more complex business processes; and *(iii)* customers expect services to become more efficient.

Accordingly, process flexibility has to be enhanced, especially when having further development of information technology and market globalization in mind (Tao et al., 2008). Flexibility is the ability to adapt to ambient changes (Soffer, 2005) (Burkhart and Loos, 2010) (Regev and Wegmann, 2005), in particular, context changes. As a consequence, flexible process modelling requires additional information, in particular, context information. A context refers to any circumstance of a process. It includes factors that have an impact on process design and execution such as location, weather, and policies (Rosemann and Recker, 2006). The important question w.r.t. taking the contextual information into consideration is how to identify and derive contextual factors. This leads to other questions such as what their main characteristics are. The contribution of this paper is to define a model which conceptualizes a process context. The focus of this conceptualization lies on the contextual factors that are derived from the fundamental process perspectives introduced above. This objective is achieved by defining a methodology for the approach of deriving contextual factors. The methodology distinguishes between dependencies of designing and executing processes by discerning intrinsic and extrinsic dependencies. The approach can be used in different scenarios like in the development of technologies such as web services, mobile devices, and sensors. Capturing contextual information – such as detecting the current agent's geographical location or agent's device – is thereby facilitated (Modafferi et al., 2005) (Zhu et al., 2016). Therefore, the approach at hand offer the possibility to design processes that are adaptable to contextual changes as well

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as the accurate assignment of process steps to participants at runtime. A prototypical implementation and it's application in two case studies shows the practical applicability of the work at hand.

The structure of this paper as follows: Section 2 illustrates the motivating examples. Section 3 presents related work. In Section 4 process dependencies are described. Section 5 explains the methodology of extrinsic dependencies. Section 6 shows the case studies and introduces a prototype to evaluate the identified approach and Section 7 finally concludes the paper.

2 RUNNING EXAMPLES

Two simple real-life scenarios will illustrate how the endogenization of contextual changes can improve business process design and execution.

2.1 Emergency Car Repairs

Consider the process of having your car repaired. Ordinarily, drivers would call their insurance company to solve their car problems. The driver provides some information about the car such as the insurance number, the car type, and the location of the car. Upon claim receipt, the company opens a task to have the car repaired at a specific location. This task needs to be assigned to an eligible technical team. Finally, the technical team writes a report for the issue after solving it. In the execution steps, a process needs to define a resource and find a team to do the task.

In a normal execution procedure, all of the available eligible technical teams will be notified that they are able to perform the task. One of the possibilities of optimizing process execution is to find the most eligible team to do the process. This can be achieved by classifying the eligibility of the teams. The contextualized eligibility can be ascertained by data on team availability, experience level, and location. By assuming that all the eligible teams are available and have the same level of experience when they are located in different locations, however, process execution could be optimized by location-sensitive task assignment. In this case, the nearest team could be notified as a highly recommended team while all other teams would be less recommended. The optimized procedure will make the execution more flexible. Moreover, it reduces customers' waiting time.

2.2 Remote Configuration of Device

Network companies are divided into different departments such as a call center, a network operations center (NOC), and an operations maintenance center (OMC). Generally, the call center sends a ticket to the other departments after a call from a customer. One of the issues posed to the NOC is to reconfigure a network device remotely. This requires access to remote network devices via the internet. Due to security risks, a network engineer has to be authorized to access these devices. Simple authorization steps are used when an engineer works from the company office because he is working from an authorized IP domain. A more complex procedure of authentication is applied to an engineer who works outside the company network domain (e.g. home office). This procedure requires additional checking steps to avoid intrusion by unauthorized persons such as hackers. Uncontextualized BPMS assigns the process to any eligible network engineer's task list, irrespective of their location. With context-aware BPMS, an induced location preference, which can be used for location optimization, needs to simultaneously use a location sensitive authorization procedure that discriminates between company office and home office for different authorization steps. Company-office engineers who go through the simpler authorization protocol are strictly preferred to outside engineers. Additionally, the preference could be made based on other factors, for example, the quality of internet connection of the engineer's device which is an important aspect to ensure the success of the process. Therefore, taking context information into account will improve process assignment step by creating different levels of preference between agents.

