Integrated Logistics and Transport Planning in Disaster Relief Operations

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ABSTRACT

Decision making in the area of humanitarian logistics and supply chain management often suffers because of the interrelations between planning horizons, tasks, and crisis management lifecycle phases. In this paper, we present a method, an exemplary prototypical implementation and its evaluation within a relief organization. Based on a structured literature analysis (a review of existing information systems as well as a consideration of ongoing research projects), basic requirements for an integrated logistics and transport planning approach were derived. Together with end-user involvement, these results were used to design and prototype a concept of an appropriate information system, which was applied and evaluated in a tabletop exercise. The generated results are promising in terms of having a positive impact on the logistics effectiveness. In combination with the identified limitations, our results promise to have an impact on future ISCRAM research.

Keywords

Humanitarian Logistics, Logistics Planning, Transport Planning, Use Case, Simulation, Routing

INTRODUCTION

Natural disasters affect significantly human kind. In the last years, Europe was troubled by several natural disasters (e.g. extreme flooding in June 2013 in Central Europe), which become more frequent and cause more damage (Bevere et al., 2013). The emerging nature of disasters has a deep impact on the requirements for humanitarian operations.

Being the main driver for the effectiveness and efficiency, the humanitarian logistics preparedness level of all involved actors, from non-governmental organizations (NGOs), over governmental organizations up to commercial providers, plays an important role for the responsiveness to major disasters. Procurement activities can sum up to 60 % of the total sum spend by humanitarian organizations and backlogs can lead even to break downs of operations. Another success factor of humanitarian operations is the ability to source goods from pre-positioned inventories. It is not only the most important time advantage that can be utilized here, but – as pre-positioning networks examples like the UNHCR show – well planned inventories offer a range of response coordination and cost benefits. As the practices of DG ECHO show, the importance of transportation support is considered as a crucial function of humanitarian operations. The transportation system is of outstanding importance not only for the mobility and the supply of the population, but also for professional responders who depend on functioning and reliable transportation infrastructures to reach the corresponding action places, to ensure evacuation and to provide the affected population as well as the emergency forces with goods and services.

Agility is a key attribute for logistics and transport planning. Information Systems can improve the preparedness and the responsiveness of humanitarian operations in Crisis Management by contributing to more agile responder coordination. As preconditions, information systems must have the abilities 1) to diagnose the divergence between the actual and the expected situation (detection) and 2) to adapt the current strategy coherent with the diagnostics (adaption). Moreover, it is vital that both tasks have to be performed fast enough and in a pertinent and accurate way to ensure a timely and effective reaction to the situation (reactivity and effectiveness).

The aim of the paper is to explore, how the combination of information systems from different phases of the crisis management cycle, functions and planning horizons can lead to a more agile crisis response and management. Therefore, the DLR and the WWU initiated a cooperation for the exploration of joined logistics and traffic management information systems within the EU FP7 project DRIVER (2014)*. The systems provide relevant information for crisis managers to cope with challenges of the logistics and transport chain during the preparation, respectively response phase in the crisis management cycle.

Within the paper, we first provide the results of a structured literature review and give then an extensive overview on available information systems for the planning (preparation) and response phase as well as on related work, concerning integrated logistics planning and transportation management systems. The goal is, to carve out the potential of integrating such systems, including identifying chances and risks, as well as to depict requirements and framework conditions for the implementation. In the second part of the paper, we present a concept of how such a connected system could look like. The theoretical consideration is complemented by a prototypical implementation and its evaluation of operating experience collected during a tabletop exercise performed with the Federal Agency for Technical Relief (THW).

RELATED WORK

Research in crisis management and humanitarian logistics has increased over the years, especially since the tsunami catastrophe in Southeast Asia in 2004. A growing part of this research is dedicated to the usage of information and communication technology in the field (Altay and Green, 2006). Humanitarian organizations more and more recognize the fact that also humanitarian supply chains can profit from and should be supported by supply chain management systems. In the year 2004, the International Committee of the Red Cross (ICRC) was the first organization starting to implement an IT-system comprehensively supporting them in tasks connected to the material flow in the supply chain. Nonetheless, only every fourth organization uses such a system while the others rely on spreadsheets or even pencil and paper (Blecken, 2010).

To get an overview of the current research on decision support systems in the context of disaster relief logistics, a structured literature search has been conducted. Three requirements, which a source needs to fulfill to be counted as relevant, have been defined:

1. It has to describe a tool, model or idea, which aims at supporting decision makers, i.e. provide decision support in some way.
2. The decisions to be made, resp. the problem dealt with, should specifically be within the scope of logistics or supply chain management. Sources dealing with general crisis management problems will not be considered relevant.
3. Finally, the environment in which these decisions need to be made should exhibit features of a crisis or disaster situation.

