Mixing RASCI Matrices and BPMN Together for Responsibility Management⋆

Cristina Cabanillas, Manuel Resinas, and Antonio Ruiz-Cortés

Universidad de Sevilla, Spain
{cristinacabanillas,resinas,aruiz}@us.es

Abstract. Organizations need to manage the responsibility of the employees with respect to all the activities that are carried out daily. RACI matrices are used to this end, providing information about who must do what, i.e., the responsibility of each human resource regarding each activity, e.g. responsible for its execution, responsible for approving it once executed, etcetera. On the other hand, nowadays organizations increasingly use modelling notations to represent their processes, being BPMN the standard for business process modelling. In this paper we focus on a concrete type of RACI matrices called RASCI and introduce a novel approach to build RASCI-aware business process models in BPMN based on what we have called *RASCI patterns*. Furthermore, we explain how the transformation of information between RASCI matrices and RASCI-aware BPMN models can be (semi-)automatically performed. We believe the transformation from RASCI to BPMN and vice versa may be very useful to organizations, since it releases them from having to manually maintain BPMN models and RASCI matrices separately and it allows them to focus on only one of them for responsibility management.

Key words: RACI matrix, BPMN, RASCI pattern, RASCI-related BPMN activity, responsibility management

1 Introduction

Organizations need to manage the assignment of responsibilities of their members with respect to the activities that must be carried out within them. This means that not only associating functions to each member of the organization is necessary in order to have an action plan of the work performed by every member for every activity, but also providing a global view, that is, a way to display and organize these responsibility assignments, is required. This can be done by means of a Responsibility Assignment Matrix (RAM), also known as RACI matrix or Linear Responsibility Chart (LRC). This kind of matrices provide a way to plan, organize and coordinate work and consist of representing

certain associations for each activity, such as who is in charge of performing the activity and who must be informed when the activity is done [1]. Several variants extending the functions considered in traditional RACI matrices have appeared (e.g., RASCI matrices).

Besides, organizations need to manage their business processes somehow in order to organize the execution order of the activities carried out in the company, both to complete internal work and to provide services to external users. We remind the reader that a business process represents the execution flow of the activities necessary to complete certain procedure within one or more organizations.

The joining point between RACI matrices and business processes are the activities. The activities to which RACI matrices refer may be actually activities included in business processes. Specifically, we could think of building one RACI matrix for each business process model. Business processes can be modelled in different ways, using different modelling languages. Business Process Modelling Notation (BPMN) is the de-facto standard for this purpose [2]. Its current version includes improved mechanisms to deal with data objects and resources, but there is not yet an easy-to-use standardized way to express and manage resource assignments in the activities of the processes. This makes it harder to join the information included in RACI matrices with the activities represented in business process models, which would be necessary in order to make it easier the management of human responsibilities together with the business process activities performed in an organization. Having RACI matrices and BPMN models separately has several drawbacks:

- An organization usually tracks the execution of business processes. However, *complete* information about resource assignments is still missing in business process models, so there is not a way of knowing all the responsibility assignments without taking a look at the RACI matrix.
- Keeping the information of both elements consistent is difficult, since the RACI matrix must be updated manually when the business process is modified.
- The RACI matrix does not understand about organizational models and, thus, inconsistencies between the responsibilities assigned to the activities and the hierarchical structure of the organization could come up. For instance, the RACI matrix could capture a situation in which an employee delegates work to a boss, which is unlikely to happen in an organization.

Therefore, coming up with a way to synchronize all the elements is necessary. The main goal of this work is to integrate a specific type of RACI matrices, *RASCI matrices*, with BPMN, with the aim of easing responsibility assignment management to organizations that use BPMN to model their business processes. Integrating a RASCI matrix into a BPMN model means enriching the process model with RASCI information, i.e., making the model RASCI-aware. In this paper we explain how this is possible manually or semi-automatically, and how we can automatically update a RASCI-aware BPMN model from changes applied

to the RASCI matrix related to the corresponding business process. To do so we use the extension capabilities provided by BPMN 2.0 to create new types of activities (referred in this paper as *RASCI-related BPMN activities*), and we introduce a set of *RASCI patterns* that make it easier the transformation from RASCI to BPMN.