3 RELATED WORK

This section presents and discusses literature which is strongly related to the goal and methodology of this paper from different points of view. Mainly, it covers the context-awareness and location-awareness in BPM domain. (Modafferi et al., 2005) suggests a workflow application solution to the provision of customized services based on user context, one form of context awareness. Key to their methodology for the development of context-sensitive business processes is the concept of the context-sensitive region. This concept enables the process parts, the behavior of which may vary with the context, to react to a context change. The research presented in (Rosemann and Flender, 2007) focuses on the extrinsic drivers for process flexibility instead of intrinsic ways of adaptation to environmental changes. Another paper (Saidani and Nurcan, 2007) proposes a taxonomy of the context related knowledge into four kinds as an initial stage: ”location-related context”, ”time-related context”, ”resource-related context”, and ”organization-related context”. They introduce the ”context model” to structure the contextual information. It consists of three dimensions: 1) aspects are used to capture the context, 2) facets are used to address each aspect, 3) each facet is described by attributes which could be measured. In the above-mentioned researches, the location is considered as one of the important factors in the process context. In (Rosemann and Flender, 2007), the location is considered as an important variable in the environmental context layer of the onion model. In (Saidani and Nurcan, 2007), the location is presented as one of the four aspects of context. However, the importance of geospatial information in the execution of processes has increased due to the technological progress (Zhu et al., 2016). In (Schönig et al., 2014), the location is treated as a new perspective of the process in addition to its fundamental perspectives. This paper introduces the Declarative Process Intermediate Language (DPIL) (Schönig et al., 2017) for modelling business processes. In order to take the locational information into account, the meta-model of DPIL is extended to model locational entities and constraints.

4 DEPENDENCIES IN BPM

Any business process relies on some information for its design and execution. This information should capture the important aspects of the process such as the process steps and the time and order of their execution. In addition to that, any optimization of the design or execution relies on some other information. For example, contextual information is needed to support flexibility in processes (Rosemann and Recker, 2006)(Saidani and Nurcan, 2007). Here, a distinction between the required information for design and execution of the process and for the optimization is needed to analyze the applicability of context for increasing flexibility. This distinction should facilitate the conceptualization of the process context and provide a structured way of deriving the contextual factors. The process dependencies are divided into intrinsic and extrinsic dependencies in the following two subsections.

4.1 Intrinsic Dependencies

To complete a BPM lifecycle, information about a process description is required. Each phase of the lifecycle needs specific information that must suit the respective phase. In principle, the five fundamental perspectives of a process provide the required information for these phases. This information provides a description of a process. Therefore, each process should have the basic information from these five perspectives. To illustrate that, take an ”oral exam” process as a simple example. First, the student needs to register for the exam. Upon registration, the student is given a confirmation notice and the date of the exam. The second step is to conduct the oral exam. This step needs to pre-specify the examiner’s name and room number (normally, the examiner’s room). Finally, the examiner evaluates the student’s answers and gives him or her a final grade. If executed normally, the execution depends on the information from the five perspectives as a basis. One of the execution steps is specifying an organization for the process. It requires general information about the agent such as the agent’s group. Normally, there are two groups who are able to play the examiner role: the group of the professors and the group of the professors’ assistants. Further information, such as the location of the agent, is not required in this execution. Therefore, some information from these perspectives is considered as the mandatory information for designing and executing the process. Here, this mandatory information is referred as the intrinsic dependencies of the process. According to this understanding, the intrinsic dependencies can be defined as **Intrinsic dependencies:** the minimum information which is required to describe the fundamental perspectives of a process for the purpose of enabling the process designing and executing

