Modeling Highly Collaborative Processes

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Abstract—**Difficulties creating process descriptions can occur because the processes extend beyond coordination, including for instance conversations, meetings, and discussions. These tasks are difficult to describe using conventional business process modeling languages, which tend to emphasize coordination. There is a need then to provide facilities for the description of highly collaborative activities. This paper proposes an extension to the Business Process Model and Notation (BPMN) modeling language. It includes notation to handle some of the commonly occurring tasks in highly collaborative processes. A case study concerning emergency response is presented showing how the proposed notation can be used, and how the extension provides additional expressiveness to BPMN.**

Keywords— Processes description; BPMN; workflow languages; collaboration; modelling.

I. INTRODUCTION

A process consists of a number of tasks that need to be carried out and a set of conditions that determine the order of the tasks [12]. Processes are routinely described nowadays in many organizations. These descriptions serve as input to Business Process Management (BPM) systems. They may also be used for training new employees on their future duties. Alternatively, process descriptions may be used for establishing procedures and standards in highly regulated activities, such as air traffic control.

Processes are typically described by analysts, who use languages that are mostly visual. Typical languages are Business Process Model and Notation (BPMN) [9] and Business Process Execution Language (BPEL) [10]. A general modeling language like the Unified Modeling Language (UML) [2] can also be used.

However, some highly collaborative processes are difficult to describe using these languages. For example, suppose two tasks are strongly interconnected in a fuzzy way and yet, it is desirable to describe them as logically distinct tasks. None of the previous languages have primitives to specify this paradoxical situation. Of course, the modeler could complement the description with text explaining the situation, but this is not desirable. The extreme argument for this is: why do we need a formal description language at all if we can describe processes with text? Moreover, in many cases the most complex processes are precisely the ones that need to be formally described, e.g. for knowledge externalization. A much better solution then is to have a notation to describe the situation.

Another problem occurs when people's informal procedures are going to be described. This is the case of many collaborative activities within or among organizations: discussions, conversations, meetings, etc. Typical process description languages become then inappropriate [11]. The difficulties are the excess of "coordination overhead" [1], the appearance of cobweb and labyrinth problems [7], and insufficiency of the diagrams [5].

One approach to incorporate new notation to describe complex processes is to create a new language. This is technically feasible but it is not practical: analysts will not easily drop current languages to learn a new one and become proficient in its use. Thus, the best choice is to improve current languages by proposing extensions to them.

This paper deals with such an extension. Chapter 2 reviews some related work whereas Chapter 3 presents an extension to the BPMN language. Chapter 4 discusses examples where the extension is applicable. Finally, Chapter 5 presents the conclusions and future work.

II. RELATED WORK

An interesting study by Goorman and Berg [4] criticizes the simplified mechanistic descriptions of work in the health care environments. The descriptions present idealized work routines instead of the real ones, thus losing insight.

Hourizi et al. [6] studied a highly collaborative process and tried to describe it in UML: what happened in an aircraft cockpit before an accident. Their conclusion was that the language was insufficient to model many goal structures and communication problems.

De Troyer and Casteleyn [3] worked on the description of tasks for a complex case. They chose to study an e-commerce Amazon process as an example. Their WSDM diagrams include notations for elements such as transactions, deactivation, enabling, suspend/resume, iteration.

Stuit and Wortmann [11] developed a specialized language for describing human interactions; their goal was to specify where the interactions took place, between whom and the

connection of one interaction with others. A multi-agent environment is assumed; the local view of each agent is described and the interactions serve to coordinate the agents' work.

III. EXTENSION TO BPMN

We studied several highly collaborative processes in order to explore the difficulties in modeling them, e.g. air traffic control, surgical work, and emergency management, through a revision of related literature and interviews with involved actors, e.g. a firefighter and a surgeon. We provide as an example, an extract of the process involving an Alarms central operator, to serve as motivation of the type of knowledge about a process that cannot be easily modeled in modeling languages such as BPMN and UML.

An operator at the Alarms Central is in charge of receiving information about an emergency and assigning resources to it. When the emergency has been confirmed and she has some context information about it (e.g. location, magnitude), she starts assigning resources (fire trucks, firemen), adjusting this assignment as more information becomes available (e.g. dispatching a hazardous materials truck if she learns a chemical factory is near to the emergency site) and notifying the involved resources. The operator must notify the involved personnel to dispatch them to the emergency.

