Resource Modeling in Workflow Applications

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Abstract. Collaborative applications such as workflow management systems separate between a process model and an organizational model. While the process modeling capabilities of current workflow management systems are at a high level, the organizational meta models provided by these systems are very often at a very elementary level. Moreover, most systems fail to provide means to integrate non-human actors in workflow applications such as intelligent agents or technical resources, such as PPC systems or CNC machines. We provide a generic framework for the representation of resources that can be addressed by a workflow activity. In addition to a generic meta model we discuss dynamic issues that occur during the assignment process. A proposal for the realization of feedback evolution in order to enable organizational learning and security considerations conclude this paper.

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1 Resource Modeling for Collaborative Work

The representation of organizational structures has become an increasingly important part of information system design. Beyond the traditional functions of accounting or human resources management, collaborative application systems such as groupware or workflow management systems rely on a division between the business processes, i. e. the temporal and logical order of those activities that are necessary to process a business object [1], and the structure of the resources that perform these activities.
The resource model itself can be separated into the static resource meta model, i. e. the entity and relationship types provided by the resource model, the dynamic assignment rules (policy resolution, cf. e.g. [2,3]) and the synchronization mechanisms that coordinate the resource access to workflow activities. In this paper we present a resource meta model and discuss several dynamic issues relevant to a unified resource model.

The terminology used within this paper follows the reference model of the Workflow Management Coalition, the relevant definitions can be found in [4]. We distinguish a buildtime, during which the model of a workflow process is created by a workflow designer, and a runtime, during which workflow instances are derived from the workflow model and executed under the control of one or more workflow management systems. During the enactment of a workflow instance, workflow activities are executed by workflow participants that use invoked application systems eventually.

A *resource* is an entity that is assigned to a workflow activity and is requested at runtime to perform work in order to complete the objective of this activity. A *resource model* contains the definition of human and technical resources that are involved in the execution of a workflow model as workflow participants. We use the

term resource model in order not to focus solely on workflow in administrative environments. Workflow management systems may also be used in industrial applications, interfacing with production planning and control (PPC) systems, computerized numerical control (CNC) machines and software agents among others, which have to be defined for use in the workflow management system through the resource model.

The division between a process model on the one side and a resource model on the other side fosters the separate evolution of both models. We assume that the life-cycle of human resources within an enterprise varies from the life cycles of the enterprise's processes. Therefore, this separation enables workflow designers to create workflow models that are independent of changes in the organizational structure of the enterprise, adding to their robustness. On the other hand, a separate resource model may be shared by several workflow engines that are used within one enterprise, reducing administrative overhead and preventing possible redundancies, thus increasing the quality of the data maintained.

Within the reference model of the Workflow Management Coalition the management of resource information lies within the responsibility of the workflow engine [4]. Therefore, most workflow vendors have implemented proprietary resource management facilities for their workflow management systems. This can lead to problems in larger organizations, if several workflow management systems are involved in the execution of a complex process. These systems cannot share common information about the resources of the enterprise, leading to data redundancies. In addition to this, information such as the workload of single resources can only be determined if the distributed information of the single workflow management systems is consolidated. This information may not be easily accessible, therefore, the efficient use of the enterprise's resources can only be realized locally.

2 Related work

Several areas of related work can be identified with regard to resource modeling. Besides economical organization theory these field are role-based access control, research on organizational meta models and assignment policies. In this paper we focus on the technology-oriented fields of resource modeling, an overview about organizational theory can be found in [5,6].

2.1 Role-based access control

Role-based access control has been developed as an alternative to traditional approaches to handling access control in information systems [7]. While discretionary and mandatory approaches originated from the Orange Book specification of the Department of Defense in the mid 1980s [8], there were criticized as either too weak or too much focused on the requirements of governmental regulation [9]. The majority of research on role-based access is directed towards the development of an efficient, flexible and secure access mechanism that abstracts from the single user and uses abstract roles as a grouping of either users or permissions to administer the

organizational population that needs access to an information system. The role-based approach has been applied to object-oriented systems to enhance their manageability and security (cf. e. g. [10]). Nevertheless, traditional findings of organizational theory that could enhance the quality of role meta models as well as dynamic assignment concepts that satisfy certain economical criteria such as the cost of an assignment have not been addressed by most researchers in this area.

