Supply Chains in the Context of Resource 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. A short overview on enterprise modelling as well as business process modelling will be given in the paper. The basic conceptualisation of the resource modelling language is presented in more detail. The notion of transportation channels is motivated by some examples and defined by a meta-model. The potential of transportation channel is shown by an example process from a company producing steel constructions.

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1 Motivation

The analysis, representation and management of knowledge about an organisation and its processes have always been very important (cf. [KoPl00], p. 142). Methods for enterprise modelling usually offer different languages for describing an organisation from different perspectives and on several levels of abstraction (cf. [Fra94]). Perspectives comprise static (e.g. organisational charts, data and object models) as well as dynamic aspects (cf. [Fra02]). Examples for model types for describing dynamic aspects on different levels of abstraction are *value chains* and *business process models*. 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. [PSLO99a]). 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. [Zelm03]). Modelling resources offers the opportunity to determinate the economic efficiency of a process. Usually resources are not available in an unlimited quantity (cf. [Nübe01], [PSLO99a] and [PSLO99b]). Hence, the usage of scarce resources has to be taken into account during the analysis or simulation of processes as well as in the development of an information system.

Some methods for enterprise modelling offer language features for modelling resources in the context of business process modelling (an overview is given in section 2). Nevertheless the transportation of resources is covered only in a limited manner in the context of enterprise modelling. This includes physical (e.g. spare parts) as well as intangible resources (information). There are several approaches for modelling and improving supply chains available (a short overview is given in [Kasi05]). One prominent approach is the *Supply Chain Operations Reference* model (SCOR model) by the *Supply Chain Council* (cf. [BoRo03], 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 unit. Our approach is slightly different: Transportation channels are one language feature in a set of languages for multi-perspective enterprise modelling.

The paper at hand presents a language feature for modelling transportation channels. This feature is part of a resource modelling language of a method for 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*. A short overview on related work on resource modelling is presented in section 2. The resource modelling language and the corresponding enterprise modelling method are presented in section 3. Section 4 covers the notion of transportation channels. This is motivated by some examples in section 4.1. Section 4.2 explains the part of the resource modelling language's meta-model covering transportation channels. An example for the application of the notion of transportation channels for modelling supply chains is given in section 4.3.

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*, *or-*

ganisational units and *roles* as special resources (cf. [RvHS04]). 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 of an organisation. 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. [zMüh99] and [Nori02]). Podorozhny et al. present a language for the modelling of resources in the context of the process modelling language Little-JIL (cf. [WeVo98], [PSLO99a] and [PSLO99b]). 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. [Sche98] and [Sche99]). Those include organisational units, human resources, machine resources, computer hard- and software as well as information objects.

This is a rather small selection of publications dealing with resource-modelling in the context of business process modelling. The selection 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. Typical relationships are the decomposition of organisational units and superior/subordinate-relationships. Resources might be attached to an organisational unit. Other important types of resources are machine resources (production machinery, computer hardware and periphery) 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. [Pet80] and [DeOb96]). 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. For example the availability of a resource can be represented by one place: If there is a token on the place, the corresponding resource is available. Otherwise, it is not available. Different states of a resource can be modelled in the same way: There is a place for every possible state of a resource and a token on the place represents the current state. Additionally, the quantity of available resources can be represented by the number of tokens on a place. 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. [Gen87]). 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

[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).

for enterprise modelling (cf. [JRH+04]). 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. IDEF uses similar modelling languages (cf. [MeMA98]). Information objects and resources are modelled by entity-relationship-models (IDEF1X, cf. [MeMa98], pp. 221) object diagrams (IDEF4, cf. [MKB+95]).

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. A modeller can use these language features as a template for domain-specific objects. He does not need to describe those objects from scratch. Furthermore, well-defined concepts fundamental for analysis functions. Such a definition can be implemented in a modelling tool.

3 MEMO-ResML

The MEMO-ResML is a language for the modelling of resources in the context of business process modelling. 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 [Fra94] and [Fra02]. 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 (*MEMO Object Modelling Language*) allows for the specification of object models (cf. [Fra98] and [Pra02]). There are languages for modelling an organisation's strategy and organisational aspects (cf. [Fra99]). 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. A short overview of the ResML is provided in the following. More in-depth descriptions on the modelling of resources in the context of the MEMO-OrgML can be found in [Jung03a] and [Jung03b].