4.2 Extrinsic Dependencies

As explained in the previous section, a comprehensive description of a process depends on the information provided by the five fundamental perspectives. Some of this information has been considered as mandatory information. That raises the questions of what other information the fundamental perspectives provide, how to exploit it, and in which step the process depends on this information. Generally, this information provides many details about the process that could be used for execution optimization. To illustrate that point, two simple scenarios of optimizing the execution of the ”oral exam” process (which presented in the previous subsection) are given as follows: *(i)* The first scenario is about the step of assigning the process to an examiner. Generally, the process would be assigned either to the professor or the professor’s assistants. In case of an emergency at the exam date, the exam could be postponed. One of the possibilities to optimize this process is to reassign the exam to somebody who is able to play the examiner role at that date. This optimization needs some other information such as the availability of other agents and their location; *(ii)* The second scenario concerns the room assignment for the oral exam. Normally, any available room inside the faculty could be selected as a place for the exam. This step is optimized by taking other information such as the location of the room into account. Thereby, the room nearest to the examiner's office would be chosen in an optimized execution. Some other information such as room size and the number of chairs might be important in some other cases. In these scenarios, it is clear that some information of the fundamental perspectives is not directly related to the process. Therefore, this information is not necessary for designing and executing the process. Nevertheless, it might have an impact on the execution steps. As a consequence, this information could be connected to the mandatory information (intrinsic dependencies) and create objects that make an impact on the process execution steps. Here, these impacts are considered as the extrinsic dependencies of a process. Based on this understanding, the extrinsic dependencies are defined in this paper as **Extrinsic dependencies:** the information required to improve the execution of a process on the condition that it is produced by the entanglement of objects of this process according to specific requirements.

4.3 Context Classification

The notion of context has been defined many times across different disciplines and subdisciplines. In the BPM domain, some research has been published on developing context-aware business processes. Leading up to the definition of a business process context used in this paper, the other definitions in this domain are presented first. In (Rosemann and Recker, 2006), business process context has been defined as *"the minimum set of variables containing all relevant information that impact the design and execution of a business process"*. (Saidani and Nurcan, 2007), instead, focuses on the impact of context on the assignment relations, so the context is defined as *"the collection of implicit assumptions that is required to activate accurate assignments in the BP model at the process instance level"*. In a third approach, (de la Vara, Jose Luis et al., 2010) specifies it as the environment properties in which the business processes are executed. A context is characterized as 1) a set of states, 2) a subjective, and 3) a relative. It refers to the environment of the process and is defined as *"any information that is relevant to and might affect the execution of a business process"*.

Taking the above-mentioned views as a basis, we can subsume the meaning of a business process context with regard to our area of focus. A context includes information that can refer to any circumstance of a business process (for example, "the weather is hot", "the agent is not available"). This information constitutes factors called context factors. For example, information about the agent's occupancy status (busy or available) can form a factor called "availability". These factors could impact the process execution steps such as the assignment of a task to an agent. Generally, these factors can be captured and measured by variables which are called context variables. The values of these variables vary with the changes in circumstances of a process (Rosemann and Recker, 2006). As presented in the example "repairing a car" in section 2.1, one of the possibilities to improve the execution of this process is to assign the task to the geographically nearest team. To do that, the context variable "distance" can be used to measure the distance from each team's location, which is specified in the form of latitude and longitude (Imagery and Agency, 2000), to the location of the event. Comparing the values of the "distance" variable, the nearest team could be specified.

According to the above understanding of business process context, we could define it in accordance with the previous definitions as a global (general) term which consists of factors impacting the business process execution steps. These factors could be derived from information about the process description or process environment changes. The main focus of this paper is on the contextual factors that are related to the process internally (i.e., they are related to the process perspectives), in particular, organizational and operational perspectives are of most interest here. These factors have a direct impact on the process execution. In addition to that, they can be captured and measured accurately, especially given the development of mobile technologies. According to our above-mentioned definition of process context, the context factors can be classified into two types. The first one is related to the process itself and the second type is related to the environment in which the process is executed. The classification is explained as follows: **Extrinsic factors:** They include elements that can be computed from the intrinsic objects of a process (i.e., they are related to the fundamental perspectives). In other words, the process description is the main source for deriving these elements. These factors make a direct impact on the process execution steps. As explained in section 4.2, this impact is considered as the extrinsic dependencies of a process. **Environmental factors:** They refer to any information outside the process construction (i.e. they are not related to the process description). Generally, it covers all the elements of the system in which the process is executed. Elements come from the organization side (such as customers, competitors, strategy) and the environment (such as weather and culture). This type could be classified into some other types (based on (Rosemann and Flender, 2007)) but the current classification suffices for this research. Based on the above-mentioned area of focus, the derivation of the extrinsic factors is provided in the next section. Additionally, an appropriate model for the conceptualization of the factors is set up.