On the other hand, the inverse procedure is also interesting, i.e., given a RASCI-aware BPMN model we could think of automating the generation and maintenance of the associated RASCI matrix. We describe how this can be done automatically.

The main advantages the RASCI patterns, the BPMN extension and the transformations from RASCI to BPMN and vice versa introduced in this paper provide to organizations are the following:

- The transformations of information between RASCI matrices and BPMN models allow focusing on only one view of a business process (being it the execution flow shown in the models or the responsibility assignments included in the matrices) instead of manually maintaining both views separately. We believe it may imply important effort saving to organizations.
- As the proposed solution to insert RASCI information in BPMN is based on BPMN semantics, the resulting RASCI-aware business process models are BPMN-compliant, so they can be run in any BPMN engine.

In section 2 we describe RASCI matrices and introduce a scenario that will be used as use case in the rest of the paper. Section 3 introduces aforementioned RASCI patterns and RASCI-related BPMN activities. In Section 4 the procedures to generate and maintain RASCI matrices from BPMN models and vice versa are described. Brief related work can be found in Section 5. Finally, conclusions drawn from this work and future work on this field are presented in Section 6.

2   RASCI Matrices and BPMN. Use Case

RACI matrices are usually used to associate activities with resources (individuals or groups).The following functions, called *roles* in RACI[1], must be indicated for each activity performed in an organization:

- *Responsible (R):* person who must perform the work, responsible for the activity until the work is finished and approved by an accountable. There is typically one person responsible for an activity.
- *Accountable - also Approver or final Approving Authority - (A):* person who must approve the work performed by the person responsible for an activity, and who becomes responsible for it after approval. There must be one and only one accountable for each activity.

---

[1] We will use the term *RACI/RASCI role(s)* from now on in order to not mistake them for organizational roles.

– *Consulted - sometimes Counsel - (C):* this role includes all the people whose opinion is sought while carrying out the work, and with whom there is two-way communication.
– *Informed (I):* person who is kept up-to-date about the progress of an activity and the results of the work, and with whom there is just one-way communication. There may be more than one person informed of the work of an activity.

Using these four RACI roles we can build a matrix where rows represent activities, columns are (human) resources and each cell contains zero or more RACI initials indicating the degree of responsibility of *such* resource on *such* activity. The definition of resources can be done at different levels: (i) although it is not very convenient, small companies may use individual resources (persons) in each column; (ii) in most cases, columns are likely to represent positions or roles played inside an organization; (iii) at a very high level we could find RACI matrices in which each column would refer to, for instance, a work group or organizational unit.

There are several variants of the original RACI matrix. Some are based on extending the number of RACI roles to be considered for every activity, e.g, RASCI or RACI-VS. Others give different meaning to the RACI initials. In this paper we will build on RASCI matrices (cf. example in Table 1) because they use a function that may be interesting specially to IT organizations, where work can usually be delegated to other people in order to complete certain activity.

– *S (Support):* people who may assist in completing an activity, i.e., the person in charge can delegate work to them. Unlike *Consulted*, who may provide input to the activity (i.e., information helpful to perform some work), *Support* will contribute in the completion of the activity.

As aforementioned in this paper, we could think of having one RASCI matrix for each business process run in an organization. The matrix would thus contain information about every activity carried out in a business process and the organizational roles involved. Figure 1 shows a BPMN diagram that represents a *collaboration* in which two business processes participate: one business process at pool *Research Vice-chancellorship* and another one at pool *ISA Group*. We remind that in BPMN a process takes place in a single pool. Diagrams with two or more pools, in which messages between the pools are exchanged, are called collaborations[2]. The collaboration in the figure illustrates a simplified version of the process to manage the trip to a conference (according to the rules of the University of Seville), from the submission of the final version of an accepted paper to the booking of the transport tickets and the accommodation. The collaboration starts with the submission of the Camera Ready version of a paper, and it continues when one of the authors fills up a form requesting for authorization both to travel to the venue place and to take the funds from some funding source. This authorization must be signed by some person in charge of account

