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A CONCEPTUAL MODELING APPROACH FOR SUPPLY CHAIN EVENT MANAGEMENT (SCEM)

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Abstract

The management of supply chains is a very comprehensive task. Predictability and response to incidents in process executions are challenging. With Supply Chain Event Management (SCEM), researchers propose an approach for overcoming these problems through proactive monitoring and notification of crucial process activities across the supply chain. The identification and definition of such crucial activities and information needs are necessary to handle possible abnormalities although they are challenging task which have not been solved in SCEM research so far. Hence, we propose a modeling approach which allows the conceptual specification of an adequate information exchange along the supply chain. With our approach we focus on the specification of relevant logistical objects, the definition of possible events, and the design of notifications for decision makers in the supply chain.

Keywords: conceptual modeling, supply chain event management, SCEM.

1 MOTIVATIONS

Divisions of labor and distributed value chain activities require a good management of logistic networks as a strategic competitive advantage (Steven & Krüger 2001). The role of Supply Chain Management (SCM) increases. Interorganizational integration of processes, logistics, and information supply becomes necessary in order to efficiently cooperate (Bechtel & Jayaram 1997; Holten & Schulz 2001). The provisioning of information and information systems throughout the supply chain is a key point within SCM (Barrat 2004; Bechtel 1997; Knolmayer & Mertens & Zeier 2000; Göpfert 2002).

Characteristic information systems for SCM such as Advanced Planning and Scheduling Systems are mainly used for the planning and implementation of logistic processes but offer only limited functionality for the monitoring and management of the operative execution of logistic activities. On the contrary, Supply Chain Event Management (SCEM) allows the short-term planning, management and controling of information regarding the operative logistic processes. It is a proactive concept that allows diverging high process complexity. Therewith, it helps overcoming a bad predictability or forecast reliability within the different steps of a value chain. It fosters the interorganizational visibility of critical objects throughout the supply chain (Nissen 2002; Wieser & Lauterbach 2001). Proactive and automated monitoring and management of supply chain critical objects (e.g. palettes, customer orders) help identifying failures and disruptions in material, product, and information flows. Hence, countermeasures can be induced earlier and more systematic (Wiener 2007). An increased reactivity from various parties or stakeholders of the supply chain to possible disruptions or events can increase an effective information supply and an accomplishment of superior business objectives (Klaus 2004; Steven & Krüger 2004).

An adequate and prompt supply of information is a prerequisite for the realization and execution of SCEM. Hence, the conception and implementation of appropriate information systems is a basic condition. Nevertheless, the identification of critical objects or steps in the supply chain, the specification of information needs to cover possible incidents in process executions and the adequate provisioning of responsible decision makers with necessary information to handle such incidents as well as the implementation of an appropriate information technology are challenging tasks in SCEM (Liu & Kumar & van der Aalst 2007; Nissen 2002; Steven & Krüger 2004). Although there is much research on the overall concept of SCEM and related information technology challenges, a methodical support for identification and definition of such crucial activities and information needs of persons responsible to handle possible disruptions is neglected up to now. Conceptual models serve as an instrument for structuring and documentation of such complex problems and encourage a common understanding between different stakeholders, e.g. managers, domain experts, and technical experts (Rosemann, 1996, Kottemann & Konsynski 1984; Karimi 1988). Therefore, the exploitation of such a modeling approach for the management of supply chain events—that is for the identification and specification of incidences and for the preparation of necessary notification based on information needs as well as their implementation in information systems—seems reasonable. The article proposes an approach for the conceptual modeling of interorganizational events within the supply chain.

2 RESEARCH METHOD

In literature, the usage of conceptual models for the documentation and construction of real world events is broadly accepted (Rosemann 1996). Hence, using such models and modeling methods for an interorganizational supply chain information management seems to be reasonable. Information systems engineering is a process of change in order to achieve certain goals in information systems design (Hirschheim & Klein & Lyytinen 1995). With this article, we will present certain representation forms of the object systems that are necessary for the systematic and exact conceptual modeling of SCEM in the context of interorganizational needs.

The research process (cf. Figure 1) started with the awareness of a practical problem (Takeda & Veerkamp & Tomiyama & Yoshikawa 1990). We were faced with the question of how to specify a management system for supply chain events on a conceptual level. The aim of such a research process was to provide a conceptual modeling approach guiding the development of a SCEM information system from functional specification to technical implementation. The practical need for such a method became apparent during discussions with various retailers about their experience with Collaborative Planning Forecasting and Replenishment (CPFR) and Efficient Consumer Response (ECR) and their problems with data exchange between different stakeholders (Winkelmann & Beverungen & Janiesch & Becker 2008). It became obvious that there were many obstacles in sharing all information between the stakeholders within the supply chain. It was not possible to individually define notifications and information allocations for each member of the supply chain. Hence, a conceptual approach turned out to facilitate a consensus between the different stakeholders about the information sharing within the supply chain. To solve the identified problem we were looking for a method that:

(R1) supports the conceptual modeling of event-driven information flows according to business processes, information needs and restrictions in the supply chain (Requirement 1),

(R2) facilitates the technical implementation of an SCEM information system in accordance to address different stakeholders (e.g. domain and technical experts) (Requirement 2).