Accordingly, the following search term has been defined:

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"decision support" AND (crisis OR disaster OR emergency OR "relief operation" OR humanitarian) AND (logistics OR "supply chain")
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Since all sources only presenting a model, which can be applied as a mean of decision support, or suggesting ways to enhance sense making in a crisis situation should be included in the literature review, two further search terms have been built by replacing “decision support” with “decision model” as well as “sense making”. The resulting three search terms have been applied to three literature databases: EBSCOhost, ScienceDirect and Scopus. The search has been limited to tiles, keywords and abstracts. Apart from this, no further restrictions (e.g. specific years of publication) have been selected. After a manual review of the results’ abstracts, relevant sources have been identified, which were used to provide an overview on how the topic of decision support in crisis logistics is treated in research.

Decision support systems developed and described in research mostly deal with problems from the preparedness and response phase. The most prominent problems handled are the facility location problem (e.g. Charles et al., 2016; Degener et al., 2013) and the delivery scheduling problem (e.g. Ben Othmann et al., 2014; Kuo et al., 2015). Very little research has been done on systems supporting decisions in the mitigation and recovery phases. An exception are Fallucchi et al. (2016) and Lorca et al. (2016), who deal with debris-related problems. Moreover, the results of the literature search show that decision support systems developed for logistics in crisis management in research are usually addressing one specific problem and therefore one management level and one crisis phase. Although it has already been recognized that decisions at different management levels or cycle phases are dependent on the ones taken at other levels resp. in other phases (e.g. Irohara et al., 2013; Kelle et al., 2014), only a very limited number of sources suggest decision support systems or models producing integrated recommendations across the crisis management cycle (Ransikarbun and Mason, 2016). Exceptions to this observation are for example, the stochastic programming model by Garrido et al. (2015), which aims at optimizing the inventory level of prepositioned relief items and the flow of those items after a flood crisis and consequently integrates decision problems from the preparedness and response phase.

Regarding the methods which are applied to provide support to decision makers, the by far most used one is mathematical optimization, including goal programming, stochastic programming etc. Especially when specifically considering sources which propose or even implement a system – in contrast to describing a model or framework – the minority applies techniques from other fields and an even smaller fraction of them use simulation. While most of those sources use simulation (e.g. D'Uffizi et al., 2015; Fikar et al., 2016b), there are others which combine simulation with optimization (Ben Othmann et al., 2017; Fikar et al., 2016a). Problems treated in these sources are all connected to the response phase and mostly deal with delivering relief items to people in need or more general with the status of the road network, i.e. with the question which effect sudden damages of single elements will have on the whole network. Fikar et al. (2016a) also investigate a collaboration between private and relief organizations.

Overall it can be observed, that decision support systems proposed in literature typically apply optimization techniques to solve a specific and restricted problem. Even though there are exceptions, still most sources follow this pattern. The usage of exact solution procedures deprives the possibility to include decision maker's experience and observations into the decision-making process. Moreover, optimization models are often not sufficient to depict the high complexity and uncertainty of a crisis situation. Especially the formulation of an adequate objective function is difficult because in a crisis different factors which are hard to express quantitatively, such as the life or suffering of people, play a major role in decision making. Simulation might be a technique to overcome the shortcomings of solely applying optimization (Ben Othmann et al., 2017; D'Uffizi et al., 2015). As a mean for supporting decision-making, simulation has already been widely researched in the context of commercial logistics (compare e.g. Terzi and Cavalieri, 2004). Reasons for utilizing simulations as a decision support tool are e.g. that a simulation model facilitates understanding of the real system and its behavior, provides a basis for discussion about it and is able to show previously hidden relationships and interdependencies. Moreover, the main advantage is the possibility to perform "what-if" analyses and be able to estimate a decision's effects before actually implementing it (Semini and Fauske, 2006). Nonetheless, for simulated solution proposals to be relevant, planning tools need to incorporate information from operative tools, which often provide exact solutions. Such a combination of simulation and exact solution techniques or operative tools can lead to the capability of adequately handling the complexity of a crisis situation (Fikar et al., 2016a).

Apart from decision support systems proposed in literature, there are also research projects, existing products and experiments dealing with the topic of decision support in disaster relief logistics. In the context of such projects, various tools are developed and suggested to serve as a mean of decision support for crisis logistics managers. The following table gives an overview about the tools obtained through an internet search and its intended crisis management lifecycle. Many tools for crisis management and decision support exist but with different levels of maturity. Due to a limited accessibility and varying available information, a rather general overview of the identified tools is provided. The tools identified in the search vary in terms of scope, purpose and degree of actual deployment. Further, it has to be noted that the list does not claim to be exhaustive, but it is meant to provide a first overview of the current landscape on logistics management and transportation tools.