---

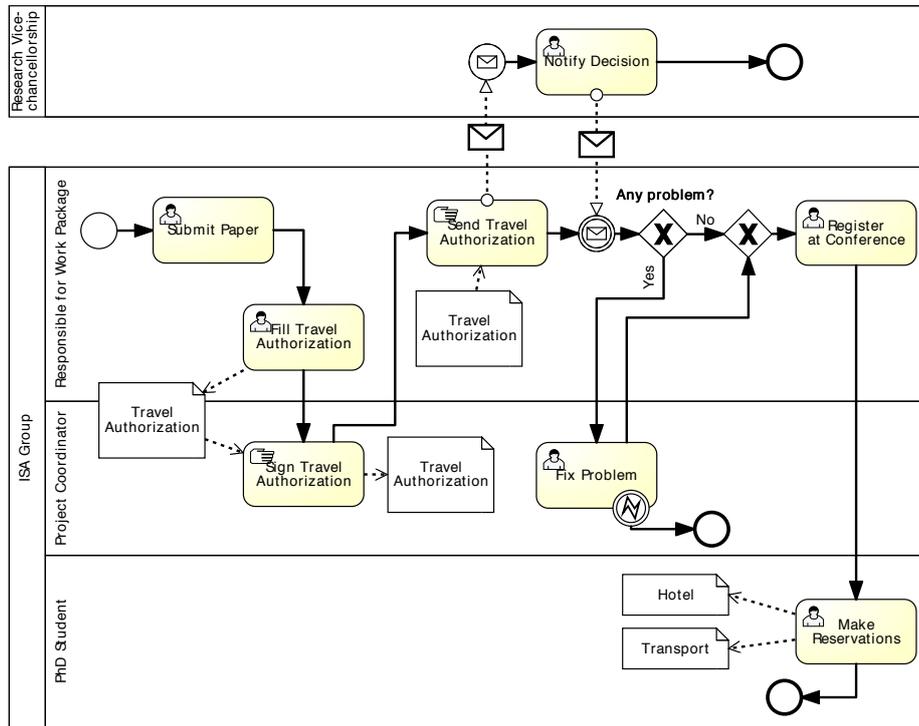[2] We are using concepts from BPMN 2.0 throughout the paper [2].

Fig. 1: Conference Travel Management Process

management related to the applicant. The travel authorization is then sent for revision to entity *Research Vice-chancellorship*, where someone might approve and sign the document. The approval decision is communicated to the applicant. If it is favourable, then the process continues with the registration to the conference and the booking of the proper tickets. Otherwise, corrective actions must be carried out in order to fix the problems with the travel authorization, and the process will go on until the reservations are made, as long as nothing wrong happened when fixing the problems.

We will focus on the business process carried out at pool *ISA Group*. Imagine that process takes place in an organization whose organizational model is the one in Figure 2. This model corresponds to an organization that uses the concepts Person, Position, Role and Organizational Unit according to an organizational metamodel described by Russell et al. [3]. Specifically, the model in the figure contains six positions (Project Coordinator, Account Delegate, Senior Technician, Administrative Assistant, Responsible for Work Package and PhD Student) that are members of one organizational unit (Project THEOS), and seven persons occupying these positions. Given this structure, Table 1 could be the RASCI matrix implemented in the organization. We are using positions as resources in the matrix, but any other kind of resource could have been used.
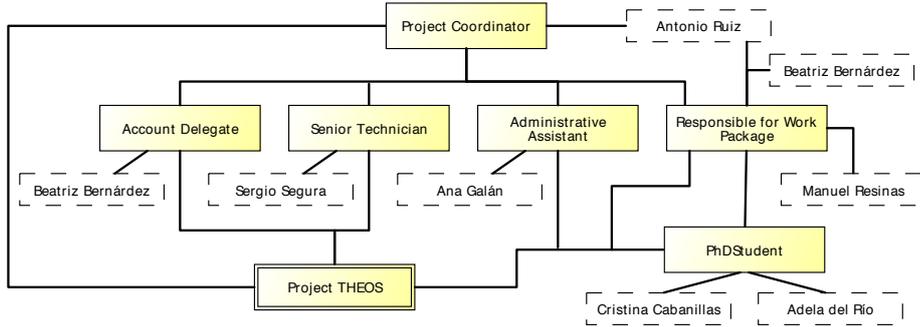
Fig. 2: Excerpt of the organizational model of *ISA Group* from a project perspective.