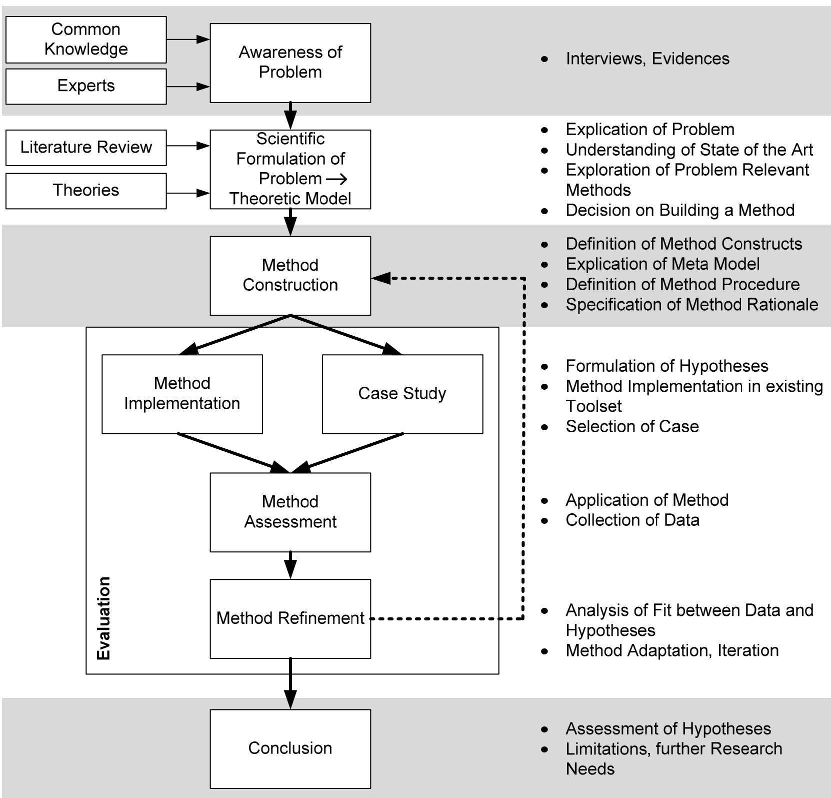

Figure 1. Research Procedure

Having this in mind, a literature review was performed in order to consider available research on conceptual modeling techniques for SCEM. Based on the requirements R1 and R2 we were able to identify existing modeling methods which are possibly capable of fulfilling these requirements. However, within a detailed analysis of the approaches based on the comparison process of (Song & Osterweil 1994) we came to the conclusion that none of the existing approaches fully met our requirements. Hence, we decided to develop a new methodological approach.

The construction process of the approach is similar to the procedures proposed by Greiffenberg (2004) and Gupta & Prakash (2001). Based on previous discussions, interviews and literature reviews, we derived language concepts that were necessary for supporting our requirements R1 and R2. Afterwards, the resulting concepts were supplemented with attributes and, thus, relations between the concepts were defined in order to establish the conceptual modeling approach. All elements of the conceptual modeling language have then been consolidated in common specification.

For the evaluation of the artifact, we implemented the model in order to visualize and apply its implications. For a practical assessment and a better method refinement, we evaluated the approach with the help of a case study in retail. Based on our requirements we generated the following propositions for the evaluation:

(P1) The application of our modeling approach improves supply chain spanning information exchange in the context of SCEM. (Proposition 1)

(P2) The application of the approach facilitates the implementation of an information system for the management of events in the supply chain. (Proposition 2)

(P3) The approach is capable of modeling the appropriate information needs of the persons responsible to handle occurring events of fault. (Proposition 3)

(P4) The approach allows a linkage to existing process modeling languages in order to specify process events and information that should be promptly processed at occurrence of such events. (Proposition 4)

The results from interviews, literature reviews, method implementation, and case study research were then compared to the propositions. We were able to derive new requirements on the approach, to identify deficiencies, and refine the concept by omitting and modifying language constructs.

Our way of conducting research is based on the design science paradigm (Hevner & March 2004). We aim at developing a domain neutral IT artifact, namely a modeling approach for the management of supply chain events. The research method is built on works of Takeda & Veerkamp & Tomiyama & Yoshikawa (1990), Rossi & Ramesh & Lyytinen & Tolvanen (2004) and Greiffenberg (2004), in which a practical problem is the focus of the construction process.