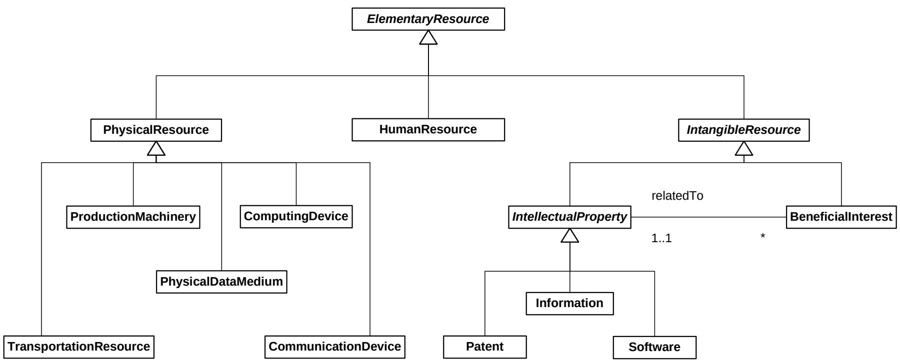

Figure 1: Resource types in MEMO-ResML

The MEMO-ResML specifies three kinds of language features: resources, resource relationships and the allocation of resources to business processes. Some of the resource types are shown in the part of the meta-model given in Figure 1. All attributes and most relationships are omitted in the figure. Elementary resource types can be classified as human, physical or intangible resource types. The meta-type HumanResource is not further specialised. PhysicalResource has five subtypes representing different kinds of physical resources. IntangibleResource can be divided into IntellectualProperty and BeneficialInterest. Concrete subtypes of BeneficialInterest are Software, Information and Patents. A beneficial interest represents the right to use an intellectual property. Software licenses are an example for a beneficial interest referring to software. In the same way, someone can receive the beneficial interest for using a patent or for the usage and/or reproduction of information. Both, intellectual property and beneficial interest can be seen as resources. Intellectual property is a resource for the copyright owner and a beneficial interest is a resource for the licensee.

