Structure and Elements of Disaster Response Processes – A General Meta-Model

Hans Betke
Martin Luther University Halle-Wittenberg
Chair of Information Management
Hans.betke@wiwi.uni-halle.de

ABSTRACT

Executing effective, efficient disaster response processes (DRPs) in the immediate aftermath of disaster is crucial to minimizing any potential damages to life and assets. Existing approaches from the business process management background seem to promise to support the management of DRP with process-aware IT systems and tools. However, domain-specific challenges of disaster response management (DRM) and especially the importance of place-related process features, require new concepts in process-aware IT systems. This report of ongoing research thus introduces and discusses a class-based meta-model consisting of fundamental DRP components and their interdependencies. The aim of this model is to make these domain-specific issues tangible for IT-supported processing and provide a sound data structure to facilitate the adaption and future development of process-aware IT systems for DRM.

Keywords

disaster response process, data model, class diagram, process management

INTRODUCTION

Natural and manmade disasters can be countered by immediately executing planned disaster response processes (DRPs), as often done by governmental and aid organizations, as well as affected companies. Since the effective and efficient performance of these DRPs is essential to preventing additional damage to life and assets, they are usually planned well in advance yet must be concretized for execution in the case of a disaster (Chen, Sharman, Rao, and Upadhyaya, 2008; National Research Council, 2006; Rao, Eisenberg, and Schmitt, 2007). Recently, the application of business process management (BPM) approaches to disaster response management (DRM) has shown promise for improving the planning and execution of DRP (Betke and Hofmann, 2014; Fahland and Woith, 2009; Rüppel and Wagenknecht, 2007; Sell and Braun, 2009). Current research activities have resulted in the development of a first round of special methods and tools involving the use of information technology (IT) to support the execution of DRP in various ways (e.g., automation, decision support, monitoring) (e.g., de Leoni, Mecella, and De Giacomo, 2007; Hofmann, 2014; Riedel and Chaves, 2012).

However, the direct application of BPM methods and tools is often hampered by domain-specific issues in DRP such as unplannable execution context, temporal urgency, unexpected events, uncertain resource situations, the involvement of multiple authorities, and imperfect information, among others (Chen et al., 2008; Franke and Charoy, 2010; Swenson, 2010). Although DRPs and business processes are similar regarding their basic elements, including activities, events, and resources, the handling of the abovementioned issues in planning and executing DRP requires the consideration of additional influencing factors. In this context, current research has shown that the factor of place especially influences interdependencies among a DRP's most important components (Catarci, de Leoni, Marella, Mecalla, Steinmann, and Bortenschläger, 2011; Sackmann, Hofmann, and Betke, 2013). While influential factors are often discussed in a textual way, no approach describes the most important DRP components and their respective interdependencies in a structured, formal way that is accessible for the development of better IT systems in the domain.

The research discussed in this paper has thus aimed to derive a class-based meta-model comprising the most important components and interdependencies of DRPs. This model is developed at a general level and may serve as an extendable basis for future design science research focusing on process-aware IT systems for DRM. The development of a suitable model requires a comprehensive literature review of available research addressing common process structure, as well as of research concerning special elements in DRP and their interdependencies. Since the analysis discussed here is still ongoing, Section 2 of this report shows the current state and first insights as the bases for further tasks. By extension, Section 3 addresses the design and explanation of the current state of the meta-model. In Section 4, the paper closes with a description of open research and the limitations of the approach, as well as a summary of the findings.

DRP ELEMENTS AND THEIR INTERDEPENDENCIES

Common Process Elements

One key argument for the application of BPM methods and tools in DRM is the similarity of their basic structure and of the elements (e.g., activities, resources, events) of the processes in both domains. This section thus first highlights existing research approaches for outlining and formalizing these basic process elements. A preliminary glance at the literature reveals that existing approaches originate mostly from two subareas: business process modeling and workflow management. Regarding the first, formal meta-models of the basic process elements and their interdependencies serve as a design basis for the development of modeling languages (e.g., Bastos and Ruiz, 2002) or as criteria for their comparison. An oft-quoted early standard literature in this regard is Curtis, Kellner, and Over (1992), in which all basic process elements are discussed. One remarkable approach is the meta-model presented in List and Korherr (2006), which provides a very comprehensive depiction involving not only abstract basic process elements but also subtypes (e.g., differentiation between tangible and nontangible resources). The elements in the model are clustered according to different views on processes (e.g., organizational view, behavioral view), which are also applicable to the disaster domain.

