EXPLORING LOCATION-DEPENDENCY IN PROCESS MODELING

Abstract

Purpose - Context-awareness has emerged as an important principle in the design of flexible business processes. The goal of our research is to develop an approach to extend context-aware business process modeling towards location-awareness. The purpose of this paper is to identify and conceptualize location-dependencies in process modeling.

Design/methodology/approach –This paper uses a pattern-based approach to identify location-dependency in process models. We design specifications for these patterns. We present illustrative examples and evaluate the identified patterns through a literature review of published process cases.

Findings – This paper introduces location-awareness as a new perspective to extend context-awareness in BPM research, by introducing relevant location concepts such as location-awareness and location-dependencies. We identify five basic location-dependent control-flow patterns that can be captured in process models. And we identify location-dependencies in several existing case studies of business processes.

Research limitation/implication – We focus exclusively on the control-flow perspective of process models. Further work needs to extend our research to address location-dependencies in process data or resources. Further empirical work is needed to explore determinants and consequences of the modeling of location-dependencies.

Originality/value – As existing literature mostly focuses on the broad context of business process, location in process modeling still is treated as ‘second class citizen’ in theory and in practice. This paper discusses the vital role of location-dependencies within business processes. The proposed five basic location-dependent control-flow patterns are novel and useful to explain location-dependency in business process models. They provide a conceptual basis for further exploration of location-awareness in the management of business processes.

Keywords location-awareness, location-aware BPM, location-dependency, location-aware process modeling, location-dependent control-flow patterns

Paper type Conceptual paper

1. Introduction

Business Process Management (BPM) has become one of the abiding approaches to manage enterprises and create process-aware information systems. In practice, BPM can lead to significant improvements in business processes in terms of performance, operating costs, and compliance (Hammer and Champy, 1993). A common application of BPM in most organizations concerns the investment in the standardization and automation of core processes through workflow management systems (Jablonski and Bussler, 1996). These initiatives can lead to improvements in standard processes, but these efforts also lead to system-enabled business processes that are increasingly insensitive to external process variables in changing environments (Rosemann et al., 2008).

Context-awareness as a new paradigm of BPM deals with dynamic business process environments, in which processes need to be rapidly changed and adapted to changes in the external context (for example, weather, regulation or location dependency). The so-called contextualization of processes builds upon a more explicit consideration of the environmental setting of a process (Rosemann et al., 2008). As the distinctive role of location in better understanding of the context, the term *location* becomes a demonstrative pronoun to understanding context in general (e.g. what types of tools for emergency management staffs need to rescue victims in a specific location? How can I choose an un-ruined road to drive to a safe place?).

We suggest **location-aware BPM** as a research branch that extends the notion of context-aware BPM. In this paper, we distil and specify relevant elements of location-aware business process modeling as a first contribution to this line of research. This is because process modeling is a core activity underlying all BPM projects (Indulska et al., 2009). We follow a patterns-based approach as an appropriate strategy for examining fundamental constructs in business processes (Russell, 2007), and we identify and describe relevant patterns of location-dependency in process models, which in turn can be used to specify location-aware business processes. Importantly, through this work we can address two basic research questions around location-aware BPM, namely (a) where and (b) how does location impact business processes?

We proceed as follows. Section 2 introduces the research background of context-aware BPM and the basic definitions include location, location awareness and location dependence. It argues the roles of location in process modeling grammars. Section 3 describes five location-dependent control-flow patterns identified in the context of location-dependent business processes. Section 4 provides an illustrative example to contrast regular process modeling with the new approach featuring location-dependent patterns. Section 5 provides an evaluation of the patterns through a review of published process cases. Section 6 discusses the research limitations and future work directions. Section 7summarizes the contributions of the paper.

2. Research background

2.1 *Context-aware Business Process Management*

The implementation of business process management usually follows a lifecycle of design, implementation, enactment and diagnosis (van der Aalst, 2011). A key foundation for implementing BPM is provided by business process models. These models describe as-is or to-be processes by capturing at least the activities, events/states, and control flow logic of a process (Recker et al., 2009).

Process models are specified using *process modeling grammars* (Recker et al., 2009). These grammars provide sets of graphical constructs, together with rules for how to combine these constructs, to graphically express relevant aspects of business processes, such as the tasks to be performed, the actors involved in the execution of these tasks, relevant data, and, notably, the control flow logic that describes the logical and temporal order in which tasks are to be performed (Mendling et al., 2012).

Context-aware BPM (Rosemann et al., 2008) extends the traditional BPM lifecycle by focusing on extrinsic capabilities that influence the operation of the processes. Recognizing the relevance of additional process-related variables, an increasing amount of literature has emerged that has attempted to capture process-relevant information in process models beyond the pure control flow to also include organizational, financial or indeed environmental variables (e.g., Wieland et al., 2007; vom Brocke et al., 2010; Houy et al., 2010). Looking at how traditional models of business workflows can be extended to provide more contextual information for specialized decision-making, two fields can be identified. One field is concerned with financial dimensions of business processes (e.g. cost, risk, value) from a micro perspective. Vom Brocke et al. (2010), for example, put emphasis on the original purpose of business activities to maximize the contribution of a process to the potential economic value gain. Conforti et al. (2011) developed an approach for the explicit consideration of risk-related information (source, impact and mitigation of risk) within the immediate context of a business process, thereby aiming to improve the ability to detect risks at a run-time and to mitigate them .

Another field of research has started to study business processes from a macro perspective, i.e., the external viewpoint of the context of a business process. Rosemann et al. (2008) conceptualized the contextualization of business processes in a taxonomy that differentiates four types of context (immediate context, internal context, external context and environmental context). In a broader interpretation of the notion of context-aware BPM, other studies have worked on green-aware BPM (e.g., Ghose et al., 2009; Seidel et al., 2012). For example, Recker et al. (2012) described an approach for documenting and measuring the carbon footprint of business processes in an extended business process model.

2.2 *Location, location-awareness and location-dependency*

We treat "location" as one of the key variables in the wider context of a business process. Specifically, in the model by Rosemann et al. (2008), location describes an important variable situated in the environmental context layer. The environmental context, as the outermost layer, describe process-related variables that reside beyond the business network in which an organization is embedded but still pose a contingency effect on the business processes. Location is such a variable that cannot be nominally ascribed to a component of a business network alone (say, to a supplier or client organization), but instead it is a wider variable that affects both an organization and its external business network.