Table 1: RASCI matrix for the process at pool *ISA Group* of Figure 1

	Project Coordinator	Account Delegate	Senior Technician	Administrative Assistant	Responsible for Work Package	PhD Student
Submit Paper	I				R/A	S
Fill Travel Authorization	C	C		S	R/A	S/C
Sign Travel Authorization	R/A					
Send Travel Authorization				S	R/A	S
Fix Problem	S/C	S/C	C	S	R/A	S/C
Register at Conference	C/I				R/A	S
Make Reservations	I			S/C	A	R

This scenario will be used as use case in this paper. Another RASCI matrix based on the organizational model of the corresponding organization would be required for the process at pool *Research Vice-chancellorship*.

In the following we will describe some procedures that could be used to put RASCI matrices and BPMN models together, and some guidelines on how to take into account the organizational structure will be provided as well.

3   Introducing RASCI into BPMN. RASCI Patterns and RASCI-Related BPMN Activities

The first and main goal of this work is to find a way to include RASCI information in BPMN models. In the following we propose a set of RASCI patterns that represent the responsibility assignments used in RASCI for each RASCI role, in order to make business process models RASCI-aware. Firstly, we must find a way to represent resources in a BPMN model. We could use the pools and lanes provided by BPMN for this purpose, by giving them a semantics that

(a) Accountable Pattern
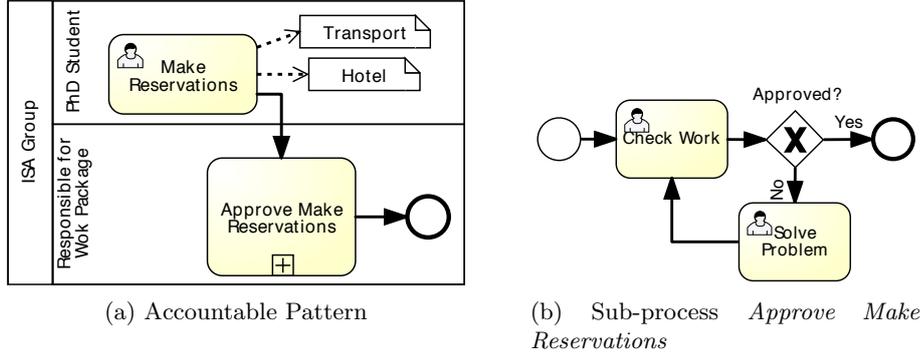
(b) Sub-process *Approve Make Reservations*

Fig. 3: Implementation of the Accountable Pattern. Example

now is missing [2]. We remind the reader that, according to BPMN definitions, a pool usually represents a participant in a business process, and may contain several lanes, which can be seen as participants at a lower level (e.g., a partner entity) or as a way of grouping and organizing participants. However, these two concepts are still a bit abstract and are not used in a standardized way.

Responsible Pattern. If we give the name of persons, positions, roles, or even organizational units to the lanes of a process and consider that the corresponding resource is responsible for all the activities within its lane, RASCI role Responsible (R) becomes implicitly represented in BPMN models. This way, *Responsible Pattern* consists of interpreting that the resource corresponding to the pool/lane in which an activity is placed is responsible for its execution. To support this interpretation, we must assume that there is only one resource responsible for the execution of each activity. In Figure 1 we are using this implementation and, hence, the model has three lanes representing the R's that appear in Table 1. We can consider that pools have the same meaning as lanes as long as they do not contain lanes within. Otherwise, they will be meaningless and the information will be provided by their lanes. Notice that the number of lanes in a pool might increase with respect to the traditional meaningless swimlanes.

Accountable Pattern. This pattern consists of an approval activity placed in the lane of the resource accountable for the activity in question. It can be seen (and modelled) as a sub-process. Only if R and A coincide this "extra" sub-process will not be necessary. We cannot generalize what to do if the approval process fails (i.e., the work is not approved), since it depends on the specific business process being modelled. The simplest case is to assume that either the activity is approved and the process goes on, or that otherwise the organization gets to solve the problem and the process can continue. Therefore, in our use case we should add at least an activity called *Approve Make Reservations* in the lane representing position *Responsible for Work Package* (cf. Figure 3).