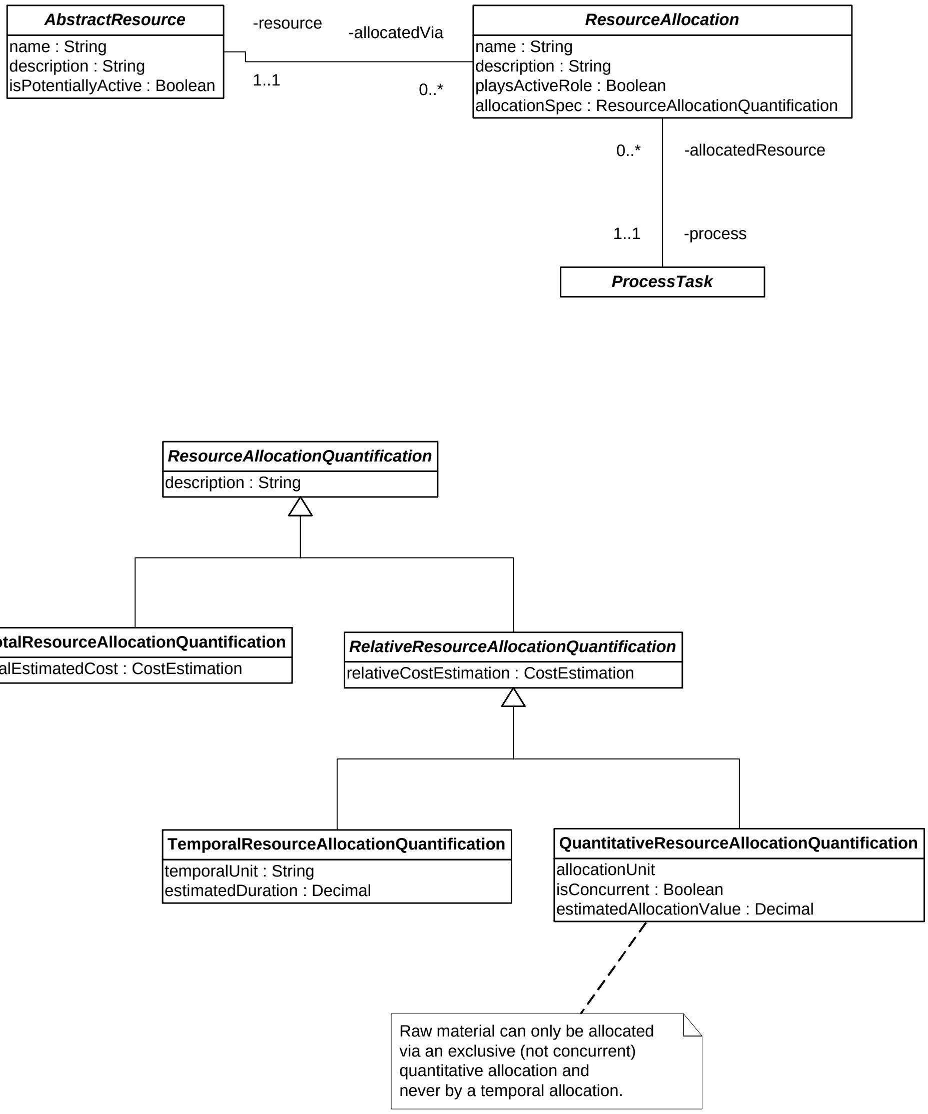

Figure 2: Meta-model of resource allocation

The MEMO-ResML offers several types of relationships between resources: substitution, concurrency and a generic relationship. A substitution relationship between two resources represents the fact that one of the resources might replace the other. A concurrency relationship represents a mutual exclusion between two resources. If one of the resources is assigned to a process, the other one must not be assigned. A generic relationship only relates two resources and has no further semantics. A modeller – using the ResML – can further refine such a generic relationship. Usually, resources are necessary for the execution of a process. The usage of a resource in the context of a process can be described in more detail, depending on the kind of usage. Resources can be consumed during the execution of a process (they will not be available for succeeding processes) or they can be used (no consumption). We subsume the assignment of a resource to a business process under the term *allocation*.

The meta-model for resource allocation in MEMO-ResML is given in Figure 2. The abstract type ProcessTask is part of the meta-model of the MEMO-OrgML and represents processes. AbstractResource is a supertype of ElementaryResource and specifies the attributes name, description and isPotentiallyActive. The latter one indicates whether the resource is able to play an active role in any process or not. If it is set to true, a resource can play an active role in at least one process. It is set to false if not. Resources (AbstractResource) are allocated to processes via an allocation (ResourceAllocation). The attribute playsActiveRole indicates whether an allocation plays an active role in a given process. It can only be set to true if the resource is potentially active. allocationSpec quantifies the allocation of a resource to a process. The quantification can be divided into a total or a relative quantification. A total quantification only consists of cost estimation for the usage of the resource in the context of a process. A relative quantification relates the costs to the extent of the resource allocation. Concrete subtypes are TemporalResourceAllocationQuantification and QuantitativeResourceAllocationQuantification. A temporal resource allocation consists of a temporal unite (e.g. minutes) and an estimation of the time span a resource is used during the execution of a process. Total costs of a resource's usage can be calculated basing on the hourly rates of a resource. Examples for temporarily allocated resources are employees or production machinery. A quantitative allocation is used for resources which are consumed during the execution of a process (e.g. raw material). The attribute isConcurrent indicates, whether a resource can be used by different processes simultaneously. An example for a simultaneously usable resource is a database server. It can be used by several users at the same time. Hence, it is not allocated to one process for a given duration and can therefore not be allocated using a temporal allocation. Nevertheless, there is usually a capacity limitation for the usage of shared resources. A database server has a maximum number of transactions per second. This capacity can be exceeded, if the sum of required transactions per time unit of all processes is larger than the maximum.

4 Transportation Channels

Three major types of relationships between resources have been presented in section 3. A more complex kind of relationship involves the transportation of objects (resources can also be classified as general objects) from one actor to another. The transportation often requires other resources. The MEMO-ResML provides a special language feature for modelling a *transportation channel*. Some examples for motivating *transportation channels* as a special language feature are presented in section 4.1. The meta-model of transportation channels in the ResML is described in section 4.2. The potential of such a language feature is outlined in section 4.3.

4.1 Introductory Examples

Figure 3 shows some 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 3a. 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 3a.