Location is an important environmental context variable because unlike other variables on this layer (e.g. the social-cultural system, the political-legal system, the workforce), which typically have a long life span and remain relatively stable over time, location can both force and aid processes to be performed or to responded immediately, dynamically and repeatedly.

We define location as a geographical symbol that captures a position plus its topographical information (e.g., earth's surface features, vegetation, human-made structures). For example, a location variable may capture an address, the name of a city etc. or a specific building, a mountain that can be distinguished from others, and so forth. The notion of location-awareness thus puts forwards the idea that a location and the services that relate to this location (e.g., identifying the location or its topographical information) can be considered by a business process in terms of *sensing*, *awareness* and *adaptation*.

In turn, we define location-aware business process management as the ability of a business process to (1) *sense* the current process status in a specific location or sense the location of a particular element of a business process (e.g. a task during execution), (2) be *aware* of location-based information that is of relevance to a business process, and changes thereof, over the lifecycle of a business process (e.g., during design as well as execution), and ultimately (3) *adapt* the process based on location-based information (e.g., availability of a task execution in a particular location). The notion of location-aware BPM thus suggests the inclusion of location as an attribute of business processes that can be tracked anytime and anywhere, elevating sensitivity to any behavior in a process. With location becoming a trigger for process execution or adaptation, location-aware BPM defines an ability to react to location-based information intelligently, in turn making location an important decision variable for the management of business processes.

This definition suggests that awareness and sensing are key pre-requisites to developing an ability to identify location dependencies within a business process. Therefore, location dependency specifies the recognition of resources' requirements or functions on a specific location in a location-based service (LBS), while location awareness describes the ability to react to some behavior in an identified situation, for example, to change a process at run-time.

Some work has been carried out on location dependencies in specific processes such as scientific workflows, where researchers focus on spatial-favored optimization connecting a location to related resources (e.g., geo-referenced data, localization, positioning). For example, several approaches utilize scientific workflow knowledge to optimize spatial decision-supporting system such as GEO-WASA (Medeiros et al., 1996), Geo-Opera (Alonso and Hagen, 1997), or to support environmental management information systems or Kepler scientific workflow systems (Ludäscher et al., 2006). These researches are mainly using current workflow knowledge to improve information systems, but they are not concerned with the workflow structure itself.

The research we are interested in is about how location variables can impact business processes or workflow structures. The study from this perspective is limited, with some notable exceptions. De Leoni et al. (2012) suggest using Map metaphors to visualize work items and resources in process-aware information systems. Decker et al. (2009) defined location constraints for individual workflow activities when modeling a workflow schema to restrict the location where an activity can be performed. Different from those two, we will explore location-dependencies in workflow task patterns to specify how location impacts the basic logical relationships in a process control flow, that is, in a sequence, parallel split, synchronization, exclusive split or simple merge.

2.3 *Location information in current process modeling approaches*

Location as a variable in the modeling of business processes is partially supported already . Several existing BPM tool suites allow for the definition and capture of additional variables in the modeling of business processes (Recker, 2012). In principle, such attribute fields could be used to capture location-based information. Still, the explicit attention of such variables and their consideration in the modeling and management of location-aware business processes is scarce in the literature.

Similarly, in existing business process modeling grammars (Recker et al., 2009), location variables do not yet play a dominant role in defining the behavior of business processes. They may exist as secondary elements or additional text information for readers to understand the graphical diagram. For example, in BPMN, location could theoretically be modeled through the use of three elements, viz., swimlane, text annotation and data (OMG, 2011). In EPC models, location variables may be grouped via organizational objects (Brabänder and Davis, 2007). And in YAWL, static attributes could be attached to work items as additional text information (Ter Hofstede, 2010).

This treatment of the location variable as an implicit "second class citizen" in process modeling can be problematic in several scenarios. Most notably, if captured in annotations and free attributes, location information can typically not be considered as a parameter in process executions. Also, the role of location information captured in an attribute cannot be propagated to other elements of the process model, e.g., it is not possible to specify control flow routing decisions based on free text or similar attributes.

2.4 *The value propositions of location-aware process models*

We expect that location-aware process models can increase the quality of process decision-making, for instance, by making these decisions more reliable, adaptable and flexible than those based on traditional, location-unaware process models. The potential value of the location-aware model is thus not only to make the process agile, but also to reduce the consumption of unnecessary resources in certain decision-making scenarios.

We expect four benefits to emerge from location-aware process modeling, these being dependency, adaptability, flexibility and efficiency. We define each type of potential benefit in Table 1.

Benefit	Description
Dependency	Capabilities to evaluate whether task, event, condition, data and resources are associated with locations or influenced by location constraints. A location constraint is an optional statement concerning the location where an activity in a process has to be performed or is not allowed to be performed (Decker et al., 2009).
Adaptability	Capabilities to make modifications in a workflow system on the condition of particular location context variable changes. For example, a manager may monitor the severance of the weather conditions and trigger the different escalation categories leading to different variations of the process.
Flexibility	Capabilities to reconfigure tasks accurately and rapidly on conditions that location variable changes in processes, which is explored as an identifier of bottle necks and as a trigger for change actions (Georgoulias et al., 2009). For example, in a flood rescuing process, after receiving a rescuing signal, a workflow system could provide suggestions to schedule rescuing people, organization, and tools from nearest places to minimize process execution time.
Efficiency	Capabilities to increase the business value when processes are involved with the idea of location-awareness. For example, the cost in a logistics process with transport routes can be optimized based on location information both at design and run time.

Table 1. *Potential benefits of location-aware process models*

3. Defining location-dependencies in process models

3.1 *Approach*

In this section, we provide a semi-formal specification of location-dependencies in business processes and provide mechanisms for capturing these dependencies in process models.

In describing these specifications, we use a pattern-based approach to define location dependencies. Identifying patterns for capturing and generalizing recurring design problems in the field of architecture, interface design, web design and software design have a long tradition. The term pattern is defined as “the abstraction from a concrete form that keeps recurring in specific non-arbitrary contexts” (Riehle and Züllighoven, 1996; Borchers, 2001).

In BPM research, patterns are used, for instance, to describe the abstraction of specific workflow requirements that are relevant to the implementation of workflow systems. Russell (2007) conceptualizes patterns from three orthogonal dimensions in a business process: control-flow patterns, workflow data patterns, and workflow resource patterns. In order to explore the feature of location dependency in processes, we will analyze the control-flow perspective as a first step. We have focused on the control-flow perspective due to the fundamental principle that distinguishes a process-oriented view from other perspectives onto information systems (e.g., data- or object-oriented).