5 DEPENDENCIES MODELLING

In this section, a detailed approach for the conceptualization of a business process context is presented based on the definition and classification of context in Sec. 4.3. A conceptual model of the formation (or derivation) of contextual factors is provided.

5.1 Process Objects

Based on the concept expounded in (Jablonski and Bussler, 1996), every process has a number of relevant artifacts. These artifacts are modeled as objects. In addition to that, an object type is used to model a single artifact type. The object has properties which are used to provide specifications of the object. By following this concept, the process constitutes a set of the relevant objects refer to its description (i.e. the five fundamental perspectives). Generally, the objects could also belong to any other perspective that describes the process such as causality, integrity, quality, history, and security.

In this paper, any object that describes the process internally (i.e., it is related to the fundamental perspectives) is called an intrinsic object. The important question is which kind of relation relates the intrinsic objects to the process. Depending on our distinction between process dependencies, there is some information which is mandatory to design and execute the process whereas some other information might be required for further steps such as optimization. As a consequence, there are some objects mandatory to complete process description. These objects are directly related to the process perspectives. For example, an agent is an object which directly describes the organizational perspective of a process. In this paper, these kinds of objects are called direct objects. By contrast, there are some other objects which do not directly describe the perspectives. Normally, these objects are connected to the direct objects. That means they are indirectly related to the process. These objects are called the indirect objects of the process. For example, the agent's device is an object connected to the agent which is a direct object of a process. In short, the process objects might be directly or indirectly related to the process. These types are defined as follows: **Direct objects:** the set of objects mandatory for the design and execution of the process which directly describes the process perspectives. **Indirect objects:** an additional set of objects that is connected to a specific direct object to provide additional information about the process. In summary, the intrinsic objects of a process include any information that refers to the process perspectives. These objects can be divided into direct and indirect objects, in accordance with the relation of the information provided to the process. While the direct objects are necessary for process lifecycle phases, the information provided by indirect objects is useful for other steps such as optimization. The division of process objects facilitates the computation of the context variables values as presented in the subsequent subsections.

5.2 Formation of Extrinsic Factors

Extrinsic factors greatly influence different process execution steps, especially, as they relate to process perspectives (cf. Sec. 4.3 for the classification of process context). The impact of these factors is considered as the extrinsic dependencies of a process (cf. Sec. 4.2 for definitions). Therefore, identifying and computing these factors is one of the important steps of modelling extrinsic dependencies. Generally, extrinsic factors include elements that can be derived from the intrinsic objects of a process. In other words, the direct and indirect objects are intertwined to create new information. This information is represented in variables which are called extrinsic variables (or context variables).

At the end of this step, questions about the main characteristics of extrinsic factors and their derivation have to be answered. For that, a well-defined procedure which is able to derive the extrinsic factors and compute its variables should be followed. Basically, two main steps can be executed as a procedure to form the extrinsic factors: 1) identification and 2) computation of the extrinsic variables. The procedure is explained as follows: **Identifying the extrinsic factors:** This step is responsible for identifying the relevant extrinsic factors that have an impact on the execution of a process. This identification needs information about the required optimization. Normally, this information is provided by the context requirements. The deter-

