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Real-time information acquisition in a model-based integrated planning environment for logistics contracts

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Abstract In the past, logistics used to be a core function of production and trading companies but many of them started to outsource at least parts of their logistics functions to specialized logistics service providers in terms of logistics contracts. With this, sophisticated business models such as value added logistics service providers evolved which focus on tasks of planning, coordination and monitoring of entire supply chains involving multiple logistics providers. Challenges remain though, for instance how a complex logistics contract can be planned and how it can be assured that the providers comply with the planned process. In this article, we present a conceptual as well as technical solution to the monitoring of logistics services and show how to reuse this information in a model for the integrated planning of logistics contracts. A simulation model thereby ensures validity of the overall planning. An approach for integrating different models helps to overcome the problem of utilizing multiple models. Finally, an example scenario shows how each part contributes to a successful planning process for logistics contracts.

Keywords logistics; model integration; model transformation; planning; simulation; CEP; information acquisition.

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1 Introduction

Logistics is defined as the management of the flow of goods and information between a point of origin and a point of destination in order to meet the requirements of shippers and recipients. The main objective of logistics is the delivery of the right goods, at the right point of time, to the right place, with the right quality and quantity and to the right costs (6Rs, [tHSN07] and see [AIKT08, GK12] for a general overview).

In recent years, the logistics industry remarkably changed in that the planning and monitoring of logistics functions is no longer a task performed by customers of logistics providers (e.g. vendors, manufacturers) but by a number of so called value-added logistics or fourth party logistics service providers (4PL) respectively [NB02, Sch06]. Outsourced logistics functions encompass basic services such as transportation, handling or storage but also services such as packaging, finishing or clearing of goods. Due to specific requirements each company has (amount of demanded services or integration level) and due to industry-specific requirements (security or tracking issues) each requested logistics service (LS) is individual in scope. Thus, value-added logistics service providers (LSP) need to provide highly individual service offerings to their clients. Within a network of affiliated logistics providers a 4PL selects matching providers according to the needed services and integrates them in order to meet customer's requirements. Moreover, a 4PL governs the overall process and optimize it and as such act as a prime contractor for the customer. Thus, a 4PL is the main contact person, coordinates the involved logistics providers and has the responsibility for the overall process and its quality of service. To determine the quality of service, the 4PL has to monitor and to measure the performance of each participating partner. The provision of LSs with all the corresponding tasks can be represented in the form of a service life cycle. Fig. 1 illustrates a 4PL's service life cycle which consists of the phases: analysis, design, implementation, operation and retirement [RD12].

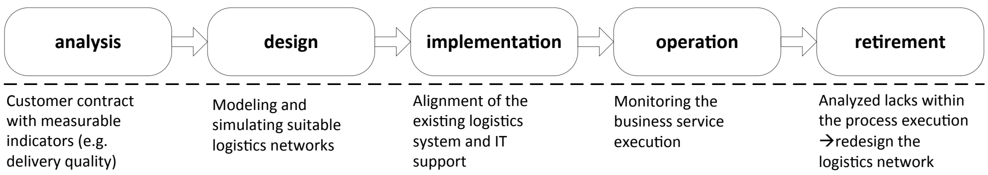

Figure 1 – 4PL service life cycle

Prior to service delivery (*operation phase*) one of the main activities of a 4PL is to perform a multi-step planning process for its customers. Depending on specific requirements (*analysis phase*) this planning process (*design phase*) includes the selection of providers, the definition of the service chain and building long-term forecasts in order to assure a viable and robust logistics process. While the definition of the service chain primarily depends solely on the specific contract, provider selection and building forecasts does not. Suitable providers are those who could in the past successfully fulfill their subcontracts and provide the needed services. Therefore, it is necessary to monitor ongoing contracts and the steeply rising amount of data must be stored and processed (*operation phase*). The acquired data must be enriched with context to gain information, which then also can be used in order to build forecasts for provider and contract performance. For each of these tasks a number of specialized models are used in different tools (see Fig. 2). For instance, we use an XML-based model to represent data and information from providers and contracts, use BPMN as an exemplary process modeling language and developed a suitable simulation model to validate the planning steps. Nevertheless, all steps of planning a complete logistics process described so far are still isolated (i.e. we still have to provide the same information in multiple systems). According to [MKLF12], this can result in high costs and an error-prone overall planning process and they therefore recommend to provide an integrated planning process which can reduce the overall time and effort.

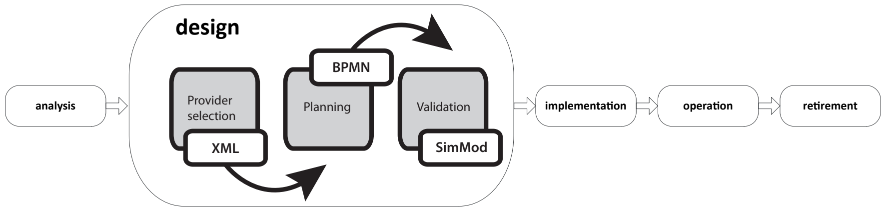

Figure 2 – Exemplary multiple planning steps

In this contribution, we thus present a comprehensive approach for gathering runtime information from logistics contracts, for the integration of several models which are part of defining a complex logistics service and for an integrated overall planning process. Based on the integration of models we present a comprehensive view on a logistics contract consisting of various implemented services. Firstly, we start with prerequisites and requirements our planning approach is designed for, followed by an overview on adjacent approaches and fields of study. Then we come up with a method for combining different heterogeneous planning models in order to force the reuse of already modeled information. We then show how to apply this method in order to build a simulation model from an already modeled process and from additional information outlined in later sections. Afterwards, we outline how the information of each participating provider required for simulation can be measured within provider models using a CEP-based (complex event processing) approach. To illustrate the relationship between the presented artifacts, a scenario is used. Thereby, we show a typical workflow of a 4PL (see Fig. 10) based on the service life cycle (see Fig. 1). We finally end up with a conclusion on the approach.

2 Planning prerequisites and requirements

A core competence and an important task of a 4PL is the planning and orchestration of complex logistics services and thereby integrating various subsidiary LSPs [TH10]. Therefore, different IT-systems are used. Within the planning step, relevant services have to be identified and reliable providers have to be chosen and coordinated in the overall process. Thereby, the various participating LSPs do not have the knowledge about the overall contract conditions and also not about other involved providers. Hence, the 4PL is responsible for the modeling of the overall LS. Moreover, the entire structure of the supply chain with regard to their temporal dependencies has to be validated. Appropriate instruments for this purpose are for instance process modeling languages like Business Process Model and Notation (BPMN) and Event-driven Process Chain (EPC). Davenport defines a process as *"a specific ordering of work activities across time and place, with a beginning, an end, and clearly identifies input and outputs: a structure for action"* [Dav93]. Processes can be also described as follows: a process is defined as a coherent, self-contained sequence of activities required to fulfill an operational task in order to produce a specific service or product [Sta06]. Similar to this is the description in [MAKS12] in which a process is described as a collaboration between process roles which perform tasks on concrete artifacts. Though processes have been widely used within a company, the definition above also allows making use of processes in an inter-company context with the same purpose. Thus, process modeling as an activity for the definition and description of a process combines executors (organizational units), design objects (information objects) and tasks (activities) and connects them via different control flows regardless organizational boundaries. Fields of application and purpose of process modeling are for example documentation or the preparation for automation or optimization. As processes are described as a structure for action, process modeling languages represent the static structure of business processes but the dynamic aspects are not considered. Hence, in many cases process models are the basis for building simulation models [RSD05] but additional information is still needed.