2.2 Organizational Meta Models

In the workflow literature only few organizational meta models have been presented, the following section provides a brief overview about these models.

The OMM Organization and Role Model described by CHENG aims at a separation of organization and roles in the context of of electronic commerce applications [11]. It consists of the entity types enterprise, organization, member and virtual link. While an enterprise is a collection of a number of organizations, each organization consists of a number of members that share common attributes. Member objects are the elementary resources that map to the actual resources of the enterprise. Virtual links provide relationships between members of the same or different organizations. Virtual links can be defined as transitive or reverse.

A generic organizational model has been described by BUSSLER. This meta model has been implemented in the research prototype MOBILE [2,3,12,13]. The meta model is on a very high level of abstraction and provides agent types that can be addressed directly by workflow activities, non-agent types that have to be resolved before a workflow activity can be assigned and attributes, operations and consistency rules on a type and an instance level. In order to depict a real-world organization the meta model has to be instantiated, i. e. a domain-specific model has to be derived from the abstract entity types. For example, in order to depict an organization that consists of users, groups, departments and project teams the abstract entity type agent would be instantiated as the entity type user, the entity types group, department and project team would be instantiated non-agent types. The maximum number of members in a group would be an instance-level consistency rule and the process of assigning a member to an organization would be implemented as a type-level operation.

The Organization and Resource Model (ORM) presented by RUPIETTA is an independent repository for organizational structures that has been used by the (discontinued) workflow management system WorkParty [14,15]. It provides a semantically rich meta model that can be modified through the inheritance of the existing entity types. The entity types provided reflect the German organizational theory, such as organizational positions, position types, tasks and units. However, some of the entity types provided cannot be used for the assignment process, such as resources or the ownership of these.

The Object Management Group has worked on a request for proposal for a resource management facility [16]. This facility shall complement the jointFlow specification for an object oriented workflow facility [17,18] as part of the CORBA framework, by adding services for the assignment of resources to workflow objects. Since the modeling of processes and resources lies outside of the existing jointFlow specification, these aspects are addressed by separate RFPs. While the RFP contains

requirements for the services provided by the resource management facility, it explicitly states that the design of a resource meta model is outside the scope of this proposal. An approval of a proposed resource management facility is not likely before the middle of the year 2000.

The resource management facility presented by HUANG et al. [19,20,21] has been implemented in the workflow management system Chang*e*ngine. Their approach presents an independent resource manager that integrates existing local and site resource management systems under a common schema. The proposed system implements an SQL-like language for the querying and assignment of resources. The underlying schema for representation of resources differentiates between resources that can belong to units and managing entities of these units.

In an earlier paper we presented an organizational meta model as the result of an analysis of four workflow management systems [1,22]. Like the ORM this model is a semantically rich organization model, that reflects the German organizational theory. The resource meta model presented in this paper has been developed starting from all the meda models described above. It has been subject for discussion for integration into the Interface 1 specification of the Workflow Management Coalition [23]. The version described in this paper is used to illustrate the design philosophy behind this meta model and to outline open issues, that are still to be resolved by researchers and vendors.

2.3 Assignment Policies

A dynamic perspective on the resources involved in workflow execution is the handling of the resource assignments at runtime. The most common mechanism for this is a hierarchical assignment through the workflow management system, which places work-items on the worklists of qualified resources. A resource can either accept, reject, delegate or postpone the execution of a work item (depending on the services provided by the workflow management system). However, except for monitoring facilities provided by some workflow management systems, a resource has no means of viewing work items that are not intended to be handled by this resource. Hierarchically coordinated worklists are rather easy to implement, since a filtered view on a centrally managed general worklist provides the individual worklists.