When modeling this extract of a longer, complex process in BPMN, we can identify four types of problems, illustrated in Figure 1. First, the process of assigning resources, adjusting this assignment and notifying them is fuzzy: although they have some logical sequence, it is not clear how to distinguish each activity - while at the same time, they are three distinct activities. BPMN only allows separating the activities sequentially or including both as a sub activity, so we would have to choose separating the activities as in Fig. 1a. Second, we want to express that any subsequent activity may cause an adjustment in the assignment, which requires incorporating many connections in BPMN (Fig. 1b). Third, information about resources assignment may change at any time (e.g. a bigger emergency requires some trucks that have already been assigned, or the news reports schoolchildren are trapped in a nearby building), so the involved "artifact" also may continuously change (Fig. 1c). Finally, when not supported by automated software, the resource assignment task is complex and may need adjustment, which may only be expressed through a gateway, not as a characteristic of the activity (Fig. 1d).

From this scenario, it is possible to see that further information or an easier way to express it is needed in four dimensions: flexibility, fuzziness, context richness and collaboration. Therefore, we propose a set of elements that can be used to complement BPMN and other modeling languages by providing additional information for aspects that are not supported, as described in Section 1. We especially seek to provide BPMN with a tolerance to variations inherent in highly collaborative processes that need to continue in spite of e.g.

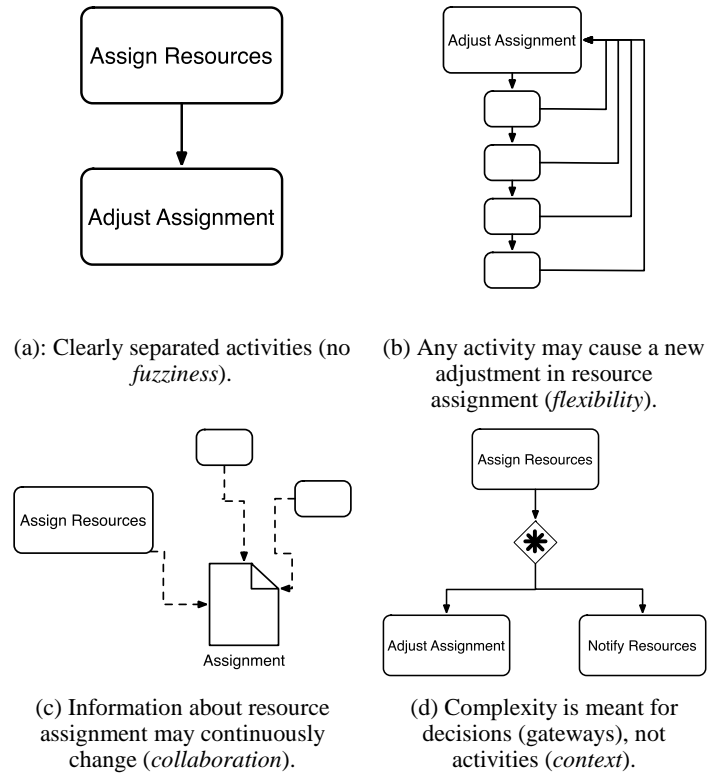lacking a complete definition or being in unexpected exception states.

(a): Clearly separated activities (no *fuzziness*).

(b) Any activity may cause a new adjustment in resource assignment (*flexibility*).

(c) Information about resource assignment may continuously change (*collaboration*).

(d) Complexity is meant for decisions (gateways), not activities (*context*).

Figure 1: Problems modeling using BPMN

The aspects that are not supported by BPMN are the following ones:

Flexibility: In highly collaborative processes, it is necessary to incorporate the possibility of variations from the predetermined execution of a process, i.e. it is important to provide ways to manage exceptions. Exception handling allows ***activity jumps*** in which control is exerted by the actors and not by a prescribed flow model, dynamic changes in the responsible actor if another actor is perceived as more adequate to handle a situation (***responsibility shifts***), and due to the fact that tacit knowledge is involved in these types of processes, which makes it difficult to model them, the possibility of leaving elements as ***incomplete***.

Fuzziness: Often modellers specify activities based on their logical organization, but in practice such activities may be significantly blurred, especially when considering rules of precedence and temporality (***fuzzy connections***). On the other hand, sometimes modellers represent the logical sequence of activities that, in practice and to actors, are not related (***unfuzzy connections***).