Simulation allows the current behavior of a system to be analyzed and understood. *"Simulation is the imitation of the operation of a real-world process or system over time. [...] Simulation is an indispensable problem-solving methodology for the solution of many real-world problems. Simulation is used to describe and analyze the behavior of a system, ask what-if questions about the real system, and aid in the design of real systems. Both existing and conceptual systems can be modeled with simulation."* [Ban98]. In logistics, simulation methodology is becoming increasingly important for securing the planning, management and monitoring of material, personnel and information flows [TC04]. As complex logistics services are established for a long period of time, radical changes during the operation phase are very expensive and often consume an enormous amount of time [ARW09]. Thus, it is necessary to anticipate the future behavior of a logistics system prior to its implementation. Hence, simulation models of logistics networks can be used to improve the decision-making process in the planning phase. Especially discrete-event simulation (DES) is appropriate to enhance decision support in the planning process by analyzing several system configurations, which differ in structure and behavior [VR10].

The use of simulation also leads to a number of problems. As mentioned previously, different models (process model, provider models, simulation model) are used within the planning process. This is a major problem because each time a model is slightly modified any of the other models must also be revised. This increases the modeling effort. In addition, building simulation models requires special training and experience to avoid errors. It is a methodology that is learned over time. Furthermore, building simulation models and their analysis is expensive and consume an enormous amount of time. This can lead to a non-profitable use of simulation [Ban98]. Another problem is the availability of valid input data in the right quality, quantity and granularity [BPA+11]. These are essential preconditions for high-value results [BW05]. In addition, the used data must be available and visible as fast as possible. Conventional approaches use data stored in data warehouses and are request-driven [EN11]. Thereby, a simulation works on retrospective data. With the greater use of automatic identification and data capture technologies (AIDC) such as RFID or wireless sensor networks as well as social networks the amount, velocity, variety and value of data has changed dramatically [SP14]. This evolution is called Big Data and also takes place within the logistics sector.

For these problems, the following requirements are derived. The effort for the development of simulation models must be reduced. Especially, in the planning of logistics systems several models are used. These models build upon one another and have dependencies among each other. A change in a model also leads to changes in subsequent models. Therefore, simulation techniques have to be integrated in the planning process [MKLF12]. It must be ensured that the created process models within the planning process, based on a separate description of each logistics service, can be transformed automatically into a simulation model. So, an approach to combine different heterogeneous planning models in order to force the reuse of already modeled information is needed. On the one hand, this requirement aims to minimize the planning effort of a 4PL. On the other hand, manual errors in the creation of a simulation model should be avoided. Furthermore, the need for special training and special experience in simulation model building is reduced. Another requirement concerns the information acquisition. As a result of the information overload the investment in simulation projects for information acquisition and model design is almost 50% of the total project time [GHG13]. This leads to the need of an efficient approach for gathering information to support the logistics planner in all planning activities. To gain a robust simulation result the used data have to describe the current state of all logistics networks.

3 Related work

With our approach of integrated planning we build upon the integration of several service models and upon the reuse of at least parts of the contained information. In this contribution we present an example in which we show how to combine two different types of service models namely a process model and a model describing the participating service providers (provider model) in order to get the necessary information from both and reuse this information in a simulation model. We further describe the origin of data from the provider model and how these data are acquired. To present related work we firstly searched for approaches fitting best with all of our concepts and which thus have a major impact on our research. We ended up mostly with approaches covering parts and thus decided to describe such approaches and their influence to us. Prior to this we present approaches covering the field of integrating models for service definition and description. These approaches are very relevant to us in that they discuss methodologies and techniques to combine multiple models for a holistic view on services. [KVSC08, SVB$^+$09] describe a model-driven engineering approach with four perspectives on and five aspects of services resulting in a matrix of modeling languages for each combination. Although this approach provides a very structured and thus easy to adapt approach to multi-dimensional service modeling, but it is not flexible enough for our purposes. It is our goal to provide an overall solution which allows users to apply those languages they are familiar with (see section 4). A similar approach is presented in [SIL$^+$12]. They also make use of different models in order to represent service aspects and present thus a model-driven approach. In their approach they use six aspects and four levels of abstraction and present a broad role model. The so called ASD framework is designed to deal with change and to foster service development in dynamic company environments. Similar to ours their approach contains an integrated service model with which a comprehensive view on services is given. However, their structure is fixed and contains a lot of prescriptive concepts so that companies have to adapt their model instead the framework is flexible enough to be adapted to companies' structure. Furthermore, it seems very challenging for us to provide a set of essential concepts for a universal approach of modeling services. Finally, the approach of [NdAFA$^+$13] uses ontologies in order to structure essential service concepts in a modular way.

Based on a so called foundation ontology which contains the most basic concepts and relationships they construct further ontologies for a multi-dimensional view on services. In contrast to the above mentioned and to our approach their views are more abstract and on a highly conceptual level, e.g. service co-creation, capabilities or service interaction. They also present a three-phase service life cycle and focus on service provision instead of service composition or service development. Although this is also an interesting and promising way to deal with service descriptions and could help us to gain insights into different service research areas like the other two, we cannot deal with ontologies as well as we do not focus on a conceptualization of services. The primary aim of our integration approach is to be usable in a multitude of different environments and to support the infrastructure and methodologies already applied to within companies. Additionally, we have a strong focus on logistics and especially on collaborative logistics service provisioning. In the remainder we will proceed with presenting selected methodologies and techniques which are essential to parts of our overall solution.

Model transformations: model transformations or model weaving approaches are primarily used in (model-driven) software development and for building software architectures respectively. A thoroughly overview on transformation approaches is given in [CH03]. In particular model transformations are important for us from two points of views. On the one hand, we use model transformations in order to identify model correspondences between different models and their metamodels respectively. Relevant approaches for finding correspondences in a multi-model environment are [RJV09] as well as [SK07]. While the former define intensional aspects on the metamodel level and extensional aspects on model level for building software architectures the latter also works on software architectures but define rules for connecting different models based on the same metamodel. Finally, the approaches of [Ake00] and [ADE$^+$11] are software development approaches working with UML and combine several models. On the other hand, we make use of transformation approaches for defining transformation models as a mediator between process and simulation models. In both approaches of [PSNH08, KSPN10] a transformation model is used in an additional step in order to derive a simulation model from an already existing process model. Both approaches take the fact that process models are independently defined from simulation requirements. In practice, process models serve to foster transparency or documentation and to analyze the requirements for the introduction or implementation of new information systems. However, both approaches assume that a process model is defined using EPC.

Simulation: simulation approaches are widely used in logistics in order to plan logistics systems. [Ing98] discuss the benefits of simulation as a method to study the behavior of supply chains. Additionally, advantages and disadvantages are presented for analyzing supply chains with the help of simulation models in general. In [CLM10] a commonly applicable simulation framework for modeling supply chains is presented. Instead of [Ing98] they focus on a more technical perspective as they show an overview over event-discrete simulation environments but also show how and when to use certain programming languages as a viable alternative for such environments.

