Web-based transport management tool-suite (KeepOperational) for crisis management

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***Abstract*— A well working transportation infrastructure is crucial for modern societies and the mobility of people. The general public relies on a sound infrastructure to fulfill their increasing and individual mobility needs. This means a wide range of transport necessities – e.g. daily way to work and daily (consumer, service) needs. In the event of a crisis, e.g. caused by a natural hazard, the transport infrastructure becomes vital for different reasons. The people have to be evacuated or rescued from the affected area. Furthermore, relief aid and supplies, as well as rescue forces do require unimpaired access to the crisis area. Natural disasters, like an earthquake or a flooding, are disturbing the transport infrastructure negatively. Cascading consequences are, for example, impassable roads, disturbed railway connections and a reduced transport capacity of persons and goods. To develop evacuation strategies, to plan logistics operations of emergency forces in the affected area and to safely route these forces through the affected area, among others, routing tools are required that take into account the current state of the infrastructure [1]. The Institute of Transportation Systems of the German Aerospace Center has developed KeepOperational, a web-based, integrated decision support tool for traffic management and crisis logistics. As a key feature, this system can directly inject impairments of the transportation infrastructure – derived from various sources – into the routing network so that these disturbances will be considered by the routing algorithms.**

Keywords— crisis response, crisis management solutions, routing, isochrone maps, transport management, logistic, KeepOperational

I. Introduction

Effective crisis management requires planning tools, which are considering the whole operational picture. Routing tools considering the state of the traffic network infrastructure are vital for planning of relief actions and dispatch of rescue and operational vehicles.

To support the planning and response phase of a crisis management, the DLR has developed KeepOperational, as a web-based, integrated decision support tool for traffic management and crisis logistics, tailored to the needs of tactical and operational level actors. KeepOperational provides the ability to import restrictions of the traffic infrastructure in standardized formats like GeoJSON and KML. These network restrictions are applied to the underlying routing graph and are considered by the routing algorithms. It incorporates traffic information from different sources, like loop detectors and floating car data [2] and provides tools to utilize this information. KeepOperational is based on the DLR Traffic Data Platform. The Traffic Data Platform is a service framework to collect process and utilize traffic data. The data can be obtained from different sources, for example loop detector data or floating car data [3, 4].

KeepOperational provides two primary routing features. The first feature can be used to plan routes for convoys. Convoys of emergency units are not always composed homogenously. Furthermore, it is not unlikely that some of the vehicles are not generic cars, but heavy trucks or other kinds of special vehicles. These vehicles may be too high to pass certain tunnels or underpasses. Furthermore, they require more time for turning. KeepOperational allows specifying the characteristics of the vehicles to be routed. These characteristics are taken into consideration, given that the underlying used network contains the required information. For example, if the network was imported from OpenStreetMap, the maxweight tag would be checked if a vehicle with a given weight (like a heavy truck) is able to pass a certain bridge. The same applies for tunnels regarding the maximum height or road narrows by the tag maxwidth.

The second feature of the routing algorithm is an isochrones router to analyze the accessibility of a certain area. Isochrone maps are useful to visualize areas of similar travel times and are an established tool in transportation planning [5, 6]. For the planning of an assembly area or the location of a control/operation center it is important to have an overview of the area covered with regard to the reachability in terms of travel time. With the information provided by the isochrone router, the operator can easily see how long it takes to reach the assembly point or how long it takes for the emergency vehicles to reach any point in the vicinity. Isochrone maps are also useful to determine if certain response times can be fulfilled.

II. Transport and Traffic Solutions in Crisis Management

In the last years, a lot of research in the area of crisis management was done from the logistic and interoperability perspective and the range of relevant crisis solution has increased. A growing part of this research is dedicated to the usage of information and communication technology in the field [7]. Only a small part considers transport management in their research work and they are mostly addressing only a specific problem at a certain management level of crisis management. In the context of crisis management, it is one of the most under examined subjects in the research field. Though, it is a vital prerequisite for supporting the decision-making process in disaster response activities. During a crisis, the transport system is both, vital and vulnerable. On the one hand it is of outstanding importance for the mobility of personal and goods. On the other hand, it embodies an infrastructure system which is affected first e.g. by natural hazards [8].