3 STATE-OF-THE-ART IN SUPPLY CHAIN EVENT MANAGEMENT

The term *Supply Chain Event Management (SCEM)* is widely used ambiguous. On the one hand, this term is characterized as an overall concept, which abstracts from specific technical aspects. On the other hand, the term SCEM is considered as a specific technical implementation of application systems (Alvarenga & Schoenthaler 2003). In the following, we abstract from technical details and rather focus on the conceptual perspective of SCEM. Thereby, the core aspects of SCEM and especially the major tasks of the conceptual design are taken into account to derive requirements for a conceptual modeling language.

From a conceptual point of view, SCEM is primarily subdivided into the core aspects *monitoring*, *notification*, *simulation*, *controling*, and *measuring* (cf. Figure 2), which are representing the core functionalities of this approach (Knickle & Kemmeter 2002). The basic aspect of SCEM is the *monitoring (1)* of logistic objects within supply chains in respect of occurring events. A logistical object represents a logical or physical item (e.g. a customer's order or a container), an activity within a logistic process as well as a whole logistic process. In order to monitor such objects, they serve as reference points for possible events. An event is an indicator for differences between actual and planned conditions of a parameter, which is monitored for a logistical reference object (Wieser & Lauterbach 2001; Alvarenga & Schoenthaler 2003). Possibly, the occurrence of events has effect on the planning and execution of other (up- and downstream) logistic processes. To handle critical effects on relating processes, the automatic *notification (2)* of corresponding decision makers is necessary. Hence, providing relevant information to persons responsible is an essential prerequisite in order to take countermeasures to resolve variations while process execution. Based on provided information, *simulations (3)* are used to verify and benchmark handling alternatives to resolve variations and resulting effects to other processes along the supply chain. Subsequently, a selected alternative of handling is implemented in logistic processes and the supply chain is adjusted (*control (4)*). To ensure planned conditions while process execution, *measuring (5)* functionalities allow continuous observations and analysis of actual and planned conditions along the whole supply chain.

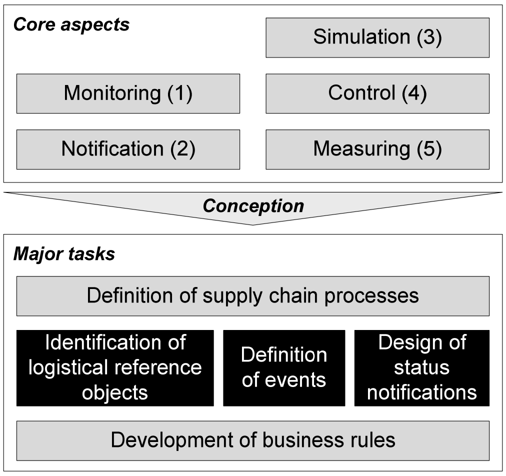

Figure 2. Components of the SCEM Approach (Steven & Krüger 2004)

Due to the core concepts of SCEM, the major tasks of the conceptual design are the *definition of supply chain processes*, the *identification of relevant logistical reference objects* and the *definition of related events*, as well as the *design of status notifications* with relevant information (again cf. Figure 2). Further, countermeasures are defined by *developing business rules* (Nissen 2002; Steven & Krüger 2004).

The initial point of the conceptual design of a SCEM solution is the coverage and *definition of supply chain processes*. These processes are perceived as a logical order of logistical activities and described hierarchical in different levels of abstraction (Steven & Krüger 2004). According to methodical facilitation of describing supply chain processes in supply chain management, methods and languages of business process modeling are also used for the definition of supply chain processes. Modeling languages like value chain diagrams or simplified process chains are mostly proposed for the description and modeling of such processes (Arndt 2008; Kruppe 2007). These approaches have in common, that they are mostly used to describe processes on a high level of abstraction. In contrast to this, detailed descriptions of supply chain processes are necessary for the identification and specification of relevant logistical reference objects and related events (Steven 2004). In the field of business process modeling, Event-driven Process Chains (EPC) (Scheer 2000), Petri Nets (Petri 1962) or the Business Process Modeling Notation (BPMN) (White, & Miers 2008) are established universal modeling approaches, which take these requirements into account. Using these modeling approaches supply chain processes can be described in detail as well as hierarchically structured on different levels of abstraction. In addition to these universal modeling approaches, with the Supply Chain Operations Reference (SCOR) (SCC 2008) a specific method for designing and modeling of supply chains is given. Therefore, the SCOR serves as a reference model for supply chains and provides predefined building blocks of supply chain processes. Additionally, supply chain related ratios are provided by the SCOR for monitoring and measuring purposes.

