Understanding Humanitarian Supply Chains – Developing an Integrated Process Analysis Toolkit

Adam Widera
University of Muenster
adam.widera@ercis.de

Hanns-Alexander Dietrich
University of Muenster
dietrich@ercis.de

Bernd Hellingrath
University of Muenster
hellingrath@ercis.de

Jörg Becker
University of Muenster
becker@ercis.de

ABSTRACT

In this paper we present the development of an integrated process analysis toolkit for humanitarian logistics. The toolkit integrates a conceptual and a technological component. Our approach follows a case study-based modeling and design approach. The developed concept was evaluated in two humanitarian organizations. Based on these results we extended and integrated the tool-supported process analysis approach, which is ready to use for the structural and quantitative analysis of humanitarian logistics processes. The toolkit can be applied in humanitarian organizations as a decision support tool for designing, planning and executing their logistics processes. Thus, the application affects the preparedness of humanitarian organizations as well as their response performance. The process analysis toolkit is embedded in an overall research agenda with the objective to provide humanitarian organizations with the capabilities to identify, monitor, and improve their logistics processes respecting the organization specific objectives.

Keywords

Humanitarian logistics, reference modeling, supply chain management, performance measurement, process analysis.

INTRODUCTION

Humanitarian logistics have a major contribution to the effectiveness and efficiency of humanitarian operations (Tomasini and van Wassenhove, 2009). However, the interface and management function of logistics is underestimated: roles and responsibilities in humanitarian supply chains are not clear, performance is not measured adequately, and the use of technology and institutional learning are inadequate (Blecken, 2010). One way to address these issues is to systematically identify and visualize all involved entities, processes, and their interrelations. To do this for commercial supply chains there are several proved process modeling and analysis approaches, esp. in the area of reference models like the Supply Chain Operations Reference (SCOR) Model. The applicability of existing solutions from the corporate world to the humanitarian sector is limited though, because of the fundamental differences between the sectors (Beamon, 2004; Charles, Lauras and Tomasini, 2009). That is, all actors who are involved in humanitarian operations face a high degree of uncertainty and have to deal with unknown and multiple suppliers, hardly predictable demand, and the main requirement for minimal lead times. The focus of this paper thus lies on the development of an integrated conceptual and technological process analysis toolkit that meets the humanitarian sector's specific requirements for process modeling. This shall improve the humanitarian sector's process modeling capabilities.

In order to evaluate the RTM's applicability to and relevance for humanitarian logistics, it has been exemplarily evaluated in two humanitarian organizations. The second step was to deduce the conceptual and technological requirements from the results of the evaluation, and to integrate them within a process analysis toolkit. The resulting tool-supported process analysis approach is ready to use for structural and quantitative analysis of humanitarian logistics processes. The software prototype, which implements the approach, can be applied in humanitarian organizations as a decision support tool for logistics process design, planning and execution. Thus, it allows humanitarian organizations to benefit from better preparedness as well as increased response performance. The results presented in this paper are embedded in an overall research agenda with the objective to provide humanitarian organizations with the capabilities to identify, monitor, and improve their logistics processes respecting the organization specific objectives.

APPLICATION OF HUMANITARIAN LOGISTICS REFERENCE MODELS

The Reference Task Model for Humanitarian Logistics

Humanitarian logistics is described as the "process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people." (Thomas and Kopczak, 2005). Supply chain management (SCM) in humanitarian organizations currently evolves towards increased effectiveness and efficiency in terms of responsiveness and improved resource allocation as e.g. the military sector gained from the corporate world in the latest past (Moor and Taylor, 2011). As humanitarian and commercial supply chains differ (Beamon, 2004; Charles et al., 2009) and successful concepts from the commercial sector might not fit disaster relief, such transfer has to be done very carefully. The main differences between commercial and humanitarian supply chains influence three building blocks: supply chain flows, structures, and project life cycle management (Widera and Hellingrath, 2011b). Perhaps the most fundamental and important difference is the strategic goal of humanitarian supply chains: saving lives and relieving human suffering. This causes various sector-specific attributes: highly responsive (effective) instead of efficient (cost effective) processes, uncertain and unpredictable demand, the role of donors as buyers and beneficiaries as end users (Beamon, 2004), a highly volatile environment (Charles et al., 2009), partly temporary and unknown supply chain design (Jahre, Jensen and Listou, 2009), and the focus on procurement and distribution within the logistics value chain (Blecken, 2010). Acknowledging these is highly important in order to understand and analyze humanitarian supply chains, as well as to identify and apply appropriate process analysis approaches.