Information acquisition for simulation: [BW05] gives at first a theoretical overview of research results including theoretical definitions of terms like information, data, and knowledge. Based on this, a process-oriented procedure model for information acquisition in a superordinate procedure model for simulation according to VDI 3633 [VR10] is presented. Furthermore, different taxonomies of methods from information acquisition, statistics and visualization and their utilization were analyzed and classified. In contrast, [RSW09] propose the separation of the steps of information and acquisition from the modeling process. Therefore, the procedure model for simulation was extended by a separate handling of the model and the data. So, a continuous and iterative verification and validation process should be provided. [KW10] argue that a distinguished consideration of data collection and preparation is missing and fill this gap by another procedure model extended by a chain of sub-processes within information acquisition. The paper proposes a procedure model of information acquisition which is more a task- and user-oriented approach. All these contributions have one thing in common: they assume that simulation projects are isolated from an overall integrated planning procedure and the development and analysis of simulation models is a project for its own. In our approach, simulation is part of an integrated planning process and an overall approach for a 4PL.

Complex event processing: [RD12] outline the use and advantages of complex event processing (CEP) for the 4PL business model for monitoring business processes and collecting real-time data. [YCL11] analyze the application of CEP in hospitals by using RFID. They introduce a framework and provide a possible solution to improve patient safety, whereby the power of CEP is shown. Some parts of the approach can be partly adopted, but the framework is too abstract and not suitable for the presented application area. [BPA+11] investigate event processing in production, logistics and transportation. They describe how service-orientation and event processing can be combined and how the application area can benefit from real-time data. This paper covers the logistics area and discusses CEP as a powerful approach without going into detail. Because of the high level consideration the paper only provides partial input for the work presented in this article, but the discussion underpins the thoughts of the authors. Furthermore, these approaches do not meet the requirements of a 4PL business model, more precisely for the simulation. In this contribution we present how CEP can be used for gathering and processing real-time data and transform them into information, which are afterwards used for simulation purposes.

4 Model integration

Models used for planning logistics processes (see Fig. 2) are designed to keep specific information of involved services. Each planning tool has therefore a distinct metamodel as a formal base. In order to model the process of such a complex service we for instance use BPMN but there is no explicit limitation in the choice of a process modeling language. Thus, during the whole process of defining a LS, such a service is comprehensively described using various models. Dependant on the distinct modeled aspect the resulting models might then contain either disjoint or overlapping information in a sense that the same information is contained in multiple models. If many people are involved in modeling this situation can even get worse in that the same aspect is modeled differently (e.g. using homonyms or synonyms). At the same time, we have to ensure that new modeling / planning tools can be integrated and that the overall planning, monitoring and controlling process for LSs is kept efficient. So, in our approach we foster the reuse of already modeled information and with this we are also able to avoid the modeling of the same aspect in different manners.

To overcome the above mentioned situation, our Service Modeling Framework (SMF) and its components ([ALF12, AL13b, AL13a]) serve as a mediator and is central for model and information management. In SMF services are defined using a variety of models which represent certain aspects, for instance an interface or a process description, a service level agreement specification or specific characteristics in terms of runtime performance. The SMF is responsible of coping with these models, of integrating and storing them in order to ensure consistent engineering and management and thus allows for a standardized handling of service descriptions and service models. The main purpose for SMF is to interconnect all involved models on metamodel level in such a way that contained information can be extracted and reused at which each model is seen as a projection on a comprehensive model within the framework. Applied to the concepts in this article, SMF is responsible for interconnecting models from development and operation phase in order to transfer information from previous and actual executed logistics processes (CEP-based) to simulation models. SMF also supports development of a proper simulation model from a initially developed process model.

4.1 Interconnecting models

Especially, for an efficient planning and execution, services and their descriptions have to be handy in terms of analyzing and processing. The SMF editor component provides a flexible way of interconnecting models and model elements so that appropriate information is picked from the individual models and merged into a more complex service definition. To provide a basis for interconnection of service models, SMF contains a metamodel called Common Service Model (CSM, [ALF12]). The CSM serves as a basic structure for the SMF in that essential concepts in general are defined and connected to each other. It also introduces specialized elements, namely *ServiceAspect* and *ServiceDescriptionElement* in order to connect models and their elements respectively. The CSM is also point of origin for a set of artifacts, like the SMF editor. In contrast to automated model transformation approaches, SMF relies on a descriptive, informal interconnection. Existing approaches for a model-to-model transformation connect elements from different models on metamodel level and then perform a semi-automated transformation on model level. This isn't appropriate for our approach for the following reasons: On the one hand, transformations are realized directly and only on metamodel level. If we then wanted to add a new model type we would have to define multiple transformations for each already existing metamodel. On the other hand, transformations can only be implemented in an automated fashion by comparing the abstract syntax of a language. Very often however, manual steps have to be added in order to make sure that the transformation is correct and complete (e.g. see the definition of extensional connections in [RJV09] or see the definition of intermodel-correspondences in [SK07]). Model transformations are valuable and easy to perform if both models (source and sink) cope with the same issue (e.g. transformation of a BPMN-model into a BPEL-model). Within the SMF we however have to cope with models which are totally different in scope and functionality. On a conceptual as well as technical level we use a modified version of the CSM within the editor and thus are able to model only valid relationships (in matters of SMF) between different services and their models respectively. Because the CSM is the metamodel of the editor the resulting model is thus a version of the comprehensive service model for a certain service. We can later on also extend this version if new service models are added to the service or if requirements changed and dependencies between models have to be updated. The comprehensive model is then used as input for an information extraction step which takes the contained models and their elements respectively and sees to transfer information into the appropriate places.

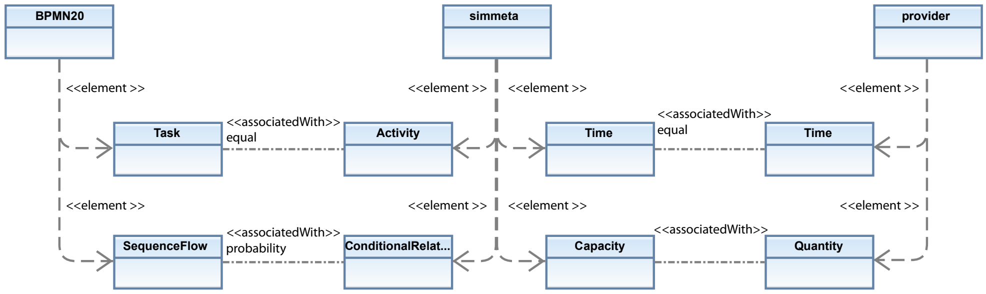

Figure 3 – SMF editor modeling (excerpt) [AL13b]

In the following we present by whom and how the SMF editor should be used. SMF components in general are designed for use at the 4PL's site. Participating partners like customers or LSPs are not confronted with these concepts as they are not directly involved in tasks like network management or building complex supply chains. Instead, the editor is intended for use by logistics domain experts. They are able to analyze logistics processes and descriptions from subsidiary providers, to model information in logistics service models and therefore have deep knowledge about different model types. Logistics domain experts use the SMF editor in order to identify and mark model elements of different models which contain equal or similar information. From a repository component we can drag services and models into the editor and define relationships as depicted in Fig. 3. To successfully implement our scenario (see section 7) we have to integrate information from a process model (*BPMN20*) and from different provider models (*provider*, see also next subsection) into a simulation model (*simmeta*, see section 5). Thus, we look for elements in the source as well in the sink models which contain equal or similar information with respect to conceptual identity. For instance, a task in a process is semantically equal to an activity in the simulation model as well as information from modeled sequence flows can be used in simulation in order to model flows of goods and information. Defining such connections is repeated for each used model and the resulting service model is used as input for the extraction component of SMF which in turn is responsible for creating and updating models.