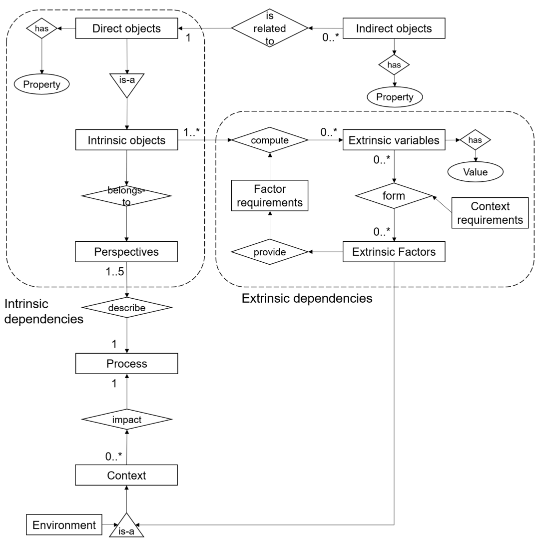

Fig. 1: Process dependencies model.

mination of context requirements strongly depends on the objectives of a process. Therefore, it differs from scenario to scenario. Generally, it is defined as information that indicates the required elements for a specific optimization. **Computing the extrinsic variables:** This step specifies the variables of the relevant extrinsic factors that have been identified in the first step. Here, these variables are called the extrinsic variables (which are part of the context variables). The values of these variables change in accordance with the changes in the related circumstances. To compute these values, the intrinsic objects of a process (both direct and indirect objects) are intertwined with each other. This computation is strongly based on the requirements of the relevant extrinsic factors.

To illustrate the above procedure, a simple scenario of optimizing the repairing a car process (cf. Sec. 2.1) is discussed. This process can be optimized by using various pieces of contextual informations such as location, availability, and the teams' capabilities. By taking only the location information into account, the optimization can be achieved by assigning the task according to the team's location. The procedure of forming the extrinsic factors is applied as follows: *(i)* The context requirement of this optimization is to find the nearest team to the location of the car. According to this requirement, "the accessibility" could be identified as the extrinsic factor for this optimization; *(ii)* The variable for the "accessibility" factor is the "distance" where its value varies with the change of the team's location. To compute this value, the geographical location for the event and the team should be available. According to these coordinates, the distance is measured.

5.3 Process Dependencies Model

A process model focuses on capturing the elements that are related to the control flow. That means it supports processes with predictable paths (Schönig et al., 2014) (i.e., it does not comprise the context elements). Thus, it focuses only on the intrinsic dependencies of a process. In keeping with the methodology of this paper, the contextual factors need to be integrated into a process model. A model to conceptualize the process context is introduced (depicted by Fig. 1). This model clarifies the ability to take the context factors into account. The extrinsic and environmental factors are considered as subclasses of context. In addition, the identified procedure for the formation of the extrinsic factors is fully illustrated. **Intrinsic dependencies part:** It refers to the information mandatory for the design and execution of the process. Hence, this part of the model covers the direct objects of the process and their properties (i.e. they are directly related to the fundamental process perspective; see section 5.1 for more detail). **Extrinsic dependencies part:** This part indicates the impact of the extrinsic factors on the process execution. It illustrates the procedure of the identification and computation of these factors. The procedure starts with computing the values of the extrinsic variables from intertwining the information of the intrinsic objects (both direct and indirect objects). This computation is based on the requirements that are provided by the extrinsic factors. After this computation, the relevant extrinsic factors could be formed from these variables according to the context needs. The defined model can be applied to different areas as it optimizes the execution of business processes based on different factors. In the next section, the approach is applied to different scenarios which are further discussed.

6 IMPLEMENTATION

This section discusses the ability to apply the methodology of extrinsic dependencies to the running examples. These scenarios clarify the process dependencies by representing the distinction between process objects. In addition to that, they apply the procedure of identifying and computing the impact of extrinsic factors. As explained in the example of the "repairing a car" process (cf. Sec. 2.1), one of the optimization issues occurs at the execution step of task assignment if there is more than one eligible team. This step could be optimized by identifying the most eligible team. For this end, the direct and indirect objects are identified first in Table 2.

Table 1: Extrinsic factor of ”repairing a car” process.

Context requirement	**Extrinsic factor**	**Factor requirement**	**Factor variable**
Nearest team	Accessibility	Location of the car	Distance
		Team’s location	

Table 2: Objects of the ”repairing a car” process.