According to Thomas (2006) a reference model "is an information model used for supporting the construction of other models. (…) The reutilization of reference models connected with this can be seen as a fundamental idea resulting from the paperless, tool-supported data-processing consulting at the beginning of the 1990ies and must be emphasized as a fundamental characteristic of reference models." For commercial supply chain management and logistics, various reference models exist, which are well established and widely disseminated, such as ARIS and SAP R/3 (Scheer, 1991), the Retail-H (Becker and Schütte, 2004) or the SCOR-Model (Supply Chain Council, 2010). Additionally, many business process reference models are only published as paper copies (Fettke, Loos and Zwicker, 2006), without any tool support. This is considered as one major deficit of reference modeling (vom Brocke and Thomas, 2006). Turning to humanitarian logistics, it can be noted that several works on process modeling have been presented in recent years, which fall in two categories. The first category focuses on organization or case specific process models from scratch (e.g. Charles et al., 2009). Models from the first category can hardly be applied to the whole sector, because of the specific organizations' underlying structures, predefined standard operational procedures, conventions in terms of objectives, and scope. The second category focuses on reference models that are applicable in various humanitarian organizations with their different logistics processes (e.g. Tufinkgi, 2006). An investigation and comparison of the models from the second category that are provided by Tufinkgi (2006), McGuire M(2006), and Blecken (2010) qualifies the RTM as an adequate basis for the purpose of this paper (see also Widera and Hellingrath 2011a). The RTM respects the required adaptability, manageability, and accuracy for process analysis. Thanks to the application of the Business Process Model and Notation (BPMN) within the RTM, an established and continuously approved modeling language is used (White, 2004; Franke et al. 2011). BPMN can be described as a "readily understandable" notation providing a "standardized bridge for the gap between the business process design and process implementation" (Object Management Group, 2011). Thus, major requirements for the design of reference models as well as adequate input from the humanitarian sector seem to be fulfilled.

The development of the RTM was based on a combination of a comprehensive literature analysis and interviews with more than 30 humanitarian organizations (for the following paragraph see Blecken (2010)). Thus it reflects the current state of the art in supply chain management research as well as real world awareness of humanitarian organizations in disaster relief. The RTM provides a common terminology and repository of interrelated activity descriptions for humanitarian logistics processes during the immediate emergency response phase after a sudden-onset disaster. Additionally, clear roles, responsibilities, and definitions can be defined in order to enable a structured and standardized supply chain network picture. The BPMN is used in order to be flexible about the specific application area and robust in terms of accuracy, sustainability, and active modeling research community. In the BPMN the individual structures of organizations can be modeled by using lanes, while several organizations can be modeled by using pools (Object Management Group, 2008). The framework of the RTM is shown in the next figure.

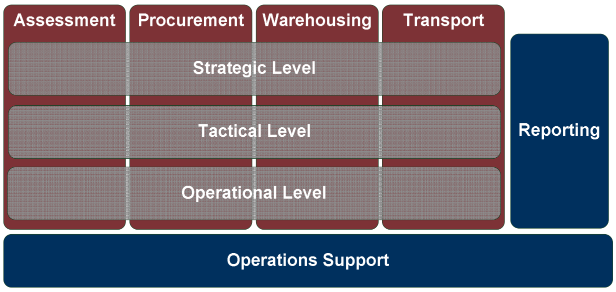

Figure 1. Framework of the Reference Model for Humanitarian Logistics (acc. to Blecken, 2010)

The RTM will be presented briefly in the following as its structure seems very useful for the structure of the process analysis tool. The strategic, tactical and operational planning horizons are depicted on the vertical axis. On the horizontal axis, the main humanitarian logistics functions are divided: assessment, procurement, warehousing, and transport. On the strategic level general supply chain design related tasks are executed with a time horizon beyond two years. The planning and optimization of the entire supply chain with a time horizon between six month and two years is located on the tactical level. The operational level covers the optimization of resources, which were allocated on the tactical level. Decisions and processes the operational level deal with supply chain execution issues and have a horizon of up to six months.

The first functional pillar represents assessment, which is the decision basis for all logistical plans of relief operations. Assessment tasks, e.g. the strategic mission statement or the operational assessment of local supplies, can have different time horizons. On the basis of assessment results, procurement tasks have to be considered. This means that suppliers have to be considered, and sourcing strategies need to be defined in order to deliver the right goods, equipment, and services in the right quantity and quality, in the right time, at the right place, and respecting the planned or existing budgets. The warehousing pillar then reflects all relevant warehouse structures, strategies, and tasks starting on a strategic design level (e.g. pre-positioning of warehouses) up to operational decisions (e.g. setting up interim storages in the last mile). The tasks within the transport pillar cover all decisions regarding modes of transport as well as all stages of delivery, ranging from suppliers to the Last Mile. The meeting points of time horizons and functional pillars (e.g. operational assessment, tactical procurement, or strategic transport) contain tasks with detailed descriptions about what to do, as well as how to do it and/or what to consider. The execution and documentation of these tasks is accompanied by numerous operations support and reporting tasks.

Application and Evaluation of the RTM

The RTM has been applied in two different humanitarian organizations and has proven very beneficial for the domain of humanitarian logistics. The aim of the application was to map, visualize, and analyze logistics processes of two humanitarian organizations as well as to evaluate the applicability of the reference model. For this purpose, the RTM was completed by the development of reference processes and transferred into an appropriate modeling tool that supports the BPMN. A detailed documentation of the use cases can be found in Widera and Hellingrath (2011a). As a result, two organization specific process models were created following a structured process mapping session. The process mapping support by the RTM and the modeling tool have proven very useful (for the following paragraph see Widera and Hellingrath 2011a):