Especially, the *identification of relevant logistical reference objects*, the *definition of events*, and the *design of status notifications* are commonly referred as challenging tasks in SCEM (Nissen 2002; Liu & Kumar & van der Aalst 2007). In the literature, these tasks are often discussed from a more general point of view, conceptual or technical aspects are mostly neglected (Steven & Krüger 2004; Nissen 2002). To define events, monitoring relevant ratios have to be specified in relation to a logistical reference object as well as planned conditions and critical notification levels. The design of status notifications comprehends the definition of organizational units (addressees), which have to be informed in case of incidents in process execution as well as the identification of necessary information needs to cover such interruptions. Methodical assistance of these tasks is only provided for specific aspects, e.g. the definition of events. For the modeling of events Liu & Kumar & van der Aalst (2007) propose the use of time-related Petri Nets. In this approach, only the formal definition of critical notification levels is addressed. Other aspects of SCEM are neglected.

To sum up, the need of a methodical support of the conceptual design and implementation of information systems in the context of SCEM is identified. Especially, a comprehensive view of the definition of events, the identification of logistical reference objects as well as the design of status notifications and the identification of information needs is necessary. In order to overcome the identified methodical shortcomings, we propose a modeling approach which allows the conceptual specification of an adequate information exchange along the supply chain and facilitates the technical implementation of information systems to benefit the realization of SCEM.

4 CONSTRUCTION AND APPLICATION OF THE MODELING APPROACH

4.1 Language Construction

To describe the events and the triggered notifications we have developed a modeling language by applying meta-modeling as a design technique (Strahringer 1996). The Entity-Relationship Model (ERM) (Chen 1976) is a widely established approach for the conceptual representation of modeling languages (Becker & Seidel & Pfeiffer & Janiesch 2006). As a result of the development process, we constructed a modeling language whose conceptual specification is shown in Figure 3. Additionally, the implemented language constructs, relations, and the proposed modeling process are illustrated in Figure 4. The constructs are classified into different modeling contexts according to the different components and tasks of SCEM. For a better understanding, from now on, constructs are highlighted italic with capital initial letters; the steps of the modeling process are numbered in round brackets.

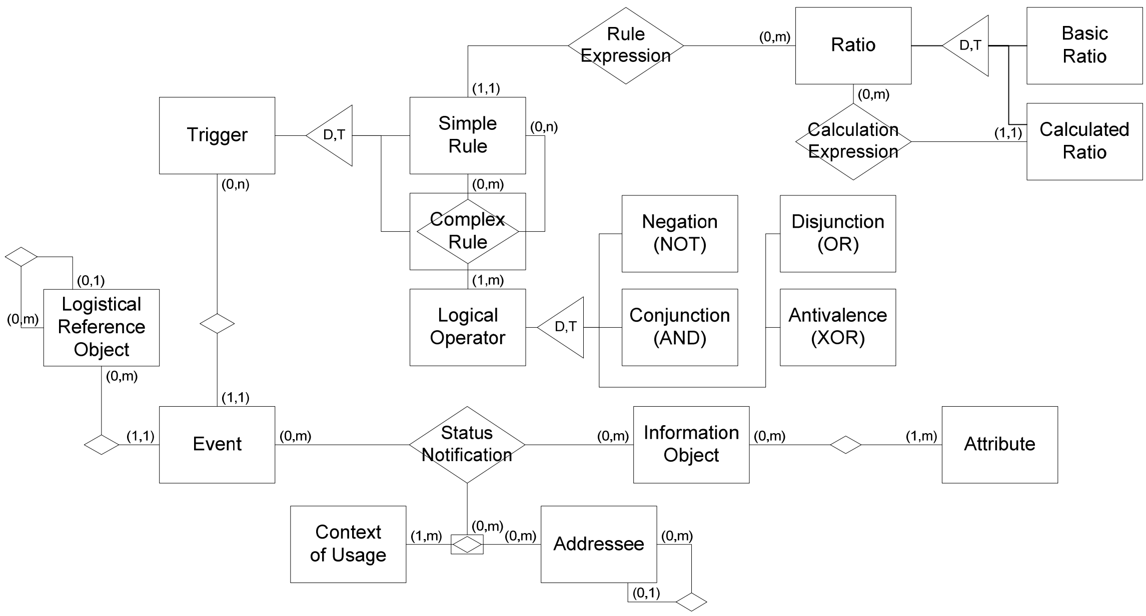

Figure 3. Conceptual Specification of Modeling Approach

First of all, *Events* are set in relation to *Logistical Reference Objects* and *Rules* in order to trigger the particular *Event.* Moreover, *Addressees* of dedicated *Information Objects* are also related to *Events.*

