Supply Chains in the Context of Enterprise Modelling

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Abstract: Methods for enterprise modelling usually offer limited support for the description of logistical aspects. The paper at hand presents a concept for modelling supply chains in the context of enterprise modelling. This concept, called *transportation channel*, is part of a resource modelling language which complements a business process modelling language. Both languages are part of a method for multi-perspective enterprise modelling. The term transportation channel also covers the transport of information between information systems or humans. The latter one is sometimes referred to as *communication channel*.

1 Motivation

The analysis, representation and management of knowledge about an organisation and its processes have always been very important (cf. [KP00], p. 142). Methods for enterprise modelling usually offer different languages for describing an organisation from different perspectives and on several levels of abstraction (cf. [Fr94]). Ideally, there is only one model of an organisation and different model types represent different views. Hence, languages used for enterprise modelling have to be integrated. For example data needed for the execution of business processes can be described using a data or an object model (integration of dynamic models with software-technical abstractions). An organisational unit in an organisational chart might be responsible for a business process (integration of static and dynamic models). Resources are an additional concepts and essential for the execution of processes (cf. [Po99]). Processes and their relationships only describe *what* has to be done. Resources assigned to processes specify *who* has to work on a process and *what* is required to perform a process (cf. [Ze03]). Modelling resources offers the opportunity to determinate the economic efficiency of a process (cf. [Nü01] and [Po99]).

Some methods for enterprise modelling offer language features for modelling resources in the context of business process modelling. Nevertheless the transportation of resources is covered only in a limited manner. This includes physical (e.g. spare parts) as well as intangible resources (information). There are several approaches for modelling and improving supply chains (a short overview is given in [Ka05]). One prominent approach is the *Supply Chain Operations Reference* model (SCOR model) by the *Supply*

Chain Council (cf. [BR03], pp. 1). The SCOR model and other modelling languages foster a view on the supply chains concerning one or more organisations. Basic concepts are logistical processes and their links between different companies. Hence, they are specialised on describing supply chains and offer additional concepts for modelling resources and organisational units. Our approach is slightly different: Transportation channels are one language feature in a set of languages for multi-perspective enterprise modelling.

The work presented in the paper at hand has been done in the context of the design of a resource modelling language called MEMO-ResML. The ResML (short for *Resource Modelling Language*) is one of the languages provided in the MEMO method. MEMO (acronym for *Multi-Perspective Enterprise Modelling*) is a method for modelling enterprises using different views and levels of abstraction. Further information on MEMO can be found in [Fr94] and [Fr02]. The modelling of views in MEMO is accomplished by providing different modelling languages, each of which provides special language features for a view on an organisation's information system. The MEMO-OML (*Object Modelling Language*) allows for the specification of object models (cf. [Fr98] and [Pr02]). There are languages for modelling an organisation's strategy and organisational aspects (cf. [Fr99]). Regarding organisational aspects, the MEMO-OrgML (*Organisation Modelling Language*) comprises languages for describing an organisation's structure and business processes. The ResML is part of the OrgML and defines language features for modelling resources, used in the processes. An overview of the ResML is provided in [Ju03].

2 Related Work

The need for modelling resources is documented in various publications on business process modelling languages and methods: Richter-von Hagen and Stucky for example list *resource classes*, *organisational units* and *roles* as special resources (cf. [RS04]). They define a resource class as a set of resources sharing similar properties. Organisational units are special resources which can be found in the organisational structure. Roles refer to resource classes which can be derived from skills and competencies of resources. Succi et al. subsume *human resources*, *roles* and *skills* under the term *resources* (cf. [SPV00]). Human resources are the people working in an organisation and people can fill roles. Every human resource has special skills and skills are needed to fill a special role. Consequently, Succi et al. assume a close coupling between people, skills and roles. In the context of Workflow Management, typical resources are participants (person, information system or role) and applications (cf. [Mü99] and [No02]). Podorozhny et al. present a language for the modelling of resources in the context of the process modelling language Little-JIL (cf. [WV98] and [Po99]). The authors provide language features for the description of resource instances and types as well as relationships between resources. The ARIS-method for enterprise modelling denominates several different kinds of resources (cf. [Sc98] and [Sc99]). Those include organisational units, human resources, machine resources, computer hard- and software as well as information objects.