Introducing location-specific information as a resource into a workflow can either be realized though push patterns (the system pushes tasks to an actor in certain location or the system pushes tasks to a location where an actor executes) or pull patterns (the system pull process information in certain location or an actor in certain location pull tasks to the system). Location-specific information can also be treated as workflow-relevant data to be transmitted between tasks, instances or cases. Finally, information about specific locations can be treated as an event to trigger a process instance. All of its multi-role characteristics can be explained by the term of location patterns which extends the scope of static control flow driving both structural and dynamic properties (van der Aalst et al., 2003).

We use location patterns to expose different types of location dependencies. Then, we use location patterns to serve as an analysis mechanism for interpreting and understanding location-aware BPM. As an extension to the workflow control-flow patterns, location-dependent control-flow patterns attempt to answer two research questions, viz., where and how location impacts business processes in process models. We propose a set of five location-dependent control-flow patterns as a first answer to these questions.

Following the specification of workflow patterns in (van der Aalst et al., 2003), we present the five location-dependent process model patterns using a standard format that includes four parts: definition, notation, example, explanation, issues and solutions:

- Definition: a concept to summarize the pattern.
- Notation: suggested new modeling concept to visualize the pattern, plus explanation where required.
- Example: illustrative examples for the occurrence of the pattern.
- Explanation: an explanation of its behavior.
- Issues: relevant problems in relation to the pattern.
- Solutions: potential solutions to the issues.

3.2 *Preliminaries*

To be able to specify the five location-dependent control-flow patterns, we first have to define the concept of a **location-dependent task**. The term ‘location-dependent’ implies that a task relates to a specific location in which it executes.

We define a location-dependent task as a task that is allowed to be executed in one or more locations but not any location. It is always performed at a pre-defined location. In some processes, most of the existing tasks can be distinguished from each other through their respective locations in a location-aware business process.

For example, consider the task ‘dispatch jacket and hat’ in Figure 8. This task in our definition is location-dependent because this task has to be executed at one or more locations, but not just any location. In the example this means, quite literately, that jacket and hat may be dispatched from WUHAN, SHANGHAI etc, but not from HONGKONG, MACAO. In contrast, the task ‘check inventory’, as per our definition is location-dependent because it can be executed at any location (by means of a web-based system). The execution of this task therefore is not dependent on a physical location.

In the following, to define location-dependencies in tasks in an intuitive manner, we only consider the notion of location as an aspect of the normal geographical nature of a position, i.e., an address, city, post codes, and disregard (at this stage) topographical information and its related context, e.g., costs, time, weather and so forth.

To differentiate location-dependent tasks from regular tasks in a process model, we suggest representing a location-dependent task by a land marker symbol in top left corner of a single thin lined rectangle (see Figure 1).

Figure 1. Location-dependent task

On basis of this simple concept, we can now explore control-flow patterns in which location-dependent tasks might occur.

3.3 *Location-dependent sequence*

Definition: A task of a location-dependent process is enabled in a particular location after the completion of a preceding task in a different location.

Notation: none required.

Example: After finishing 'Security check' task at the service counter, passengers walk to the gate in order to board the plane (see Figure 2).

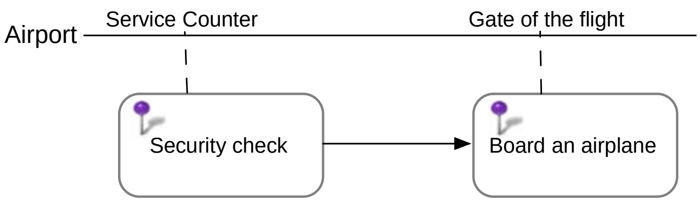

Figure 2. Location-dependent sequence example

Explanation: The location-dependent sequence pattern is a fundamental principle for location-aware business process modeling. It describes scenarios in which, because of process requirements or limited resources, two consecutive tasks cannot be accomplished at the same place. Instead they need to execute in turn from one place to the other place without any condition associated in any responded place.

Issues: It is supposed that the first location-dependent task is being executed. One problem is making process participants sense the process status in a specific location or sense the location of the first task being executed. Another problem is making the process aware of the location-based services to guide the execution of the second task in another location. In other words, it may be problematic that consecutive location-dependent task sequences cannot be finished at one place.

Solutions: In the above example, as there is a long distance between the security-check lobby and the boarding gate, passengers may have to walk 20 minutes to board the flight. However, if these consecutive tasks could be executed at one place or in an indispensable short distance, it would provide more convenience for passengers and overall reduce the cycle time of the process (i.e., allow passengers to board an airplane earlier or arrive at the airport later). One possible solution for such an issue is to provide enough resources to allow the tasks to be performed sequentially at the same place (e.g., check-in at the gate).

3.4 *Location-dependent parallel split*

Definition: A task is separated into two or more parallel tasks, each of which should execute concurrently in the same or different locations.

Notation: none required.

Example: Assume that there is no warehouse in Brisbane. When the e-commerce service centre receives the payment from a customer, it triggers the 'dispatch T-shirt' task from a Melbourne warehouse to Brisbane and the ‘dispatch pants’ task from a Sydney warehouse to Brisbane simultaneously on the condition of no available inventory of both products in the same location (see Figure 3).

Explanation: Depending on the requirement of the previous task or under the guideline of the case, the next tasks have to be executed concurrently in two or more different locations.

Issues: A location-dependent parallel split requires the tasks being executed concurrently. However, in Figure 3, it is impossible for a delivery staff to execute two tasks in two different places at the same time. Furthermore, when the process senses the location information in each parallel task, information is still missing about to choose the best location set facing the existence of various location-dependent strategies to organize those tasks.

Solutions: For the issue of limited resource with multiple tasks being executed in more than one place at the same time, one way is to ask for additional resource to execute the tasks. Another way is to find a chance to accomplish the tasks in the same location. Otherwise, two or more tasks can be only enabled one by one until all of them have been completed. For the second issue, it is suggested to adopt one of the most adaptable location-dependent strategies following the principle of minimum cost and maximum efficiency.