On the conceptual level all relevant and already existing tasks of the RTM were applicable for two different cases. Besides, organization specific standard operational procedures (SOPs), which are on a very detailed level and not contained in the RTM, could be added easily and accurately within the generated process models. The inventory control in the last mile warehouses could act as an example for a new and refined warehousing process. Here we identified some unconventional workflows with a high degree of manual tasks (such as daily count of stocks). The discussion of pros and cons of such procedures has been facilitated with the according process models. Based on these outcomes – two organization specific process models – a first strength-/weakness analysis as well as the potentials and restrictions of the tool-based process modeling approach were identified. On the technological level the process mapping support by the basic version of the modeling tool (i.e. the modeling engine) was very helpful in terms of time invested and automated securing the accurate modeling notation. The tool enables the modeler to concentrate exclusively on the selection of relevant tasks and the correlation of processes. The following process needs to be done exemplarily for the modeling of operational warehousing processes: (1) select the reference process "operational warehousing" → (2) de-select process elements which are not executed within the organization → (3) specify the process considering the organizational structure using appropriate BPMN pools and lanes → (4) add missing process sequences or refine bigger processes using the BPMN shape, e.g. "inventory control in the last mile". Thus, the tool-based application of the RTM promises to easily systemize and visualize logistics processes of humanitarian organization within a short period of time.

Two major limitations have been identified reflecting the overall objective of providing capabilities for identifying, monitoring, and improving logistics processes of humanitarian organizations. First, the RTM has to be extended in order to act as a process analysis toolkit. The extension of the RTM is executed in the area of new processes as described exemplarily above (i.e. on the horizontal level of the process model) as well as in the area of new information about processes (i.e. on the vertical level of processes as meta information such as metrics). The most important extensions on the horizontal can be understood as the deduction of reference processes for a structural analysis. A corresponding extension lies in the refinements of processes and consideration of external supply chain partners, esp. supplier and logistics service provider, because such processes directly influence the performance of humanitarian organizations. On the vertical level new information about all processes needs to be identified, which for our purpose mainly means metrics and their assignment to processes for quantitative analysis Second, adequate managerial components have to be identified and integrated within the RTM in order to act as a process management toolkit. These limitations and the further research agenda affect both the conceptual extensions (e.g. the identification and assignment of metrics) and technological changes (e.g. visualization of metrics within the modeling tool). Both aspects need to be integrated and aligned within the process analysis toolkit. Presented in the following are our results concerning the first step of the further research agenda, namely the analysis dimension, will be presented. The management dimension that extends the process analysis into a process management toolkit as the second step of the research agenda will be briefly described in the outlook of this paper.

DEVELOPMENT OF THE PROCESS ANALYSIS TOOLKIT FOR HUMANITARIAN LOGISTICS

Conceptual level

The analysis of humanitarian logistics processes requires the consideration (1) on the structural (design) level as well as (2) on the quantitative (operational) level in order to evaluate supply chain performance.

- (1) For the purpose of a structural analysis the first assessment criteria can be found in the RTM itself. The application of the RTM in various organizations results in specific process models. Usually, such process models differ from the RTM as a conceptual model on the level of organizational structures and on the level of the processes itself. The direct result of the process mapping (i.e. RTM application) is an AS-IS scenario which needs to be reflected by a TO-BE scenario created based on predefined reference processes of the RTM. For this purpose it is necessary to develop reference processes on a conceptual level by the identification and interrelation of relevant RTM elements. Figure 2 gives an example of the interrelation procedure for an sequence of the operational process of warehousing. The figure illustrates the modification from independent RTM tasks into an interrelated reference process. The upper field represents an excerpt of reference tasks from the operational warehousing RTM-box. These tasks are interrelated and formalized in the lower field into a logical process sequence which we call reference process. Deviations from the reference processes compared with organization specific AS-IS scenarios indicate inconsistencies or reasonable organizational characteristics. Within the reference process in Figure 2 the task "Verify Shipment Information" (highlighted in bold) can appear in deviating ways compared to the reference process: it can be missing completely, or it can be executed redundantly (e.g. before as well as after executing the quality check[1]). Once such deviations are recognized, improved TO-BE scenarios can be designed. For this purpose the RTM was enriched with reference processes for all functional areas (from assessment to transport) and planning horizons (from strategic to operational). Additionally, the ability of the identification, modeling, and description of new processes was successfully tested and integrated. The RTM can be extended in case of a justified process by refining existing or adding new processes with the basic BPMN. Redundant processes can be highlighted in the AS-IS scenario in order to be considered (i.e. avoided) within the design of a TO-BE scenario. The result of this structural analysis can be seen in a first strength-weakness analysis.

[1] For the complete reference process of operational warehousing see Figure 6.