This rather small selection of publications emphasises two aspects: First, resources are important for business (process) modelling and research is done on resource modelling. Second, different authors have a different understanding of the notion of resources. Many authors regard human work as one kind of resource. Work can be assigned to human beings (concrete resources), organisational units (an abstraction over a set of human resources) or roles. Roles can be filled by human resources and usually require special skills or competencies. The latter are often referred to as resources but they are rather properties of (human) resources. Skills and competencies are of relevance for an organisation if there are some human resources possessing those skills (and competencies). In the same way, organisational units are orthogonal to resources. Organisational charts are a tool for structuring an organisation and consist of organisational units and their relationships. Resources might be attached to an organisational unit. Other important types of resources are machine resources as well as raw material, software and information.

Besides modelling languages offering explicit language features for modelling resources, there are more general languages: Entity Relationship Diagrams (ERD) or UML class diagrams. Those languages can be used to describe structural aspects and can also be used for modelling resources. Petri-nets[1] can—for example—be used for modelling processes and associated resources (cf. [Pe80] and [DO96]). Petri-nets are bipartite graph with one node-type called place (representing passive aspects in a process model like object stores or conditions) and transitions (processes or events). In classical place-transition-nets (P/T-net) places can contain anonymous token. Resources can be modelled by a subnet of a Petri-net. Higher Petri-nets with non-anonymous tokens allow for the modelling of complex token types. Predicate-transition-nets (Pr/T-nets) have tuples as tokens on places (cf. [Ge87]). Property values of resources (and different states) can be represented by different tuples. The *Unified Modeling Language* (UML) mainly addresses software development but offers rudimentary features for enterprise modelling (cf. [Je04]). Processes can be modelled using activity diagrams which consist of activities and the control flow between them. Static aspects of an enterprise model can be modelled using class diagrams. As resources qualify as static, they are described by class diagrams. UML activity diagrams also allow for the modelling of flow of objects between activities. IDEF uses similar modelling languages (cf. [MM98]). Information objects and resources are modelled by entity-relationship-models (IDEF1X, cf. [MM98], pp. 221) object diagrams (IDEF4, cf. [Ma95]). In contrast to general purpose languages, providing domain-specific language features offers the opportunity for reusing already specified concepts in that domain. Those concepts are defined as special language features with typical attributes and relationships to other language concepts.

[1] There are other process modelling languages available. We present Petri-nets in more detail, because they are very popular for formal process specification. There exist a plethora of variants of Petri-nets allowing the modelling of processes on different levels of abstraction (e.g. hierarchical, timed or probabilistic nets).

3 Transportation Channels

Transportation often requires different resources. The MEMO-ResML provides a special language feature for modelling a *transportation channel*. Figure 1 shows two examples illustrating the need for the notion of transportation channels. A simple communication between a customer and a call-center employee is shown in Figure 1a. The customer uses a telephone for contacting the call-center of an organisation. The call-center employee uses a telephone system for receiving calls. Hence, there are two parties participating in a communication connection and they both use a special resource for accessing the communication channel. This channel is a phone connection between the participants. The channel can be used for exchanging information between customer and call-center-employee – the information is not included in the diagram in Figure 1a.