4.2 Reuse of CEP-data using provider models

To be able to simulate supply chains we are in the need for runtime data from potential LSPs. These data are gathered using CEP-mechanisms in already existing and ongoing contracts during operation phase (see section 6). In a subsequent analysis of runtime data, provider profiles can be extracted and stored for further use, e.g. as parameters in a simulation environment. A provider model for each LSP is thus created which conforms to the metamodel depicted in Fig. 4. Each model contains master data as well as dynamic data for a specific LSP, is stored in the SMF repository and regularly updated when a LSP participated in a logistics contract and was thus monitored using CEP.

Speaking in terms of SMF a provider model represents a ServiceAspect and model elements to be reused within other contexts represent ServiceDescriptionElements. Each LSP is defined using a *provider* element and is allowed to offer a set of *SLAs* for its *services*. These SLAs in turn can be broke down onto specific SLOs for the use

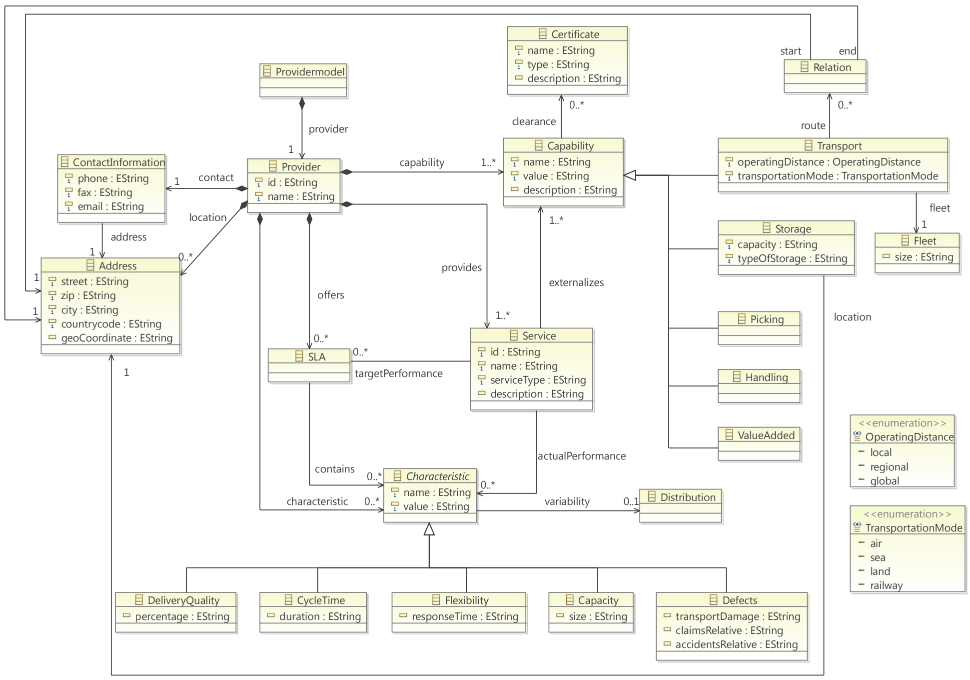

Figure 4 – Service provider metamodel

with CEP-mechanisms (see section 6). Aside from provided services essential descriptive elements are key figures or *characteristics* which define the actual (measured) performance of each service and which are derived from execution monitoring. For a smoother integration, characteristics can also be typed more specifically and stored as *DeliveryQuality*, *CycleTime*, *Flexibility*, *Capacity* or *Defects*. To select LSPs for simulating contracts, characteristics are not useful however. Instead the use of *capabilities* (e.g. transport, storage or handling functionality) is recommended in search patterns. These reflect internal resources which are externalized through one or more services. In contrast to offered services, capabilities are more detailed and thus allow for a better identification. Although capabilities and characteristics seem similar, there is a difference in storing these properties. While characteristics are continuously updated with every contract a LSP is engaged in, capabilities are only recorded once and represent types of services instead of actual performance. In conjunction with a structural description of the process we use this information to generate simulation model as depicted in Fig. 11 and described in the next section.

5 Simulation

Section 4 notes that different models (e.g. process models, provider models, simulation models) are used for planning logistics processes. The importance of simulation within the planning of logistics contracts together with the specific goals and requirements of a 4PL's simulation approach are discussed in [MKLF12]. In addition, the need for an approach to transform process models to simulation models is highlighted in this paper. This section specifies how the transformation of process models into simulation models is implemented prototypically as a planning editor as part of our integrated planning process (*design phase*) for a 4PL.

The transformation approach is based on three different model types, *process model, transformation model* and *simulation model*. A process model (e.g. BPMN, EPC, Petri Net) is simulation independent, i.e. the model contains no information relating dynamic aspects such as arrival times, processing times or capacities. The process model is transformed into a transformation model (generic simulation model), and enriched with the required simulation information. The provider model presented in section 4 makes this information available. Thus, the transformation model contains all data necessary to perform a simulation. However, the transformation model is platform independent and therefore can not be executed in a specific simulation environment. The specific simulation models (e.g. Enterprise Dynamics (ED)[1] and Arena[2]) are generated from the transformation model. Fig. 5 depicts our approach graphically.

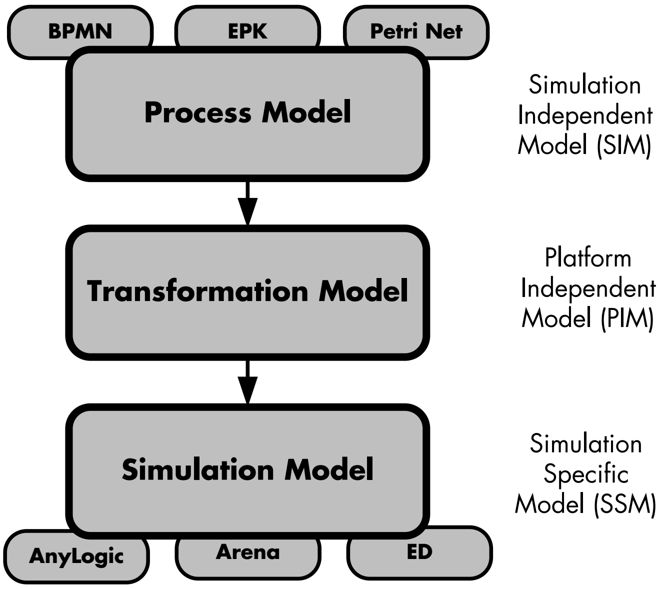

Figure 5 – Transformation approach from process models to simulation models

In the following the approach is described in more detail and it is shown how the generic simulation metamodel (platform independent) was created considering the basic concepts of DES and the specific requirements from the perspective of a 4PL (see section 2). Process models describe functional or structural aspects which are relevant for a process. Depending on the used process model notation, these functional aspects (e.g. Task in BPMN, Function in EPC, Transitions in Petri Net) represent the different partial LSs as part of the overall process in the scope of a 4PL's planning process. In [HSB10] an approach for formal and semantic description of services in the logistics domain using concepts of service orientation and semantic web technologies is presented. The approach also categorizes and describes modular

[1] http://www.incontrolsim.com/
[2] http://www.arenasimulation.com

LSs such as transport, handling, storage, value-added services, etc. using a logistics ontology. Concepts of this ontology are used in this research paper to refer from the functional aspects depending of the used process model language (Task, Function or Transition) to the description of specific LSs. Thus, each functional aspect is assigned to a specific logistics service type. So, the result is a process model including all LSs necessary to meet customers' requirements. Despite having a process model and using this model as the basis for creating a simulation model, for simulation additional information as to the pure visualization of the processes is necessary. Therefore, it was analyzed in literature what information is additionally required to create a simulation model and what are the basic concepts (Entities, Events, Attributes, Activities and Delays) [MRLF13]. In addition to these basic concepts of DES, a simulation also has logistics-specific properties.