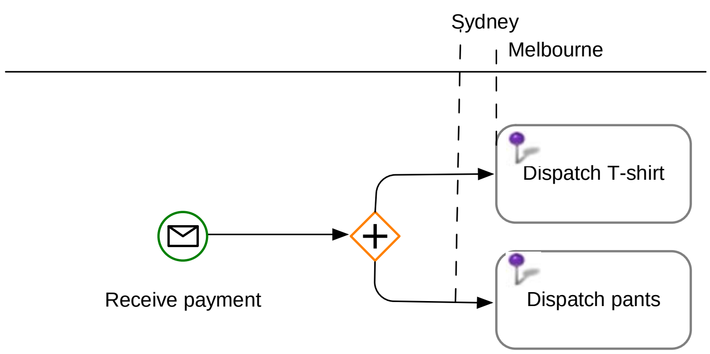

Figure 3. Location-dependent parallel example

3.5 *Location-dependent synchronization*

Definition: Two or more tasks are accomplished at different places before they converge into a single subsequent task in one location, which can be the same or different location with regard to the locations of the previous tasks.

Notation: none required.

Example: At the student service centre at an Australian university (in the A-block building), a manager approves the submission of ‘apply for student card’. Within the city business district (in Queen Street), the student opens his bank account successfully. Based on the information of those 2 locations together, the next step ‘request phone card’ should be performed in another location (at Kelvin Grove). The execution of that task is dependent on the successful completion of the previous two tasks because otherwise required information about the applicant for obtaining a mobile phone card will not be available (see Figure 4).

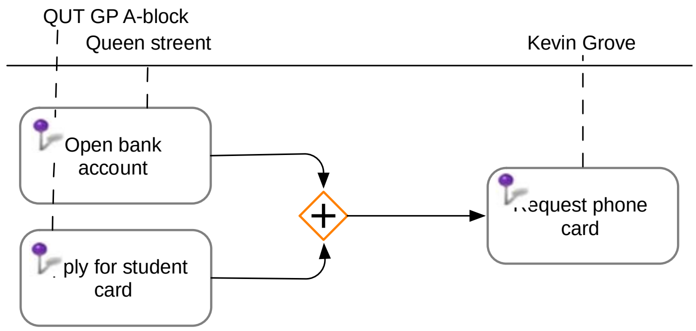

Figure 4. Location-dependent synchronization example

Explanation: Two or more tasks performed at the same or different locations are merged at one place. Location-dependent synchronization is created in two ways. On the one hand, the synchronization may be used as part of an AND gateway as the counterpart of location-dependent parallel split. On the other hand, if only limited resources are available (e.g., only one user) in specific locations to execute two or more tasks, these tasks would need to be completed sequentially before the location-dependent synchronization can be trigged.

Issues: Typically it is assumed that location-dependent synchronization is created when the next task is ready to be executed at one location. When any of the previous tasks fail to sense the locations to be executed or be aware of the location-dependent information, the process would deadlock as the synchronization would wait for all tasks to be successfully completed at the specific locations.

Solutions: Facing a deadlock situation, it is recommended to set an exception handler event on each boundary of the tasks prior to the location-dependent synchronization. Once an intermediate event listens to an exception at any of previous locations, the workflow system can execute a compensation task, if required.

3.6 *Location-dependent exclusive split*

Definition: Location-dependent exclusive splits describe an exclusive decision based on the conditions of specific location information named location-dependent conditions.

Notation: A location-dependent condition is represented by a land marker symbol in top left corner of the condition text (See Figure 5).

Figure 5. Location-dependent condition

Example: In a shipping process, after checking the inventory, which logistic company will be responsible to dispatch the item? Is this decision dependent on the condition of where the item stored? If the item is stored in Sydney, the EFS Express delivery company would be charged with dispatching the item. However, if the item is stored in Darwin, the national Australia Post would be requested to manage the delivery (see Figure 6).

Explanation: After the successful completion of one task, the flow is divided into two or more sequence flows, ending in tasks that are executed in different locations. Once the incoming task is enabled, the following task is executed as soon as possible. The decision about which task should be executed depends on the evaluation of the respective conditions related to the respective locations. The location-dependent conditions, therefore, influence the sequence flow and the selection of the following task(s).

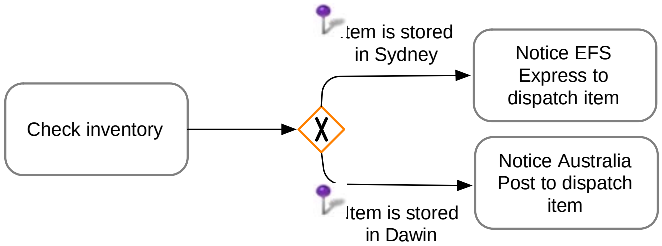

Figure 6. Location-dependent exclusive split example

Issues: One of the difficulties associated with this pattern is ensuring that precisely one outgoing task is triggered when the Exclusive Choice is enabled (van der Aalst et al., 2003).

Solutions: The use of location-dependent exclusive splits requires explicit definitions of each of the conditions. Conditions must be specified mutually exclusive and complete. If these requirements are not met, a process instance can deadlock, if none of the conditions are true (e.g. the location of the item is not defined in the location list of the conditions). Consequently, a default flow should be defined to ensure that the process instances do not deadlock.

3.7 *Location-dependent simple merge*

Definition: Location-dependent simple merge defines a decision to merge two or more previous tasks in different locations to a subsequent task involving a choice where to execute it.

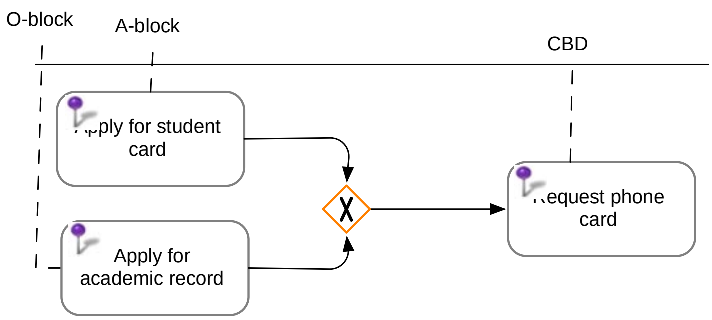

Figure 7. Location-dependent simple merge example

Notation: none.

Example: After either applying for a student card at the Student Centre in A block or applying for an academic record from the faculty, the request for a mobile phone card in the city business district can be triggered (see Figure 7).