Figure 3b illustrates the delivery of books from an online bookseller to the customer. A customer orders one or more books at the online store of the bookseller and the books are delivered using a delivery service. Both bookseller and customer have a special interface to the delivery service. Deliveries are collected at a branch of the transportation service (Figure 3b left). This notion of a branch might be a concrete location of a network node of the delivery service or might represent a transportation service's vehicle collecting deliveries from the bookstore. A customer – on the other side – can collect his books at a nearby branch of the delivery service or the deliveries are sent directly to his home. Both options are modelled by the logistics branch on the right in Figure 3b – the branch represents the interface of the customer to the delivery service. The book seller usually prescinds from the concrete routing of deliveries to his customers. This job is done by the logistics partner. Nevertheless, the sender might sometimes want to influence some parameters of the route. One simplified example is shown in Figure 3b: transportation of book to the customers is usually done by trucks. Other examples are the transport using airplanes and ships. Each example does not directly represent concrete parameters of the transportation like speed, distance or availability. The transportation vehicle shown in a model only stands for a prototypical vehicle representing some typical properties[1]. Consequently, these properties are not part of the transportation channel but properties of the transportation resource.

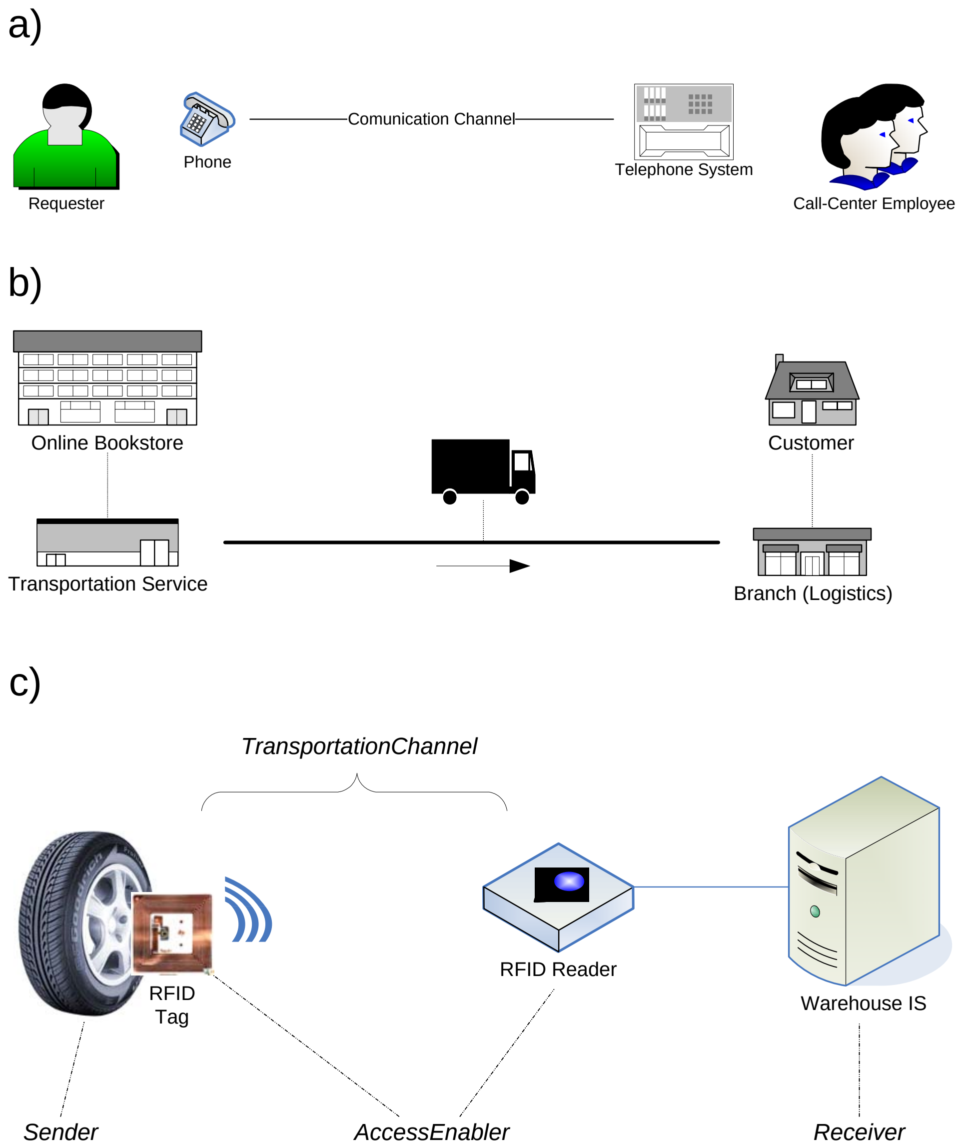

Figure 3: Examples for transportation channels

[1] An airplane can transport goods over long distances very quickly but depends on the availability of an airport. Ships are slow but inexpensive – compared to airplanes. They also depend on ports. Trucks can deliver goods everywhere (on land) but are slower than planes and more expensive than ships.