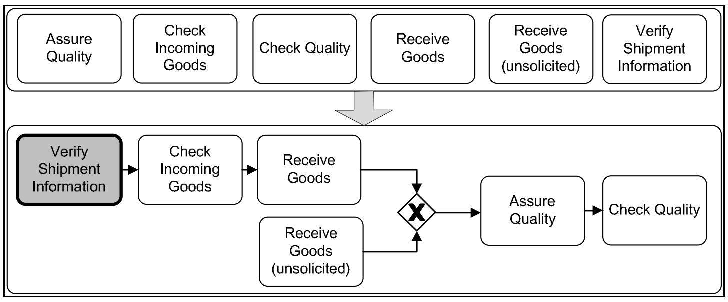

Figure 2. Example of Reference Processes

- (2) For the purpose of a quantitative analysis, all identified and modeled processes need to be quantifiable with appropriate key performance indicators (KPIs). KPIs can be defined as "a set of measures focusing on those aspects of organizational performance that are most critical for the current and future success of the organization." (Paramenter, 2010) An open set of appropriate KPIs respecting various recommenced requirements was identified in (Widera and Hellingrath, 2011b). One major requirement needs to be highlighted at this stage: the relevance of the performance metrics. For this purpose, a comprehensive literature review has been conducted with the aim to identify primary objectives of humanitarian organizations. The identified objectives form an orientation framework for relevant KPIs (see Widera and Hellingrath, 2011b). One example for a KPI could be the "Mean quality inspection costs per incoming goods item", which is related to the objective "Inventory Performance". In the following, the KPI is named IP.4 including the relation to the objective ("IP"=Inventory Performance) and the identification number (=4) within the KPI set (see VDI (2001) for further information about this KPI).

In order to (re)focus on the analysis of the process level, the orientation framework with KPI-objective relations needed to be reflected with actual humanitarian logistics processes. The Association of German Engineers (VDI, 2002) pointed out that existing SCM tools document relevant processes by the identification of events in form of quantity and time data as each KPI has to be quantifiable. In that sense all identified KPIs had to be assigned to specific processes. The following figure depicts how the Association of German Engineers (VDI) recommends identifying and assigning measurement points to processes.

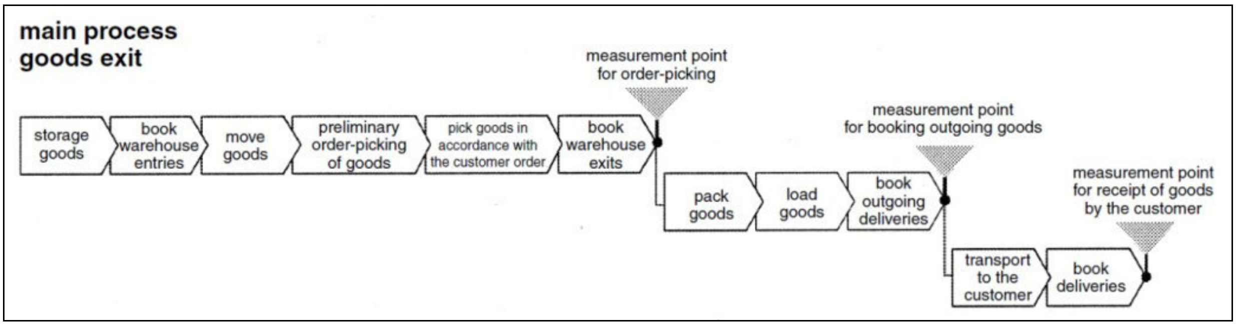

Figure 3. Extract of the process model for distribution with appropriate measuring points (VDI, 2002)

Figure 3 illustrates on the example of the main process "goods exit" how process sequences, e.g. picking of goods, can be formed by setting concrete measurement points, e.g. the measurement point for order-picking. The identified sequences reflect the activities that should be measured with the related KPIs. For the example of operational warehousing and the KPI "IP.4" the corresponding assignment is illustrated in Figure 4.

The measurement of IP.4, which is depicted with a blue line in Figure 4, has two starting points. On the one hand it starts with the process "Verify Shipment Information" of goods that the humanitarian organization orders directly. On the other hand it starts with the task "Receive Goods (unsolicited)" on the in-kind donations flow. According to the definition of IP.4 the accounting costs goods arrival, materials and equipment costs, and personnel costs are considered with a predefined calculation rule. The measurement point of IP.4 ends with the process "Check Quality". In result the KPI "Mean quality inspection costs per incoming goods item" (IP.4) equals the relation of quality inspection costs (defined as the sum of personnel costs plus material and equipment costs) to the number of incoming goods that occur during the warehousing process handles on different network levels of the supply chain (VDI, 2001). In a similar way to how it was just described, KPIs and measuring points were defined for all activities of the RTM (see Widera and Hellingrath, 2011). Two other KPIs are illustrated exemplarily in Figure 4: the KPI BM.3 "delivery date reliability (procurement)" with the objective of an adequate bottleneck management (=BM) and the KPI RS.6 "donation-to-delivery time" with the objective of a high responsiveness and speed (=RS). Once the RTM is applied within a specific organization all relevant KPIs can be found within the generated organization-specific process models. This tells the modeler which data shall be collected, monitored, and analyzed by the organizations in order to influence their performance, as desired by management. Managing all necessary processes, KPIs and interrelations requires adequate tool support. Accordingly, the technological level that implements our findings is described in the following sub-section.

