Putting plans on track in unforeseen situations

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ABSTRACT

The dynamically evolving environment of the post-disaster scene—where unpredictable scenarios and uncertain data are commonplace—can bring about considerable complexity into response tasks. The multiplicity and interdependence of approaches to undertaking these tasks may yield many decision alternatives, further complicating the response effort. Additionally, because emergencies are evolving, expectations regarding the post-disaster scene may not match those that are actually encountered. Plans compiled before the disaster may therefore be judged as inadequate, requiring personnel to adjust or even redefine them during the response activities. This paper outlines and illustrates one approach—drawing upon the paradigm of improvisation—for providing management-level response personnel with information and tools to support on-the-fly adaptation of emergency response plans. A case study illustrates the approach application.

Keywords

Emergency response, Plan revision, Disruption diagnosis, On-the-fly adaptation.

INTRODUCTION

Teams may find difficulty in identifying well-specified procedures that can address all contingencies that arise in complex environments (De Man, 2009; Lakshmanan et al., 2012; Rychkova and Nurcan, 2011). Characteristics such as subjective definitions, dynamic execution, unexpected restrictions, unpredictable decisions and incremental response, impose new issues to be considered, making planning and treatment non-trivial tasks.

The dynamic and unpredictable nature of emergencies reduces opportunities for predicting many of the details that arise as the emergency event unfolds. In such contexts, planners normally select a subset of possible scenarios to detail and describe generic procedures. Thus, during the plan enactment, teams usually need to transform these general procedures into operational and executable actions. The lack of prior knowledge may lead to the discovery of unanticipated scenarios that need to be handled. Moreover, even for known scenarios, not all possible outcomes can be identified and unexpected external events may occur. These unforeseen situations may render the plan inapplicability, creating a need to find alternative treatments, to offer further detail on existing procedures and to make decisions at runtime (Beroggi and Wallace, 1994; Böhringer, 2010; Lakshmanan et al., 2012; Mendonça and Wallace, 2007).

This research aims to provide managers with mechanisms to generate adequate plans at runtime following the onset of an unforeseen situation. The method

proposed here involves identifying unforeseen situations, interpreting their impact on response and adapting plans at runtime to address the problems identified. The proposed approach is applied to emergency response plans and critiqued to guide further work, including research outside the emergency response domain.

The paper proceeds as follows. The next section reviews prior work on identifying potential disruptions and performing adjustments in emergency situations. The third section describes the approach for on-the-fly adaptation of plans. The fourth section evaluates the approach via implementation for a hypothesized disaster scenario involving a rainstorm. The last section concludes the paper.

UNFORESEEN SITUATIONS DURING RESPONSE

While devising an emergency plan, planners aim to name the applicable hazards and design procedures that, if followed, should make the emergency evolve to an expected state, returning the affected environment to a stable condition with minimum losses (Haddow et al., 2011; Penadés et al., 2011). Thus, during response, the developed plan will guide emergency teams to make decisions and perform actions (Haddow et al., 2011; Khan et al., 2008).

However, the use of this plan is not always straightforward. It is difficult for planners to predict all possible scenarios, especially those resulting from the unexpected evolution of the emergency and from ineffective actions. Planners also have to decide what will and will not be included and the level of detail used throughout the plan. Moreover, actions may not deliver the expected outcomes, changing the state expected by subsequent actions. Finally, there is also the possible occurrence of unexpected external events that might change the devised scenarios.

When procedures for handling these situations are not predicted in the plan, teams need to assess the negative and/or positive impact that these situations have on response and decide if the plan requires some change. If so, teams should observe response operation conditions, identify goals, try to understand the effects of actions performed, find alternative treatments, detail the existing plan and make decisions at runtime to handle the ongoing emergency (Böhringer, 2010; Lakshmanan et al., 2012; Ley et al., 2013; Mendonça and Wallace, 2007).