Explanation: Two or more tasks converge to a subsequent single task at one location. Sometimes, the location-dependent condition for one task may have a direct influence with regard to the place for the subsequent task execution. Vice-versa, sometimes, where to execute the subsequent task also has an effect to the decision of choosing which location-dependent condition.

Issues: If the place at which to execute the subsequent task is not the same place in any location-dependent condition, there is a chance to fail to transfer the previous task (e.g. after completion the previous task or before start of the subsequent task).

Solutions: In a location-dependent simple merge scenario, a location in a location-dependent condition may be the same as the location in the subsequent task, depending on process requirements.. However, if the issue occurs, the location in conditions is not the same as the location of the subsequently executed task. It is thus suggested to set an exceptional event to check the status. For example, in the above process, the student card or the academic record statement may be lost on the way. So the phone card cannot be requested. Therefore, it is suggested to set an intermediate event on the boundary of subsequent task. This intermediate event fires when any mistakes are made before the subsequent task starts.

4. Illustration

In order to illustrate the effects of connecting location variables into process models, we now compare two different modeling methods, viz., a traditional process model (Figure 8) and a location-dependent process model (Figure 9) to study a simple on-line shopping process. This process describes how an on-line shopping retailer dealing with a customer's order e.g. a jacket and a hat to location E (e.g., the postal address of the on-line shopping customer in WUHAN). The process mainly consists of 9 key tasks. The process is triggered by 'receive payment of a jacket and a hat' message. Then, the service center will 'check the inventory' using the inventory management software and decide to 'notice joint shipment' or 'notice separate shipment'. If the two ordered items are stored in the same location (e.g., SHANGHAI), 'dispatch jacket and hat' task can be executed in location A (SHANGHAI). If the two items are stored in different locations (for example, jackets are available in location B, e.g., BEIJING, while hats are in location C, e.g., GUANGZHOU), 'dispatch the jacket' from location B to location D and 'Dispatch the hat' from location C to location D need to be executed. When hat and jacket both arrive at the WUHAN dispatch center, a staff can execute the task 'deliver items' to the customer. The process ends when staff successfully 'collect the customer's signature' at the customer's address.

The intent of this illustrative comparison is to visualize how the location-dependent process model provides a more explicit and extended documentation of the processes before providing extended informational support for more accurate and agile decisions that relate to the process. Furthermore, the location-dependent modeling allows to consider a series of questions: whether the items are executed in the same location or not, the nearest warehouse to the destination, the cheapest delivery route to the destination, whether delivering items to customer either individually or together and so forth.