Tool	Short description	Preparation phase	Response phase	Recovery phase
ELITE	web-based 'living document' for post-crisis lessons learning	X		
CRISMA	simulation-based decision support system	X		
FORTRESS	incident evolution tool that will assist in forecasting potential cascading effects	X		
CRIMSON	generic platform to train crisis managers and field crews	X		
SECTOR	secure European common information space (CIS)	X	X	
KOKOS	IT tools to involve the active participation of the general public for self-help activities		X	
Disaster LAN	Web-based task, mission and resource management system (only in the U.S.)		X	
SAHANA	Web-based collaboration tool for disaster response coordination between governments, NGOs etc.	X	X	
Fusionpoint	a web-based collaboration tool between emergency operation centers		X	
EmerGeo (EmerGeo Maping)	Common Operating Picture helping government and industry to mitigate, prepare for, respond to and recover	X	X	X
RIB / LUPP	tool for decision-making and follow-up of emergency response operations		X	
Ushahidi	Map-based web application to crowdsource data from people on the ground to aid relief efforts		X	X
SensePlace2	map-based web application that integrates multiple text sources (Tweets, News, Bloqs etc.)		X	X

Table 1. Overview of decision support tools for crisis management (Boin and Schaap, 2010; Chan, 2013; CRISMA, 2015; ELITE, 2014; FORTRESS, 2014; KOKOS, 2015; Morrow and Bachoura, 2013; SECTOR, 2014)

In the project CRIMSON a system was developed that offers an effective and generic platform combining simulation and virtual reality technologies for inter-organizational preparation, rehearsal and management of crisis situations, in order to train crisis managers and field crews. It allows the analysis and the evaluation of complex incidents, their impact on the population and contingency scenarios (Boin and Schaap, 2010).

Projects such as KOKOS (KOKOS, 2015) invent methods, technical concepts and IT tools to involve the active participation of the general public for self-help activities and communities integrated in processes of authorities. To enable the interoperability between first responders and police authorities during crisis situations or disasters, the project SECTOR (SECTOR, 2014) aims at establishing a secure European common information space (CIS). The CIS should give continuous and shared access to all necessary data and information, besides the use of collaboration process models to support coordination and cooperation between the organisations.

Another information management tool for the response phase is Disaster LAN (https://www.buffalocomputergraphics.com/dlan/emergencymanager). This web-based task, mission and resource management system for use in emergency operation provides tracking and reporting tools, emergency communication tools and visual situational awareness tools (e.g. Monitor and respond to Twitter and social media feeds, displays traffic cameras and video feeds, displays current weather, forecasts, warnings, and animated radars, includes user-to-user and system-to-system messaging…) to guarantee efficient team work. It is accessible for desktop and mobile devices. The tool seems to have a wide acceptance but appears to be only US-based and therefore not useful for European crisis managers (Boin and Schaap, 2010).

Besides, the Foundation SAHANA (https://sahanafoundation.org/) provides free and open source disaster management software. The offered information management solutions shall enable practitioners to better prepare and respond to disasters. It is a web based collaboration tool that addresses the common coordination problems during a disaster that help solve concrete problems (e.g. finding missing people, managing aid, managing volunteers, tracking camps) and ensures efficiencies in disaster response coordination between several participants (governments, aid organizations, the civil society (NGOs). The SAHANA Eden software offers a flexible, modular platform rapidly deploying information management systems separated to five categories (emergency, health, logistics, population and collaboration) with sub-categories for disaster management and humanitarian use cases. Except that the system is web-based and vulnerable if connection is not available, the system seems to be an appropriate tool for coordination during humanitarian aid operations and it addresses the problems of a common coordination during disaster (Boin and Schaap, 2010).

EmerGeo Solutions (http://www.emergeo.com/) offers a worldwide emergency and crisis management software and services that include two integrated products: Fusionpoint and EmerGeo Maping to use for planning, training and response. It is a subsidiary of Sai Infosystems Ltd. and the product is already used in market. Fusionpoint is a web-based software application that supports communication, collaboration and coordination within and between emergency operation centers (EOCs) and the field. EmerGeo provides a Common Operating Picture (mCOP™) technology, based on open standards, reliable world-class risk management technology and professional services that are proven effective in helping government and industry to mitigate, prepare for, respond to and recover from emergencies, natural disasters, acts of terrorism, and planned events (Morrow ad Bachoura, 2013).

Swedish Decision Support System RIB is a system for prevention and emergency management. It includes the computer system LUPP which is a tool for decision-making and follow-up of emergency response operations. Since LUPP is a partial system within the support system, it implies the necessity for exchange of data between different systems (Boin and Schaap, 2010).

Use of social media for crisis management: Ushahidi (https://www.ushahidi.com) and SensePlace2 (https://www.geovista.psu.edu/SensePlace2/): During the Haiti Earthquake (2010), the downloadable software tool Ushahidi was first deployed. It enables people to submit eyewitness reports during a disaster that can then be displayed onto a map in order to crowdsource data from people on the ground to aid relief efforts. Responders can use the data to improve their situational awareness and make informed decisions. SensePlace 2 is another map-based web application that integrates multiple text sources (news, RSS, blog posts) that can then be translated onto a map to allow emergency responders to easily filter through by place or time e.g. to analyse changing issues and perspectives (Chan, 2013).