Many solutions for crisis management differ between their operating range within the crisis management lifecycle and their levels of maturity. Crisis management can be distinguished in three phases. The preparation phase deals with the anticipation of a crisis event, as well as the preparation to effectively counter a threat. The response phase deals with reacting to an ongoing and countering its immediate effects. The recovery phase deals with recovery from the long-term aftereffects of a crisis.

Ref. [8] provides a good overview about decision support tools for crisis management and their intended crisis management lifecycle. Aspects such as the analysis of the current logistics and traffic situation or an assessment of the infrastructure are seldom considered. Systems of decision support are usually applied in the preparation and the response phase. Often these tools do rely on optimization techniques to solve verify specific or restricted problems [8, 9].

Logistic and transport planning are both very important for effective relief operations. These tasks are often inter-related from a decision-maker perspective. Still, the available information systems do not address this inter-relation properly, because often they are too focused on a particular task. Therefore, an integrated approach which connects logistics and transport planning as well as situational awareness would generate an added value [8].

Besides this overview, several industrial providers exist, which offer commercial decision support tools that can be useful for many crisis related events. These solutions, obtained by literature research, are listed and described below.

CommandX – is a product offered by Eurocommand and combines two systems: GEOMAPS and GeoFES that are integrated in the ArcGIS Platform of ESRI. GeoFES is a command and control system for unit leaders within a crisis. It provides information regarding operation management, situational awareness, location management and analyses. GEOMAPS provides different geographic data information [10].

ESRI – distributes ArcGIS, a mapping and analysis software. The platform offers a variety of ways to use geographic data which can also be used for decision support, like mapping and visualization, remote sensing or spatial analyzes [11].

Intergraph – offers a wide range of products and solutions for different needs. One of the solutions is Hexagon Geospatial addressing, among others, disaster management and transportation. For disaster management the Hexagon Geospatial offers targeted disaster planning and effective communication. Regarding transportation, trends and trouble spot analyzing as well as asset management and creating an efficient workflow will be offered [12].

All these solutions provide relevant information for situational awareness and situation analysis. Up to Intergraph, none of them considers aspects such as the analysis of the current logistics and traffic situation or an assessment of the infrastructure.

III. System overview

KeepOperational is designed in a modular fashion. It consists of several independent services to provide different functionalities. This design allows a degree of flexibility, which would not be possible with a monolithic design. Crisis management needs are diverse, and it is often required to adjust tools to specific requirements and procedures of relief organizations. These adjustments would be much more difficult with an inflexible design. KeepOperational is developed using the Java language. We consider KeepOperational to be at Technology Readiness Level 7. The whole service framework is available as docker application, making it easy to deploy.

The design and components of KeepOperational are displayed in Fig 1. Like the Traffic Data Platform, it is designed using a Service Oriented Architecture. It consists of a geospatial database (db-net), regular database for user information (db-users), two routing engines (mit-router, isochrones-router), a routing broker (global-router), a service for user authentication (user-service), a service for processing network restrictions (netadaption-service), a message broker (message-broker) and a webapplication server to provide the webinterface (webapplication-server and webapplication-client). All services are operating independent from each other, by exchanging well-defined message. To communicate among one another, a message broker is used.

Apache ActiveMQ is used as message broker, due the fact that it is open source and supports many different programming languages. ActiveMQ implements the Java Message Service (JMS) API and JMS ObjectMessages are being used by the different service [13]. These messages are composed from serialized Java objects and being send using TCP. However, the message formats are not standardized, but of an internal format. The exception is the netadaption-service. It supports GeoJSON and KML, as well as our internal format.