Support Pattern. RASCI role S is played while carrying out the specific activity being represented. Therefore, the activity that requires support must be
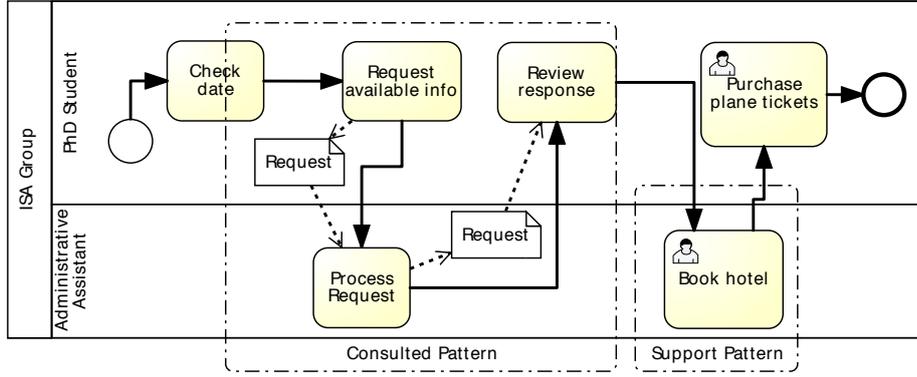
Fig. 4: RASCI patterns *Support* and *Consulted* in sub-process *Make Reservations*

modelled as a sub-process that contains the proper assignments to represent the delegation of work to other resources, which consists of tasks to perform in order to complete the work of the main activity (called *responsible sub-process* from now on in this paper). These tasks are associated to the corresponding resource (lane) in the sub-process, according to the RASCI matrix. Figure 4 shows the content of the now responsible sub-process *Make Reservations* and illustrates the use of *Support Pattern*.

Consulted Pattern. RASCI role C is also played inside the responsible sub-process and it can be seen as a request-response procedure in which intuitively no work is required. It could thus be modelled as messages exchanged between two resources, so one resource asks for something and another resource answers. However, in BPMN messages cannot be passed between lanes of a pool, so we would need at least two pools to model this pattern, making it no longer be a process but a collaboration. As we are associating RASCI matrices with single business processes, modelling a collaboration inside a responsible sub-process including resources of the main process in different pools would cause an inconsistency. Furthermore, the resource consulted may need some time to process the request and respond to it, so the request-response procedure is time-consuming and there is actually work to be done. To deal with this RASCI role we propose to use BPMN common tasks using the pattern shown in Figure 4. Notice that we make data objects play a role similar to messages' in collaborations in order to provide a mechanism to exchange information.

Informed Pattern. Unlike in RASCI role C, in RASCI role I no response is expected. We are focused on intra-organizational processes (related to a single organizational model) and, thus, the resource informed can be included as a participant of the process (if it was not yet) by means of a new lane. This resource receives the information but the normal execution flow of the process can continue in parallel. As defined in Section 2, people can be informed also about the progress of an activity, so we could include this pattern inside the responsible sub-process as well. *Informed Pattern* is shown in Figure 5, in which
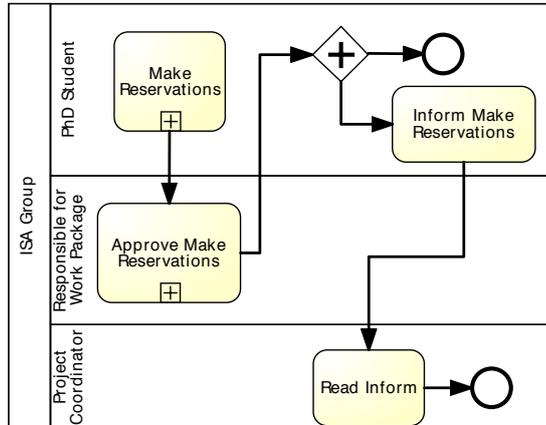
Fig. 5: *Informed Pattern* and summary of all patterns for activity *Make Reservations*

there is also a summary of all the patterns for activity *Make Reservations* of our use case. Note that in this case the process ends up after informing but, as aforementioned, in other scenarios the business process may continue.

