Towards a Model-Based Analysis of Place-Related Information in Disaster Response Workflows

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ABSTRACT

Processes in disaster response management (DRM) and business processes are similar due to their general structure and goals. This encourages us to analyze the suitability of business process management tools and methods in the domain of DRM. One main challenge is the coverage of disaster specific aspects by existing process modeling languages. Since interdependencies between time, activities, and place are critical for process planning, we discuss the necessity for model extension. A special focus lies on the integration of place-related information as well as interdependencies resulting from stationary and mobile activities and resources. The integration of such place-related information is discussed as pre-condition for effective and efficient planning of disaster response processes and their successful management by disaster response workflow management systems.

Keywords

Disaster response management; workflow management systems; place-related dependencies; spatial information, management of interdependencies

INTRODUCTION: MANAGING DISASTER RESPONSE PROCESSES WITH WORKFLOW MANAGEMENT SYSTEMS

Methods and tools from the domain of business process management (BPM) and especially workflow management are considered as promising approaches to improve disaster response management (DRM) (e.g. Hofmann, Sackmann and Betke, 2013; Jansen, Lijnse and Plasmeijer, 2010; Sell and Braun, 2009). However, to the best of our knowledge, their application has not yet been realized in practice. This is deplorable, since workflow management offers manifold opportunities to improve DRM, e.g. by so-called disaster response workflow management systems (DRWfMS) – especially by providing enhanced process transparency and, thus, facilitating an effective management and the coordination of response resources and activities.

The reasons for not using DRWfMS in practice are manifold: for instance, disasters are unpredictable and planning of disaster response processes (DRP) ex ante is generally a difficult endeavor (e.g. Franke, Charoy and Ulmer, 2010; Swenson, 2010). In addition, disaster reality is uncertain and chaotic, consequently, DRP are subject to ongoing adaption during run-time. Providing such flexibility by DRWfMS has not yet been achieved and is a current field of research (e.g. Lanz, Krehe, Reichert and Dadam, 2010). In our view, one further reason lies in the differences between the domains of DRM and BPM that are not yet addressed either on the level of modeling or on the level of IT support. One crucial challenge is the handling of numerous restrictions and interdependencies of resources, time, and place. Especially spatial information about the place of DRP execution and resource location are of major importance to DRM. Taking them into consideration requires further research in regard to modeling and representing DRP relevant objects, data, and restrictions adequately. Since spatial information is at best considered indirectly in BPM, common modeling languages do not offer adequate possibilities to explicate them to the extent required in DRM. Therefore, in this contribution, an extended view on place-related information is discussed and two new modeling elements for modeling DRP are presented.

The contribution is structured as follows: in the following section, a short overview on current DRM approaches considering restrictions in regard to time, place, and resource is given. Subsequently, we focus on place-related information and show that existing approaches for process modeling lack in expressiveness. We present a general categorization of place-dependencies and propose a model extension. Subsequently, opportunities for a model-driven analysis of different interdependencies in DRP are discussed and, as conclusion, a first approach for integrating the identified categories into modeling language is sketched, leading to further research topics.

CHALLENGES IN MANAGEMENT AND PLANNING OF DISASTER RESPONSE PROCESSES

Disaster management is usually categorized as pre-, during-, and post-disaster management. While the first phase focuses on readiness in the case of an emergency, the last phase comprises activities to recover from disaster and to restore the pre-disaster state to an acceptable level. The second phase addresses disaster response management (DRM) on a strategic, tactical and operational level. This phase is concerned with counteracting a disaster in the immediate aftermath of its occurrence and, thus, with the management and execution of DRP. In this regard, especially on a tactical level of DRM, the coordination of one or several interrelated events as well as information management are major challenges (Bharosa, Lee, Janssen, and Rao, 2009)

DRM, again, covers two main parts: the planning and the execution of DRP. The former aims at concretizing (usually ex ante designed) response plans according to the disaster reality and available context information so that a DRP can ultimately be initialized. During the execution, single process activities have to be assigned to the on-field staff and executed on-site. Simultaneously, continuous re-planning and adaptation of on-going processes, e.g. to new context information or to changed goals, has to be managed (e.g. Chen et al., 2008).