Despite the existence of the manifold tools, one major challenge regarding humanitarian supply chain management systems is the fact that there is no tool being able to support all processes and tasks of logistics and transport planning while fulfilling general requirements such as easy setup, good usability and low costs. Aspects such as the analysis of the current logistics and traffic situation or an assessment of the infrastructure are not considered by any of the projects (Detzer et al., 2016). Tools developed specifically for humanitarian supply chains indeed mostly cover operational tasks leading to practitioners underestimating the tactical dimension when making decisions. Consequently, the combined usage of several tools seems to be the best option. But such a combination has to be well-considered as risks regarding data integration etc. are always arising when using different systems (Blecken, 2010).

CONCENPTUALIZATION OF AN INTEGRETAD LOGISTICS AND TRANSPORT PLANNING APPROACH

Dealing with the consequences of a crisis requires various tasks and activities in a humanitarian supply chain. Blecken (2010) has developed a reference task model to describe those and to point out how and where information systems can support crisis manager professionals in a disaster situation. The reference task model distinguishes between a strategic, tactical and operational planning horizon as well as functions assessment, procurement, warehousing and transport. This braking down in distinct management levels and functional dimensions results in twelve different areas each encompassing various tasks and in two additional activities - reporting and operations support.

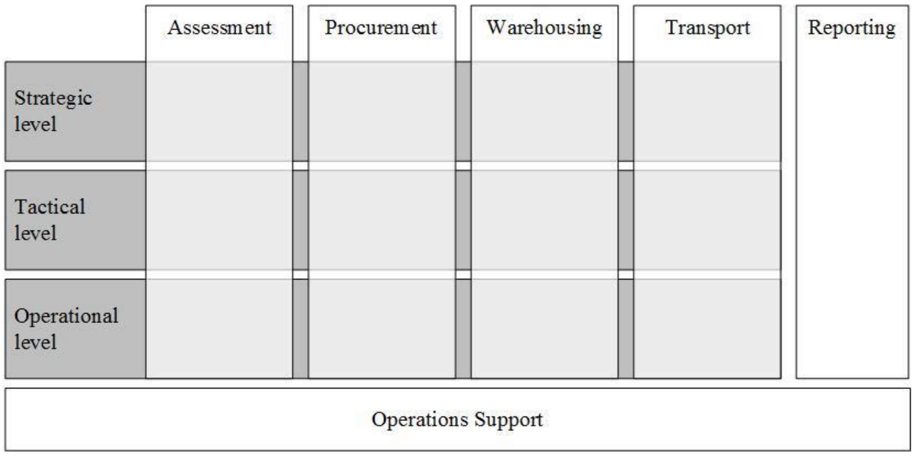

Figure 1. Reference task model framework (cf. Blecken, 2010)

Information systems can be used as a means of support for most of these tasks in several ways and this may have a beneficial effect on enhancing humanitarian aid. In fact, the four components of agility – detection, adaption, reactivity and effectiveness – define the way, how an information system can improve the execution of the tasks described above (Bénaben, 2017).

- Detection: Regarding all functional dimensions, i.e. assessment, procurement, warehousing and transport, monitoring capabilities of an information system can provide decision makers with relevant data about the current situation, i.e. stock levels or condition of the road network. In this way, the task to recognize and to keep the overview of deviations from expectations can be simplified.
- Adaption: Information systems can be applied to estimate the consequences of a certain strategy or decision without actually implementing the strategy or decision, e.g. by using simulation tools. This allows decision makers to select from a pool of suitable solutions and therefore enables to make decisions on more than experience.
- Reactivity: Information systems can accelerate the process of detecting deviations from the expected situation and reacting accordingly by providing timely and valuable information and presenting this information in a simple and comprehensible way.
- Effectiveness: Measuring the effectiveness of implemented strategies and decisions can be enhanced by information systems that for example collect and evaluate data about all performed crisis activities. Overall, an assessment of an operation's success is easier when it is based on a comprehensive data basis.

Available information system tools limit their scope in at least one dimension of the reference task model framework (see Figure 1). While often several functionalities are covered, the planning horizon is typically only considered on one level (namely strategic, tactical or operational). The majority of the provided tools concentrate on the operational level and only a few tools address the strategic or tactical level. This leads to the fact that decision makers in crisis situations usually underestimate tactical and strategic decision making and focus more on operational actions. One disadvantage of such isolated tools is that they cannot benefit from results or insights gained by other tools although decisions on different levels are dependent on each other. For example, the set of possible solutions for an operational decision is restricted based on the decisions made on strategic and tactical level. Such dependencies can be controlled, if information systems would be integrated on different levels. Thus, each tool can benefit from the information and results of all embedded tools.