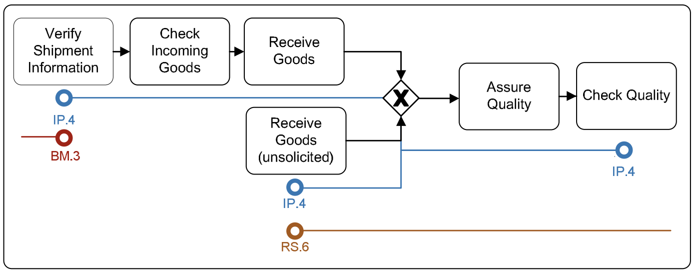

Figure 4. KPIs assigned to RTM processes

Technological Level: Benefits from a Configurative Meta Modeling Tool

As many process reference models are only published as paper copies (Fettke, Loos and Zwicker, 2006) and the missing tool support is considered as one major deficit of reference modeling (vom Brocke and Thomas, 2006) we prove the ability of the extended RTM by the development of a suitable modeling tool. Against the backdrop of reference modeling and process analysis, we researched several modeling tool requirements. Reference models are created for a class of domains and can be used as blueprints to, e.g., for the description of the organization, business process reengineering, and knowledge management (Fettke and Loos, 2003; Thomas, 2006). To facilitate the reuse of reference models and simplify their adaptation to current needs, the modeling tool should adequately assist the modeler. In the literature, this is generally known as the configuration of models (Becker, Delfmann and Knackstedt, 2007; Van der Aalst, Dreiling, Gottschalk, Rosemann and Jansen-Vullers, 2006). As our extended reference model is not yet a configurable reference model though, advanced configuration techniques are not necessary. However, basic techniques are very helpful to simplify the process of instantiating a new model for a specific humanitarian logistics provider from the reference model. For instance, if a humanitarian organization does not possess a warehouse to store or collect relief supplies, the corresponding process models of the RTM dealing with warehousing processes can be deselected.

As the reference model should be a (diagrammatic) process reference model for humanitarian logistics, a suitable modeling language has to be supported. In our case this is BPMN as it is widely accepted and already used in Blecken's reference model. Furthermore, a hierarchy concept for the different abstraction layers and navigation in a reference model is necessary. For instance, a regulatory concept can be used as a top hierarchy model, so that it would be possible to navigate to sub hierarchy models and thus structure the reference model.

To integrate the aforementioned KPIs into the reference model, the modeling language has to be extended by KPI attributes. To allow for reuse in the context of knowledge management the reference model should be searchable. The topic of searching models is named model querying in the literature. On the one hand, it should be possible to search for structural elements in models, like weakness patterns or syntactical errors. On the other hand, the model elements assigned to KPIs should be identifiable.

Most of the currently available modeling tools are available commercially, and focus mainly on process modeling and analysis (Gardner, 2011). Common commercial modeling tools provide a predefined set of modeling languages, e.g. the ARIS Toolset or Signavio. To address different attributes in the application domains, the ARIS Toolset for example has a predefined set of 256 customizable attributes. However, the modeling languages are not customizable by the user, so that, for instance, deleting unnecessary language elements for a given application domain is not an option. Furthermore, none of them has sophisticated support for configuration or adaptation of models (Delfmann and Knackstedt, 2007). They mostly restrict model to searching names in models.

A software tool fulfilling the aforementioned requirements, which is not sold commercially, has been developed in a former research project though (Delfmann et al, 2008). As it belongs to the class of meta-modeling tools, it is characterized by an easy definition and adaption of (diagrammatic) modeling languages. Furthermore the tool supports language independent configuration mechanisms, like hiding specific language elements (e.g., data objects) in a model perspective or hiding a complete model (see example above). The configuration mechanism also accounts for variants of a graphical notation for different groups of stakeholders that can be selected by a user. By providing all these configuration features the tool allows to reuse a reference model effectively. The model query feature is provided as a plugin, which allows the definition of arbitrary model queries for languages that have been defined in the tool (Becker et al. 2008). For the creation of the reference task model in the software tool, we created the BPMN 2.0 modeling language and implemented the RTM navigation framework (cf. Figure 1). This again points to the reference task models created with BPMN. As a next step, we extended the BPMN language definition by adding attribute types for the KPIs. Thanks to the definition of the attribute types it is now possible to add the corresponding attribute values to the BPMN model elements.

Structural analysis

First, the modeling tool is applied in the process mapping step for creating the AS-IS process models of the humanitarian organization. For this purpose the RTM's framework can be used as a navigation guide. The following figure is a screenshot of the entry page of the modeling tool.