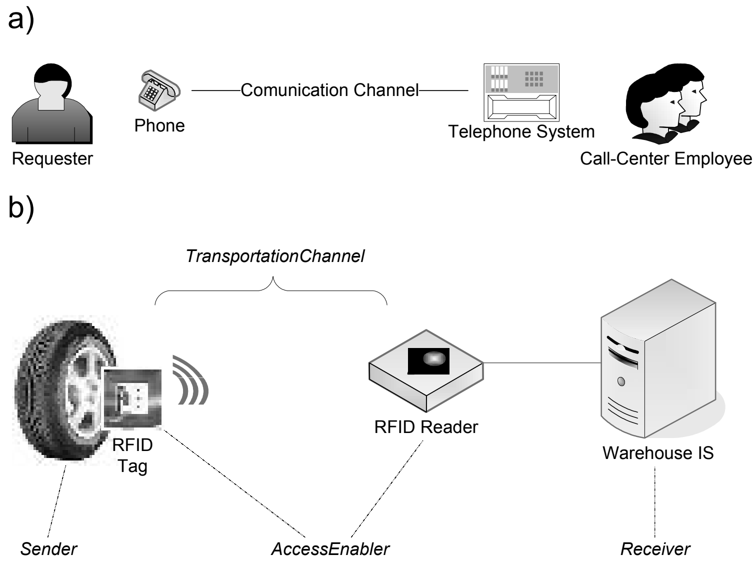

Figure 1: Examples for Transportation Channels

Figure 1b shows a different example for a special kind of transportation channels: Transmission of a product's data to a warehouse system. Radio-based technology allows for transferring data from a product using RFID-technology. RFID stands for *Radio Frequency Identification* (cf. [SF05], p. 45) and is based on special RFID-tags attached to a product (cf. [SH04], p. 373 and [LL05], pp. 198). Such a tag stores data on a product and transmits it to a receiver if it is close to it. Data might only be a unique identifier or a record of information (cf. [Fi02]). In case of an identifier, concrete data on the product is stored in an information system (i.e. a central database). Otherwise, all data is stored on the RFID-tag and has to be transmitted to the receiver. The diagram in Figure 1b shows a product with an RFID-tag attached to it on the left side and a warehouse system using an RFID-reader on the right side. The transportation channel is restricted by the maximum distance between RFID-tag and reader.

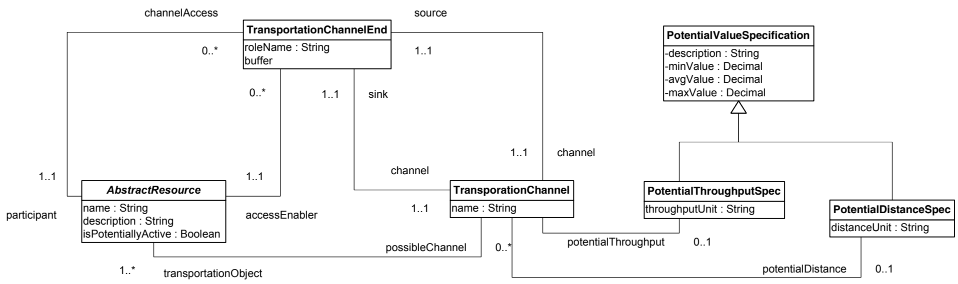

Figure 2: Meta-model for Transportation Channels

Properties of transportation channels are reflected in the ResML meta-model shown in Figure 2. A transportation channel (type TransportationChannel) has a unique name as well as a source and a sink (represented by TransportationChannelEnd). Every transportation channel end can be associated with a role identifier and may contain a buffer. There is one resource, which has the role of a sender and has to be associated with the source of a transportation channel. The receiver is connected to the sink. Sender and receiver (participant) are resources. There are resources, which establish the access to a transportation channel. Examples are phone and RFID-tag in Figure 1 as well as a branch of a delivery service or a network computer. Those *access enablers* to a communication channel are shown in Figure 2 using a relationship between TransportationChannelEnd and AbstractResource with the role name accessEnabler. The transportation object is also a resource and attached to the transportation channel by the relationship between TransportationChannel and AbstractResource.

The transportation of objects is usually limited by internal or external factors. Moving a physical object from one location to another takes some time. Transferring data between two network nodes is restricted by the bandwidth of the communication network. Those attributes can be described by PotentialDistanceSpec and PotentialThroughputSpec. Both have a minimum and a maximum value for specifying the range and/or an average value. Additionally, each of the meta-types has an attribute for the unit. One might argue that modelling concrete values in a conceptual model is not adequate. The distance between an online bookseller and its customers has, for example, a large interval from a few up to several hundred kilometres[2]. This information and a possible average value are not useful for further analysis in the given context. Moreover, those values might vary over time but a conceptual model usually should be stable for a longer period of time. Consequently, a user should only model those values, which are fairly invariant over time and which can be determined reliably. Examples are distances between branches or the bandwidth of well established communication channels.