Another option of assigning activities to resources is the co-ordination of resources through a market-based mechanism. This can be implemented using the mechanisms of electronic auctions or a pricing/benefit system for work-items where resources either pay a certain amount of a virtual currency to perform activities or where they receive credits for the execution of activities. Market based approaches have been described by ALT, KLEIN and KUHN [24,25], as well as by HARKER et al. [26,27]. Market based coordination mechanisms are of interest especially in domains that can be managed using agent technology. An intelligent agent with a sufficient self-awareness about its competencies is capable of selecting those work items from a general list, towards whose completion it can contribute. A detailed discussion about the runtime handling of resources is outside the scope of this paper, therefore, interested readers should refer to the cited references. An overview about

coordination mechanisms that can be employed in the process of assigning activities to potential performers is provided by MALONE and CROWSTON [28].

3 Requirements for Resource Models

Resource models should satisfy a number of core requirements, in order to be universally applicable. These requirements, which can be derived from general quality criteria for software systems (cf. e. g. [29]), are robustness, flexibility, scalability and domain-independence.

- *Robustness*: Changes to the resource model should not affect the workflow model. On the other hand, changes to the workflow model (like the addition of an activity) should leave the resource model unaffected, too. Therefore the resource model needs at least one abstract entity type that serves as a separation between the physical population and the logical address referenced by the workflow activities.
- *Flexibility*: The resource model should be flexible enough to allow a transfer of existing organizational structures without changing the terminology of the enterprise or the structure of the organization too much. Therefore, it should be possible to rename entity types and/or to create new entity and relationship types from the resource meta model.
- *Scalability*: The integration of additional levels of hierarchy or new permissions should be possible. If a company acquires another company it should be possible to integrate the two organizations under a single managing authority, adding new levels of hierarchy.
- *Domain-Independence*: A resource model for a collaborative software system should be as domain-independent as possible. With regard to discrete processes a common definition states that a process consists of activities (steps) that have a certain order (sequence) in time. Such a generic definition is not suitable for a resource model since there may be situations where only human actors are involved in the execution of a workflow as opposed to the situation where only technical resources are involved (e.g. in a PPC-environment). The resource model has to be flexible enough to handle this variety. On the other hand it should only contain a minimum number of entity types in order to preserve maintainability.

4 Assigment Concepts for Resources

With regard to the assignment of resources to activities, three different concepts can be distinguished: Direct designation, assignment by role and assigment using a formal expression.

4.1 Direct Designation

In the first case an activity is assigned to one or more entities of the resource model directly. At run-time, the workflow-engine can directly look-up these resources in the

resource repository and place the relevant work-items on their worklists. This kind of assignment is easy to handle for the workflow administrator, because he is concerned with a single entity type: the workflow performer. If an activity is to be made available to a group of people, all members of the group have to be assigned to the workflow activity one by one. The direct assignment concept provides no independence of workflow model and organizational model, i. e. every change of the organizational population is reflected in the workflow model, which has to be changed as well. Therefore, the direct assignment mechanism is rarely used in industrial practice.

4.2 Assignment by Role

Most workflow management systems provide workflow modelers with a role entity type. Within this domain, one role entity is used as a synonym for one or more resource entities. EDWARDS defines a role as a category of users within an application system that inherit a common set of access control rights to objects specific to this application system [30]. The main purpose of the role model is the separation of workflow and resource model, where changes of the organizational population do not affect the workflow model directly. The use of roles instead of a direct assignment also provides means of indirect workload balancing, because all members of a qualified role are notified about the pending work-item, but only one member of this group needs to perform the activity. From a technical point of view, the workflow management system has to perform a resolution process to determine the members of a role before it can notify these resources. Therefore, an error handling procedure has to be implemented, if this resolution process returns empty set of resources.