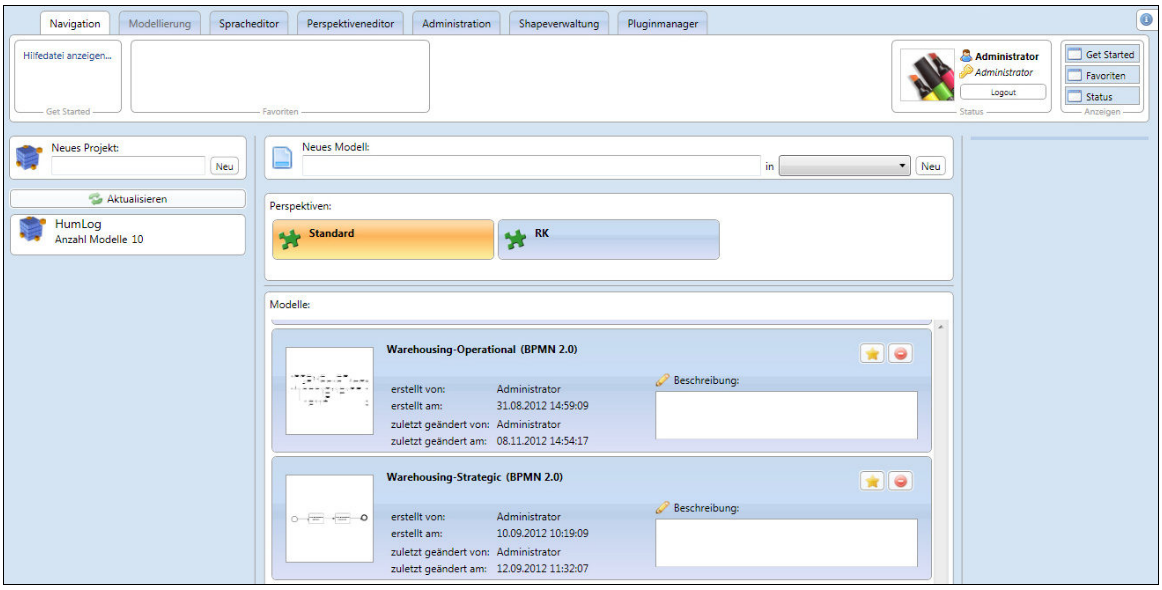

Figure 5. Navigation Framework of the Modeling Tool

The first view represents the RTM-boxes (e.g. operational warehousing) on a level of reference processes. Once the user selected a specific RTM-box the process model behind it will be displayed as shown in Figure 6. This "standard" view can act here as a central point of discussion within the process mapping sessions. The actual purpose is to support the process analysis which can be executed by creating organization-specific process models. For this aim we change the standard view into an organization specific view, which is called a new model perspective. For each organization one specific perspective needs to be modeled in order to generate the required AS-IS scenarios.

As a next step the AS-IS models should be aligned with reference processes, e.g. to check if important tasks missing or redundancies are occuring. One example from our use cases were missing quality assurance processes in the area of warehousing. Although the organization checked the incoming goods intuitively, there was no dedicated responsibility and standard procedure for this task which decreased performance. The model query approach would provide the necessary features to automate such a structural analysis, but would require additional specification, like the redundancy checks. Furthermore, to implement such an automatic analysis the terminology used in the models must be standardized. To avoid these automation problems, we developed an extension to generate reports as text files. For each model a text file is generated depicting the model in terms of a picture and each model element is described by its name and attributes. When the structural analysis has been completed and the deficits are identified, the TO-BE models are created with the modeling tool based on predefined reference processes of the RTM. Here, the configuration mechanism of the tool can be used to hide unnecessary models or specific language elements (e.g., data objects) in a model perspective. The final reports can be used to (1) manually analyze the current AS-IS scenario with the help of the reference model as well as to (2) communicate the standard operating procedures within the organization and with their partners Thus, these reports may contain general and specific descriptions of processes, their interrelations and additional meta information, such as responsibilities, KPIs or applied IT tools.

Quantitative analysis: Attributes as enabler for model query and reporting

The KPIs directly relate to starting and ending measurement points and thus to the corresponding model elements of the RTM (cf. Figure 4). From a technological perspective, these model elements were assigned to corresponding KPIs (and vice versa from a conceptual point of view). In order to create awareness for both the required data collection and analysis, and for the relevance of the logistic processes, the humanitarian personnel need to become aware of the interrelations between processes and performance. Thus all relevant KPIs, their measurement points, and importance for the humanitarian organizations need to be visually highlighted and explained in detail, with frequent links to the process level. To allow the highlighting of model elements that are assigned to a specific KPI, the plugin for model queries is used. The plugin uses a query language that applies set theory and functions on these sets to perform the actual query. A detailed description of the approach can be found in (Delfmann et al. 2010, Dietrich et al. 2011). An example to find the KPI IP.4 is given below:

```
SelfUnion(
        DirectedPaths(
                ElementsDirectlyRelatedInclRelations(
                        InstanceAttributesOfValue(O, KPI, IP.4), O),
                ElementsDirectlyRelatedInclRelations(
                        InstanceAttributesOfValue(O, KPI, IP.4), O)))
```

There are three basic sets: the set E (consisting of all model elements), the set O (representing all objects or vertices), and the set R (including the relations or edges between the objects). The evaluating algorithms start at the leaves of the treelike model query. Therefore, the first function to be evaluated is InstanceAttributesOfValue(O, KPI, IP.4). This function searches for all attributes of the type "KPI" with the value "IP.4" that are assigned to an element of the set O. Because the set O is used, all KPI attributes with the value IP.4 can be found. This newly created set is then supplied to the lower function, ElementsDirectlyRelatedInclRelations, that searches for elements of the first set (attributes) which are directly assigned to the elements in the second set (O). Now all objects with the specific attribute are identified, and the function beneath, Directed-Paths, creates all possible directed paths between the objects. As we would not like each single path to be highlighted but all elements on all possible paths, the function SelfUnion creates a new set containing each element of all possible paths only once. The resulting set is depicted in Figure 6.