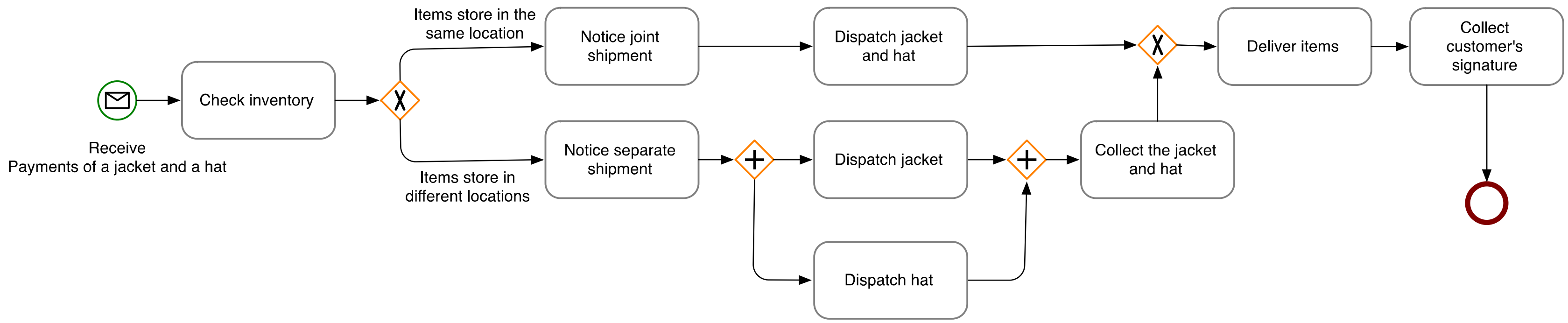

Figure 8. A traditional process model of the on-line shopping process

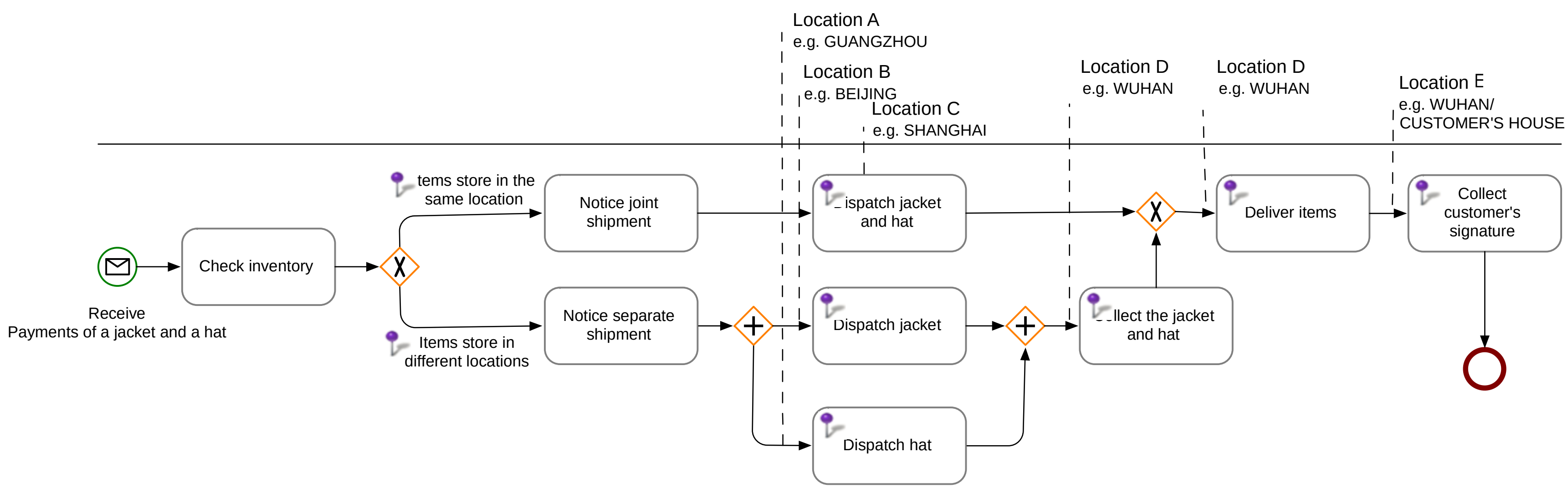

Figure 9. A location-dependent model of on-line shopping process

5. Evaluation: Location-dependencies in existing case studies

To demonstrate the applicability as well as the relevance for the identified patterns, we reviewed the literature to provide an analysis of location-dependencies in business processes as existent in case studies. We reviewed papers in information systems, computer science, organization and management science, with the goal to identify case descriptions and narratives of business processes that exhibited (implicitly or explicitly) notions of location-dependency. To illustrate the relevance, we identified 10 papers that discuss processes that operate in a variety of industry domains (ranging from manufacturing and logistics to hospital, traveling and so forth). The identification of these papers already indicates that location-dependencies are prominent in many business processes across several domains. Table 2 provides a summary of our evaluation.

In Table 2 a '+' indicates that the particular pattern was found to be present in the process described in the paper. For instance, in the case of process for checking packages in (Decker et al., 2009), a location-dependent sequence pattern was observed in the following part of the process: The first task 'chose package' with small items can be executed at that part of the warehouse where those packages are stored. The completion of this task triggers the second task 'check package' at either commissioning station 1 or station 2.

In Table 2, a '-' indicates that the relevant pattern was not found to be relevant to the process discussed in the paper. For example, location-dependent parallel split and location-dependent synchronization patterns are not illustrated in the amended CPN model for campus life in (Han and Youn, 2012). Note that the absence of a pattern may also stem from the lack of description of relevant details of the process in the paper.

Finally, the '+/-' symbol indicates that ambiguous information that makes hard to ascertain whether one of those particular patterns of location-dependency was present in a case. However, we do not take this issue into the final analysis. For example, in (Wamba et al., 2008), the scenarios integrating RFID and EPC network are described from the more general to the more detailed without condition descriptions in the figures. However, in the part of explaining tasks to identify pallets, the paper distinguishes the full pallets from mixed pallets. We cannot affirm whether the condition is location-dependent condition or not.

Considering how the proposed patterns were identified in the published cases, consider the following illustrations of our analysis. For example, we identified the location-dependent sequence pattern within the A refinery process discussed in (Decker et al., 2009) within the description of how the process handled reports: "a report was generated during the inspection of a refinery in a particular region then the company's back-office in a distinct city has to do the post-processing." Analogously, we identified location-dependent exclusive split patterns in instances such as this passage of the campus life example in (Han and Youn, 2012): 'John is at campus or not / the weather is good or not', with this information influencing the choice of activities John can take. Notice that the tasks that connect to the exclusive choice do necessarily have to be location-dependent tasks, demonstrating the example in Figure 9. The pelvic treatment process in (Guo et al., 2013) provides some illustrations for the location-dependent parallel split pattern and the location-dependent synchronization pattern: For example, after the 'receive the patient' task, three tasks ('preparing treatment' task by orthopedic surgeon at the surgical preparation room, 'transfusion' task by blood bank resident at the patient's ward and 'chest X-Ray' task by the interventional radiology at chest X-Ray room) all have to be completed within these specific locations (i.e., hospital rooms) before the subsequent task 'ultrasound abdomen' at the ultrasound observation room can be executed.

Case No	Cases	Field	Process	Example location-dependent process elements	Location-dependent control-flow patterns					Level of location-dependency (relative and absolute)
					Location-dependent sequence	Location-dependent parallel split	Location-dependent synchronization	Location-dependent exclusive split	Location-dependent simple merge	
1	(Wamba et al., 2008)	Logistics	Shipping process, receiving and put-away processes	e.g. pick pallet from the packaging area using a forklift, transfer the trailer to the shipping destination	+	+	+	+/-	+/-	*100%(3)*
2	(Rüppel and Wagenknecht, 2007)	Emergency	Operational flood management	e.g. check traffic route to generator location	+	+	+	-	-	*60% (5)*
3	(Han and Youn, 2012)	Campus life	Daily life activities	e.g. if John is outside of campus	+	-	-	+	+	*60% (5)*
4	(Maglogiannis and Hadjiefthymiades, 2007)	Healthy	Emergency medical incident operation process	e.g. doctor relocation	+	+	+	-	-	*60% (5)*

5	(Wieland et al., 2007)	Manufacturing industry	Machine maintenance process	e.g. perform maintenance work	+	+/-	+	+	+	*100% (4)*
6	(Gottschalk and La Rosa, 2010)	Shipment	Carrier Appointment process	e.g. arrange delivery appointment, modify pickup appointment	+	-	+	+	+	*80% (5)*
7	(Guo et al., 2013)	Hospital	Medical treatment workflow	e.g. Preparing treatment, Transfusion, send patient to the ward	+	+	+	-	-	*60% (5)*
8	(Jakimavièius and Burinskienë, 2010)	Travel	Route planning process	e.g. the shortest route	+	-	-	+	+	*60% (5)*
9	(Decker et al., 2009)	Agriculture	Harvesting process	e.g. detect an obstacle on the crops	+	-	-	+	-	*30% (20)*
		Refineries	Performing inspections	e.g. enter the inspection report of a technical component	+	+	-	-	-	

		Road Maintenance	Maintenance of Road Network	e.g. repair works, final inspection	+	-	-	-	-	
		Hospital	Medical treatment	e.g. pertinent task	-	-	-	+	-	
10	(Karim and Arif-Uz-Zaman, 2013)	Manufacturing	RC cubicle assembly process	e.g. deliver Cubicle to Unit 1	+	-	-	-	-	*20%(5)*
11	(Ouyang et al., 2011)	Hospital	Surgical care process	e.g. do procedure, register procedure	+	-	+	-	-	*40% (5)*
	Occurrence of pattern across cases (relative and absolute)				*86% (14)*	*38% (5/13)*	*50% (7/14)*	*46% (6/13)*	*31% (4/13)*	

Table 2. *Survey of Location-dependent control-flow patterns in published process*

The data in Table 2 suggests that all considered processes in the published papers provide some implicit or explicit evidence about the *occurrence* of location-dependency (ranging from 31% to 86%) and the *level* of location-dependencies in the respective processes (ranging from 20% to 100%). This data provides some evidence for the external validity of our location-dependent control-flow patterns. This is notable especially because the considered papers do not explicitly study aspects of location, except for the work by Decker et al. (2009).