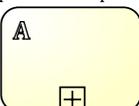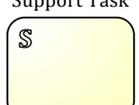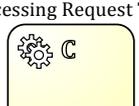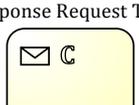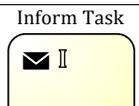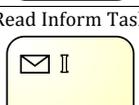### 3.1 Improving RASCI Patterns by Extending BPMN

One of the problems related to the introduction of RASCI into BPMN models like explained above is that we can mistake RASCI structures for common BPMN structures, since they all use elements defined in BPMN 2.0 and the different interpretation comes from the meaning we have given to the structures used to model the RASCI patterns. This makes it difficult to recognize RASCI patterns and, hence, also the automatic extraction of RASCI information from a RASCI-aware business process model.

We propose the extension of BPMN with a set of RASCI tasks and collapsed sub-processes to help represent the RASCI patterns defined in Section 3. Table 2 contains such proposal, together with some constraints regarding where these activities can appear in a model and the naming conventions. Furthermore, the last column indicates whether the presence of the activity is necessary to be able to analyse a RASCI-aware BPMN model. Notice that it does not say whether the RASCI role is mandatory (cf. RASCI roles descriptions in Section 2), but whether the RASCI-related activity *must* appear in a RASCI-aware BPMN model in case the RASCI role exists in order to be able to identify relevant RASCI information.

4 Transformation of Responsibility-Related Information

The RASCI patterns and the RASCI-related BPMN activities provide the support necessary to include RASCI information in BPMN models maintaining the

Table 2: RASCI-related BPMN activities

RASCI Role	RASCI Sub-process/Task	Placement & Naming Constraints	Mandatory Icon?
Responsible	Responsible Sub-process $\mathbb{R}$ ⊞ Responsible Task $\mathbb{R}$	- Placed in any lane - Whatever name	No. The resource in whose lane the activity is placed is automatically responsible for the activity
Accountable	Approval Sub-process $\mathbb{A}$ ⊞	- Placed in any lane - Its name must contain the name of the referred activity	Yes
Support	Support Task $\mathbb{S}$	- Always inside a responsible sub-process - Whatever name	No. Inside a responsible sub-process, any task in a lane representing a RASCI role (except R) may be interpreted as support
Consulted	Request Task ✉ $\mathbb{C}$	- Always inside a responsible sub-process - In the same lane as the referred responsible sub-process - Whatever name	Yes
Consulted	Processing Request Task ⚙ $\mathbb{C}$	- Always inside a responsible sub-process - After the request task but in a different lane - Whatever name	If there is a request task
Consulted	Response Request Task ✉ $\mathbb{C}$	- Always inside a responsible sub-process - After the processing request task and in the same lane as the request task - Whatever name	If there is a request task
Informed	Inform Task ✉ $\mathbb{I}$	- In the same lane as the referred responsible sub-process/task - Its name must contain the name of the referred activity	Yes
Informed	Read Inform Task ✉ $\mathbb{I}$	- After the referred responsible sub-process/task but in a different lane - Its name must contain the name of the referred activity	If there is an inform task

BPMN 2.0 semantics, at the same time as they ease the transformation between both views of the responsibility assignment, as explained below.

4.1 Transformation from RASCI to BPMN

The basis to do this transformation has been set in Section 3. The automatic introduction of RASCI information in a BPMN model from scratch (i.e., in a BPMN model that knows nothing about RASCI) may not be possible, since it may require to modify the control flow of the business process and this could distort the real behaviour expected for the process. However, once a BPMN model is RASCI-aware, some changes[3] performed in the RASCI matrix could be automatically updated in the model without negative implications:

- *Changing the resource in charge of an activity.* It implies moving the responsible task/sub-process to a different lane of the process model according to the new resource responsible for the activity. If it is not a current participant in the process, the lane will be added. The corresponding activities approval sub-process and inform task, if existing, must be moved to the new lane as well in order to comply with the constraints described in Table 2. If the activity is a responsible sub-process, its content may also change.
- *Changing the resource accountable for an activity.* Like before, this change implies moving the approval sub-process to a different lane of the business process model according to the new accountable for the activity. If it is not a current participant in the process, the lane will be added.
- *Changing the support of an activity.* If any S is changed in the RASCI matrix, the support task(s) related to the activity for such resource must be moved to a different lane in the responsible sub-process. If it is not a current participant in the process, the lane will be added to such sub-process.
- *Changing the consulted of an activity.* Similarly to the previous case, this change implies moving the processing request task(s) to a different lane in the responsible sub-process. If it is not a current participant in the process, the lane will be added to such sub-process.
- *Changing the informed of an activity.* This change implies moving the read inform task(s) to a different lane in the main business process model and/or inside the responsible sub-process, adding new lanes if necessary.

Obviously, if any lane becomes empty after the update, it should be removed from the model. We assume the new RASCI matrix is consistent regarding the responsibility assignments, i.e., every resource in the matrix belongs to the organizational model and the matrix does not contain situations in which, for instance, the same resource is responsible for an activity and plays the RASCI role C too. This checking could be done directly from the RASCI matrix or while doing the transformation into BPMN (so detection of inconsistencies could be automated), but it is out of the scope of this paper.

---

[3] A change means assigning the responsibility to a different resource. The addition and removal of RASCI roles in the matrix could modify the process behaviour and, thus, these actions are not considered changes.

4.2 Transformation from BPMN to RASCI

Both generation and update of a RASCI matrix from a RASCI-aware BPMN model can be automated, since all the information required can be found in the process model and filling up a RASCI matrix given the necessary information is nothing complicated.

We are going to describe how to generate a RASCI matrix from a BPMN model, for which a RASCI analyser should be developed. Knowing that, applying the updates of the model to the RASCI matrix is straightforward.

- *Filling the name of rows and columns.* In principle, there will be a row for each non-RASCI activity and/or responsible task/sub-process in the BPMN model. We could opt for being stricter and consider only the responsible tasks/sub-processes (thus ignoring the rest). Columns will correspond with the lanes of the BPMN model and the lanes included in responsible sub-processes.
- *Obtaining the resource in charge of an activity.* An R will be added to the cell corresponding to the resource represented by the lane where the non-RASCI activity or responsible sub-process/task (depending on the degree of strictness) is placed in the model. We remind the reader that we are assuming there is only one resource responsible for each activity.
- *Obtaining the resource accountable for an activity.* An A will be added to the cell corresponding to the resource represented by the lane where the approval sub-process related to the activity is placed in the model. The absence of approval sub-process will be interpreted as if R and A were the same resource.
- *Obtaining the support of an activity.* An S will be added to the cells corresponding to the resources represented either by the lanes where the support tasks are placed in the responsible sub-process, or by any lane in such sub-process (different from the lane of RASCI role R) that contains tasks, according to the degree of strictness.
- *Obtaining the consulted of an activity.* Letter C will be added to each cell of the matrix corresponding to the resource represented by the lane where a processing request task is placed in the responsible sub-process.
- *Obtaining the informed of an activity.* An I will be added to the cells corresponding to the resources represented by the lanes where the corresponding read inform tasks are placed in the BPMN model.

5 Related Work

To the best of our knowledge there is not yet work aimed at mixing RASCI matrices (nor RACI matrices) and business processes together. Some information about how to interpret the information of RACI matrices can be found in [4].

However, there is some work related to the introduction of responsibility assignments in business process models. Meyer has worked on the extension of BPMN 1.1 to manage resource allocation in business process models [5]. In

the same direction, Cabanillas et al. have developed language RAL (Resource Assignment Language) to express resource assignments with the aim of using it as an extension of BPMN 2.0 [6]. The authors have managed to reason about resources by giving formal semantics to RAL. La Rosa et al. have presented a rich metamodel for capturing role-task and object-task associations embodied in the EPC notation, which can be transposed to other notations [7]. Nakatumba et al. have analysed and characterised resource behaviour after business process execution from event logs using process mining [8]. An optimal approach to allocate the most proficient set of employees for a business process from event logs based on Hidden Markov Models is introduced in [9]. Finally, Russell et al. have described a set of Workflow Resource Patterns aimed at capturing he way resources should be managed in workflows and have analysed the support provided by some workflow tools [3].