The fundamental goal of simulation in logistics is the study of transport volumes and capacities of the partial LSs over time to ensure that customers' demand can be met. So it is possible to analyze the runs of goods through the logistics system with regard to the capacity in order to identify bottlenecks early on. To create simulation models of a specific domain, primarily application-oriented modeling concepts are used [Ban98]. Typical in logistics is the use of "modular concepts". These provide topological, organizational and/or informational elements - appropriately aggregated, predefined and parameterized from an application perspective - for a specific application domain [KW08]. Two simulation tools using application-oriented modeling concept (ED and Arena) have been used to create different examples of simulation models in order to study transport volumes and capacities. These tool-dependent models have been analyzed and compared in terms of used modeling concepts and the required data. The common concepts of these tool-dependent models and the basic concepts of DES were then used to create the metamodel shown in Fig. 11.

The generic simulation metamodel basically consists of *SimulationElements*, *SimulationParameters* and *Relations*. A *Source* generates goods at predefined time periods and they leave the model at the *Sink*. The purpose of an *Activity* is to manipulate goods in some ways like to store or to transport them. Therefore, *Goods* enter an activity and remain there for a certain time period. Moreover, an activity is assigned to a certain *ServiceType* which defines the specific functionality of this activity. These three main concepts are subsumed under *SimulationElements*. All *Time* periods can also be specified more precisely with the help of *Distribution* functions. Regarding the service type, a *Capacity* is an additional characteristic of an activity. For instance, an activity with the service type "warehouse service" is restricted by a maximum capacity and has a certain queuing strategy. Time, capacity, goods and distribution are subsumed under *SimulationParameters*. The connecting elements between the activities are represented by two different kinds of *Relations*. On the one hand, relations can be simple i.e. without specific characteristics. On the other hand, a connection between activities can be represented by *ConditionalRelations* with additional, specific characteristics (conditions, probabilities). Depending on values of these characteristics in a simulation either one or the other path is used. With this metamodel, it is possible to create simulation-tool-independent models, which contain all information necessary to perform a simulation.

Now, the question arises of where to get the information for building a simulation model and how is the planning procedure from the perspective of the 4PL. As already mentioned, modeling business processes including different partial LSs is part of the 4PL's planning process. These process models can be regarded as given in the service repository. So, we can use the structure (start, end, tasks, relations, gateways) of the process to derive the structure (source, sink, activities and relations) for the simulation model (see Fig. 3). Gateways in process models for example, are represented by conditional relations. Information regarding runtime characteristics is available in the provider models (see Fig. 4). So these models contain the specific information required to characterize the activities in the simulation model, e.g. time, quality or capacities. An approach how this information can be collected is presented in section 6. To combine the process model with the provider information our planning editor contains a provider selection. Based on the process model for each partial LS represented as functional aspects (Task, Function or Transition) a suitable provider and thus the required information is selected. With this information and the underlying simulation metamodel a 4PL can automatically generate a simulation model for a specific simulation tool. This requires that for each simulation tool transformation rules have to be defined only once. This approach enables a 4PL to make use of the advantages of simulation for securing the planning process and to improve decision-making without any special training and special experience in the creation of simulation models. Simulation models can be created in an easy and efficient way and the effort for comparing a set of different logistics network configurations is reduced. Furthermore, the simulation results serve to improve the planned process in form of a planning cycle (see Fig. 6).

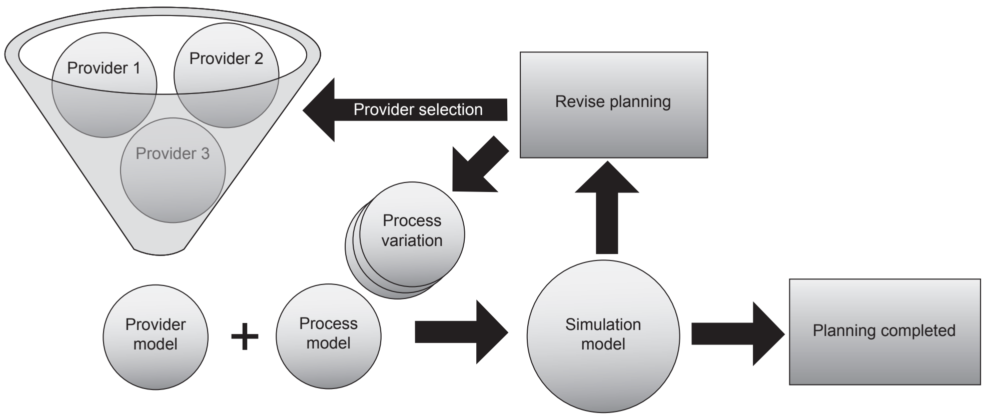

Figure 6 – Automated planning cycle

As the collection of correct and robust data is a crucial success factor in the implementation of simulation projects, the next section discusses a monitoring approach for logistics contracts during the operation phase of the service life cycle. An initial approach for data collection within an integrated simulation approach for a 4PL was already discussed in [MRLF13]. Although historical data can be used for the parameterization of simulation models more accurate data are preferred because of a better explanatory power of the simulation results. Thus, the next section describes the gathering of data during process execution and describes how these data can be used to match them with customers' requirements in terms of service level objectives (SLO). Finally, information derived from data is stored in provider models and then reused for simulating future contracts.

6 Information Acquisition Using Complex Event Processing

In this section we outline how ongoing contracts can be monitored in real-time by using concepts and methods of CEP. CEP is a relative young discipline, whereby the most important concepts and tools already exist (e.g. Rapide EPL[3], Esper[4]). Technical problems like scalability are mostly solved, but functional issues are not treated sufficiently [BD10]. The overall approach and the use within the logistics area, especially for the 4PL business model, are not covered in current research (see section 3). The acquired information is used in different contexts, e.g. for provider selection, parameterizing the simulation. The consideration is thereby on an abstract level without going into detail of a particular tool or technique.

CEP is defined as a set of tools and techniques for analyzing and controlling the complex series of interrelated events. In CEP, events are therefore processed as they happen, continuously and in a timely manner [EN11, Luc02]. An event is the central aspect of CEP and is defined as *"anything that happens, or is contemplated as happening (change of state)"* [LS11], e.g. a RFID-enabled good is recognized by a RFID reader. If an event summarizes, represents or denotes a set of other events, it is a so called complex event, e.g. a RFID-enabled good left the issuing area [LS11]. In this paper it is assumed that CEP is already used to monitor an instantiated logistics network [RD12]. The next paragraph exemplifies this and emphasizes the adequacy of applying CEP in the area of a 4PL (based on the service life cycle, see Fig. 1).