The meta-model in Figure 2 omits the specification of relationships between transportation channels. Possible kinds of relationships might refer to alternatives,

[2] An alternative to this is specifying the distance using a temporal unit. One can model a minimal time period, which will be needed for delivering a physical object to a customer. In the same way an average time span and a maximum period – which must not be exceeded – may also be given.

dependencies or combinations of channels. The modelling of alternatives offers the opportunity for describing different kind of channels. Each of these channels can be used for the transportation of the same kind of resources from a given sender to a receiver. Differences between the channels might be their distance, throughput or costs for access enablers. Some transportation channels usually require the existence of others. A logical network connection (e.g. a TCP connection) depends on a physical connection between network nodes. Combinations of transportation channels represent a set of channels which are used together for the transportation of resources. These channels might be used in sequence or in parallel. The sequential usage of transportation channels implies that one resource is transported via several channels. Parallelism between channels reflects the fact that a resource can be divided. Each part is transported using a different channel.

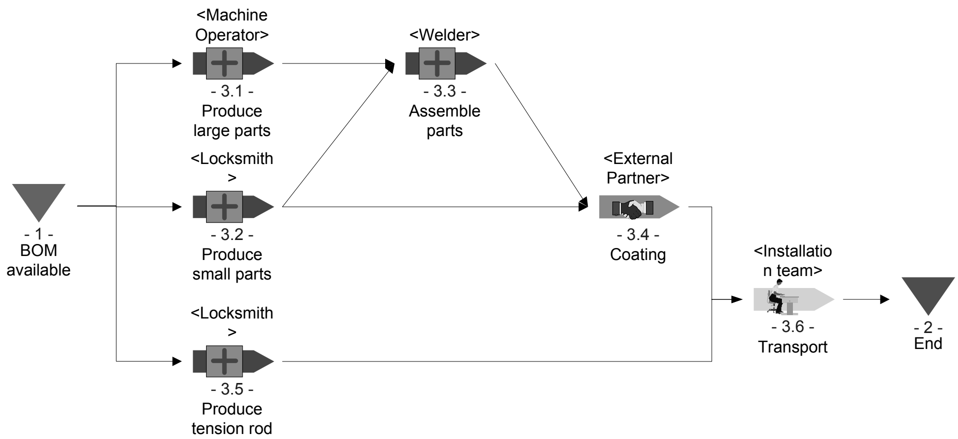

Figure 3: Sample Production Process (source: [Di01], p. 36)

4 Modelling a Supply Chain using Transportation Channels

Figure 3 shows an excerpt of the process model of a production process. The process model has been developed in a project concerning the optimisation of resource allocation in a trade company whose main business is building steel constructions (cf. [Di01]). The process usually starts with the availability of the bill of material (BOM) for the production of a building. Large parts are produced using a special machine and small part by locksmiths. Some of the small parts are attached to large parts by welders. All parts have to be coated by an external partner. Finally, they are moved to their final destination (i.e. the location of the building).

The process model in Figure 3 documents two problems concerning the description of transportation tasks in business process models: (1) The transportation of objects is not modelled at all (e.g. moving parts to the external partner). Relevant information on time or distance is not considered for resource optimisation. (2) Transportation is modelled by a process. Processing time (time needed for the transportation of an object) can be specified. But, we do not consider "process" as the right abstraction for transportation. The notion of a process usually does not include relationships between spatial information (e.g. moving an object from a source to its destination). Therefore, the model of the production process has been redesigned using *transportation channels*. Figure 4 shows the model of the transport of parts from the welder to the coating line. Sending parts is coordinated by the line manager of the trade company. Available storage in the trade company is 65 m³. The line manager initiates sending parts when the capacity of the storage is to be exceeded. The line assistant of the external partner handles incoming parts and allocates them to the coating line. The transportation of the coated parts back to the trade company and moving them to their final location is modelled analogously. Some of the information given in Figure 4 is used for the computer-supported optimisation of the resource allocation in the trade company (cf. [Di01]). Others are only used for documentation purposes (the size of buffers has not been taken into account because the parts have been grouped to lots by the line manager). The integration of a transportation channel and a business process model is realised by the allocation of resources. The sending resource (welder) is allocated to the business process where the part is produced. The receiving resource is associated with the process receiving the part. Further control flow between sending and receiving process is not necessarily needed.