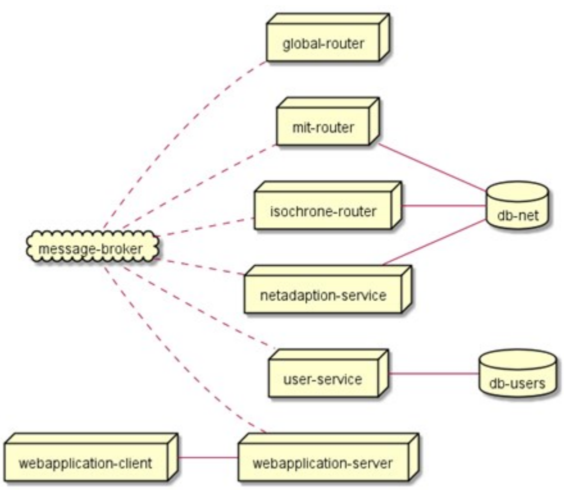

Fig. 1. KeepOperational Service Oriented System Architecture

The geospatial database (db-net in Fig1.) is containing the net information as well as any net restriction (like a flood mask). KeepOperational currently supports PostGIS and Oracle Spatial and Graph as geospatial databases.

The so-called mit-router and the isochrone-router are the two primary routing engines used by KeepOperational. They are more tightly coupled to the database and do not use the message broker for accessing the data.

The netadaption-service is also directly connected to the network database. The service provides the ability to add restrictions to the underlying routing network. The service can be connected to an external data source to automatically import restrictions into the database. Currently, GeoJSON, KML and DLR internal format are supported. New restrictions or updates to existing limitations can also be provided to the service by using the web interface (webapplication-client).

The global-router acts as a broker itself. It distributes routing requests to suitable, connected routing engines. In the current design of KeepOperational, this is either the mit-router or the isochrone-router, depending on the requested information. It also acts as an adapter, translating routing requests from a generic format, like the one used by the webapplication-server, to the specific formats used by the routing engines.

The webapplication-server provides the webinterface to the user. It is connected to the necessary services, like the user-service or the global-router with the message-broker. Both, server and client side of the web application are written using GWT (Google Web Toolkit). Client and server are using GWT Remote Procedure Calls for communication. To visualize routes, restrictions and points of interest on the map, OpenLayers is used.

The user-service and the user database are used for authentication. Currently, only the webpage requires user authentication.

Map data is usually obtained from OpenStreetMap. The SUMO tool osmGet.py is used to download OpenstreetMapp data in the OSM XML format for the desired region. The netconvert tool from SUMO is then used to convert the map data into the internal format [14]. The DLR importer tool can read this format and is able to import it into the network database (db-net). As mentioned before, this database can either be PostGIS or Oracle Spatial and Graph. The imported data can later be manually refined by incorporating other sources of information, like data from local authorities or the municipality. This is especially important if the imported map data lacks completeness. Information like the street width or the load-carrying capacity of a bridge is not always present.

IV. Application of KeepOperational in Crisis Exercises

During large scale crisis events, rescue services – e.g. police, fire brigade - depend on a reliable road network to transport persons and goods as well as to reach their place of operation. Some of the rescue forces send service units to the affected area with a large convoy transporting heavy equipment and need dedicated routing information. Other service units need to know the optimal location of an assembly area regarding transport aspects, like a logistic hub or a shelter. Sometimes it is necessary to define and secure strategic routes for evacuation (e.g. evacuation of a hospital). Rescue forces have to know, which street would be most suitable for certain operations. Therefore, working roads (e.g. passable and safe) are a necessary precondition for transport related service units to stay operational.

Within research projects it was noticed that some rescue forces use maps in paper version or open access programs like Google Maps [9]. This information gathering is associated by several disadvantages – e.g. no reliable real time information about the current traffic situation and traffic infrastructure within a crisis event (e.g. road blockages by flooding or closures), no quality assessment and time stamp of such information or information about height and bearing capacity of bridges/tunnels/streets in the affected area. This up-to-date information is necessary for an effective and successful transport management during a disaster.