When dealing with less complex environments, where it is possible to handle processes with well-structured flows, repeatable or with little possibility of change, proposals perform modifications when deviations are identified during instances execution to be suited to the context faced (Bucchiarone et al., 2011; Hermosillo et al., 2010; Nunes et al., 2011; Santos et al., 2011). Plan abstraction (Silva & Lemos, 2011) and decomposition (Wang et al., 2008) have both been proposed as methods for diagnosing plan applicability and undertaking plan adaptation. For ad-hoc environments, where is necessary to handle not well-structured processes, Dorn et al. (2010) propose recommendations of the next action according to the analysis of what is happening during the ad-hoc processes execution. Rychkova & Nurcan (2011) adapt knowledge intensive processes by describing what is necessary to the process execution; what must be done to run the process in a particular environment and what is available to do this; and configuring the process during runtime.

Nevertheless, handling unforeseen situations during an emergency response is not a trivial task. Identifying unforeseen situations occurrence is not always obvious. In addition, diagnosing the impacts they have in the response procedures and demanding a possible adaptation can prove a difficult task. Moreover, plan adaptation during runtime itself must be systematized to handle unforeseen situations properly and make the plan suitable to what is happening.

Prior work suggests various approaches to address this challenge, including those related to case-based reasoning (e.g., Chakaborty et al., 2010) and adaptive search (Coates et al., 2011). More interactive approaches include tools for assisting managers to handle newly incoming information and to decide if they are sufficiently important to warrant the scenario updating (Comes et al., 2012). Similarly, incoming information may be used to offer options for action and to assess which one may achieve the most effective result (Comfort et al., 2013) or to identify mismatches and, if necessary, a range of adaptation solutions (Barthe-Delanoë et al., 2014).

These studies use past and/or arising explicit knowledge to modify unworkable plans. However, facing unforeseen situations requires handling both explicit and tacit knowledge, so managers have elements to perform adaptations. The use of explicit knowledge provides inspiration for defining actions to handle situations

that were not previously foreseen. However, some unforeseen situations may not have relations with any past explicit knowledge, becoming necessary to provide mechanisms for identifying, handling and using tacit knowledge.

The problem addressed in this research is the challenge to diagnose and perform adjustments in a prior developed plan during its execution, thereby suggesting the need to provide mechanisms to identify unforeseen situations in plan. The perspective taken here follows from the observation that change plans at runtime entails two related activities: adjusting plans to reflect minor changes in the operating environment and developing plans to deal with more profound changes in the operating environment.

APPROACH FOR ON-THE-FLY ADAPTATION OF PLANS

This section presents the approach for on-the-fly adaptation of plans. By monitoring the selected plan application and the emergency evolution, it is possible to identify unforeseen situations. They are interpreted to assess if the plan is still applicable. If the interpretation shows a disruption in plan, it is necessary to adapt. Adaptation allows devising and selecting an alternative treatment for the disruption faced, which response teams should apply. Figure 1 shows the proposed approach steps and associated inputs/outcomes.

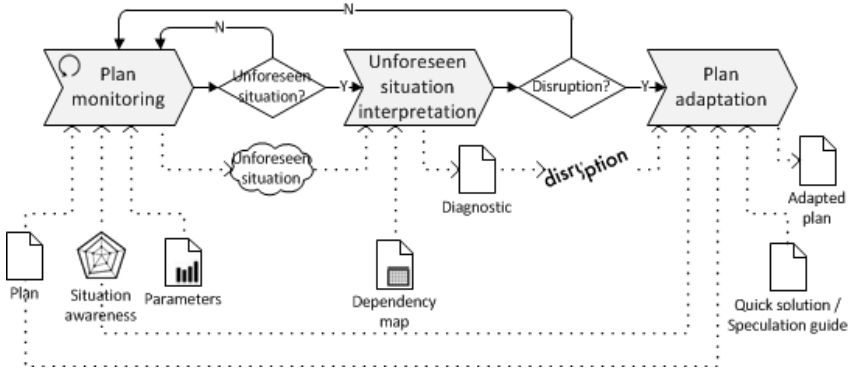

Figure 1. Approach for on-the-fly adaptation of plans

Plan monitoring

This step comprises automatic plan monitoring in light of the evolving nature of the emergency. The combination of plan, emergency evolution and pre-defined parameters determines a compliance degree between the planned treatment and the reality faced, showing if the plan is still applicable.