Perspective	**Direct object**	**Property**	**Indirect object**	**Property**
Functional	Repair a car			
Data	Insurance ID	Digits		
	Car specification	Car model	Car’s Location	Latitude
				Longitude
	Technical issue	Issue details		
Organizational	Technical team	Team name	Experience	High
				Low
			Availability	Available
		Team size		Busy
			Location	Latitude
				Longitude
Operational	Technical tools	Tools type		

By applying the procedure of forming the extrinsic factors, a preference relation over all the available teams could be identified. Generally, the ”accessibility” factor could be specified to optimize the execution by making the location-based assignment. The formation of this factor is presented in Table 1.

As indicated in ”remotely configuration of a device” process (cf. Sec. 2.2), one of the issues in the execution steps is the simultaneous assignment of the process to all (eligible) engineers regardless of their context. Based on the approach here, the intrinsic objects of the process are clarified in Table 4.

As explained in Sec. 2.2, the process execution could be optimized based on two factors. The first one is the ”network security” which has an impact on the authentication procedure followed. The second one is the quality of the internet connection to avoid any interruption might occur. The formation of these factors are clarified in Table 3.

To demonstrate the applicability of the introduced approach for taking contextual factors relevant to a process into account, an appropriate prototype is described in this section. The prototype for our extrinsic dependencies methodology is based on web services. It is developed as a web application which covers all the steps related to defining and executing the corresponding processes. It prioritizes those processes which are related to assigning a task to participants. The main components of the prototype are explained as follows: **Design core:** It is used for initializing a process in the system by simulating its fundamental perspectives. Furthermore, it allows the identification of the relevant extrinsic factors and their requirements. **Execution core:** It is responsible for executing the defined process. It is optimized with respect to taking the impact of the identified extrinsic factors into account. Therefore, it provides two execution types. The first one is the normal execution, which executes the process based on the information of its fundamental perspectives. The second type is the optimized execution, which takes the context information into account.

Table 3: Extrinsic factors of ”remotely configuring a network device” process.

Context requirement	**Extrinsic factor**	**Factor requirement**	**Factor variable**
Reliable network domain	Network security	IP domain	Network range
Highest QoS	Connectivity	Agents device properties	QoS

The application focuses on the geographical information by using the ”repairing a car” example process for the prototype application. Two agents named *agent1* and *agent2* are used for running the experiment. Both of them are logged into the system from different locations. Both agents are notified by a normal execution procedure that they are agents recommended, regardless of their contextual information. As explained before, the accessibility factor could be used to optimize process execution. This factor indicates that the nearest agent to the location of the car is preferred to perform the process. To this end, the prototype fetches agent1 and agent2’s geographical location by using web technologies, in particular, HTML5 Geolocation API (W3C, 2017), whereas the location of the car is assumed when the process is defined in the system. Based on measured distance, *agent1* is identified as the nearest agent and notified that he is recommended for the process, unlike *agent2*.

Table 4: Objects of ”Configuring a network device”.

Perspective	**Direct object**	**Property**	**Indirect object**	**Property**
Functional	Reconfiguring device remotely			
Data	Ticket number			
	Device	IP		
		Type		
Organizational	Network engineer	Name	Location	Latitude
		Age		Longitude
		Gender	Used-device	IP domain
		Job title		type
Operational	Application			

7 CONCLUSION

In this paper, a methodology for conceptualizing the contextual factors relevant to a process was presented. The core of this methodology was the distinction among process dependencies into intrinsic dependencies and extrinsic dependencies. This distinction proved itself to facilitate modelling business processes adaptable to context changes. The methodology classified the context factors according to their relation to the process. The main step of the methodology was to define the approach of measuring the impact of contextual factors that are related to the process description. It was shown that the entanglement between process objects (direct and indirect) forms these variables and computes its values. The process dependencies model was introduced to present the concept of contextualizing business processes. The applicability of this approach was demonstrated by using the prototype to test some scenarios with real information. This presented the opportunity of using developed technologies for capturing the process context. The results showed that the proposed approach leads to improved execution of business processes and the process assignment step in particular.

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