Inspecting the data in more detail, we find that the twelve cases roughly cover four fields, viz., traditional industry (e.g., manufacturing, agriculture and refineries), service industry (e.g., hospital, logistics and travel), government public service (e.g., flood emergency and road maintenance) and daily life (e.g., campus life). Seven of the twelve cases (4 hospital cases, 2 logistics cases and 1 travel case), describe a service process. Each of the cases was found to include least three out of five patterns (60%). The highest level of location dependency (100%) was found in the case discussed in (Wieland et al., 2007). We may speculate that service processes are more susceptible location-dependencies, and thus also denote processes ripe for emerging technologies such as location-based services.

In summation, our reviews show that all of the location-dependent control-flow patterns can be found in processes discussed in the literature. The location-dependent sequence pattern is the most frequent occurring pattern in the observed cases. Of the 11 papers that were reviewed, 12 out of 14 processes provide extreme high frequency to this pattern. The second most frequent location-dependent control-flow pattern is location-dependent synchronization pattern, which we recognized in 7 processes. The occurrence ratios of the location-dependent exclusive split pattern and the location-dependent parallel split pattern were 46% and 38%, followed by the location-dependent simple merge which we identified in 31% of the published cases.

Overall, our literature review provides some supporting evidence for the notion of location-dependency and provides evidence for the types of location-dependencies that occur in the form of the suggested location-dependent control-flow patterns within different business processes.

6. Implications

Our work has yielded a set of five location-dependent control-flow patterns that can form the basis for further research towards making business process management location-aware. This notion suggests business process management requiring two abilities: (a) to sense the current status of a business process within a particular set of location(s) and (b) to be aware of location-based information within the management, design or execution of business processes.

Our work on location-dependent control-flow patterns also implies that location-dependencies may be present in other business process elements. For example, it is likely that location-dependencies occur and impact the behavior of resources, events and systems. Further research is required to explore this implication, for example, by conducting studies of real cases that have shown the relevance of location to business processes as well as the suggested problem-solving methods. One possibility is to distinguish such issues in four main aspects (i.e. tasks, resources, events and systems). Such a distinction would have important implications, for example, for the modeling of hierarchical business processes.

The application of the notion of location-dependencies in the modeling of business processes has further implications for the use of such models in the management of business process.

First, location-dependencies can become one of guiding principles to design business process. Facing bunch of location-dependent processes in traditional industries, service industries and government public services, location variables should be related to some model elements. Process design and process enhancement rely heavily on this relationship. This relationship can help "embed" location information in the model.

Second, location-dependencies may become an emerging characteristic for process analysis, e.g., through process mining. Van der Aalst and Dustdar (2012) suggest to relate process mining technologies to contextual data. Location information could be stored as additional information in the event log to improve the traceability of a process to the context in which the process was executed. Following the new idea of location dependency, on the one hand, it may discover event logs and produce a location-dependent mined model. On the other hand, it may be used to compare the conformance of an existing process model with the same process's event log with location information. Last but not least, it may extend and improve the process model by using observed location-dependent event logs.

Finally, the technical implications of our work concern

(a) how to implement location-awareness evolving from location-dependency as a principle for business process adaptation, and

(b) how to technically adapt a location-dependent process.

Dynamic and automatic workflow adaptations are a major requirement for next generation workflow systems to provide sufficient flexibility to cope with unexpected failure events (Müller et al., 2004). Future experimental trials could provide evidence that support the relevance of location-aware BPM, or identify important boundary conditions to making location a process decision variable. For example, in our own future work, we plan to examine decision-making differences on basis of location-aware business process models versus traditional business process models. However, we also envisage much more extensive and holistic studies to be of relevance to studying the acceptance and value of location-aware BPM.

7. Conclusions

This paper introduced location-aware BPM as a new perspective to extend context-awareness in BPM research, together with terms about location e.g. location, location awareness and location dependency. As a first step, we discussed where and how location might influence a business process by providing a conceptualization of location-dependency within process models. The results of our initial exploration yielded five basic location-dependent control-flow patterns. Detailed data analysis from the published process cases indicates that the phenomenon of location dependency can be easily tracked in a wide range of process in different industries.

We regard our paper as a conceptual starting point for further exploration of the concept of location dependency in the management of business processes, as well as the related challenges. We sought to provide an initial framework and specification of relevant patterns to guide on-going research on process context and location-aware services. We hope that future work will further extend this research.

References

Alonso, G. and Hagen, C. (1997), "Geo-Opera: Workflow concepts for spatial processes", in *Advances in Spatial Databases*, Springer, pp. 238-258.

Borchers, J.O. (2001), *A Pattern Approach to Interaction Design*, Wiley, New York, New York.

Brabänder, E. and Davis, R. (2007), *ARIS Design Platform–Getting Started with BPM*, Springer-Verlag London Limited, London.

Conforti, R., Fortino, G., La Rosa, M. and ter Hofstede, A. (2011), "History-aware, real-time risk detection in business processes", *On the Move to Meaningful Internet Systems: OTM 2011*, 100-118.

de Leoni, M., Adams, M., van der Aalst, W.M.P. and ter Hofstede, A.H.M. (2012), "Visual Support for Work Assignment in Process-Aware Information Systems: Framework Formalisation and Implementation", *Decision Support Systems*, Vol. 54, No. 1, 345-361.

Decker, M., Stürzel, P., Klink, S. and Oberweis, A. (2009), "Location constraints for mobile workflows", in *Proceedings of the 2009 Conf. on Techniques and Applications for Mobile Commerce, TAMoCo*, pp. 93-102.

Georgoulias, K., Papakostas, N., Chryssolouris, G., Stanev, S., Krappe, H. and Ovtcharova, J. (2009), "Evaluation of flexibility for the effective change management of manufacturing organizations", *Robotics and Computer-Integrated Manufacturing*, Vol. 25, No. 6, 888-893.

Ghose, A., Hoesch-Klohe, K., Hinsche, L. and Le, L.-S. (2009), "Green Business Process Management: a Research Agenda", *Australasian Journal of Information Systems*, Vol. 16, No. 2, 103-117.

Gottschalk, F. and La Rosa, M. (2010), "Process Configuration", in *Modern Business Process Automation*, Springer, pp. 459-487.