In this approach, plans are described through: **action**, tasks performed to achieve a goal, taking the emergency from one state to another; **state**, a set of variables that characterizes the emergency at a given moment; **resource**, the necessary elements (people, information, systems, equipment, restrictions) to perform actions; **event**, phenomenon that may occur during emergency evolution, impacting the state variables; and **goal**, what should be achieved. Figure 2 shows a BPMN adaptation to describe the plan (OMG, 2015).

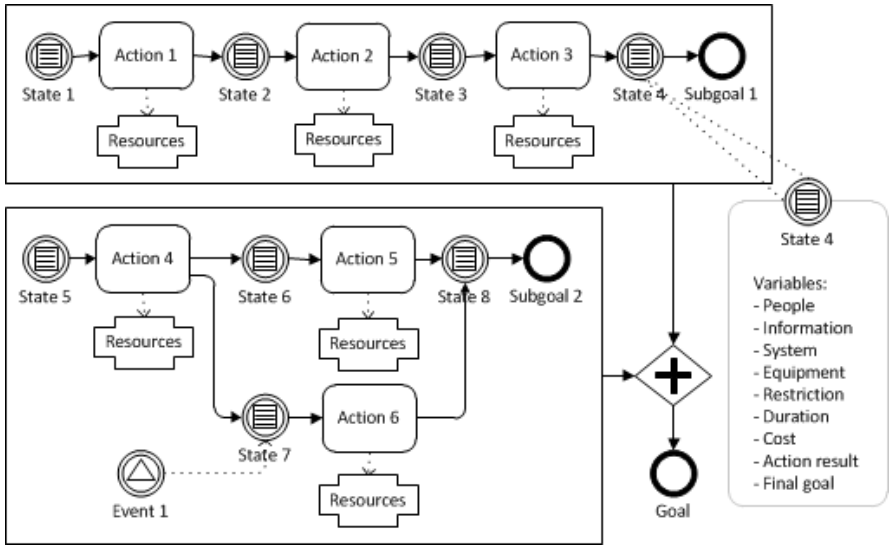

Figure 2. Plan structure

The emergency evolution is characterized by capturing the following information over the course of the event: performed/remaining actions; people involved (skills, quantity, availability, allocation); information (which one, update, reliability, completeness, availability); systems (which one, availability); equipment (which one, quantity, availability, allocation); restrictions; duration; cost; last action result (full/partial/not attended); and final goal (reached/not).

The plan parameterizing involves (a) establishing the critical state variables (those more likely to cause negative impact if not properly handled and/or that must be considered as a priority during handling) and (b) defining ranges of values within which the conditions to handle each state variable remain valid.

Unforeseen situation interpretation

After identifying an unforeseen situation, managers must assess if adaptation procedures need to be triggered. They retrieve the state variables presenting variation and use a template to determine the impact and type of the unforeseen situation. Table 1 shows part of the template used.

Table 1. Unforeseen situations affecting some state variables

State variable		Unforeseen situation	State variable		Unforeseen situation
People involved	-	Few people	Equipment	-	Absence
	-	No required skill		-	Used by another action
	-	Used by another action		-	Broken
	-	Not found		-	Not found
	-	Unknown		-	Lack of requirements
	+	More people		+	Abundance
	+	Early deallocation		+	Early deallocation
Time	-	Expired	Action result	-	Lower than expected
	+	Available		+	Higher than expected

Next, a comprehensive analysis considers the impact that the affected state variable has on other state variables (Table 2). For example, if there is insufficient equipment, the dependency map shows that it has a negative impact on people involved, time and action result. If the current values of these variables cannot handle the variation caused by the unforeseen situation, the plan has a disruption and requires adaptation.