4.3 Assignment by Formal Expression

The most complex form of activity assignment uses a formal expression e.g. a library function. An example for this type of assignment is the expression

```
activity_performer = superior(resource(activity(1)))
```

which would return the manager of the workflow initiator, i. e. the resource that performed the first activity of the workflow. In this case, not only the entity types of the resource model have to be known to the workflow modeler but also the relationship between these entity types and possible functions depending on the workflow execution history. The attributes used in such a formal expression can either be dependent on the workflow instance, such as the information about the performer of the last activity, as well as independent on the workflow instance, such as the relationship of a resource to another resource. BERTINO et al. propose a three categories for a classification of the formal expressions: Static constraints such as the relationship between organizational units, dynamic constraints that refer to the history of the workflow instance, and hybrid constraints, that comprise both forms. While static constraints can be evaluated before the workflow is initiated, dynamic constraints can only be evaluated at runtime [31]. If a formal expression is used for activity assignment an error handling similar to the one used during the assignment by

role has to be implemented, in case the expression returns an empty set of resources. Formal expressions may not only relate to the relationships between entity types of the resource model but also to specific attributes of the resources. For the assignment of a meeting room to the activity “perform board meeting”, the location of the room and its availability during a specified time frame may be the core determinants for the assignment process. Therefore, a resource management facility not only needs to handle current information about the workload of resources, but also be able to forecast available capacities. Capacity allocation algorithms, as they are used by production planning and control systems (PPC-systems), could improve the resource management of current workflow management systems. This would enable the precise forecast of processing times for workflow instances, thus increasing the quality of responses to customer inquiries about the status of single workflow instances.

5 Two Strategies for Resource Modeling

During the modeling of resources for a workflow application two approaches can be distinguished, that have an impact on the design of the resource meta model: A technology-driven approach and an organization-driven approach.

5.1 Technology-driven Approach

The technology-driven approach to resource modeling presumes no predefined set of resources in the organization. Instead, the structure of entity types needed in the workflow model is derived from the specification of the workflow model itself. Typically, roles derived from an existing workflow model are of the form “authorized to perform activity X”. This approach enables a lean specification of necessary organizational structure, because only relevant resources have to be depicted in the resource model. The use of roles instead of particular resources makes the workflow model independent of changes in the organizational population. However, changes in the workflow model can easily affect the resource model, because newly defined activities require new roles to be defined. A large number of commercial workflow management systems show organizational meta models that were designed following this approach (cf. e. g. the resource model of Staffware 97 in figure 1 or the meta model of IBM FlowMark as described in [22,32]). These meta models provide few entity types with restricted cardinalities (e. g. no matrix organizations).

Fig. 1. Organizational Meta-Model of Staffware 97.

5.2 Organization-driven Approach

The organization-driven approach can be found in environments where workflow management systems are introduced into larger organizations and a formally defined organization structure of the enterprise already exists. In this case, the current organizational structure has to be depicted in the workflow management system, either by direct modeling or by referral to an external resource repository, such as an X.500 directory or the human resources module of an ERP software. The advantage of this approach is the identity of the organizational structure within the workflow models and the real organizations. If workflow models are to be modified by domain experts as opposed to system administrators, it is easier for them to relate to the organizational model depicted in the system. However, most commercial workflow management systems lack basic entities defined in the organizational theory, such as organizational position or project team. This conflict can only be resolved, if the workflow management system allows the reference to an external repository, or if the existing entity types can be modified to suit the actual enterprise structure. An example for a semantically rich organization model is depicted in figure 2. This model can map to a large number of real world organizations, be it matrix- or hierarchical-style organizations. However, the model does not include technical resources which are of increasing importance as workflow technology is extended from the traditional administrative domain to technical applications such as shop floor automation.