The cited work does not even mention RACI/RASCI as an alternative or as something to consider for responsibility assignment. Nevertheless, it is one of the methods used in organizations nowadays to manage their resources and its relation to business processes is quite close.

6   Conclusions and Future Work

Resource management and responsibility assignment in business processes is still a quite neglected research field. Little work dealing with this issue has been published so far and most of it is focused on specifying the resources in charge of executing the activities of a process, forgetting other important roles that are daily used in organizations. Here is where the idea of RACI matrices appears as a mechanism to represent the responsibility assignments referring not only to the execution of activities, but also to the approval of the work performed and the communication of the results to the convenient resource, among other roles.

In this paper we have mixed RASCI matrices and BPMN together, providing RASCI patterns to represent RASCI information in BPMN models and proposing an extension of BPMN 2.0 consisting of new types of activities. The goal was to obtain RASCI-aware business process models that could be analysed, so transformations between RASCI matrices and RASCI-aware BPMN models became easier and could even be done automatically.

From this work we can conclude that providing BPMN with mechanisms to express responsibility assignments maintaining the basic semantics of BPMN is possible and may be quite useful to avoid organizations having to handle business process models and RASCI matrices separately. We believe the notions given in this paper may save human effort to organizations and constitute an important first step towards introducing resource management into the standard notation for business process modelling. Although this approach has the advantages defined in Section 1, there are also some drawbacks to be taken into account:

- Much information must be added to the business process models to make them RASCI-aware, even for small ones. It implies bad scalability, since complex BPMN models may be unreadable after introducing RASCI patterns.

– Aggressive modifications in the RASCI matrix of an organization (e.g., addition or removal of RASCI roles in some activities) may involve important changes in the BPMN model, so special attention must be put on keeping the expected behaviour of the business process.
– The approach is limited to intra-organizational business processes with only one resource responsible for each activity (this is quite reasonable though).

We plan to study different alternatives to mix RASCI matrices and large BPMN models together, e.g. using the activity properties to insert RASCI information instead of including new activities in the model. It could solve problems one and two.

Future work in the line of this paper is the implementation of the extension of BPMN 2.0 with the activities proposed in Table 2 to enable modelling RASCI-aware BPMN models, and the implementation of all the procedures described in Section 4. Besides, this work should be extended to consider cross-organizational aspects and, hence, overcome the third drawback aforementioned.

Acknowledgements

References

1. D. O. Conchúir, "Human resource management processes," in *Overview of the PM-BOK Guide*, pp. 129–145, Springer Berlin Heidelberg, 2011.
2. "Bpmn 2.0," recommendation, OMG, 2011.
3. N. Russell, W. M. P. van der Aalst, A. H. M. ter Hofstede, and D. Edmond, "Workflow resource patterns: Identification, representation and tool support," in *CAiSE*, pp. 216–232, 2005.
4. M. Smith, "Role and responsibility charting (raci)," in *Project Management Forum (PMForum)*, p. 5, 2005.
5. A. Meyer, "Resource perspective in bpmn - extending bpmn to support resource management and planning," Master's thesis, Hasso Plattner Institute, Potsdam (Germany), 2009.
6. C. Cabanillas, M. Resinas, and A. Ruiz-Cortés, "Towards the definition and analysis of resource assignments in bpmn 2.0," tech. rep., Universidad de Sevilla, April 2011.
7. M. La Rosa, M. Dumas, A. H. ter Hofstede, J. Mendling, and F. Gottschalk, "Beyond control-flow: Extending business process configuration to resources and objects," tech. rep., 2007.
8. J. Nakatumba and W. M. P. van der Aalst, "Analyzing resource behavior using process mining," in *Business Process Management Workshops*, pp. 69–80, 2009.
9. H. Yang, C. Wang, Y. Liu, and J. Wang, "An optimal approach for workflow staff assignment based on hidden markov models," in *OTM Workshops*, pp. 24–26, 2008.