Both parts of DRM, planning and execution, require a plethora of data that has to be interpreted for making "good" decisions and answering questions like: what happened and where did it happen, what is in danger, what resources are available in general and where are they located, what activities are time critical and how much time is needed to carry out single response activities? Obviously, one of the most crucial factors for successful planning of efficient and effective DRP is the knowledge of resource-, time- and place-related constraints (e.g. Avanes and Freytag, 2008; Franke et al., 2010; Sell, Winkler, Springer, and Schill, 2009). This is crucial for DRM, since they might considerably restrict the possibilities for counteracting a disaster in general but also the feasibility of single response activities. Moreover, these constraints cannot be taken into consideration in an isolated way, since they mutually influence each other. In turn, they are interdependent (see figure 1) and have to be analyzed and assessed simultaneously.

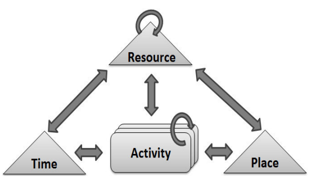

Figure 1. Interdependencies in DRM

In order to provide proper situation awareness and to manage on-going DRP effectively by the application of DRWfMS, it becomes indispensable to uncover these constraints. In this regard, interdependencies due to time and resources have already been discussed by, e.g., (Delias, Doulamis A., Doulamis N., and Matsatsinis, 2011; Franke et al., 2010; Leong, Si, Fong, and Biuk-Aghai, 2009; Russe, van der Aalst, Ter Hofstede and Edmond, 2005). However, to the best of our knowledge, there are no contributions concerning place-related interdependencies and restrictions either in the general field of WfMS or in the context of DRWfMS. Therefore, we discuss relevant information requirements for their modeling and analysis in the next section.

IMPORTANCE, CLASSIFICATION, AND FORMAL MODELING OF "PLACE"

In BPM, place of process execution, associated activities and resources (e. g. actors, material, machines, data, etc.) are usually defined and fixed in advance. Thus, process models can be created and adjusted to a given process context without requiring further place-related information. In contrast, planning of DRP in advance is limited to the planning of core activities associated with the disaster event itself (e. g. firefighting in the case of a forest fire) and supporting activities which are considered to be of relevance in each disaster situation (e. g. the need to establish a central crisis management group). Actual places of process execution (e.g. affected disaster area and supporting points) and resources (e.g. stock locations, site of physical response resources, information sources, communication facilities, or current whereabouts of human resources) are unknown during the phase of preparation. Moreover, places might change unforeseeably along with the progress of DRP context over time. This means that fixing of places in advance is usually not possible and that many place-related aspects can only be considered during the run-time of DRP.

Since places might obviously determine the operability and the efficiency of DRP especially on the tactical level of DRM collection, modeling, and analysis of place-related information become crucial for determining its impact on running DRP and to interweave resulting information with the other levels and phases of disaster management (Hofmann et al., 2013). For instance, spatial characteristics might help identifying which response activities cannot be carried out as planned and, hence, require re-planning (e.g. if accessing roads are destroyed, a flying ambulance would have to be sent instead of ambulance vehicles). The place of the disaster occurrence could also require the enhancement of existing DRP by further support activities (e.g. logistic activities to bring supplies on-site), indirect disaster-related activities (e.g. further prevention measures if surrounding assets are in danger), or additional communication activities (e.g. asking on-site stuff for environmental context information when a sensor network is failing). There are many other examples where "place" might also affect resource allocation, duration and priorities of activities, or even the sequential arrangement of activities.

These examples show that place-related information is crucial for appropriate process planning and adaptation especially on the tactical level. Taking place-related information adequately into consideration is a pre-condition for effective DRP and, therefore, provision of corresponding elements a requirement for any language used for modeling DRP. Since such elements are new to current modeling languages in the field of BPM, we present a novel approach to integrate place-related information into modeling languages. At the current stage of our research, this is done on a conceptual level and independent of a concrete modeling language. Furthermore, our approach is primarily aimed at discussing the general feasibility of taking place-related information into consideration when planning and executing DRP supported by DRWfMS. Therefore, we assume activities and resources as either locally bound (stationary) or place-independent (mobile). This leads us to at least four cases of local dependencies that should be distinguished: (1) stationary resources which can only be used at their site, (2) mobile resources which can be used independent of site, (3) stationary activities which can only be executed at a certain place, and (4) mobile activities which can be executed at different places. Moreover, local dependencies of activities and resources must be complemented by information about concrete location, i.e. geographic coordinates in order to allow further analysis. Only with location information at hand, can resources and activities be compared and coordinated when planning or adapting DRP instances, e.g. for extending an on-going DRP by auxiliary transport activities to bring mobile resources to the stationary response activities on-site. Of course, this first approach might be oversimplified and still unrealistic in the face of real disaster events. However, the approach presented should not be seen as a general and overall solution but as starting point for further research that should distinguish between different types of activities (e.g. response or transportation), resources (e.g. shareable, consumptive, or non-tangible resources) and concepts of locations (e.g. relative positions, trajectories, or areas).