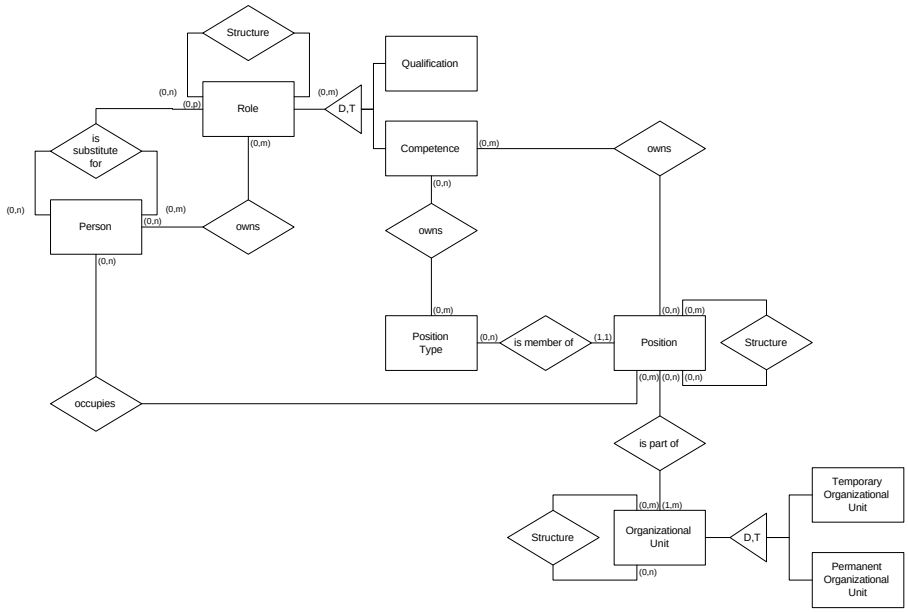

Fig. 2. Organizational Reference Meta Model [1,22]

6 A Generic Resource Meta Model

The generic meta model presented in figure 3 was designed to satisfy both workflow vendors that follow a technology-driven approach to resource modeling as well as vendors, that want to incorporate a complex organizational model into their workflow management system. It can serve as the starting point for the design of a product-specific meta model, but it can also be used for the conversion of resource models of different vendors. Central entity type of the resource meta model is the workflow participant. The participant acts as the anchor point for the workflow activities, i. e. workflow activities may reference workflow participants as performers and/or responsible actors. Processes may reference workflow participants in order to define process managers or case workers.

A workflow participant can either be an elementary resource, a role or or a set of resources. While resources are elementary entities of the organization such as human actors, intelligent agents or machines, sets of resources group these elementary resources an provide a common set of attributes for their members. Examples for sets of resources are e. g. a department, a set of machines or a multi-agent-system. Resources have an attribute `resource_type` which is used to differentiate technical and human resources, e. g. if a workflow activity requires human decision-making, the resource manager can query this attribute to return only human resources to the requesting system.