The outsourced service between the 4PL and the customer as well as between the 4PL and the LSPs is secured on a contractual level (*analysis phase*). A contract records the agreed upon obligations and responsibilities of all contractual parties in terms of business process conditions [WX03]. These conditions are often expressed as goals which must be achieved by each party. The goals can be extracted from the customers' requirements or from legal regulations and are known as SLOs, which define measurable indicators like delivery quality, delivery reliability or delivery flexibility. The contract describes the target state of each LS realized by the participants of the network and acts like a pattern. As soon as the process execution is started (*operation phase*) the 4PL has to ensure the fulfillment of the defined SLOs. To achieve this, internal (e.g. good left the issuing area) and external (e.g. traffic jam) information regarding to the good will be pushed to the 4PL. By doing this the 4PL can ensure that possible penalties (e.g. delayed or damaged good) will be handed out to the "faulty" participant of the network. If it is not traceable which member of the network is the flaw, a logistics network would not be robust and sustainable over a longer period. In so doing, CEP allows to forecast, whether an instantiated process will meet the SLOs in the future or not [RD12]. For this purpose external cloud services like traffic, weather or time table systems are integrated and processed. A simple example is: If the service execution reaches a certain point (e.g. GPS coordinates of a transport), CEP automatically checks if e.g. the departure time of the aircraft planned to use changed and if the overall contract can be fulfilled. To improve this forecasting capability, the information gathered from already completed service executions are analyzed for similarities to the ongoing contracts. In the case of a delayed departure the 4PL has enough time to take measures to compensate the delay (e.g. replan the service execution). This incoming information which describe the actual state are compared to with the SLOs which depict the target state. This

[3] http://complexevents.com/stanford/rapide/
[4] http://esper.codehaus.org

comparison takes place within the CEP engine. All information will be processed to evaluate the process execution of every logistics network partner and build up service profiles. The service profiles include key performance indicators which benchmark the LSP and their services execution. In contrast to current approaches, this evaluation takes place during the process run-time and not at the expiration of a process (*retirement phase*). If a deviation from the agreed SLOs are identified, an alarm will be triggered and information about the failure will be raised, e.g. the duration or reasons of a delivery delay. The following example and explanation should briefly describe the suitability of CEP in the area of the 4PL business model at a more detailed level.

Fig. 7 illustrates a possible material and data flow of a concrete logistics network. As seen in the material flow layer, three LSP take part in the logistics network to accomplish the contract between the 4PL and the customer. The squares symbolize the responsibilities for each LSP. Beside the actual transportation of the good, data regarding the good must be processed as well. The lower part of the data flow layer exemplifies the data sources within a LS (ERP, RFID, Barcode). These examples should clarify that there is a multitude of data sources with their own characteristics, which must be linked to an appropriate monitoring system at the 4PL site. By using CEP it is possible to link nearly every data source in a short space of time, because CEP is loosely coupled. Thereby, the 4PL gains situational awareness, because a high variety of data sources – internal and external (e.g. traffic systems) - can be linked rapidly, whereby the transparency of the logistics network is rising. Moreover, CEP can handle the rising velocity of data while processing them in real-time, which will lead to a better availability and visibility of information. Using e.g. RFID leads directly to the challenge that a flood of data is generated. Additionally, companies are only interested in information with a high value. Therefore, it is necessary that a dispatcher does not receive messages such as *"good_1 was read at reader_1 at 12:45 UTC"*. According to that, CEP provides filtering mechanisms so that all redundant messages will be percolated, which will reduce the volume of data. The result is that only one message is received by the dispatcher. Moreover, it can be stated that the message *"good_1 was read at reader_1 at 12:45 UTC"* does not have a high information value. CEP offers the opportunity to aggregate data to obtain a higher information value. By using these mechanisms it is possible to aggregate technical data (e.g. RFID reads) to business processes, whereby the message is transformed to *"good_1 for Mr. X left the warehouse at gate 2. The delivery is delayed for 45 minutes"*. This message is used to evaluate the performance of the LS (see e.g. LSP1.LS2 in Fig. 7) in form of service profiles.

The profiles of each offered and operated LS are aggregated to achieve an overall performance profile of every LSP (provider model). Furthermore, these benchmarks can be aggregated again to achieve a profile for the whole network (network profile). All of these profiles represent an essential input for other tasks like provider selection or simulation of newly planned logistics systems. CEP is a powerful approach to process data, transform the process-
accompanying data to information and link them to business processes. By doing so, CEP is a suitable technique to provide real-time information at a desired granularity level in a timely manner. Hence, CEP is a suitable approach to monitor logistics networks and to support simulation with latest data constituted by provider models. This leads to a better database, in which simulations do not have to rely on experience or outdated information. The available information includes current performance profile built up from internal and external information and can be combined as desired.

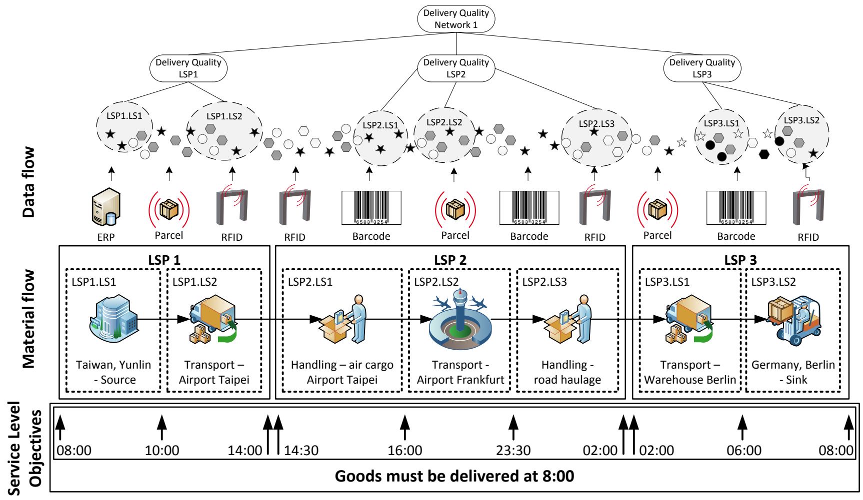

Figure 7 – Exemplified material and data flow of a logistics service instance

This information can be used to simulate logistics networks at an early point of creation (*design phase*) and generates more reliable predictions. Ideally the data of every LSP is available for the 4PL, but this does not reflect reality. Hence, we are also developing an energy efficient sensor node, which can be attached to every parcel. Based on different sensors and technologies like GPS and GSM, we can check the transport conditions of each good continuously and analyze the gathered data in real-time using CEP. Thereby, we are able to track and trace every parcel (not the e.g. whole truck) without the need of integrating IT-systems of each participating LSP.

7 Scenario

In this section the presented artifacts (model integration, simulation and CEP) are associated with each other. Therefore, a scenario is used to illustrate the typical workflow of a 4PL, based on the 4PL service life cycle (see Fig. 1). The focus is thereby on the design phase as well as the relation to the operation phase. Thereby, a part of the overall planning process is illustrated, i.e. a rough plan for the delivery of consumables (see Fig. 8).