Therefore, the relevant *Logistical Reference Objects* (1) are defined. After that, certain *Ratios* (2) are defined and combined with a *Rule Expression* to specify the triggering *Rules* (3). Those *Rule Expressions* are certain arithmetic combinations of *Basic Ratios* or *Calculated Ratios* that are assigned to specific *Rules*. For each assignment specific values are defined. For example, a rule applies if the stock of a product is lower than a specified threshold. Based on this, the actual *Events* (4) are modeled by relating them to *Logistical Reference Objects* and *Rules*. At this point, *Logical Operators* may combine those *Rules* to a combined and hence more complex expression. The *Addressees* (5) are defined and arranged in a hierarchical manner. They possibly receive *Information Objects* (6) which are modeled afterwards. *Addressees* are related to *Status Notifications* depending on the *Context of Usage*. It can be interpreted as some kind of filter that specifies under which contextual conditions the *Addressees* receive the relevant *Information Objects*. In the end, those contextual conditions are related to *Status Notifications* (7) in order to notify *Addressees* about certain *Events*. For example, an addressee may receive an information object A in case of an event X and receive an information object B in case of another event Y. Thus, sensitive information objects can be filtered and each addressee only receives the information objects with depending attributes, such as additional amount that has to be ordered.

To integrate the different modeling contexts, the concepts of the modeling language are specified context-spanning and hence can be re-used in suitable contexts. This concept prevents from illustration conflicts of occurrences of the same object and from modeling redundant issues. This integration of contexts allows a comprehensive view on the different tasks of supply chain event definition.

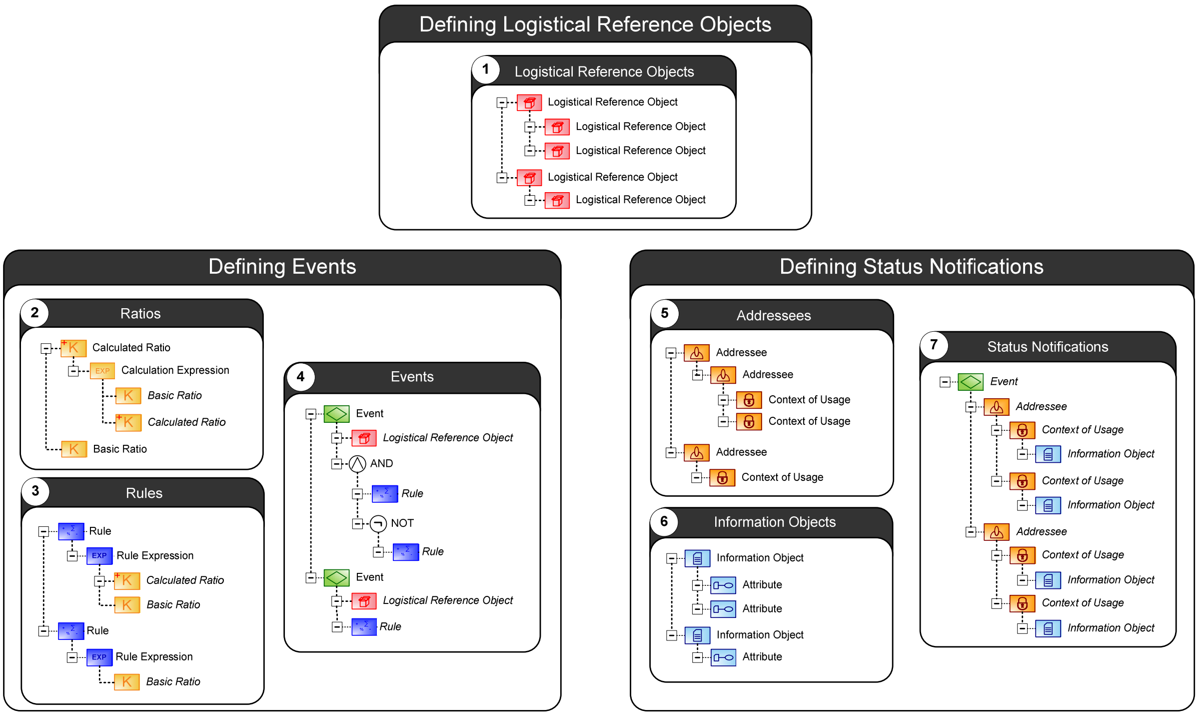

Figure 4. Representational Specification of Modeling Approach

As mentioned before, the definition of logistical reference objects, events and status notifications are parts of the overall SCEM tasks (cf. Section 3). To provide a linkage of these tasks to the definition of supply chain processes, a methodical integration of our approach with supply chain processes is necessary. Thus, defined events can be linked to specific states in supply chain processes in order to provide a detailed view and to monitor crucial states. For example, to monitor the order status in a particular process, a defined event can be related to the different states. E.g. an event to monitor extraordinary deliveries is related to process states. In case of e.g. abnormal amounts or quantities the defined event is triggered and the contracting as well as the order management will receive status notifications (cf. Figure 5).