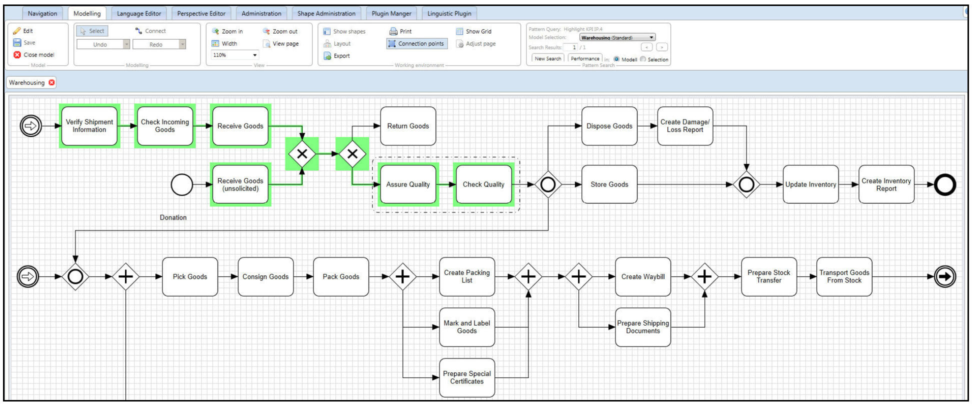

Figure 6. Highlighted KPI IP.4 in the RTM's warehousing process

The model query allows for a new model element to be inserted between the starting and the ending model elements, without losing the information that the new element now belongs to the KPI. On the other hand, if a starting or ending element is deleted, the KPI cannot be correctly highlighted anymore. Therefore a more sophisticated handling of such deletions should be incorporated into the tool, or the reference framework. On the reference model site, for instance, each model element on a path between the starting and ending model element of a KPI can be annotated with the attribute. This allows the deletion of starting or ending measurement points without (completely) losing the information. The tool can also be extended to force the user to reassign the corresponding KPI attribute to another model element.

After adapting the RTM according to the characteristics of a humanitarian organization, it is necessary to initiate and anchor adequate organizational changes (e.g. through business process reengineering, workshops and/or trainings). Given that most humanitarian organizations are very specialized and have only a few employees, of which many are volunteers, knowledge about process modeling (tools) is not institutionalized in the organizations. Here again the report generator can be used to generate text files that describe the adapted processes. This allows communicating the models in printed or digital form even to employees during humanitarian operations, e.g. to quickly show them best practices. In combination with adequate business process reengineering projects, humanitarian organizations become able to visualize, communicate, analyze, and reorganize their supply chain structures and logistics processes starting from the strategic network design level up to the operational level.

CONCLUSION AND OUTLOOK

In this paper we presented the design and implementation of a conceptual and technological basis for an integrated humanitarian logistics process analysis toolkit. After the identification of an appropriate reference model for humanitarian logistics, it was transferred into a modeling tool, and the applicability as well as potential use, have been proven in two use cases. The use cases also offered the identification of limitations which were were integrated both on the conceptual and technological level: (1) the RTM was extended by the deduction of reference processes, the identification of additional tasks, and the assignment of adequate KPIs to processes; (2) the applied modeling tool could be extended by the required report generator for the structural analysis and the model query approach for quantitative analysis. Together with the performance measurement system proposed in (Widera and Hellingrath, 2011b) the basis for a standardized, comparable and expandable process analysis toolkit could be designed.

Limitations can be seen in the low number of evaluations and in the missing managerial component, which was formulated as the completing step of the research agenda. In the area of further applications the end user are asked to give feedback in the form and value of the generated reports, the potentials and restrictions of the organizational changes based on the structural analysis, as well as on the experiences with data collection and analysis within the performance measurement component. These feedback and fine-tuning loops reflect the discussed analysis dimension though. In order to improve supply chain structures and the management of logistics processes oadequate managerial components need to be developed and integrated into the toolkit.

Accordingly, the research agenda has to be completed by the identification and integration of appropriate measures to improve the current performance. Such measures can be considered as best practices for specific tasks or functions which can be supported adequately IT (e.g. tracking and tracing). Once such measures are identified, they can be integrated into the modeling tool via attributes and the report generator presented in this paper. Besides, future work can be seen in various scenarios of the formalized RTM as a basis for humanitarian logistics process analysis. The application of process simulations based on the generated process models are very promising for various operations research approaches. The process models can also be used for material flow simulations in order to evaluate possible modifications of the supply chain networks. Thus, humanitarian organizations are empowered to evaluate different methods, measures or strategies in an artificial environment in order to improve their preparedness and relief plans.

REFERENCES

1. Beamon, B. M. (2004) Humanitarian Relief Chain: Issues and Challenges, *Proceedings of the 34th International Conference on Computers and Industrial Engineering*, San Franciso.
2. Becker, J. and Schütte, R. (2004) Handelsinformationssysteme, Redline Wirtschaft, Frankfurt.
3. Becker, J., Delfmann, P. and Knackstedt, R. (2007) Adaptive Reference Modeling. Integrating Configurative and Generic Adaptation Techniques for Information Models. In: Reference Modeling. Efficient Information Systems Design Through Reuse of Information Models, Springer.
4. Blecken, A. (2010) Humanitarian Logistics: Modelling Supply Chain Processes of Humanitarian Organisations, Haupt Verlag, Bern et al.
5. Charles, A., Lauras, M. and Tomasini, R. (2009) Learning from previous humanitarian operations, a Business Process Reengineering approach, *Proceedings of the 6th International ISCRAM Conference*, Gothenburg, Sweden.
6. Delfmann, P. and Knackstedt, R. (2007) Towards Tool Support for Information Model Variant Management – A Design Science Approach. *Proceedings of the 15th European Conference on Information Systems (ECIS 2007),* St. Gallen, Switzerland.
7. Delfmann, P.; Herwig, S.; Karow, M.; Lis, L. (2008) Ein konfiguratives Metamodellierungswerkzeug. In: Proceedings of the Modellierung betrieblicher Informationssysteme (MobIS). Saarbrücken, 2008. S. 109-127.
8. Delfmann, P.; Herwig, S.; Lis, L.; Stein, A.; Tent, K.; Becker, J. (2010): Pattern Specification and Matching in Conceptual Models. A Generic Approach Based on Set Operations. In: Enterprise Modelling and Information Systems Architectures, 5 (2010) 3, S. 24-43.