For final assembly an OEM needs consumables (e.g. screws, fuses, mounting parts, casting consumables) for its assembly lines. For cost-cutting effects the OEM orders these consumables from different sub-contractors in the Far East. During the *analysis phase* (see Fig. 1 and left side of Fig. 10), the OEM therefore specifies requirements (e.g. kind of consumables, average quantity ordered, kind of packaging, time of delivery, cycle time, destination, etc.) by means of SLOs which are depicted in Tab. 1. In this case, the 4PL acts as prime contractor and manages the inbound logistics for the OEM and at first performs a rough planning of the supply chain (see Fig. 8). Consumables are produced in two plants and put on pallets for shipping. At the moment the packaging is done, the 4PL is responsible for further handling.

good	consumables
average quantity ordered	1 palett/36 h
cycle time	6 days
delivery performance	98%
origin	South Korea
destination	Kassel (DE)
	Toledo (ES)
	Sibiu (RO)
	Östersund (SW)

Table 1 – Customer's Requirement

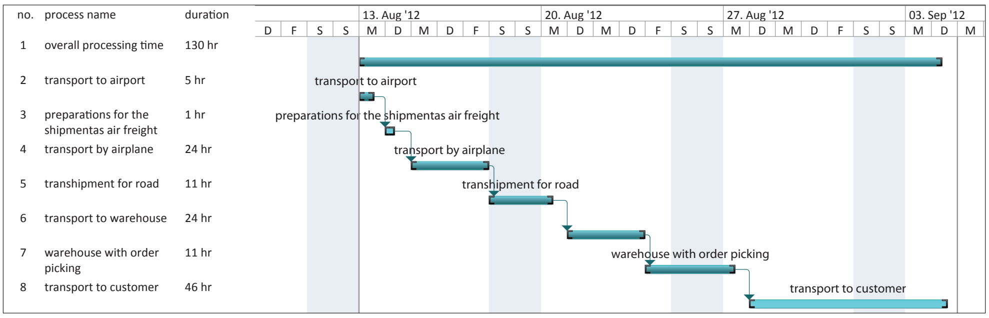

Figure 8 – Roughly time schedule

First, the 4PL has to prepare all necessary documents for transport (e.g. freight or clearing documents) and ship the goods to the airport. There, pallets are repackaged into sealed containers for air transport and shipped to Germany. At the destination airport the goods are again repacked and forwarded to a distribution center with an accompanying quality check. According to the average quantity ordered, the goods are then forwarded to the interim storage facilities and subsequently delivered just in time to the assembly lines.

Within the *design phase* a rough planning of delivery is performed which is at the same time used to identify necessary services and service providers respectively. In a further step customer's requirements, are broke down onto discrete services (see Tab. 2) and with this potential providers are selected according to the existing provider models in the repository (see section 4). Due to lack of space this procedure is not part of this contribution but the result is a matching between service providers and necessary tasks represented in a process model. On model level this is realized with the help of the CSM in that both model types, namely the process model itself (e.g. BPMN) and the service provider metamodel, are connected to the CSM as described in section 4.

In the very same way the simulation metamodel is also connected to the CSM. The following transformation (see section 5) now makes use of the modeled connections within the SMF editor and evaluates the resulting model and pushes appropriate information into the simulation model. The information acquired and generated by CEP in form of provider models is now used to parameterize the simulation (see section 6). After this, a second transformation provides a simulation model for a specific environment (e.g. ED, see Fig. 9).

service name	transport Seoul airport 2	air cargo handling Seoul airport	transport Berlin airport
type of service	Transport street	Handling of air cargo	Transport air way
cycle time	5h	1h	24 h
delivery performance	99,50%	99,80%	99,50%
origin	Busan	Seoul	Seoul
destination	Seoul	Seoul	Seoul

Table 2 – Requirements Breakdown

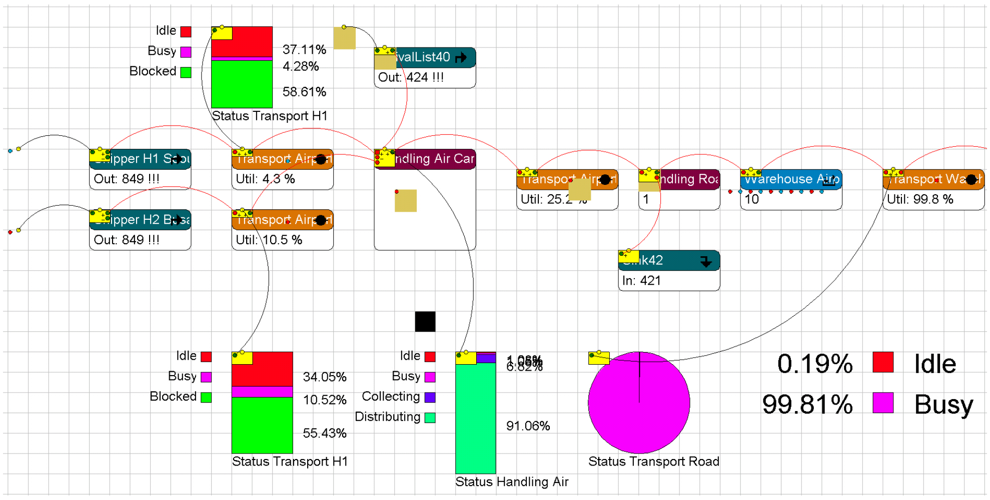

Figure 9 – Results in ED simulation environment for the scenario

As a result of a simulation experiment, a bottleneck is uncovered. The utilization of a process step is 99.8% and its upstream queue keeps growing. The 4PL therefore has to adjust the process. Either the process has to be changed in order to avoid the bottleneck at this specific point or the 4PL can also try to exchange the actual provider with another one which according to its provider model has a better performance. If the identified problems are finally solved, the planning phase is finished and the 4PL can go on with the *implementation phase*.

In this phase the 4PL is responsible for realizing the logistics contract in the real world. The 4PL therefore subcontracts the chosen providers and implements necessary IT-infrastructure by means of diverse logistics information systems and provides IT-support for its subcontractors. The implementation phase is finished if the specific provider network is capable of fulfilling the complete logistics contract. If the IT infrastructure cannot be integrated, the LS must be redesigned (see *design phase*).

During the *operation phase*, the 4PL monitors the logistics service execution (process instance) realized by the LSPs. On that account, the 4PL processes internal and external information regarding to the good by using CEP. Gathered information is then stored in the newly created service profiles and updated continuously (see section 6). Primarily, the internal information describing the target and the actual state is compared. Afterwards, external data is used, to predict, if the ongoing LS can be successfully fulfilled or not. If it is predictable (or confident) that an ongoing contract and the regarding SLOs cannot be fulfilled, the 4PL will be timely informed to adopt compensating measures. In this case, the service life cycle will be restarted with the design phase. Thus, the 4PL is able to react on unpredictable circumstances and can integrate new or re-planned LS dynamically. The gathered real-time information is an important input for new or redesigned LSs (see *design phase*) as the created service profiles are used to update the corresponding provider model.

At the end of the service life cycle the contract expires and the LS is properly terminated (*retirement*). The process execution is analyzed and the results are used for planning future contracts. Fig. 10 gives an overview on dependencies between life cycle phases and contained artifacts.