Language element	Symbol	Characteristics
stationary resource		Longitude Latitude
mobile resources		Longitude Latitude
stationary activity		Longitude Latitude
mobile activity		Longitude Latitude

Figure 2. Language elements for modeling place-related information in DRP

However, common BPM languages for business processes (e.g. eEPC, Petri Nets, BPMN, UML) do not yet have language elements to represent either local dependencies or locations for activities or resources. Thus, to foster the modeling of DRP in a formal manner and, as a next step, to enable analysis and consideration of places and resulting restrictions when adapting DRP, additional place-related elements are required. Therefore, we propose a new symbol representing local dependencies graphically and geographic coordinates formally (see figure 2) on a general level. This place symbol can be varied according to existing dependencies, e.g. by colour or inversion, and can be added to both activities and resources. In this contribution, we use the greyed out place symbol for depicting mobility, while the positive place symbol stands for stationary. The spatial characteristics, e.g. geographic coordinates described by longitude and latitude, are represented as formal characteristics of the place element and not graphically displayed. While the integration of such a symbol into existing BPM languages is still subject of our further research, in principle, the four identified cases can be represented by these elements (see figure 2).

TOWARDS A MODEL-DRIVEN ANALYSIS OF PLACE-DEPENDENCIES IN DRP

Enhancing DRP-models with place information provides new opportunities to identify existing and foreseeable conflicts between resources and activities. For instance, if the execution of an activity (extinguish fire) is fixed to the location of the fire and the required resources (e.g. the fire truck) is mobile, it has to be transported to the location and the success depends on the geographic distance. The situation becomes more interesting if the resource also is (or becomes) stationary, e.g. when the engine of the fire truck is damaged or the only available water resources are distant fire hydrants (stationary resource at another location than the stationary activity). To identify such dependencies as soon as possible is crucial for successful coordination and execution of DRP.

As first approach to identify such dependencies and the resulting restrictions to on-going DRP, a graphical display of the on-going process enhanced by place symbols for activities and resources is feasible. As depicted in a simple and exemplary DRP (see figure 3), it can easily be seen which activities might be endangered by conflicts of stationary activities and resources (e.g. extinguishing fire relies on a stationary resource) or which activities possibly require additional transportation activities (e.g. cordon area relies on mobile resources).

For a deeper analysis of such adaptation problems, the interdependency triangle of DRM (see section 2) can be used to describe the basic relations between activities and resources which are connected to "place" and, thus, have to be analyzed with a view to their local dependencies and their geographic coordinates. According to the existing dependencies, at least three cases have to be analyzed, namely activity-to-activity, activity-to-resource, and resource-to-resource. The combination of these three types of relations with the local characteristics of elements (stationary or mobile) leads to ten general situations that can be identified and analyzed by a model-based approach. The goal of this approach is to identify and classify situations that could result in a conflict due to local dependencies and, therefore, require further attention in the planning and coordination of the DRP. Therefore, we analyze the ten categories in table 1 and give first ideas about which additional activities could solve the possibly occurring conflicts. Assuming that resources and/or activities which are located at the same place are not resulting in conflicts (whether they are stationary or mobile), they are not taken into consideration in the following analysis. However, this assumption has to be critically reviewed in a consecutive and more detailed analysis.