Table 2. Dependency map

		People involved	Equipment	Time	Action result
People involved	+			+	
	-		-	-	-
Equipment	+			+	
	-	-		-	-
Time	+	+			
	-	-			
Action result	+	+	+	+	
	-	-	-	-	

Plan adaptation

If plan adjustments are required, managers should determine the proper adaptation type. An operational plan can be provided by repositioning existing plan elements, inserting new elements in plan or even creating a new plan. Establishing the required adaptation type will determine the most suitable adaptation strategy adopted.

The approach to plan adaptation includes two strategies. First, *solution suggestion* involves providing pre-defined solutions for the unforeseen situation to bring the state variables back to their normal range (Table 3). Managers assess the available solutions and select the most suitable one to apply in the ongoing emergency.

Table 3. Pre-defined solutions for unforeseen situations

Variable	Unforeseen situations		Pre-defined solution
People involved	-	No required skill	Combine complementary skills
			Reallocate people
			Recruit people
	+	Early deallocation	Reallocate in problematic action
			Anticipate future actions
Equipment	-	Broken	Fix equipment
			Use similar equipment
	+	Early deallocation	Reallocate in problematic action
			Anticipate future actions
Time	-	Expired	Skip actions
	+	Available	Anticipate future actions
Action result	-	Lower than expected	Compensate in future actions
	+	Higher than expected	Compensate in future action
			Skip future actions (if 100%)

Second, *improvisation* involves recombining the available resources, with little or no preparation, to create a solution for the disruption (Ley et al., 2013; Mendonça and Wallace, 2007; Tan and Hallo, 2008; Weick, 1998). Both disruption identified and knowledge available for adaptation (available resources, situation awareness, plans used in similar emergencies etc.) should be visible. Managers use the speculation guide to systematize solutions generation, and assess and select the most suitable solution to apply in the ongoing emergency. This artifact is under development and will be detailed in future papers.

CASE STUDY OF PLAN ADAPTATION FOR HEAVY RAIN EVENTS

The proposed approach is evaluated through a case study involving a heavy rainstorm. The case study region—a metropolitan area exposed to heavy rains—includes recent construction in areas at elevated risk to landslides, such as hills and slopes. Damage is particularly acute during the summer months, when heavy and/or prolonged rains hit the area, producing floods and landslides. The responsible emergency agency has established a procedure for evacuation in case of heavy rainstorms, which serves as the basis for the following case study. This procedure is described in a textual form (Defesa Civil, 2013). Thus, to apply the proposed approach, the first step is to reformat the procedure to the proposed elements (Figure 3).

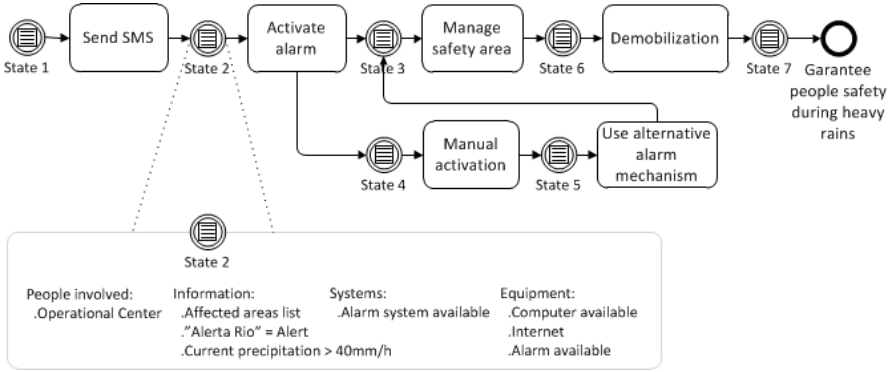

Figure 3. Mobilization during rains

With this, it is possible to **monitor the plan application**. During a heavy rain, the main goal is to *guarantee the safety of people living in risk areas*. To achieve this, the operation center *sends SMSs* to mobilize the community leaders and *activates the alarm* using a specific website. When managers try to execute this second action, the website shows that the required resource "affected community's alarm" is not working. In this case, the plan orients a *manual activation* of the alarm. When field teams arrive to the alarm's location, they notice that there was a landslide in the region, which has destroyed the alarm. As manual activation of the alarm cannot be performed, an unforeseen situation is identified.