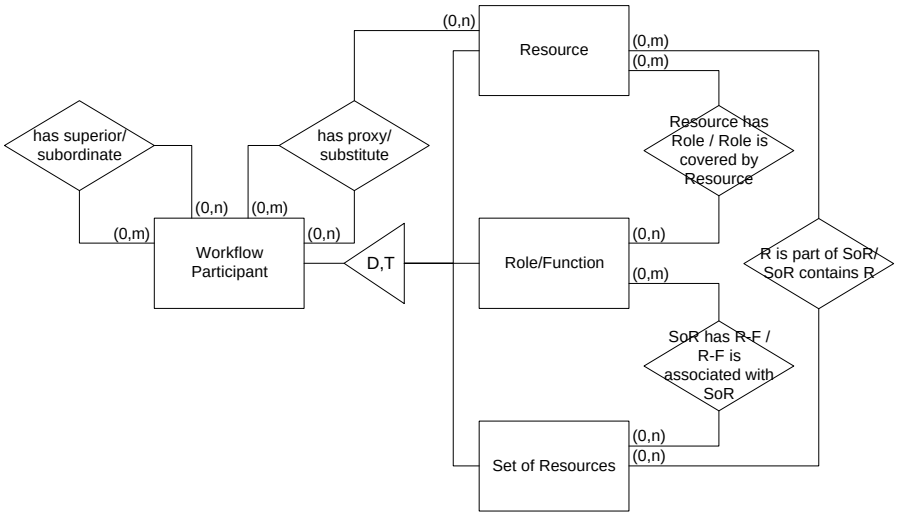

Fig. 3. Generic Resource Meta Model

Roles and functions serve a twofold purpose. On the one hand they can represent qualifications and competencies of resources, on the other hand they can represent a complex set of attributes associated with an organizational position. While a qualification can also be assigned to a resource directly by means of an attribute (such as the attribute “language skills” with the value “Spanish”), competencies should be separated from resources, because they are a result of an organizational assignment and can be granted and revoked by a third party, such as the privilege to approve expenses over a specific amount. A complex set of attributes could be grouped e. g. in the role “Department Head”. Since there is a superior/subordinate relationship defined on workflow participant, elementary roles can be grouped into complex roles. Roles and sets of resources need to be resolved at runtime, because only elementary resources are capable of performing activities. The relationship types between resources, roles and sets of resources can be interpreted as follows[1]: A resource may have several roles, a role may be covered by several elementary resources and/or several sets of resources. A set of resources may contain several elementary resources, however, it may also be empty to serve as a placeholder for future reference.

Workflow participants may be organized in a hierarchical or matrix structure, in order to represent organizational hierarchies or relationships between machine parts. The superior/subordinate relationship type is modeled at the workflow participant level and can be inherited by resources, roles and sets of resources eventually.

The substitute relationship is modeled as a ternary relationship type between workflow participant (twice) and resource, for security reasons. In most workflow

[1] Despite their similar cardinalities, these relationship types are modeled at the decomposed level of entity types in order to express their semantic differences. It is, however, possible, to model a single “is related to” relationship type at the workflow participant level instead.

management systems, a substitute inherits all the privileges of the resource it substitutes for. It may be necessary to restrict this inheritance to specific roles of a resource, thus enabling several substitutes to act for one resource without interfering with each other. An example for this is the director of a company's division that is also the leader of a project team at the same time. In case of her absence she would most likely name a substitute for her work in the department and a different substitute for her work in the project team. Moreover, she might want to exclude a specific role from the substitute's authorizations, such as her authority to sign contracts over $1,000,000.

The proposed meta model can be used for the mapping of an existing organization to the organizational meta model provided by a specific workflow management system as well as for the conversion of resource data between two different application systems that implement a resource management facility. For example, the organizational meta model of WorkParty as described in [22,15] would be mapped as follows: Organizational units, organizational positions, position types and levels would become instances of set of resource, person and resource would be mapped to resources, tasks and roles would be mapped to role. In addition to a process interchange format as described by LEE et al. [33] this fosters the exchange of process and resource models between different workflow management systems.

7 Feedback Evolution - Enabling Organizational Learning

Even in well structured processes as they can be found in so-called production workflow environments, there are still a considerable number of exceptions to be handled. Usually a workflow administrator or the superior of the current activity performer is notified if the workflow reaches an exception state. The importance of efficient exception handling is pointed out by SACHS, who states that the efficiency of work is less dependent on the structure of the workflow than on the exception handling capabilities of the resources involved in the process [34].

In the audit trail data of a workflow management system information about the execution of activities by workflow participants is stored. This data can be used to compute a level of experience that increases with the number of activity instances a participant has performed. This way, a dynamic evolution of human resources can be realized by determining a level of expertise from the analysis of stored audit trail data. Instead of a hard-coded exception handling scheme, the workflow-engine can assign work to a more experienced person in an error situation. This way, line managers are less concerned with troubleshooting activites, such as the reassignment of a work item, and can perform higher-value activities. The economical impact of a qualification-adequate task assignment can be measured using the hedonic wage model [35]. The hedonic wage model states, that the overall cost of labor increases, if workers perform tasks below their level of qualification and spend less time on assignments they have originally been hired for. The information stored in the workflow audit trail can be used to for monitoring these effects.