Especially for logistics planning and transport management, a merging of various tools would enable an improved planning of resources' prepositioning and operating of transport orders. Thereby, possible transport routes as well as future traffic infrastructure conditions can be considered when deciding where to preposition resources (e.g. food, tents, medicine…). Moreover, locations of available relief items and demands for aid material can be considered into route planning. To unite tools of resource and route planning, it is essential to exchange various relevant information that the other tool can benefit from. The logistics planning tool needs to share information about warehouse locations, their inventory level of relief items, available vehicles and human resources as well as location of emerging demand. If the transportation tool is capable of processing the received information, it will be able to adapt suggested transport routes with regard to the given information in order to respond to the depicted situation.

The transport management tool in turn needs to provide information about the road network's condition, expected travel times and most appropriate transport routes to the logistics planning tool. By combining such information into e.g. simulation systems, the logistics planning tool becomes capable of suggesting better decision alternatives.

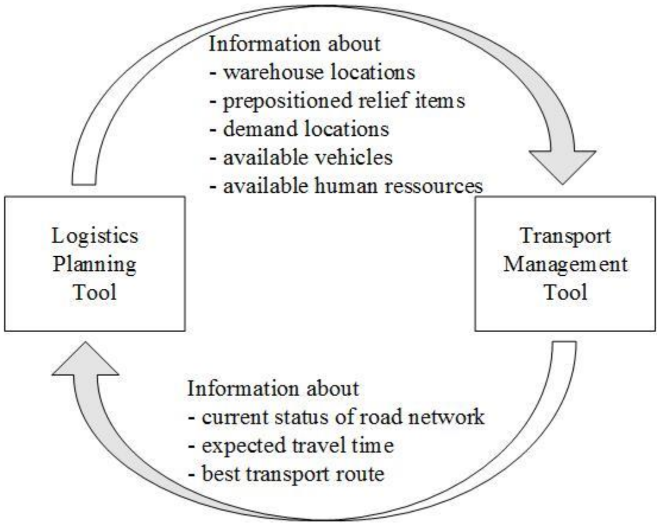

Figure 2. Information exchange between logistics planning and transport management tools

In order to be able to foster the possible benefits, different conditions must be met. Moreover, a technical integration of tools poses various risks, which need to be considered. For this, solutions to circumvent these challenges have to be developed.

Technical risks and requirements

From a technical perspective, the aspect of data integrations needs to be treated carefully. Only when integrating the different tools' data cautiously these can be interpreted and applied correctly. To ensure coherent data integration and valuable information exchange, consistent interfaces need to be programmed as well as suitable data processing functionalities have to be provided. In general, good data quality is important to enhance user acceptance.

Structural risks and requirements

Logistics planning and transport management tools operate on different planning horizon levels. Consequently, the different management levels need to be respected to avoid an uncoordinated and insufficient interaction between the tools. Moreover, risks of incorrectly shared information flows or overstimulation of information, e.g. by processing irrelevant information, need to be compensated when integrating tools of different management level. The overall aim is to consider the different levels and adapt the information flow to avoid useless information.

Socio-economic risks and requirements

From a socio-economic perspective the user acceptance is a high risk. If the integrated tools are not accepted by the user or do not address their actual needs, they will not achieve its objective and will not be capable of offering any benefits. To prevent this risk, an easy and efficient handling of the integrated tools has to be ensured.

Overall, a merging of a logistics planning and a transport management tool can be capable of closing the identified gap in decision support regarding logistics and transport related issues. At the same time, it has to be taken into account that such an integration comprises many risks and various requirements need to be considered when implementing it. Overall, an integration of a logistics planning and a transportation tool can be capable of closing the identified gap in decision support but such an integration offers many risks and various requirements need to be considered when actually implementing it.

PROTOTYPICAL IMPLEMENTATION

Based on the requirements identified above we have designed an integrated solution which can be applied for tactical as well as operational decision support within disaster relief operations covering logistics management and transport planning tasks. Until now, the integration is limited to the four specific tools mentioned below, but further integrations were considered during the design phase. Since the simulation-based logistics planning tool supports various import and export functions using Open Database Connectivity (ODBC) other related information systems (like warehouse management or enterprise resource planning systems) can be connected. The integrated tool aims at supporting practitioners to have an overview on its structures, capabilities, capacities and processes as well as to experiment with it during the preparedness and response phases. The integrated tool can be applied by different stakeholders covering disaster relief organizations, crisis management authorities as well as local and regional communities. However, the main target audience are relief organizations because the tool allows an exact depiction of organization-specific setups (e.g. physical networks or definition of standard operational procedures). The potential end users of the tool are the logistics and transportation responsibilities from tactical and operational levels (like project programmer, heads of operations or warehouse managers). By considering (global) assessment technologies, logistics planning methods as well transport management tools, decision makers are supported in terms of data-based comparisons of alternative decisions, i.e. the integrated tool is not aiming to tell practitioners what the optimal solution is, but it will demonstrate most probable consequences of individual solutions made based on the experiences of the decision makers.