Thus, managers **interpret the unforeseen situation**. They conclude that the unforeseen situation concerns to the state variable "*alarm*" from which a broken equipment is characterized. The comprehensive analysis shows the need for a plan adaptation since the related variables cannot handle the variation caused by the unforeseen situation in variable "*alarm*".

During **plan adaptation**, some pre-defined suggestions, as to restore alarm operational conditions and to use alternative mechanisms (e.g. whistle or yell), are proposed. Managers decide that the second suggestion is the most suitable to be followed: it is already described in the plan, requiring only skipping the manual activation of the alarm, and there is no conditions to rebuild the existing alarm. With this, a planned state is reached ("*State 3*") and the teams can follow the plan again.

Upon hearing the alternative alarms, population should go to the community's safety area and wait for a demobilization alarm. Field teams *manage the safety area*, receiving and assisting population. Analyzing the number of people arriving, field teams prospect that the safety area will exceed its resources capacity if the rain lasts over one hour. Once again, managers identify an unforeseen situation in the plan.

During the **unforeseen situation interpretation**, managers conclude that the unforeseen situation concerns to the states variables "*expected people*" and "*available provisions*" from which an abundance of people and a lack of required amount are characterized, respectively. The comprehensive analysis shows that a plan adaptation is also required.

However, this time, there is no pre-defined solutions to provide during **plan adaptation**, being necessary to improvise. Considering the rain evolution, available resources and previous experience of field personnel, the proposed solution is to rearrange the available furniture and food provisions to support the unexpected number of people.

After two hours without heavy rain, the operation center *activates the demobilization alarm*. It ensures that there is no more danger for people return home.

Case study shows that making runtime changes in emergency management domain has a broader goal than just adjusting plans to reflect minor changes in the operating environment. Changes are necessary to continue the plan's execution as many of the emergency details only arise as the emergency unfolds.

Besides that, executing or adapting plans requires managing both explicit and tacit knowledge. They guide teams to handle the ongoing emergency and make decisions during response operation, and are the basis for diagnosing and performing plan adaptation when it is required.

CONCLUSION

Complex environments characteristics impose new difficulties to identify a well-structured and suitable plan to handle them. More than that, even when a plan can be developed, it is possible to face unforeseen situations during its execution. In these environments, it is usual that the initial plan becomes inadequate, being necessary to identify alternative treatments and make decisions at runtime.

The approach for on-the-fly adaptation of plans supports managers to identify unforeseen situations, to interpret these situations' impact on response and to adapt plans while handling an ongoing emergency. The case study shows that the proposed approach has potential to support decision-making and to deal with unforeseen situations in emergency management domain. It enables the diagnostic and treatment of disruptions, making the plan suitable to handle the current reality.

However, some challenges still need to be overcome for the successful approach application. The first challenge concerns to reformat plans to the proposed elements. Some elements cannot be filled only by the information available in plan. The second challenge is that emergency plans are detailed in a high level of abstraction, providing a general information about the application environment and available resources and describing a set of goals without detailing the actions to achieve them. This can interfere the unforeseen situation identification and the need to apply the proposed approach. The third challenge concerns the impact of person's experience during interpretation. A same unforeseen situation can be considered a demand for adaptation or something that requires no further action. Bias can induce adaptation when it is unnecessary or not to adapt when there is a need. The last challenge is related to the speculation guide. A guide that reduces the need to transform speculated solutions into the proposed plan elements is still required.

As future work, it is necessary to finish the support tool for approach application.

This tool helps managers to monitor plan application, by presenting the plan and capturing updated information about the ongoing emergency. In addition, it allows the unforeseen situations identification and diagnostic, besides applying the strategies to perform plan adjustments during runtime. The proposed approach will also be applied in other scenarios. The results from these experiments can help the approach improvement and evolution.

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