9. Dietrich, H.; Steinhorst, M.; Becker, J.; Delfmann, P. (2011): Fast Pattern Matching in Conceptual Models – Evaluating and Extending a Generic Approach. In: Proceedings of the 4th International Workshop on Enterprise Modelling and Information Systems Architectures. Hamburg, Germany, 2011. S. 79-92.
10. Fettke, P. and Loos, P. (2003) Classification of reference models: a methodology and its application. *Information Systems and e-Business Management*, 1, 1, 35-53.
11. Fettke, P., Loos, P. and Zwicker, J. (2006) Business Process Reference Models: Survey and Classification, *Proceedings of the BPM 2005 International Workshops*, Nancy, France.
12. Franke, J.; Widera, A.; Charoy, F.; Hellingrath, B.; Ulmer, C. (2011) Reference Process Models and Systems for Inter-Organizational Ad-Hoc Coordination - Supply Chain Management in Humanitarian Operations. In: Proceedings of the 8th International ISCRAM Conference. Lisbon, Portugal, 2011.
13. Gardner (2011) Magic Quadrant for Business Process Analysis Tools.
14. Jahre, M., Jensen, L.-M. and Listou, T. (2009) Theory Development in Humanitarian Logistics: a Framework and Three Cases, Management, *Research News*, 32, 11, 1008-1023.
15. Kovács, G. (2011) So where next? – Developments in humanitarian logistics. In: Humanitarian Logistics, Kogan Page Limited.
16. McGuire, G. A. (2006) Development of a Supply Chain Management Framework for Health Care Goods Provided as Humanitarian assistance in Complex Political Emergencies, PhD Thesis, Wirtschaftsuniversität Wien, Vienna.
17. Object Management Group (2011) Business Process Model and Notation (BPMN). Available at: http://www.omg.org/spec/BPMN/2.0/PDF, access: 2012-11-30.
18. Parmenter D (2010) Key Performance Indicators: Developing, implementing, and using winning KPIs. Hoboken, NJ, John Wiley & Sons. Anonymized
19. Scheer, A.-W. (1991) Architektur integrierter Informationssysteme. Grundlagen der Unternehmensmodellierung. Springer Verlag, Berlin, Heidelberg.
20. Supply Chain Council, 2010 Supply Chain Operations Reference Model – Version 10.0. Available at: http://supply-chain.org/f/downloads/726710733/SCOR10.pdf, access: 2012-11-30.
21. Thomas, A. S. and Kopczak, L. R. (2005) From logistics to supply chain management: The path forward in the humanitarian sector, white paper, Fritz Institute, San Francisco, CA.
22. Thomas, O. (2006) Understanding the Term Reference Model in Information Systems Research: History, Literature Analysis and Explanation, *Proceedings of the BPM 2005 International Workshops*, Nancy, France.
23. Tomasini, R. and van Wassenhove, L. (2009) Humanitarian Logistics, Palgrave MacMillan, Basingstoke.
24. Tufinkgi, P. (2006) Logistik im Kontext internationaler Katastrophenhilfe: Entwicklung eines logistischen Referenzmodells für Katastrophenfälle, Haupt Verlag, Bern et al.
25. Van der Aalst, W., Dreiling, A., Gottschalk, F., Rosemann, M. and Jansen-Vullers, M. (2006) Configurable process models as a basis for reference modeling, *Proceedings of the BPM 2005 International Workshops*, Nancy, France.
26. VDI (Verein Deutscher Ingenieure) (2001) VDI 4400 Logistic Indicator for Procurement, VDI-Guidelines, Part 1, Verein Deutscher Ingenieure, Düsseldorf.
27. VDI (Verein Deutscher Ingenieure) (2002), VDI 4400 Logistic Indicator for Distribution, VDI-Guidelines, Part 3, Verein Deutscher Ingenieure, Düsseldorf.
28. vom Brocke, J. and Thomas, O. (2006) Designing Infrastructures for Reusing Conceptional Models - A General Framework and its Application for Collaborative Reference Modelling, *Proceedings of the 9th International Conference on Business Information Systems (BIS 2006)*, Klagenfurt, Austria.
29. White, S.A. (2004) Introduction to BPMN, IBM Cooperation.
30. Widera, A.; Hellingrath, B. (2011a): Improving Humanitarian Logistics - Towards a Tool-based Process Modeling Approach. In: Proceedings of the Logistikmanagement. Bamberg, S. 273-395.
31. Widera, A.; Hellingrath, B. (2011b): Performance Measurement Systems for Humanitarian Logistics. In: Proceedings of the 23rd Annual NOFOMA Conference. Harstad, Norway, S. 1327-1342.