Collaboration: In processes that are highly collaborative, it is important to identify that information and actions are

shared and adjusted constantly due to others' actions. Therefore, it is important to highlight that activities and decisions often depend on the collaboration (or mutual adjustment) of multiple actors (*sharing*) and that artifacts constitute a important asset for collaboration between multiple actors (*shared artifacts*). Since artifacts are shared among seveal actors, implicitly (within activities) or explicitly (in gateways) the flow of activities may depend on information that is constantly changing and being updated (*ephemeral information*).

Context*:* The context of collaboration may have more complexity than a description of processes allows us to see, so we provide additional symbols to describe and highlight the richness of the context. For example, decision-making may be so *complex* that modelers may need to express their inability or lack of interest to provide complete details for these situations. Furthermore, complex processes often depend on multiple contextual conditions that cannot be modeled or would require too much time to model (*optional*). Also, activities may be *continuous*, i.e., significantly different from the more prevalent repeating activities, as they refer to cognitive activities such as vigilance and attention. Finally, most process models avoid describing their dependence on contextual information, so we need to mark points in which such dependence is particularly important (*critical contextual information*).

Table I provides the list of proposed elements that arose from the previous discussion, with their visual notation and their definition. The proposed elements intend to add variability and richness to BPMN. However, trying to provide a balance between expressiveness and symbol overload, it should be possible to apply the elements to as many BPMN elements as possible. Table II provides information as to where the symbols are expected to be applied. For example, *activity jumps* due to their nature may naturally only be applied to activities, while *optional* may pertain to an activity (which may not be carried out), a connection (which may not be present), a role (which may not be involved), and an artifact (which may not exist).

TABLE I. VISUAL ELEMENTS PROPOSED IN THE NEW NOTATION

| Visual element	Definition
	Activity jump - The assigned actor can move control to the associated activity at any time and irrespective of the activity that was previously being executed.
	Continuous activity - The associated activity is continuously executed by the assigned actor.
	Fuzzy connection - The associated activities cannot be completely distinguished. The type of connection between the associated activities (sequence flow, message flow and association) is logically defined but is related with the same activity context, which means that it may not be precisely determined in practice.
	Responsibility shift - The associated actor may be changed to an actor with higher authority.
	Incomplete - It is not possible to completely determine the activity, actor or link.
	Ephemeral information - The information processed by the associated activity is ephemeral and may be modified or deleted at any time.
	Unfuzzy connection - The associated activities are completely devoid of fuzziness. The type of connection between the associated activities (sequence flow, message flow and association) is logically defined and, in practice, corresponds to distinct activity contexts.
	Complex - The associated element has additional complexity.
	Critical contextual information - The element has associated contextual information that is critical to the process.
	Sharing - The activity, gateway or artifact is based on feedback by other actors.
	Shared artifact - An involved artifact is shared by several actors.
	Optional - The associated element is optional, i.e., it could be present or absent without compromising the success of the process.

Element	Activity	Connection	Role	Artifact
(icon)	✔	✘	✘	✘
(icon)	✔	✘	✘	✘
(icon)	✘	✔	✘	✘
(icon)	✘	✘	✔	✘
(icon)	✔	✔	✔	✔
(icon)	✔	✔	✘	✘
(icon)	✘	✔	✘	✘
(icon)	✔	✔	✔	✔
(icon)	✔	✔	✘	✔
(icon)	✔	✘	✘	✔
(icon)	✔	✔	✘	✔
(icon)	✔	✔	✔	✔

IV. CASE STUDY

In regular urban emergencies (e.g. house fires and car accidents), several types of actors interact to mitigate the situation. However firefighters are involved in most of them because they are trained to be the first responders.

This is a complex and highly collaborative process where the operators of the Alarms Center (supporting the response activities) and also the officer in charge of the emergency response (a firefighter also known as the Incident Commander), play a key role [8]. These actors must perform several activities that are interconnected with those being conducted by other roles. The accuracy and timing to perform these activities directly affects the results of the response process in terms of number of victims, damages, and also resources that are required to address an emergency. Having these processes documented and training the actors in these procedures is crucial to conduct fast and effective responses.

In order to exemplify the use of the proposed extension for BPMN, Fig. 1 shows the activities performed by the Incident Commander (IC) and the Alarms Center Operator (ACO) during the emergency response process. The proposed nomenclature helps specifying several aspects of the process that cannot be represented using the regular BPMN nomenclature.