Figure 3c 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 the transportation data from a product using RFID-technology. RFID stands for *Radio Frequency Identification* (cf. [StFl05], p. 45) and is based on special RFID-tags attached to a product (cf. [StHa04], p. 373 and [LaLa05], 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. [Fink02]). 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 3c 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.

The examples in Figure 3 share some common properties. There is a sender and a receiver of (intangible or physical) objects: A customer sends information to a call-center employee (via a phone call); a book-seller sends books to a customer; a product sends data to a warehouse system. In any case, there are resources needed, which realise the access to a transportation channel (phone, logistics branch or an RFID-device). Transportation objects are usually resources like customer information, goods or product information on an RFID-tag.

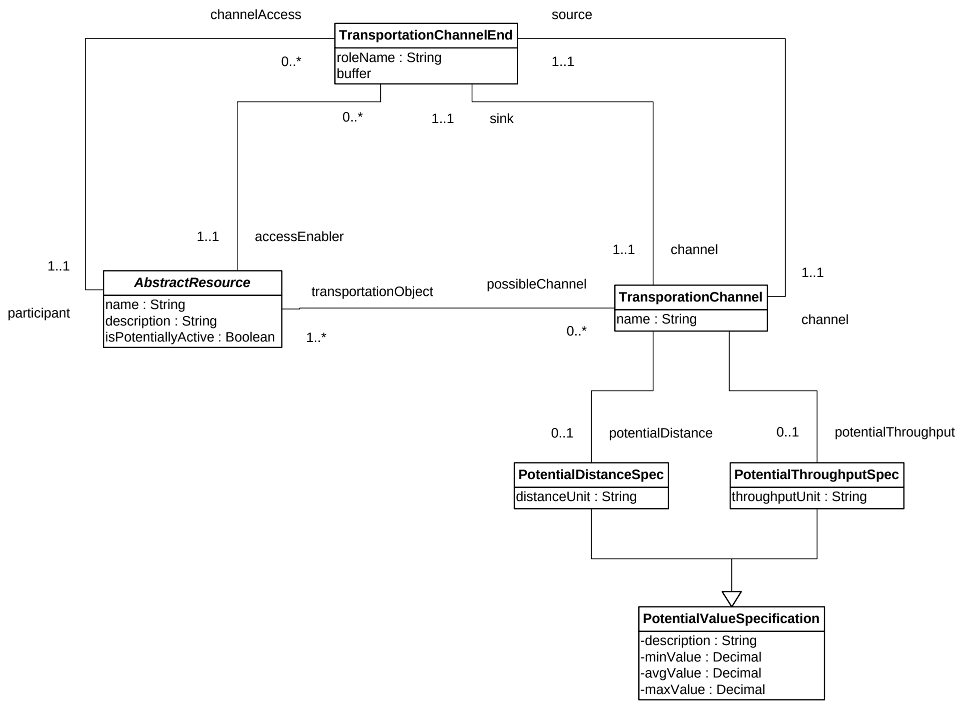

Figure 4: Meta-model for transportation channels

4.2 Transportation Channels in MEMO-ResML

As shown in section 4.1, transportation channels share common properties. Those properties are reflected in the ResML meta-model shown in Figure 4. A transportation channel (type TransportationChannel) has a unique name as well as a source and a sink (represented by Transportation-ChannelEnd). 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 the phone, branch of the delivery service or the RFID-tag in Figure 3. Those *access enable s* to a communication channel are shown in Figure 4 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.