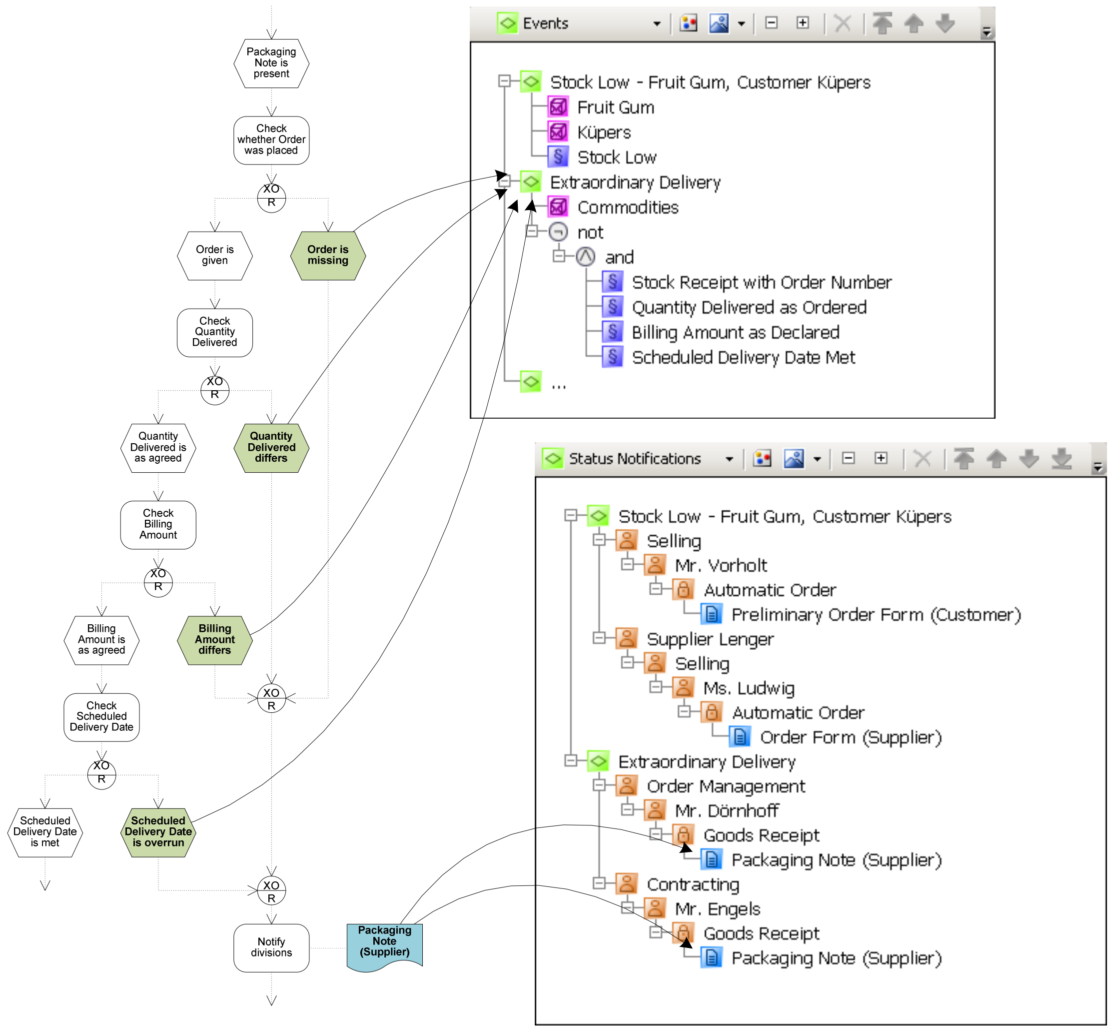

Figure 5. Relations between Process Definition and Supply Chain Events

4.2 Exemplified Application based on a Retail Example

For the purpose of application, the constructed modeling language is implemented using a meta-modeling tool. Figure 6 displays a screenshot of the (meta-) modeling software containing the corresponding model. A general introduction to the tool support is given in Becker & Janiesch & Seidel & Brelage (2005) and Delfmann & Janiesch & Knackstedt & Rieke & Seidel (2006). The exemplary case evaluation deals with two (unplanned) events. Both events are regular incidents at wholesalers. The first event is the result of a stock monitoring. In this example, the stock falls below a certain limit. With the help of our approach, we are able to specify an automatic preparation of a further delivery to the customer and an additional order at the pre-supplier of the wholesaler. The second event is triggered by the arrival of a delivery, whose billing amount differs from the declared amount. The same event is activated if the scheduled delivery date is not met, the quantity delivered is not as ordered, or the delivery has happened without any preceding order.