In the following paragraph, we first describe which technologies were integrated in the overall solution and how. In the second part, we describe one particular experiment within the DRIVER (2014) project executed with the Federal Agency for Technical Relief (THW). Within the experiment, we have modeled the THW network and practices and simulated the relief operation based on a flooding in the city of Magdeburg in Germany in the year 2013. Thus, the scope of the evaluation is restricted to a governmental crisis management organization and the transferability to international relief organizations is limited. However, grounding the simulation model with the reference task model developed with over 30 relief organizations promise to be applicable to other organizations like international NGOs or UN organizations. Several of the involved tools were already applied at other organizations like a Red Cross Society or an international operating NGO (see e. g. Widera and Hellingrath 2011, 2016).

The integrated tool suite consists of four components: (1) KeepOperational, (2) U-Fly/3K, (3) ZKI-Tool and (4) HumLog:

(1) KeepOperational is a web-portal developed by the German Aerospace Center (DLR). KeepOperational visualizes the current traffic situation using different traffic sources. The traffic data can be used as basis to simulate and predict traffic and for supporting the decision process for traffic management actions (e.g. routing) in case of an incident. KeepOperational also involves SUMO – a microscopic and open source road traffic simulation. It provides transport and traffic information for emergency services (e.g. current traffic situation, routing advice, traffic prediction, scenario modelling, Presentation of the timely reachability in dependency of the current traffic situation, display of aerial images).

(2) U-Fly/3K is a ground control station (GCS) for Remotely Piloted Aircraft (RPV). The capabilities include mission planning and evaluation for single RPAS or swarm formations. U-Fly receives aerial sensor data, processes and evaluates sensor data, and dynamically adapts RPAS missions to newly received information. The 3K camera system is integrated into the RPV D-CODE and sends down georeferenced images and derived image products to the GCS. Provision of airborne imagery data. Information on damaged infrastructure can be extracted from the gathered data and traffic data can also be extracted.

(3) The ZKI-Tool is provided by the Center for Satellite Based Crisis Information (ZKI) at the German Remotes Sensing Data Center (DFD) at DLR. ZKI provides a 24/7 service for the rapid provision, processing and analysis of satellite imagery during natural and environmental disasters, for humanitarian relief activities and civil security issues worldwide. The tool provides flood impact information, e.g. water masks, or information about affected infrastructures derived from aerial and satellite imagery; it is used as an input for tools on traffic management and logistics support (e.g. KeepOperational). Additionally, it provides 3-D visualization and GeoPDF for crisis management organizations.

(4) HumLog itself is a tool suite containing three modules: (i) HumlogEM is a modelling tool able to support various modelling languages (see e.g. Widera et al. 2013). It can be used for the application of reference models as well as for model reporting and pattern search. (ii) HumLogSIM is an AnyLogic-based simulation environment allowing a multi-method (discrete event, agent based, system dynamics) simulation. The network structure and the logistics processes of relief chains are mapped, resulting in organization-specific process models considering all relevant organization levels. The process models will be then used to adjust the existing humanitarian logistics simulation environment in the simulation model in AnyLogic. Appropriate parameter variations of the simulation model are then executed within a simulation study which is then analyzed by utilizing the (iii) humanitarian logistics performance measurement system HumLogBSC (see e.g. Widera et al. 2015, Widera and Hellingrath 2016).

The tool suite was applied in the following procedure: ZKI extracted crisis information from satellite and aerial imagery (e.g. flood layers, flood impacts) and provided 2-D and interactive 3-D cartographic solutions (map products and video animations) for the THW volunteers. By these means, the decision making processes were supported by an increased situational awareness as well as a damage and needs assessment. Additionally, the extracted crisis situation information was shared with KeepOperational. An airplane flew in advance of the experiment over the affected area to collect airborne imagery. The imageries and extracted traffic and crisis information were provided to KeepOperational. KeepOperational uses the provided information of U-Fly/3k and ZKI-Products as well as traffic data information from other sources to recommend route options for emergency vehicles by considering current traffic infrastructure, information of the traffic situation and infrastructure or a traffic prediction & simulation. The gathered traffic and routing information was finally integrated into the simulation environment HumLogSIM which evaluates different scenarios and network settings based on the stored process models (e.g. material flow calculation, procurement analysis, scheduling, bottleneck analysis, cascading effects). The architecture of the tool suite is depicted in Figure 3.