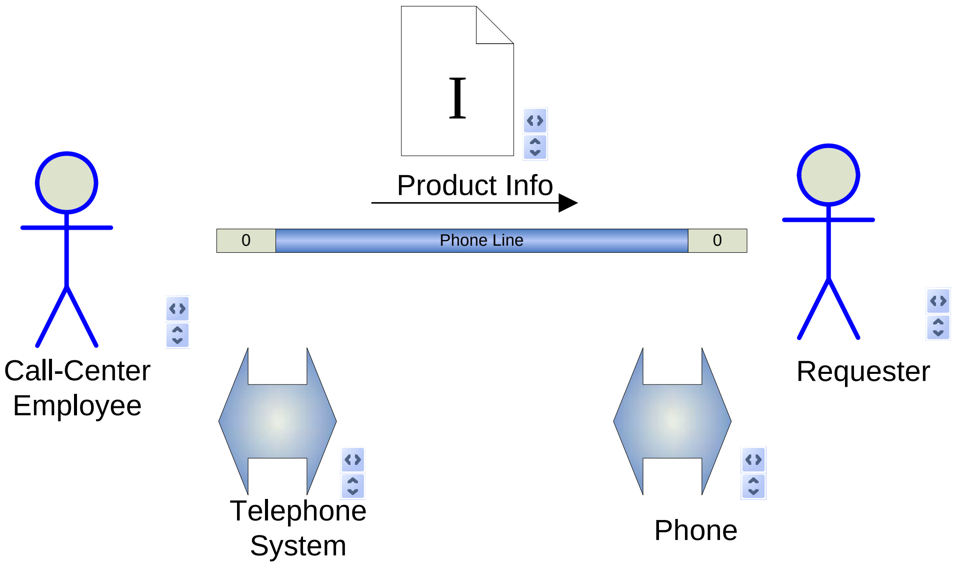

Figure 5: Example transportation channel for a call center

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, a maximum and an average 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[1]. 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 example given in Figure 5 models the transportation channel between a customer and a call-center (cf. section 4.1). The customer (Requester) requests some information from a call-center using a telephone line. He calls the center's number and the information is provided by a call-center employee. The customer's access device is his phone and the call-center employee needs an equivalent device (TelephoneSystem) for answering calls. The symbol above Requester and Call-Center Employee represent human resources. The document-like symbol with an inner letter "I" stands for an information resource. The double-arrow over Phone as well as Telephone System is the notation for communication devices. Every resource is supplemented by two small squares with rounded corners and two contrary arrows inside. These symbols are used for showing and hiding the attributes of resources

[1] 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.

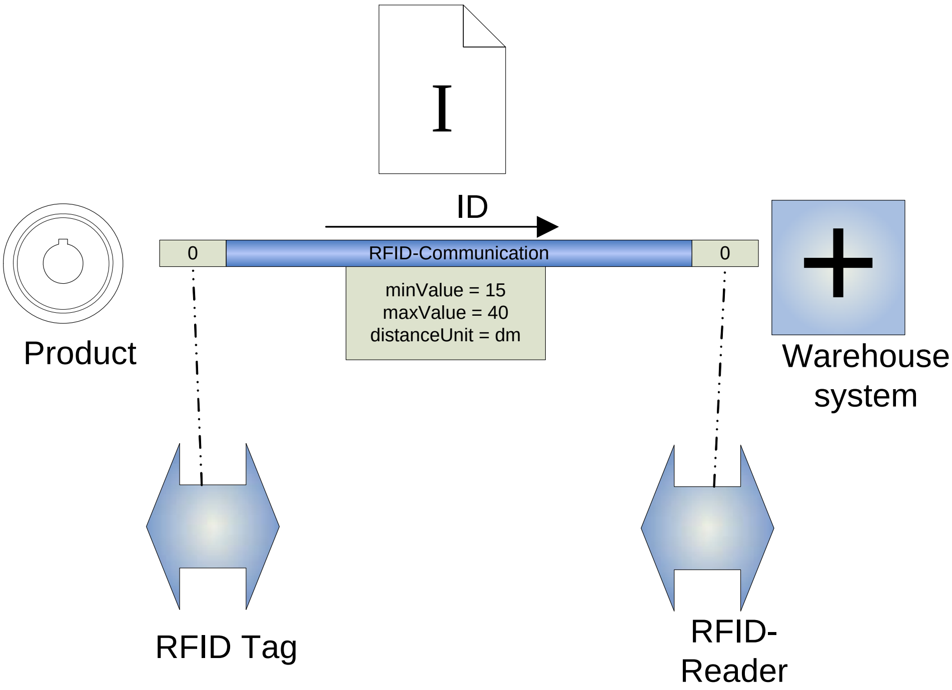

Figure 6: Example transportation channel for RFID

Figure 6 shows the resource model representing the RFID-example in Figure 3 c). The product is a physical resource and is equipped with an RFID tag. **RFID Tag** is a communication resource and serves as an access enabler to the RFID communication channel. The warehouse system is a composed resource and uses an RFID reader for receiving the signals from the tag. The transportation object is a unique ID. The model represents an RFID scenario where no information (except for the ID) is stored on the tag. The ID serves as a primary key for finding the information on a product in the warehouse system's database. The distance between tag and reader is restricted to four meters. This is the maximum range of the electromagnetic field of the RFID reader. The minimal distance results from the construction of the gate to the warehouse.