KeepOperational provides different features to address these needs (see Chapter I) and has already been applied in multiple different exercises like the G7 summit in 2015 [15] and in several national events and international projects. Each exercise emphasizes different focus areas. The events and exercises were mainly national and addressed different demands. For large scale events it was used for preparation and monitoring the traffic flow during the event (e.g. several huge German Festivals, German Church Congress, G7 Summit …).

KeepOperational was originally developed during the Project VABENE, focusing on transport management for large scale events and crisis situation. It was intended as an extension to the Traffic Data Platform, which was used as the data pool for a Crisis Management decision support system developed during the project [4] and its follow-on project VABENE++.

During the FP7 Project DRIVER (Phase I), KeepOperational has been tested in a table-top exercise in cooperation with the THW German Federal Agency for Technical Relief. The table-top exercise was based on a realistic flooding disaster in the German city of Magdeburg. Excessive rainfalls in June 2013 cause the rivers Danube, Elbe and several others to rise. The objective of this exercise was to evaluate the benefits of logistic and traffic management tools for crisis manager. In this trial, KeepOperational has been tested with two other tools. The first tool (HumLog) is a development by the University of Münster to simulate logistic operations and to provide decision support for humanitarian logistic. The second tool was the ZKI-Tool, developed by the DLR Center for Satellite Based Crisis information. The tool provided a set of satellite imageries of the affected regions (based on historic data). This extended information of the flood (flood masks) were displayed as aerial images and included in KeepOperational to highlight roads that are flooded and impassible. The masks provided timely information on the impact of the flood. KeepOperational was used to visualize the traffic situation including the current status of flooding, and to provide routing advice and information about accessibility. The key feature demonstrated was the end-to-end processing chain. It enabled a seamless transfer of aerial images to services like routing of rescue forces.

One result of the experiment was that the tools can generate an added value in crisis management at the level: "management and communication" regarding certain conditions. However, further improvements in operationalization and functional aspects are required. The volunteers mentioned that the usage of the proposed solutions in real operation would advance more if the solutions were connected to each other. Preferable is one user interface where all solutions are connected to each other [9].

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 [16].

KeepOperational is also selected to be used within the project DRIVER+ (Phase II) [17]. In DRIVER+, it is going to be operationalized and tested in collaboration with other crisis management solutions with a simulated flooding in The Hague, Netherlands. During the trial in the Netherlands, KeepOperational will be connected to receive and share information with other tools via standardized messages. The tool will receive flood predicates, derived from a hydrologic simulation, as well as data provided by the DLR Center for Satellite Based Crisis information (ZKI). KeepOperational incorporates this information in its routing engine and will be used by the Police to analyze the accessibility of the affected areas and for routing of emergency vehicles. The DRIVER+ Trial Netherland with KeepOperational will take place in Mai 2019 [18].

V. KeepOperational in Airborne and terrestrial situational awareness

KeepOperational can be deployed as a stand-alone application, but it is also part of a more comprehensive tool suite. In “Airborne and Terrestrial Situational Awareness”, KeepOperational is integrated with other DLR tools and components into a complete system for situational awareness. This tool suite was developed as a solution for several projects.

Fig. 2 displays the complete system of the solution Airborne and Terrestrial Situational Awareness. The solution combines airborne reconnaissance with terrestrial sensors and ground-based processing for improved situational awareness. The airborne component consists of a remotely piloted plane (RPV), equipped with the 3k optical camera system and the required ground control station (U-Fly). The camera system was developed by the DLR, consisting of 3 off-the-shelf, high-end, digital cameras. It was developed as an economically alternative to regular aerial imagery systems. It can be used for traffic detection and mapping and is able to record an area of 10km x 8km in approximately two minutes. The ground size of a single pixel depends on the altitude. It ranges between 13cm and 40cm at altitudes between 1000m and 3000m [19].