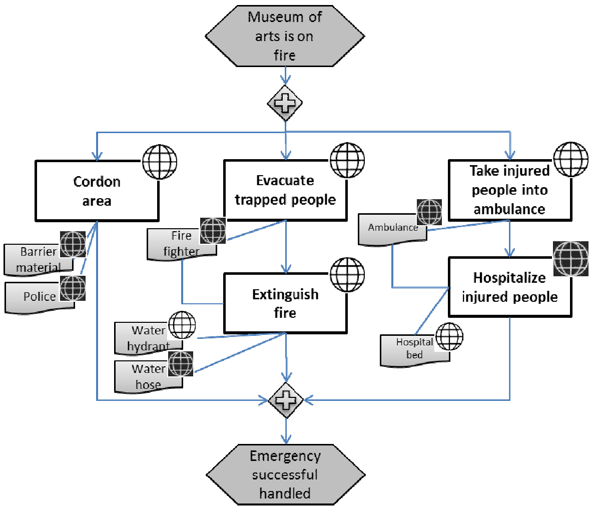

Figure 3. Simplified example DRP

This categorization shows that an identification of local dependencies is very important for planning and coordinating DRP effectively since the resulting types of conflicts and possible approaches for solving them differ significantly. On the other hand, the proposed solving approaches are not too manifold and worth being analyzed more deeply. For a model-based DRP supporting tool, like the proposed DRWfMS, further research in the area of, e.g., methodical approaches, algorithms and automation for searching alternatives, adding activities or resources, etc. seems to be very promising and should be integrated in the future.

Activity-to-resource	**Stationary resource** (Place: C)		**Mobile resource** (Place: D)	
Stationary activity (Place: A)	A!=C	• Search for alternative activities and/or resources • Search for additional connecting activity and/or resource	A!=D	• Search for alternative activities and/or resources • Transport mobile resource to stationary activity
Mobile activity (Place: B)	B!=C	• Search for alternative activities and/or resources • Transfer mobile activity to stationary resource	B!=D	• Search for optimal place • Transport resource and/or transfer activity to the optimal place
Resource-to-resource	**Stationary resource** (Place: C)		**Mobile resource** (Place: D)	
Stationary resource (Place: A)	A!=C	• Search for alternative resources • Search for additional connecting resources		Same case as field Mobile resource/Stationary resource
Mobile resource (Place: B)	B!=C	• Search for alternative resources • Transport mobile resource to stationary resource	B!=D	• Search for optimal place • Transport resource(s) to the optimal place
Activity-to-activity	**Stationary activity** (Place: C)		**Mobile activity** (Place: D)	
Stationary activity (Place: A)	A!=C	• Search for alternative activities • Search for additional connecting activities		Same case as field Mobile activity/Stationary activity
Mobile activity (Place: B)	B!=C	• Search for alternative activities • Transfer mobile activity to stationary activity	B!=D	• Search for optimal place • Transfer activities to the optimal place

Table 1. Categorization of opportunities for a model-driven analysis of DRP

CONCLUSION AND OUTLOOK

In this contribution, DRWfMS are discussed as a promising approach to improve DRM. However, to foster its application, current approaches should be enhanced with respect to the consideration of place-related information, which are of major importance when planning and coordinating DRP. Therefore, we proposed to extend BPM-languages by additional language elements to represent place-related information of response activities and resources. We demonstrated that these extensions can be used to classify situations that could result in conflicts due to local dependencies and, hence, require further attention in the coordination of the DRP.

This contribution comprises just initial ideas – further research is still needed: it is, e.g., required to extend the details of place-related information, e.g. by integrating geographic information systems in order to enable optimization on a process-oriented basis. Furthermore, the language elements are still on an abstract level and have to be implemented into existing process modeling languages. This includes adaptation to meta-models and a notation-conform graphical representation. Moreover, our research revealed that in DRM, the view on resources differs from the one in BPM: while BPM does not need an explicit modeling of locations, in DRM resources depict crucial input-factors for activities which are place-related and whose site or stock locations cannot be planned and fixed in advance. Thus, there might be need for further model extension with regard to different types of activities and/or process resources. Last but not least, further research is required regarding an automated execution and analysis of place-extended DRP-models: this demands new algorithms and methods to be found which are capable of processing this data for, e.g., an automated process design and adaption. It will be necessary to develop an enhanced DRWfMS architecture including such extended analysis functionality for interdependencies. Finally, the ability to integrate place-related information into the underlying models addressed in this contribution is the fundamental inevitable first step for all these research desiderata.

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