By contrast, formalization approaches from the workflow management perspective of BPM seek a data-related representation of process elements to allow their processing in the context of process-aware information systems. Most meta-models are designed to address a special issue of workflow management (e.g. Eder and Liebhart, 1995; Weske, 2001), meaning that the understanding and depiction of workflow structures vary. However, typical process elements appear in most of respective workflow meta-models as well, though often in alternative forms (e.g., task/activity, role/agent/resource). Notably, van der Aalst and Kumar (2001) have presented a reference model for workflow management systems (WfMSs) supporting the execution of tasks by more than one person. In this context, they also developed an organizational meta-model to describe the structure of a workflow with team-based task execution. Next to the process meta-model of List and Korherr (2006), van der Aalst and Kumar's (2001) has fewer elements yet with additional attributes of the existing elements; furthermore, the abstraction level of the model allows its application with different WfMSs. Team-based task execution may also be promising for disaster response in which helpers involved are typically organized in teams.

Besides the formalization of processes and workflows, the literature review also revealed an approach for structuring different types of resources and their interdependencies (Oberweis, 2010). Since DRM uses various resources, the approach will also be considered in this paper's development of a DRM meta-model.

Characteristics of DRPs

Despite similarity in their structure and basic elements, there are some domain-specific characteristics in which DRPs differ from BPM, as discussed in numerous studies concerning process management in DRM. Especially considerable given the focus of this paper is a WfMS approach focusing on the support of emergency plan management (Sell and Braun, 2009) that defines a workflow data model that comprises basic workflow elements such as activities and resources. However, since the approach focuses on the solution of four selected problems regarding paper-based DRP management via WfMS, the data model aligns with very general system requirements and barely addresses DRP characteristics discussed in DRM literature. The model proposed in the present paper therefore modifies and extends the existing one based on oft-discussed DRP characteristics extracted from current research that considers process management in DRM.

A comprehensive overview of the literature on this topic about the most important publications of the last decade can be found in Hofmann, Betke, and Sackmann (2015). For the purposes of the present paper, some frequently discussed DRP characteristics have been identified from papers in this literature overview as a suitable basis for designing the DRP meta-model. Due to space restrictions in this short paper, only one representative source is mentioned for each characteristic. The identified characteristics are:

(1) Importance of Spatial Interdependencies: Poor predictability in DRM is a major problem posing a great impact on the planning and execution of DRP. In this regard, especially the exact place of a disaster is unclear to begin with, though it tremendously affects the activities that can be carried out using available resources. Due to current spatial requirements and the interdependencies of activities and resources in DRP, considering spatial attributes is vital (Sackmann et al., 2013).

(2) Large Variety of Different Resources: Depending on the impact of a disaster, the respective DRP can be quite complex and involve several activities using diverse resources. Disaster managers usually have a pool of available resources in which some are highly specialized to the execution of single tasks, while others can be used in different situations. Nevertheless, one problem in large disasters is the lack of resources, which explains why resources must be planned for as efficiently and effectively as possible. In the uncertain setting of a disaster, resource planning is possible only if disaster managers can precisely differentiate each resource (Turoff, Chumer, Van de Walle, and Yao, 2004).

(3) Interorganizational Collaboration and Changing Resource Assignment: Response processes are usually carried out by more than one organization. Although these organizations may have different responsibilities, they need to collaborate in order to ensure an effective, efficient execution of activities. Moreover, some activities require the participation of different resources for their success. In this regard, interdependencies among resources must be considered and the construction and deconstruction of aggregated resources discussed (de Leoni, Marrella, and Russo, 2011).