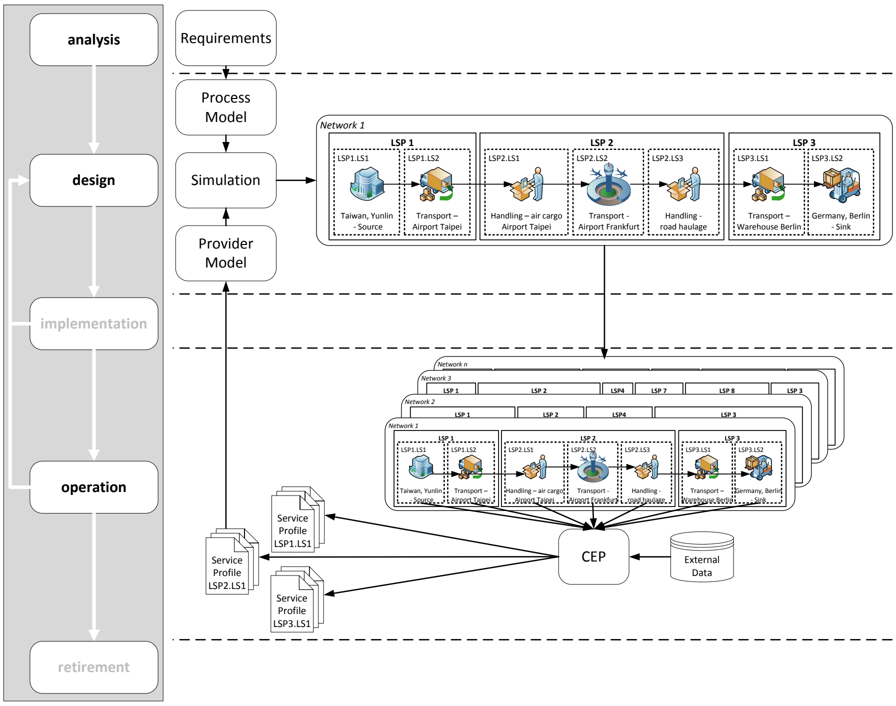

Figure 10 – Service life cycle using CEP for acquiring real-time data for simulation

8 Conclusions

Planning and monitoring of complex logistics contracts are major issues from a 4PL point of view. A multi-staged planning process is necessary in order to orchestrate all involved providers. Within this planning process a variety of actually independent or isolated steps have to be performed, i.e. to manage involved service providers, to find the proper sequence of executed LSs and to ensure that the planned process conforms to the customers' requirements. To reduce risks, time and costs a 4PL should have an integrated view on the process and derive as much planning artifacts as possible through automated techniques. Monitoring executed processes yield to high volume of data which have to be processed and turned into valuable information for participants and for future analysis.

In this article we presented an integrated planning approach based on integration and subsequent transformation of models. Crucial to a successful validation of the planning process are runtime data acquired by CEP-based approach. To make these data available for use in the planning process, a specialized provider model was created and together with a process model of a logistics contract transformed into a simulation model. The Service Modeling Framework and its components, namely the service repository and the SMF editor, then allow for uniform access to available LSs and models and see to transform or extract specific information from one model into another. In this context we also clarified the requirements of our approach in general in that we presented under what circumstances our approach can be applied. As an example we then took a process model and presented how to perform a process transformation into a simulation in order to make sure that the modeled process is robust, cost efficient and meets the customers' requirements. If the result of the simulation is satisfying and we can determine a valid combination of services and service providers respectively the planning process can be closed at this point.

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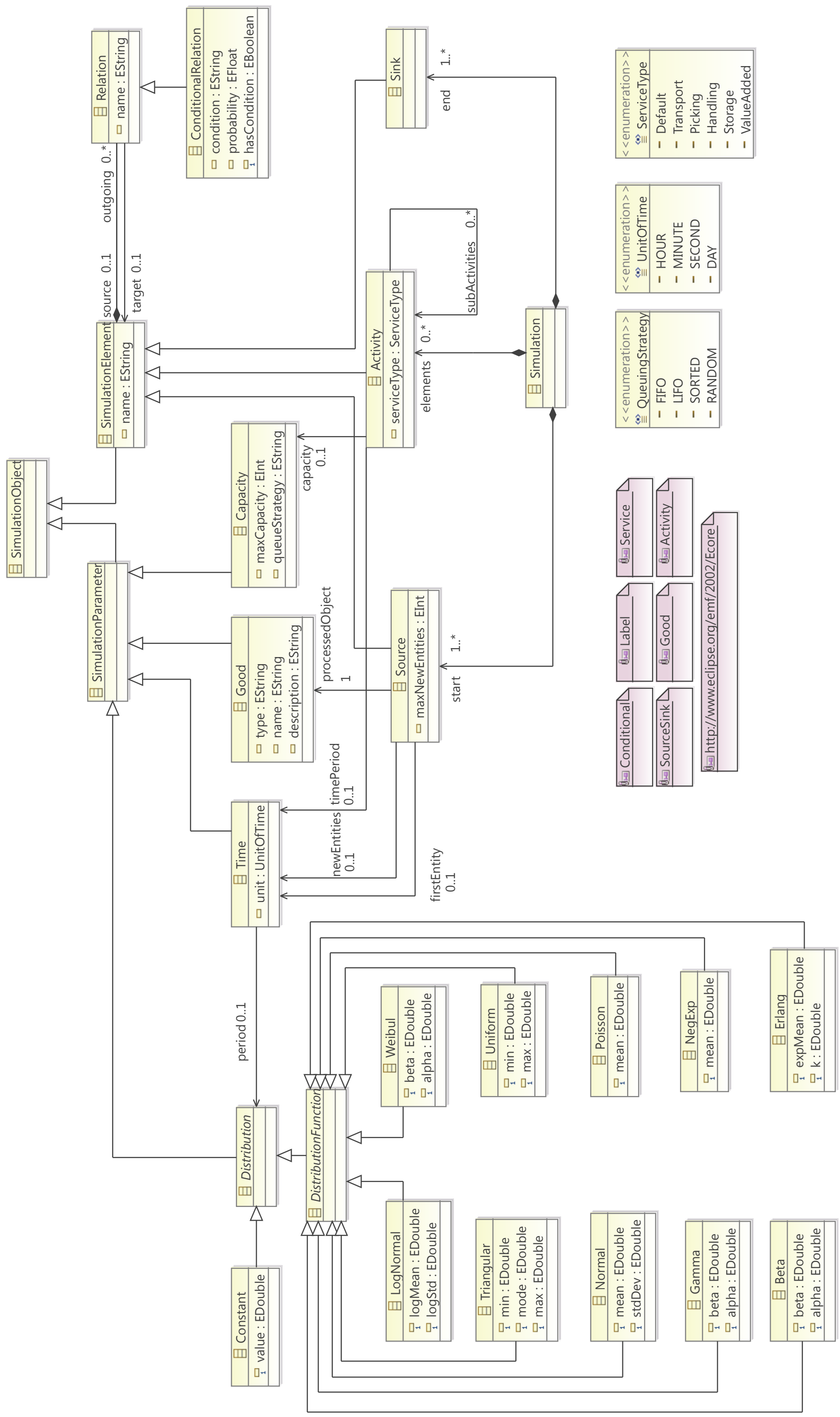

Figure 11 – Generic simulation metamodel