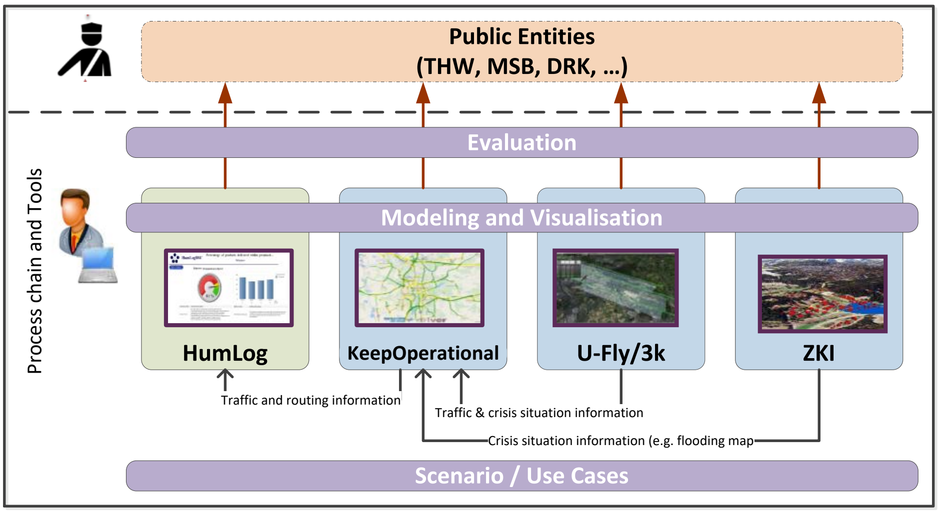

Figure 3. Toolsuite Architecture

The data of the simulated scenario were based on the existing THW network (e.g. standard operational procedures or location and vehicle information), recorded data (e.g. satellite imagery, aerial imagery) and event logs (e.g. scheduling of volunteers, demand orders). After continuous rainfall over several days the major rivers and its tributaries of Southern and Eastern Germany have reached their banks and became in danger of flooding adjacent areas. The city expected the prospect of a major flooding of large parts of the city area and has started emergency preparations for the event. The civil protection agency identified the endangered areas and affected population as well as the critical infrastructure of the city. The experiment was executed as a purely table top exercises, i.e. completely simulation-based.

We have recorded and analyzed quantitative and qualitative data. The generated results were presented to the professional responders, who expressed high interest in the provided solutions and confirmed an added value to their legacy systems and procedures. A detailed overview of the evaluation approach and the results can be found in Detzer et al. (2016). In particular, the participants perceived the provided solutions as a suitable solution for the actual transport and logistics tasks and processes. Besides, several improvements were identified with regard to technical and functional aspects of the tool suite. It was stated by the practitioners that the proposed solutions are beneficial for the THW volunteers regarding certain conditions:

- performing operation in unknown areas,
- performing tasks with considerably calculation effort,
- performing nationwide operations,
- performing complex tasks with many alternative decision choices.

Regarding the dimensions of agility, the evaluation showed that the following improvements could be established by the tool suite:

- Detection: Especially the KeepOperational feature of displaying the current traffic situation has been perceived as very good. In combination with HumLogSim’s route planning feature, it has been capable of improving situation awareness (cf. Figure 4).
- Adaption: It was realized that the solutions provide a relevant data-driven basis for decision making, because fast allocation and evaluation of alternatives was supported. Especially regarding

transportation tasks, the volunteers perceived this as useful. Nonetheless, it has been stated that the usage of the provided solutions benefits at the level “management and communication”. During the experiment it was noticed, that the benefits of the solutions below this level are limited for the volunteers.

- Reactivity: In order to understand the impact of the tool suite, a control group was carrying out the same tasks in a traditional way. At the beginning of the experiment, it was noticed that the tool group compared to the control group needed more time to complete the given tasks, especially in performing easy and common tasks they are used to. The main reason for the time delay is that the volunteers received only a very rough coaching on how to use the tool suite. The performance in terms of time and accuracy of the results increased with an increase of the difficulty of the tasks.
- Effectiveness: The tool suite collects data that allow tracking of each transport and assessing measurements such as speed, capacity utilization etc. These features have e.g. also been used to evaluate the tool group’s performance during the experiment.

Overall, the results from the qualitative data approve the results from the quantitative performance analysis. The professional responders declared a potential benefit for the tool suite and expressed their interest in applying it in their daily work. The tool suite has been approved as suitable to be used in an operation by the volunteers (cf. Figure 4).

However, several limitations were identified. The results’ regarding usability differs between the proposed solutions. The operation of HumLog was not seen as easy and the use was assessed between good and partly. The use of ZKI-Products and KeepOperational were evaluated between very good and good (cf. Figure 5). This difference in the usability is justified by the fact, that, HumLog is not designed for field staff but for a yet not existing THW system operator. The “tool” needs thus to be understood rather as a socio-technical change of the current standard procedure. The suitability and relevance was confirmed for all components. Almost all questionnaires stated that they could manage the tasks more easily, that they could finish the tasks faster due to a better situation awareness. An interesting observation has been made regarding the (technical) connection of the tool components. A deeper integration was expressed here. Another limitation was identified in an additional mobile interface of all deployed components. Finally, the handling of the solutions and the data visualization and accessibility should be further ensured improved.