(4) Multiple and Changing Objectives: Another problem in the planning and execution of DRP that comes with the unpredictability of disasters is the uncertain and possibly changing set of objectives the process targeted. Depending on the environment affected by the disaster and the respective risks to life and assets, DRPs to be performed may have highly different objectives, though the type of disaster is similar (e.g., a conflagration in an urban area or industrial park). Furthermore, objectives might change during the process and necessitate an adaption of the DRP (e.g., if a fire spreads unexpectedly). The objectives of a DRP thus determine which activities are applicable and which resources are to be used (Chen et al., 2008).

These four characteristics do not reflect all special features of DRPs but were chosen for their high impact on DRP planning and execution. A more detailed discussion of DRP characteristics will be presented in a full paper once the present research is completed.

DRP META-MODEL

The meta-model presented in Figure 1 follows the basic structure of the workflow-model in Sell and Braun (2009) since a direct comparison of existing models from BPM (List and Korherr, 2006; van der Aalst and Kumar, 2001) showed that this model covers all common elements (e.g. activities, resources, control flow operators). As such, the existing elements of this model are not described here. The following section explains how the model has been extended and modified to cover the four identified DRP characteristics.

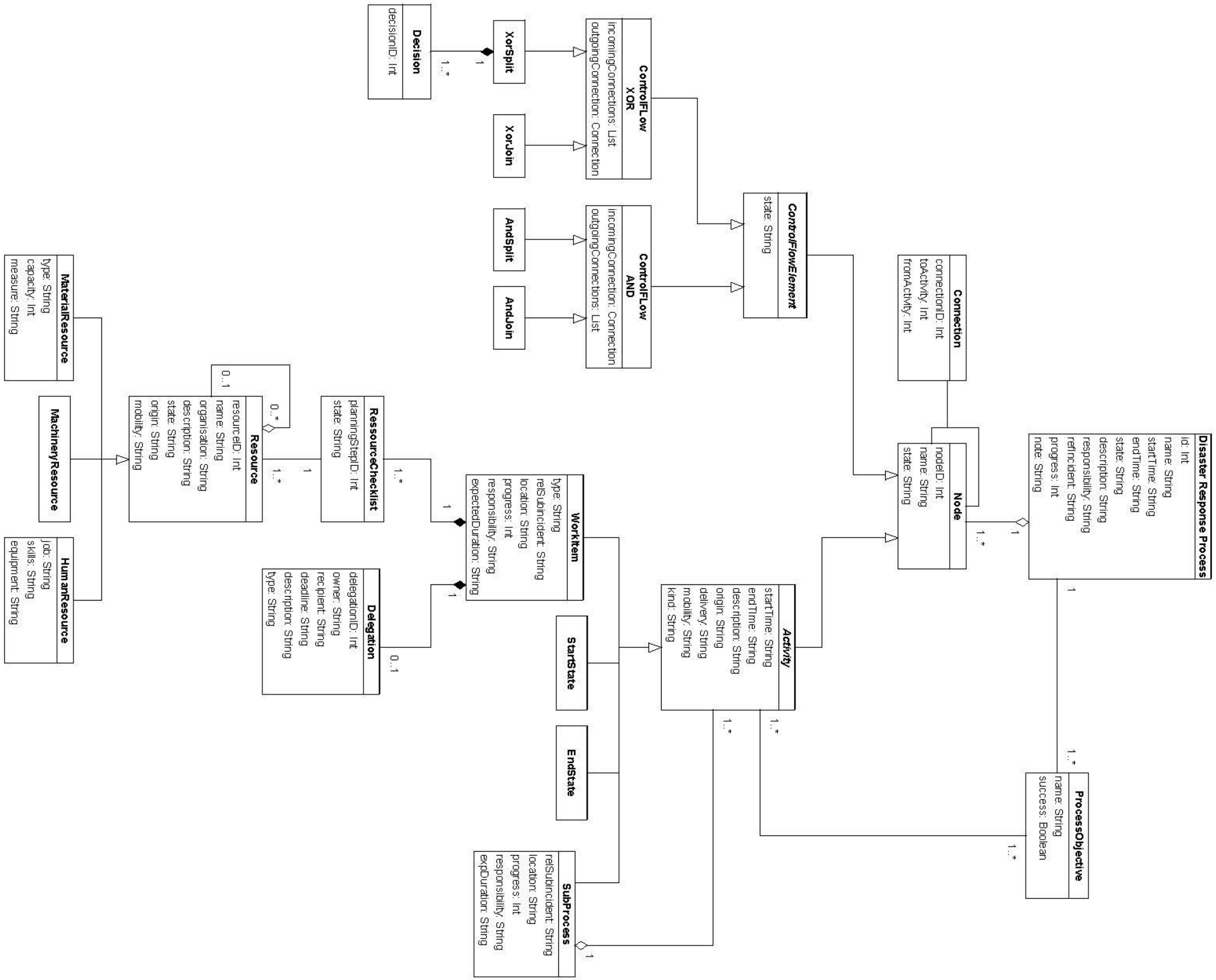

Figure 1.DRP-Meta-Model

(1) Importance of Spatial Interdependencies: Spatial features of the DRP have been integrated following Betke and Hofmann's (2014) approach, which involves adding new spatial attributes to activities (e.g., origin, delivery, mobility, kind) and resources (e.g., origin, mobility). The following is a short description of the new attributes in the Activity class:

origin: Place of origin of a transport activity or execution of a response activity

delivery: Delivery site of a transport activity; empty for response activities

mobility: ***stationary*** for activities that must be executed at a special place;
mobile for activities that can be executed at various places
kind: ***transport*** for transport activities;
response for normal response activities

These new attributes allow the acquisition and analysis of different spatial data regarding the process.

(2) Large Variety of Different Resources: The resource model presented in Oberweis (2010) has been used to extend the model by adding resource subclasses. The "type" attribute has been removed from the resource class, since categorization is now performed by classifying human, machine, and material resources in their own classes with their own attributes. These changes are just one example since the implementation of a whole complex resource model would not fit in this short paper. Nevertheless, the further specification and extension of the model (e.g., by having skill classes for HumanResources) would be possible with further inheritance to new classes.