Fig. 2. Airborne and Terrestrial Situational Awareness [18]

The terrestrial component consists of terrestrial traffic sensors and the ground control station with the processing unit. The processing unit consists of a tool, developed by the DLR ZKI, to process the obtained imagery and to derive information layers. KeepOperational is also present in the ground station to combine the acquired information with terrestrial traffic sensors [18].

As mentioned before, the plane is remotely controlled. Its flight plan and controls are executed by the ground control station. However, for the time being, an attending pilot is still required for legal and security reasons. The plane is able retrieve aerial imagery from a very large area, e.g. compared to a drone, while still being faster available than a satellite.

The obtained imagery is sent to the ground unit via a separate data link. It is processed by the ZKI-Tool and data additional information layers are derived. These information layers are specific to the current crisis. Potential information layers are for example flood mask, population distribution and land use.

Information regarding the crisis impact on transportation infrastructure is imported into KeepOperational. KeepOperational can combine this information with traffic data, obtained from terrestrial traffic sensors. In this setup, KeepOperational can also be used to display the obtained imagery to the crisis operator, providing him with up-to-date aerial imagery from the crisis area.

VI. Conclusion & Further work

Currently, KeepOperational still uses a DLR own routing kernel. In the future, it is planned to switch to the community driven GraphHopper Routing Engine. GraphHopper is an open source routing kernel, provided by GraphHopper GmbH and available under the Apache License 2.0 [20].

KeepOperational already has authentication mechanism but it lacks a comprehensive role model. Each user has access to the same features and is considered equal. However, this is not common in crisis management procedures. Usually, special roles in crisis management teams exist. One example for such a role is the information manager, who is responsible for adding information (for example blockades and network restrictions reported by units in the field) to the common operational picture.

The target deployment side of KeepOperational is inside the operation center, where dispatching of vehicles is planned and information from different sources are collected and shared. Nevertheless, having client in the emergency vehicles would likely provide added value. These clients could be smartphone applications, running on a smartphone or tablet. Currently no Smartphone client exists for KeepOperational. However, because network coverage is not guaranteed in a crisis, offline handling for the clients would certainly be required.

Visualisation of routes, network restrictions and so on is done using OpenLayers. Restrictions, for example a flood mask is drawn as a polygon. However, if the flood mask is very large and complex, this would result in performance issues during the visualisation.

As KeepOperational is based on the DLR Traffic Data Platform, it can incorporate traffic data by connecting corresponding services of the Traffic Data Platform. However, during a crisis, many of the terrestrial sources for traffic information may not be fully available or may not produce up to data results. Incorporating the traffic simulation tool SUMO into KeepOperational for a model-based bridging of information gaps would be a valuable addition to the routing tools. Besides, it is conceivable to have a connection to big data projects, for example Smart Data for Mobility, in order to integrate reliable and real-time traffic data [21].

To further improve routing of emergency vehicles, more sophisticated and comprehensive solutions are imaginable. In the project SIRENE [22], the objective of the DLR is to reduce the response times further by incorporating the local traffic infrastructure, as well as using traffic prediction. With traffic prediction, the routing engines can consider short-term changes in the traffic situation. The interconnection with the traffic lights system would provide emergency vehicles with prioritization [23]. The overall goal is to improve compliance with required response times and to reduce the number of accidents at junctions, involving emergency vehicles.

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REFERENCES

[1] V. Gstaiger, R. Nippold, R. and Kiefl, “Forschungsprojekt VABENE++: Verkehrsmanagement bei Großereignissen und Katastrophen”, in im Einsatz, Verlag Stumpf & Kossendey GmbH, December 2016.

[2] C. de Fabritiis, R. Ragona and G. Valenti, "Traffic Estimation And Prediction Based On Real Time Floating Car Data”, 11th International IEEE Conference on Intelligent Transportation Systems, Beijing, 2008, pp. 197-203.