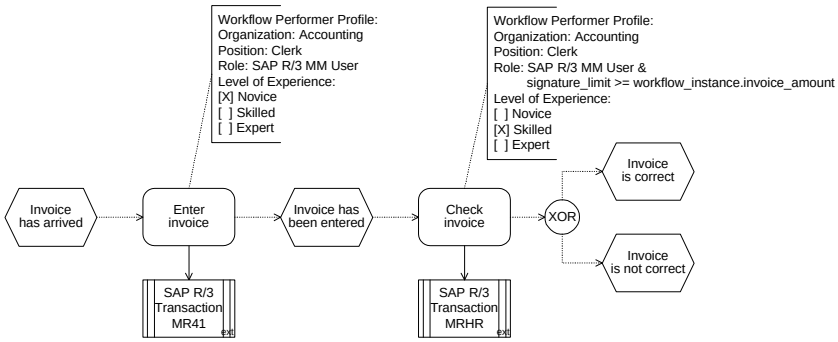

Fig. 4. Sample workflow performer profiles

The use of historical workflow data to assess user capabilities can also be used to differentiate resource qualifications e. g. with regard to processing time or acceptance rate. Depending on the overall priority of a process it might be desirable to assign an activity to the actor with the least average processing time of the specific activity. In other cases it may be necessary to minimize the time until a work item is accepted by a workflow participant. An analysis of the audit trail data can provide the resource management system with the relevant information for this decision. An example for resource assignments using the level of experience of a resource as a preference is given in figure 4.

8 Security Considerations

The assignment of workflow activities to a resource may not only depend on the qualification and competencies of the resource, but also on the time of the assignment. For example, a temporary worker in a bank may substitute for a clerk for a limited period of time, therefore, activity assignments resulting from this substitution should only be active during this specified time frame.

On the other hand, the planning of organizational development may be performed a considerable time before it is being activated. In the SAP R/3 ERP-System this fact is represented using different organizational plans within the organizational development module HR-PD, while only one of these plans can be set active. The resource management facility has to ensure that e.g. the promotion of a resource can be put in effect either immediately or on a specified point in time. ADER proposes the handling of security information as an additional entity type within the resource meta model [36]. In order not to increase the complexity of the resource model we propose the implementation of time constraints for roles should be handled on the attribute level, e. g. by adding the attributes “valid_from” and “valid_through” to the entity type role. If an activity becomes assignable during this time, it may be assigned to the resources that are members of this role. The workflow management system or the resource management facility respectively have to ensure that work items can only be selected during the activation period of the role responsible for their initial

assignment. If an activity has been assigned to a resource based on a competency and has not been executed while the competency has been revoked, the work item has to be removed from the worklist of this resource. The tracing of this information may become increasingly complex, if a work item is transferred from one resource to another by means of delegation or substitution.

For auditing purposes it should be possible to trace the changes of a resource profile, e. g. the granting and revocation of privileges over time. Therefore, a resource manager should implement a version concept that stores relationships between roles and resources with the beginning and end of validity.

9 Conclusions

The efficient and flexible modeling of corporate resources will become an increasingly important topic with the advance of distributed systems and collaborative applications. While research areas such as role-based access control and organizational meta-models mainly focus on structural characteristics of resource models, dynamic issues such as the economically analysis of assignment policies have not been thoroughly researched yet. After a brief overview about the research in related areas we identified several open areas of research within the context of resource modeling.

After discussing a technology-driven and an organizational-driven approach to resource modeling we have presented a generic resource meta model. This meta model incorporates both aspects and provides a high level of expressiveness while maintaining structural clarity through its compact form. The understanding of the approach to resource modeling taken by the vendor of a workflow engine can provide valuable information for the workflow designer. Not only does it explain the structure of the vendor's meta model, but it can also direct the modeling efforts of the workflow designer. If a system provides a technology-driven resource model, the workflow designer has to model the workflow process first, before the relevant resources should be modeled in the workflow system. Opposed to this, in case of an organization-driven meta model the modeling of the organization's resources and the workflow processes can be done in parallel, because there are less dependencies between the models.

The existing structural assignment mechanisms can be complemented by using historical data about the execution of workflow instances for staff resolution purposes. This fosters the organizational development and may provide economical benefit through a more qualification adequate assignment of activities to resources. In addition to this, the introduction of validity dates for roles could enhance the security level of a resource meta model considerably.

Acknowledgements

We would like to thank the members of the Workflow Management Coalition's Technical Committee for many fruitful discussions on the presented resource model. Moreover, we would like to thank Dr. Michael Rosemann (QUT Brisbane) Prof. Stefan Klein and Holger Schmeken (Unversity of Muenster) for their valuable insights on the contents presented in this paper.

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