The logistical reference objects (1) relevant for this example are defined in a specific context (e.g. *Commodities*, *Customers*, *Suppliers)*. As a next step, relevant information objects (6) are to be defined. Relevant information objects in this context are *Preliminary Order Forms (Customer)*, *Order Forms (Supplier)*, and *Packaging Notes (Supplier)*. To monitor events, specific ratios are to be defined (2). For example, a particular ratio *Stock* representing a customer's stock is required. To determine whether an incoming delivery is a planned or an unplanned delivery other ratios are needed. E.g.

quantity, billing amount, and scheduled delivery dates have to be checked. For this purpose the definition of calculated ratios (e.g. *Billing Amount* as result of the quantity multiplied by the price of a single item plus a possible flat rate) are necessary. Moreover, the check criteria are defined by rules (3). For example, the *billing amount* has to be matched against the expected *billing amount as declared*. Based on the matching results, the rules trigger respective events. By combining logistical reference objects with those rules, the related events (4) have to be defined (e.g. *Extraordinary Delivery)*. To this event definition four rules are assigned by combining them with a logical *AND*-operator (and negating by a *NOT*-operator). The rules are evaluated in a cascading manner. To handle possible event occurrences, organizational units, namely addresses, have to be defined (5). The addresses will receive individual notifications and information about abnormality in process execution. Defining such notifications (7), relevant information objects are related to particular addresses in order to handle a specific situation (event).