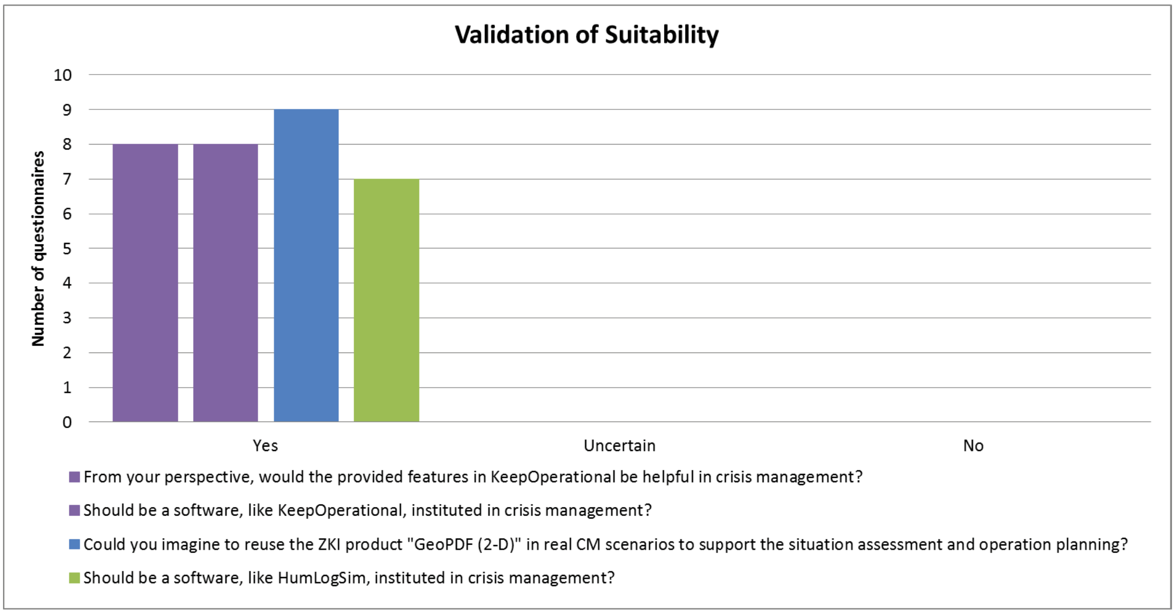

Figure 4. Validation of Suitability

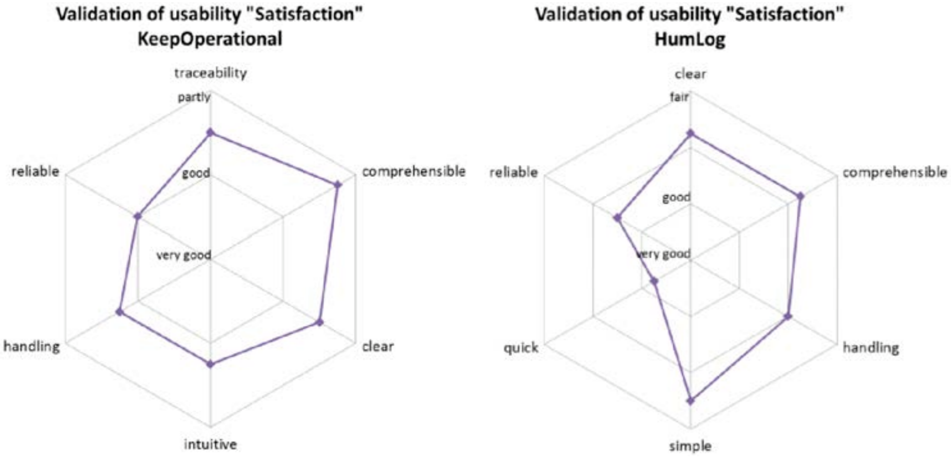

Figure 5. Validation of Usability

CONCLUSION

Logistics and transport planning can be described as a main driver for effective relief operations. In decision makers' practices both tasks are often perceived as directly inter-related and its execution is based on intuition and individual experiences of the involved staff. However, the available information systems address those needs inadequately because they tend to focus only on particular tasks for a particular sequence. Besides, those tools mostly use optimization approaches and seem to relieve final decisions of the practitioners. These circumstances lead to a poor acceptance of promising innovations and improvements of those truly challenging tasks in relief operations. We proposed and evaluated an integrated approach of logistics and transport planning which connects planning horizons and the inter-related tasks. The tabletop exercise revealed a relatively high acceptance by the practitioners and it has shown a direct impact on the logistics performance. Additionally, a couple of limitations were identified, especially in terms of embedding new practices into standard operational procedures, the usability of several tool suite components as well as their integration. We identified specific adjustments of the developed tool suite with regard to the given feedback. The next steps must consider further iterations of development and testing. For the purpose of testing it will become necessary to deeper investigate appropriate application scenarios as well as to analyze and evaluate new operational practices in close loops with the practitioner organizations. These lessons learned are based on the confirmed assumption that only a socio-technical approach promises to unfold the available benefits to improve crises management practices.

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