(3) Interorganizational Collaboration and Changing Resource Assignment: This characteristic has been integrated by adding an aggregation of resources, which allows the combination of any number of resources for building a new combined one. At the same time, a concrete resource can also be part of an aggregated one.

(4) Multiple and Changing Objectives: The class ProcessObjective has been added to the meta-model and associated with the process as well as its activities. This modification allows the assignment of all objects of a process as well as a declaration of which activity facilitates the objective. It is possible to assign more than one objective to processes and activities, since processes are often not pointed toward a single objective. The status of process objectives can be stored in its own attribute (e.g., success). Further associations with the new class are possible (e.g., with the WorkItem) yet depend on the application in the respective IT system.

CONCLUSION

The goal of this paper was to show the current state of the elaboration of a general meta-model to capture the most important elements of a DRP and their respective interdependencies, in order to provide a sound data structure for the development of process-aware IT systems in DRM. A preliminary look at the literature revealed the existence of general abstract process meta-models (List and Korherr, 2006), as well as more technical models from workflow management in the domain of BPM (van der Aalst and Kumar, 2001). However, in the domain of DRM, the process and its elements have been formalized in a single workflow data meta-model (Sell and Braun, 2009). Further investigation of literature addressing DRM process management revealed the existence of several special characteristics of DRPs that must be considered for comprehensive process management. The paper shows the extension of the workflow meta-model of Sell and Braun (2009) by adding elements to cover four domain-specific process characteristics in a new data meta-model for DRPs.

The resulting model demonstrates that the characteristics of DRPs can be mapped in a computer-processible form and gives an initial idea of what data is necessary to improve the IT-supported management of DRPs. Though the considered characteristics represent only part of the features of a DRP, they show that usual business process meta-models are incapable of addressing the special needs of DRM without first being adapted.

Since the research discussed here is ongoing, a more intense reflection of the literature will follow to reveal further DRP characteristics and facilitate the improvement of the meta-model. A further step would be to apply the meta-model to a concrete IT system such as a disaster response WfMS to evaluate its usefulness and applicability in practice. In this sense, the model already shows potential capabilities of future process-aware IT systems in DRM.

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