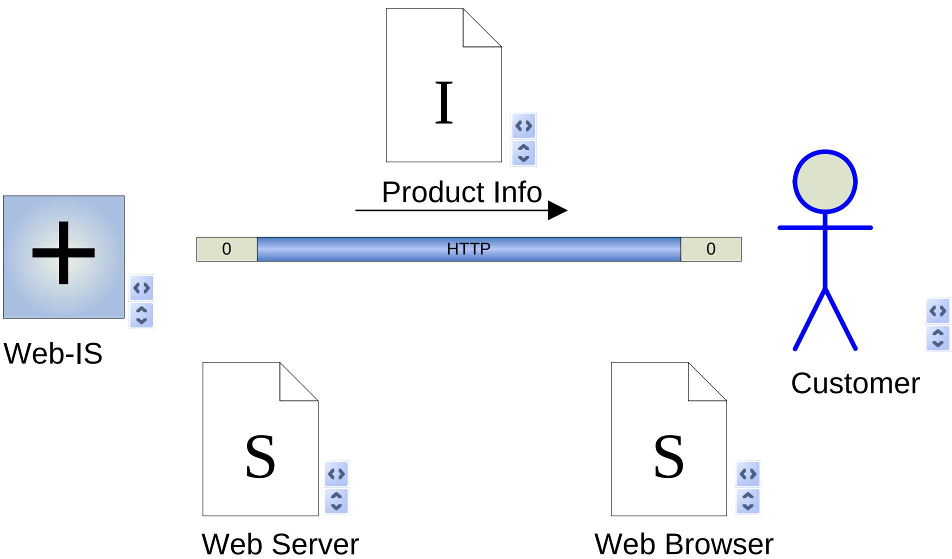

Figure 7: Example transportation channel for the web

Figure 7 shows a transportation channel for web pages. A customer requests some information on a given product. Instead of calling a call-center, he uses his internet account. The supplier of the information needs connects his information system to the web using a web server. A web server is a piece of software, which can be used for providing documents over the internet. The document-styled symbol with the letter "S" inside is the graphical notation for a software resource. The customer analogously needs a web browser for displaying the information. HTTP[1] is the protocol needed for exchanging web documents.

In contrast to the model in Figure 5, the web example in Figure 7 focuses on protocols needed for transmitting information. The call-center example in Figure 5 only shows the technical equipment. In fact, the conceptualisation of transportation channels in MEMO-ResML supports the description of various channels on different levels of abstraction. Possible channels refer to the transport of the following kinds of resources:

- Intangible resources: information, software or data
- Physical resources: raw material, goods or machines

Intangible resources—like information—can be transmitted within a computerised network or between human being. Human being might communicate face-to-face (not supported by MEMO-ResML) or via a communication system. A communication system can be characterised by physical and logical interfaces:

- A physical interface represents the hardware needed for communication. Examples are:
    - Phone
    - Fax
    - Network computer
- A logical interface usually describes the communication protocol.

There is only one possible logical interface in case of phone and fax. Nevertheless, there are several levels of abstraction for logical interfaces in the context of computer networking. Examples are given as follows[2]:

- Computers are connected via an Ethernet
- Computers can communicate via the internet protocol (IP)
- Two computers exchange e-mails using SMTP[3]
- Two users can exchange messages using e-mail (they both need an e-mail client -> SMTP)

The conceptualisation of transportation channels in MEMO-ResML offers the opportunity to model any of these channels. Sender or receiver can be of any resource type. Every kind of resources can be transported over a transportation channel. A communication device (subtype of AbstractResource) has a front-end protocol (interface to sender or receiver) and a back-end protocol (communication channel).

The meta-model in Figure 4 omits the specification of relationships between transportation channels. Possible kinds of relationships might refer to alternatives, dependencies or combinations of channels. The modelling of alternatives offers the opportunity for describing different kind of channels.

[1] HTTP stands for *Hypertext Transfer Protocol* and is a standard protocol for transmitting hypertext documents.

[2] Some of the examples are inspired by the ISO/OSI reference model for computer networking.

[3] The abbreviation SMTP stands for *Simple Mail Transfer Protocol*.

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.

4.3 Modelling a Supply Chain using Transportation Channels

Figure 8 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. [Died01]). 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).