[3] L. C. Touko Tcheumadjeu, S. Ruppe, E. Brockfeld, Y. Yahyaoui, “Traffic Data Platform based on the Service Oriented Architecture (SOA)”, 12th World Conference on Transport Research (WCTR), July 2010.

[4] S. Detzer, M. Weber, L.C. Touko Tcheumadjeu, G. Kuhns, A. Kendziorra, “Decision support for multimodal transportation systems at major events and disasters: a case study in the region of Brunswick (Germany)”, 4th International Conference on Disaster Management and Human Health: Reducing Risk, Improving Outcomes, Mai 2015.

[5] F. Gortana, S. Kaim, M. von Lupin,T. Nagel, “Isocope - Visualizing temporal mobility variance with isochrone maps”, Poster Abstracts of IEEE VIS, 2014.

[6] D. O’Sullivan, A. Morrison, J. Shearer, “Using desktop GIS for the investigation of accessibility by public transport: an isochrone approach”, International Journal of GIS, vol. 14, pp. 85–104, 2000.

[7] N. Altaym, W.G. Green, “OR/MS Research in Disaster Operations Management. European Journal of Operational Research”, European Journal of Operational Research, vol. 175, pp. 475-493, 2006.

[8] A. Widera, S. Lechtenberg, G. Gurczik, S. Bähr, “Integrated Logistics and Transport Planning in Disaster Relief Operations”, Proceedings of the 14th ISCRAM Conference, France, May 2017.

[9] S. Detzer, G. Gurczik, A. Widera, A. Nitschke, “Assessment of Logistic and Traffic Management Tool-Suites for Crisis Management”, European Transport Conference, Barcelona, October 2016.

[10] “Eurocommand”, Retrieved from https://www.eurocommand.com/, April 2019.

[11] “ESRI”, Retrieved from https://www.esri.com/, April 2019.

[12] “Intergraph, Hexagon Geospation”, Retrieved from https://www.hexagongeospatial.com/, April 2019.

[13] “Apache ActiveMQ”, Retrieved from http://activemq.apache.org/, March 2019.

[14] “SUMO, Simulation of Urban Mobility”, Retrieved from https://sumo.dlr.de/index.html, March 2019.

[15] “DLR unterstützt Bayerische Hilfsorganisationen während G7-Gipfel”, Retrieved from https://www.dlr.de/fs/desktopdefault.aspx/tabid-11152/19522_read-42973/.

[16] A. Blecken, “Humanitarian Logistics. Modelling Supply Chain Processes of Humanitarian Organisations”, Kuehne Foundation book series on logistics, 2010.

[17] “DRIVER+, Driving Innovation in Crisis Management for European Resilience”, Retrieved from https://www.driver-project.eu, March 2019.

[18] “DRIVER+, Portfolio of Crisis Management Trials, Solutions and State Profiles”, Retrieved from http://pos.driver-project.eu/PoS/solution/24.

[19] V. Gstaiger, D. Rosenbaum, “Automatische Verkehrserfassung aus der Luft – Unterstützung für das Katastrophenmanagement”, Deutscher Luft- und Raumfahrtkongress, September 2014.

[20] “GraphHopper Routing Engine”, Retrieved from https://github.com/graphhopper/graphhopper, March 2019.

[21] SD4M, Smart Data for Mobility, Retrieved from https://www.sd4m.net/#html, April 2019.

[22] SIRENE, Secure and Intelligent Road Emergency Network, Retrieved from https://sirene.ifak.eu/, April 2019.

[23] “Beschleunigung von Sicherheits- und Rettungseinsätzen durch Grüne Wellen und optimiertes Routing – SIRENE”, Retrieved from https://www.bmvi.de/SharedDocs/DE/Artikel/DG/mfund-projekte/beschleunigung-von-sicherheits-einsaetzen-sirene.html.