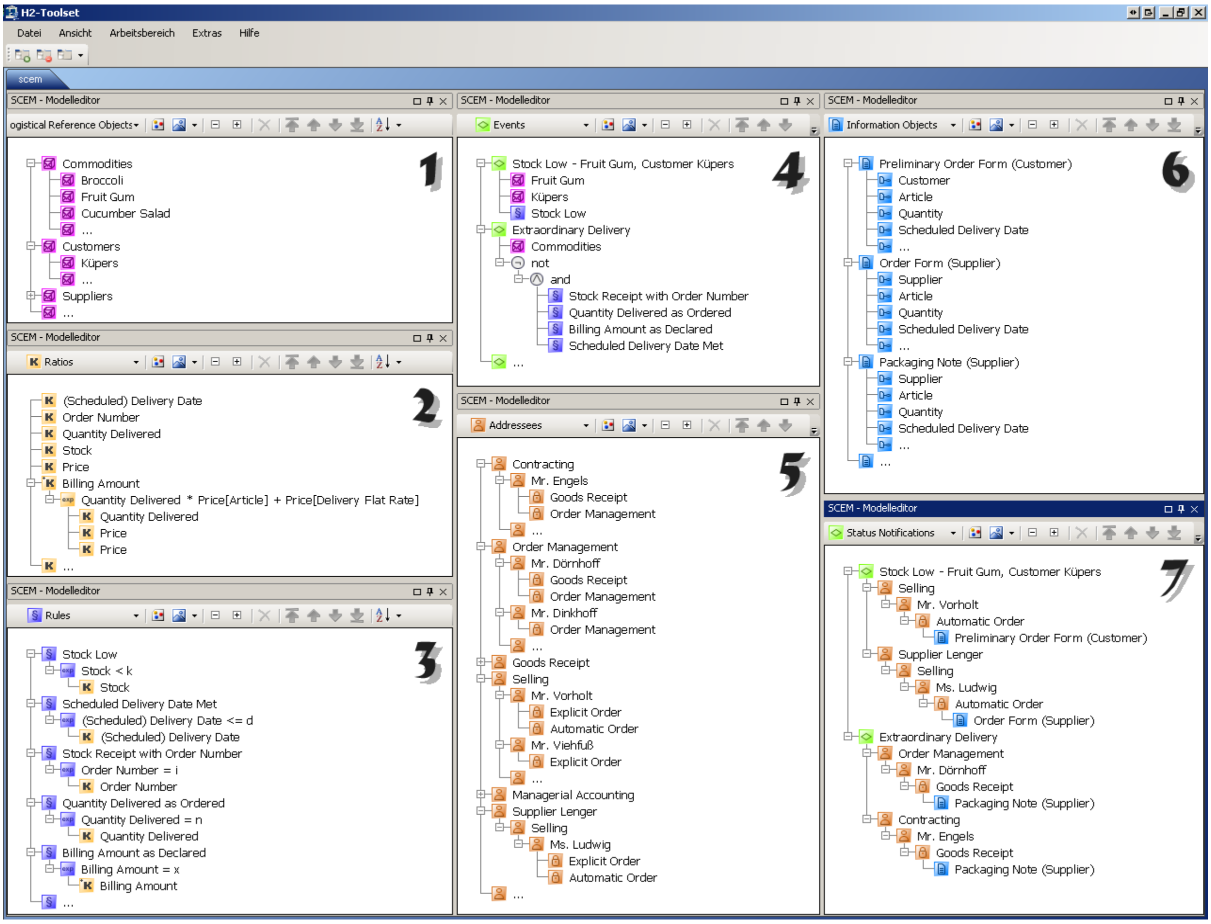

Figure 6. Exemplified Application of Modeling Approach

5 CONCLUSION, LIMITATIONS AND OUTLOOK

The concept of supply chain event management is a further development of existing supply chain management concepts. It does not deal with goods themselves but with the handling of incidents (events) concerning the flow of goods. SCEM allows the notification of people and organizations across organizational boundaries to provide a prompt response on defined events. For example, SCEM can help reducing the bullwhip effect because information cannot only be forwarded to the next stage in the supply chain but information can also be forwarded to pre-suppliers or pre-pre-suppliers. So far, the discussion on SCEM has been focused on a managerial or a process level. However, a conceptual approach for the identification and definition of information needs across a supply chain to handle possible occurring incidents is not provided in the literature up to now. With our conceptual approach we propose a concept for the identification of suitable logistical reference objects and for the definition of relevant events with regard to this reference objects. It is possible to design status notification based on reference objects and events.

As our exemplified application indicates, our initial approach supports the conceptual modeling of event-driven information flows according to the needs and restrictions in supply chain communication. Furthermore, it facilitates the technical implementation in accordance to address different stakeholders (e.g. domain experts and technical experts) in the development process and to effect a common understanding of the treated object. The application of our conceptual approach based on a tool implementation is a first evaluation step on our research agenda (cf. Table 1).

Proposition	Findings
P1	The proposed modeling approach can improve a supply chain spanning information exchange in the context of SCEM by facilitating the definition of relevant logistical objects, events, rules, notifications and addressees.
P2	The application of the approach facilitates the implementation of information systems for the management of supply chain related events. Based on this conceptual approach the technological independent specification of relevant objects and entities is possible. This allow for the involvement of different stakeholders like domain and technical experts to ensure a consensus about the requirements on such an information system.
P3	By defining rules and triggers that can be allocated to individual needs of specific actors in the supply chain, the proposed approach is capable for the specification of appropriate information needs of persons responsible to handle occurring events of fault.
P4	Due to the process modeling language independent definition of events and triggers, a combination with existing process modeling languages in order to specify process events and process related information is possible.

Table 1. Approval of the proposed approach

However, with respect to the intended objective different assumptions are made during the development process of the conceptual modeling method. Consequently, different limitations are attended with the proposed modeling method and have to be taken into account for further applications. First of all, the approach is limited to a conceptual perspective on SCEM, excluding specific implementation aspects. In this way, the managerial, functional, and technical perspective of SCEM is addressed in common. Nevertheless, interrelations to the organizational and structural implementation and management of supply chains are not covered by the proposed approach. I.e. in our approach linkage between supply chain processes and events are only defined in a logical way. A methodical integration with process modeling languages is still outstanding. As a result of this, effects of changes in supply chain arrangements and process could not be taken into consideration of the specification of SCEM. Reverse, the derivation of further details for development and improvement of existing supply chain structures is not methodically supported up to now. Furthermore, the proposed approach is focused on the field of supply chain management. With respect to unstructured domains like creative industries or research and development, the processes in supply chains are commonly structured. Hence, the application of our approach is focused on structured processes with clearly identifiable decision making entities, clearly delineated areas of authority, classifiable and predictable (planned or unplanned) events and event variations and predictable responses to such events. Unpredictable events should not be taken into consideration. An ex-ante definition of all possible but not predictable events seems to be not appropriate and would lead beyond the intention of the SCEM approach. Even though, results of such events can still be regarded.

Further research will focus on the evaluation of the provided modeling approach and on aspects of the before mentioned limitations. In the short-term, the approach will be applied in different domains and different application scenarios. In particular, the capability of our approach to cover the requisite aspects of SCEM to improve the event-driven information flows and handling of incidents across supply chains is evaluated. In a next step, possibilities and requirements for the connection with or integration into supply chain tools are reviewed. Middle-term research will address the methodical integration with common process modeling languages. Furthermore, consequence of changes in supply chain structures and processes to the definition of SCEM will be addressed by identifying interdependencies and developing response mechanisms. As a long-term research field, the approach would be enhanced by a methodical support for the improvement of existing supply chain arrangements, e.g. the identification of potential risks in supply chain execution.

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