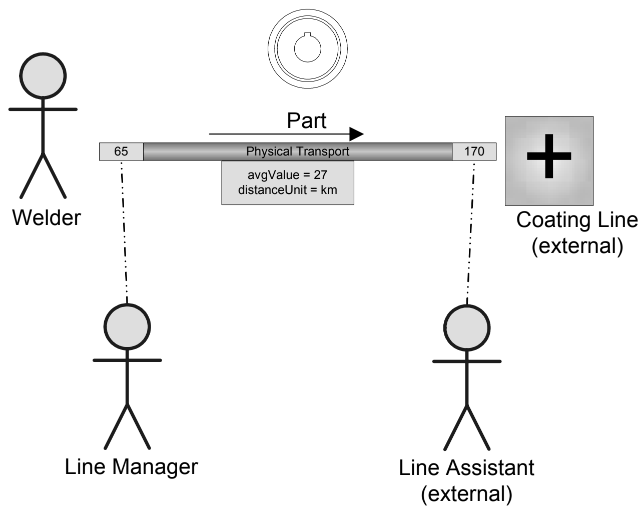

Figure 4: Transportation of parts

The notion of *transportation channels* proved to be more adequate for the modelling of transportation processes than usual processes. Both, transportation channels and (business) processes can be further described by temporal information (e.g. average duration, start and end time). Additionally, both are performed by resources. But there are also some conceptual differences. In contrast to business processes, transportation channels allow for the description of spatial aspects (i.e. distances between sender and receiver). They also support special roles like *sender* and *receiver* as well as special resource needed for accessing a transportation channel. These concepts are usually not part of business process modelling languages or other languages in the context of enterprise modelling. Instead, general purpose languages like ERM and class diagrams are provided. But, these languages do not offer domain-specific concepts and constraints on the level of the language specification. A modeller has to reconstruct these concepts on his own.

5 Future Work

The paper at hand presents the conceptualisation of a language feature for modelling supply chains in the context of enterprise modelling. Further research has to be done on the evaluation of the applicability of transportation channels in the context of business processes. Possible areas of investigation comprise:

Finding bottlenecks: If all transportation channels between resources are quantified regarding distance and throughput, bottlenecks might be identified. The identification of bottlenecks is based on the modelling of all transportation channels including distances and throughput. All these channels can represent a network of transportation channels. An analysis regarding bottlenecks identifies those parts of a communication network, which represent the part of a channel with the lowest bandwidth.

Cost optimisation: The usage or consumption of resources results in costs. Resources in MEMO-ResML can be annotated with relative costs. Examples for the annotation of relative costs are money per piece, money per time period (e.g. €/hour) or money per physical unit (e.g. €/m³). A modelling tool supporting the ResML might allow for the modelling of different alternatives for transportation channels. Each of these channels can have distances and/or throughput of its own as well as different resources. A tool can calculate the total costs of all alternatives and help the user to find the channel with the lowest cost. Furthermore, costs for usage of resources can be adjusted over time (e.g. prices for data transmission are getting lower) and a new analysis can be started.

Logistics network analysis and planning: The system of all transportation channels – regarding the transport of physical goods – in a resource model can be interpreted as a logistical network (cf. [Sc04]). Such a network shows transportation relationships between different locations. A prerequisite is that sender and receiver are associated with a location. This can be done by assigning a resource (sender and receiver are resources) to an organisational unit. Organisational units can be modelled using organisational charts which are part of the MEMO-OrgML. A location might also be determined by the organisational unit which is responsible for the execution of a process to which the sending or receiving resource is assigned to. Given such a net – nodes are resources assigned to locations and edges represent transportation channels – methods for optimising logistical networks can be applied (cf. [Fe04]).

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