As reported to us by several firefighters, the process typically starts when a new call is received by the ACO, specified as Activity 1 in Fig.2 (such activity will be referred as ACO-1).

Immediately after receiving the emergency call, the ACO asks several questions to the caller to determine the veracity of the emergency situation and also to gather context information (ACO-2). Using such information the ACO has to decide if the emergency is real or if she needs more information to decide (ACO-3). This decision is complex and may require the support of more experienced operators. A wrong decision at this point can have severe consequences; particularly if the emergency is real, but the operator is not able to determine its veracity. If the operator decides that the emergency is real, then she performs a quick characterization of the emergency (ACO-6). Otherwise, she remains aware and waiting for a new call (ACO-5). At any time a new call may arrive and lead the operator to reconsider previous decisions about the veracity of an emergency (ACO-4).

Once the emergency is characterized, the operator assigns the resources that will respond to the emergency (ACO-7). Provided this is a complex activity that has an important impact in the response process, she performs some adjustments with the support of more experienced operators and also using external information (ACO-8). Finally the operator notifies to the assigned resources (ACO-9). These three activities are fuzzy connected and should be done quickly.

Immediately after the operator notifies to the resources, the potential ICs are identified (IC-1) and dispatched towards the emergency site (IC-2). During the movement of resources, the potential ICs ask the ACO (IC-3) for specific information about the emergency.

The first firefighter officer that arrives to the emergency site becomes automatically in the current IC for such an emergency (IC-4). Then, every officer with a range higher than the current IC that arrives to the emergency place can request to be the IC for that emergency. For that reason the responsible of the IC-4 activity can change during the time, and also we can go to such an activity in any time during the response process.

Once the IC is in charge of the emergency response, he collects the information required to make the first strategic decisions (IC-5) about, e.g., how to address the emergency, which resources are really required, and how to allocate resources to activities. This is a complex task that requires external information, and it is fuzzy connected with the plan to address the emergency (IC-6). The plan is shared and sometimes created collaboratively with other firefighters officers present in the site. Typically the plan involves maps of the area (IC-7) that indicate safe and dangerous places, evaluation routes, and the location of the dry and humid networks.