Guo, H., Brown, R. and Rasmussen, R. (2013), "Human Resource Behaviour Simulation in Business Processes", in Pooley, R., Coady, J., Linger, H., Barry, C., Lang, M. and Schneider, C. (Eds.), *Information Systems Development: Reflections, Challenges and New Directions*, Springer, Edinburgh, Scotland.

Hammer, M. and Champy, J. (1993), *Reengineering the Corporation: A Manifesto for Business Revolution*, Harpercollins, New York, New York.

Han, S. and Youn, H.Y. (2012), "Petri net-based context modeling for context-aware systems", *Artificial Intelligence Review*, Vol. 37, No. 1, 43-67.

Houy, C., Fettke, P. and Loos, P. (2010), "Empirical research in business process management–analysis of an emerging field of research", *Business Process Management Journal*, Vol. 16, No. 4, 619-661.

Indulska, M., Recker, J., Rosemann, M. and Green, P. (2009), "Process Modeling: Current Issues and Future Challenges", in van Eck, P., Gordijn, J. and Wieringa, R. (Eds.), *Advanced Information Systems Engineering - CAiSE 2009*, Springer, Amsterdam, The Netherlands, pp. 501-514.

Jablonski, S. and Bussler, C. (1996), *Workflow Management. Modeling Concepts, Architecture and Implementation*, International Thomson Computer Press, London, UK.

Jakimavièius, M. and Burinskienë, M. (2010), "Route planning methodology of an advanced traveller information system in Vilnius city", *Transport*, Vol. 25, No. 2, 171-177.

Karim, A. and Arif-Uz-Zaman, K. (2013), "A methodology for effective implementation of lean strategies and its performance evaluation in manufacturing organizations", *Business Process Management Journal*, Vol. 19, No. 1, 169-196.

Ludäscher, B., Altintas, I., Berkley, C., Higgins, D., Jaeger, E., Jones, M., Lee, E.A., Tao, J. and Zhao, Y. (2006), "Scientific workflow management and the Kepler system", *Concurrency and Computation: Practice and Experience*, Vol. 18, No. 10, 1039-1065.

Maglogiannis, I. and Hadjiefthymiades, S. (2007), "EmerLoc: Location-based services for emergency medical incidents", *International journal of medical informatics*, Vol. 76, No. 10, 747-759.

Medeiros, C.B., Vossen, G. and Weske, M. (1996), "GEO-WASA: Combining GIS Technology with Workflow Management ", in *7th Israeli Conference on Computer Systems and Software Engineering*, IEEE, Herzliya, Israel, pp. 129-139.

Mendling, J., Strembeck, M. and Recker, J. (2012), "Factors of Process Model Comprehension — Findings from a Series of Experiments", *Decision Support Systems*, Vol. 53, No. 1, 195-206.

Müller, R., Greiner, U. and Rahm, E. (2004), "Agentwork: a workflow system supporting rule-based workflow adaptation", *Data & Knowledge Engineering*, Vol. 51, No. 2, 223-256.

OMG (2011), "Business Process Model and Notation (BPMN) - Version 2.0", available at http://www.omg.org/spec/BPMN/2.0.

Ouyang, C., Wynn, M.T., Kuhr, J.-C., Adams, M.J., Becker, T., ter Hofstede, A.H. and Fidge, C.J. (2011), "Workflow support for scheduling in surgical care processes".

Recker, J. (2012), ""Modeling with Tools is Easier, Believe Me" - The Effects of Tool Functionality on Modeling Grammar Usage Beliefs", *Information Systems*, Vol. 37, No. 2, 213-226.

Recker, J., Rosemann, M., Indulska, M. and Green, P. (2009), "Business Process Modeling: A Comparative Analysis", *Journal of the Association for Information Systems*, Vol. 10, No. 4, 333-363.

Recker, J., Rosemann, M., Roohi Goohar, E., Hjalmarsson, A. and Lind, M. (2012), "Modeling and Analyzing the Carbon Footprint of Business Processes", in vom Brocke, J., Seidel, S. and Recker, J. (Eds.), *Green Business Process Management - Towards the Sustainable Enterprise*, Springer, Heidelberg, Germany, pp. 93-110.

Riehle, D. and Züllighoven, H. (1996), "Understanding and using patterns in software development", in *Theory and Practice of Object Systems,* pp. 3-13.

Rosemann, M., Recker, J. and Flender, C. (2008), "Contextualization of Business Processes", *International Journal of Business Process Integration and Management,* Vol. 3, No. 1, 47-60.

Rüppel, U. and Wagenknecht, A. (2007), "Improving emergency management by formal dynamic process-modelling", in *24th conference on information technology in construction*.

Russell, N. (2007), "Foundations of Process-Aware Information Systems", in, Queensland University of Technology, Brisbane, Australia.

Seidel, S., vom Brocke, J. and Recker, J. (Eds.) (2012), *Green Business Process Management: Towards the Sustainable Enterprise,* Springer, Heidelberg, Germany.

Ter Hofstede, A. (2010), *Modern business process automation,* Springer.

van der Aalst, W.M.P. (2011), *Process Mining: Discovery, Conformance and Enhancement of Business Processes,* Springer, Heidelberg, Germany.

van der Aalst, W.M.P. and Dustdar, S. (2012), "Process Mining Put into Context", *IEEE Internet Computing,* Vol. 16, No. 1, 82-86.

van der Aalst, W.M.P., ter Hofstede, A.H.M., Kiepuszewski, B. and Barros, A.P. (2003), "Workflow Patterns", *Distributed and Parallel Databases,* Vol. 14, No. 1, 5-51.

vom Brocke, J., Recker, J. and Mendling, J. (2010), "Value-oriented process modeling: integrating financial perspectives into business process re-design", *Business Process Management Journal,* Vol. 16, No. 2, 333-356.

Wamba, S.F., Lefebvre, L.A., Bendavid, Y. and Lefebvre, É. (2008), "Exploring the impact of RFID technology and the EPC network on mobile B2B eCommerce: A case study in the retail industry", *International Journal of Production Economics,* Vol. 112, No. 2, 614-629.

Wieland, M., Kopp, O., Nicklas, D. and Leymann, F. (2007), "Towards Context-Aware Workflows", in Pernici, B. and Gulla, J.A. (Eds.), *CAiSE 2007 Proceedings of the Workshops and Doctoral Consortium, Vol. 2*, Trondheim, Norway.