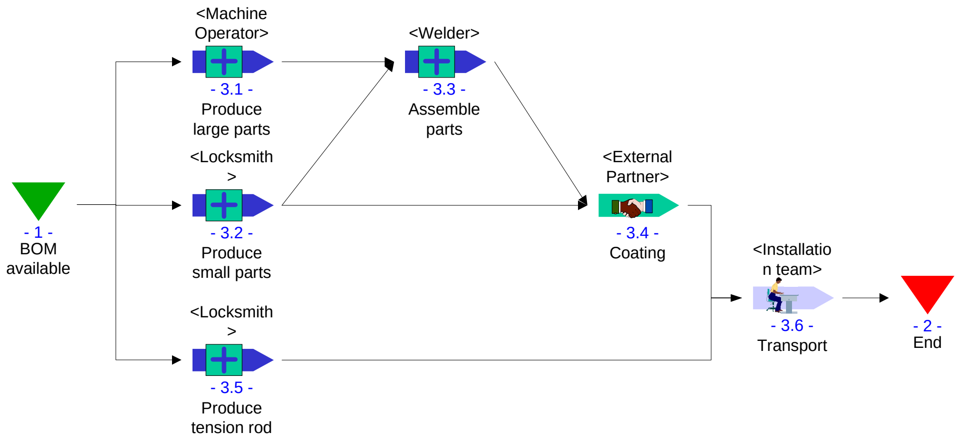

Figure 8: Sample production process[1]

The process model in Figure 8 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 9 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 m^3. 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 9 is used for the

[1] source: [Died01], p. 36

computer-supported optimisation of the resource allocation in the trade company (cf. [Died01]). 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 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 methods. Instead, general purpose languages like ERM and class diagrams are provided in enterprise modelling. 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.

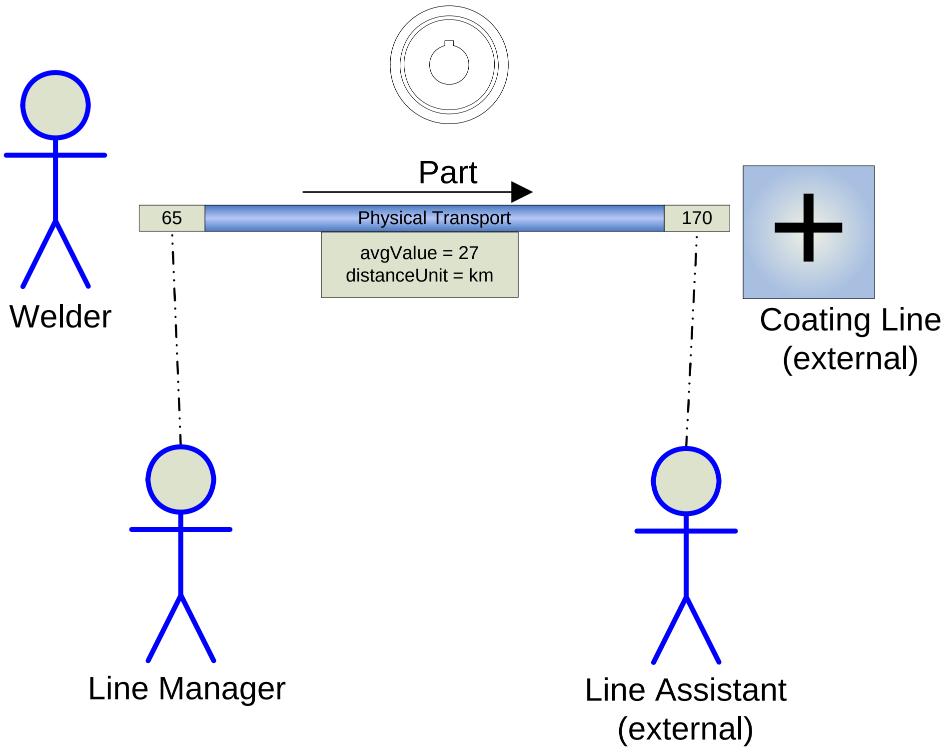

Figure 9: Transportation of parts

5 Future Work

The paper at hand presents the conceptualisation of a language feature for modelling supply chains in the context of enterprise modelling. This language feature is part of a resource modelling language which complements a business process modelling language. Transportation channels are motivated by some examples in section 4.1. Their potential is shown by an example business process concerning the transportation of steel parts in section 4.3. 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. /m^3). 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. [Sche04]). 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. [Feig04]).

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