The response plan is also fuzzy connected to the assignment of the response resources to particular tasks (IC-8). Once this assignment has been done, the IC gets in a loop in which he permanently monitors the results of the response activities (IC-9), adjusts the instructions in case of need (IC-11) and evaluates if the emergency is controlled (IC-12). These three activities are done until the emergency is under control.
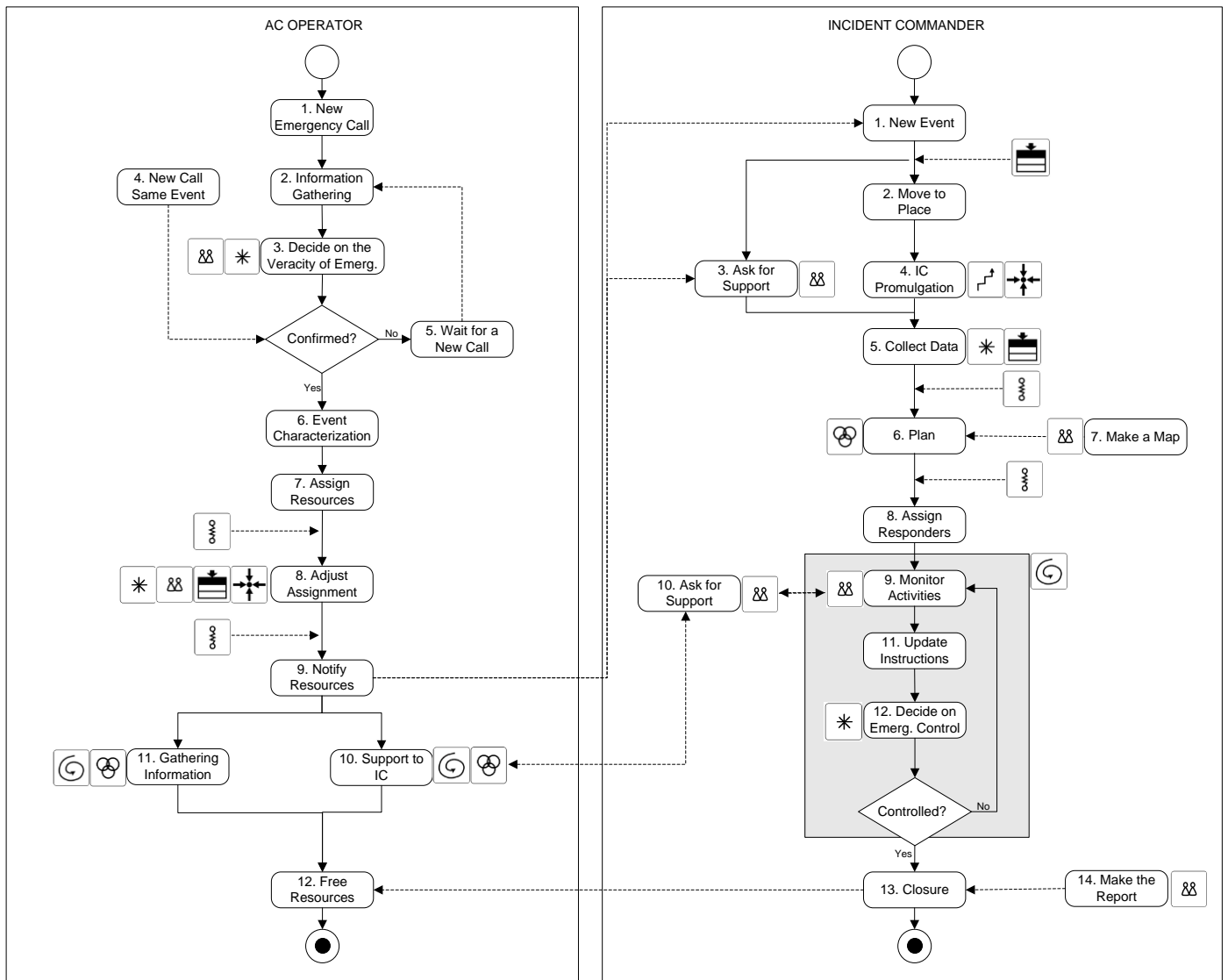
Figure 2. Collaborative response process conducted by the ACO and the IC during a regular urban emergency

Eventually the IC could require extra support to make his decisions. For instance, the constructor of a building affected by a fire could provide important information to the IC about resistance of the infrastructure or the best way to evacuate victims according to the building design. Every external support required by the IC is asked through the ACO (IC-10 and ACO-10).

Similar to the IC, after notifying to the response resources the operator keeps in a loop performing two activities: waiting for requests of the IC (ACO-10) and trying to get useful information that help the IC in the response process (ACO-11). Both activities are performed permanently and involve information sharing.

The operator will be in that loop until receiving a notification from the IC saying that the emergency is closed. In that case the operator frees the resources (ACO-12).

The emergency is closed once after controlling and mitigating the situation (IC-13). After closing the event the IC must do a report of the emergency (IC-14). For such an activity he usually counts on the support of other officers that participated in the response process.

The particularities of this process cannot be specified using the regular notation of BPMN. However, and as shown in this section, it could be done using the proposed extension to such an modeling language.

V. CONCLUSIONS AND FUTURE WORK

The case study has shown the proposed extension to BPMN has allowed us to describe a complex process. We make no claim of completeness, in the sense the introduced notation covers all possible complex processes. On the contrary, the approach has been bottom-up. We had a description problem in a concrete case of a complex collaborative process and we tried to generalize the special notation we generated.

It must be noted the process complexity we were concerned with is not originated by a high number of tasks or numerous flux options or due to tasks complexity. The complexity rather appears because collaborative processes involve much human participation and those activities are difficult to separate in tasks appropriate for simple mechanistic routing schemes. The complexity also is present because some critical highly collaborative processes (e.g. emergency management) must incorporate variability and flexibility to be able to proceed when characteristics of the process change (e.g. an actor is absent, some information is not received).

As a consequence, the resulting descriptions may not be easily automated in a workflow. However, as we discussed above, a workflow is not the only purpose of a process description. The outcome can be used for training new personnel or as part of a set of rules governing the operation of a facility or a procedure.

Future work will involve evaluating how the proposed elements can be incorporated to other modeling languages, e.g. UML, as to become an addition that can be used in many languages to incorporate the elements of highly collaborative processes.

VI. ACKNOWLEDGMENT

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