Challenges and Trends of Data Management for Firefighting in Germany and the Netherlands

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ABSTRACT

For successful firefighting, information is key. In this work, a general overview of the current challenges and trends of data management for firefighting in Germany and the Netherlands are examined. This was accomplished by conducting a literature review to find out the current state-of-the-art in research. The results of the literature review are then compared with expert sentiments and gaps between research and practice are revealed. Through the review, six challenge categories are identified: cartographic data harmonization, IS standardization, information gathering from unstructured data, canonical bodies of knowledge, and data-driven firefighting support. The challenges and trends are discussed in the context of Germany and the Netherlands and significant differences are presented. Lastly, the gaps between research and practice are thoroughly analyzed and potentials for future work revealed.

Keywords

Data management, challenges, trends, firefighting

INTRODUCTION

To understand how data management can facilitate successful work practices in the domain of firefighting we must look beyond the for-profit context (Walton et al. 2016 p. 85). The National Institute of Standards and Technology (NIST) released a research roadmap in 2015 which also addresses data management during an emergency event (Grant et al. 2015). In the roadmap, it is concluded that "[t]here are several factors which affect the ability of individual jurisdictions to address the delivery of actionable data to first responders during an event" (Siebert and Venkatasubramanian 2015 p. 139). Additionally, periodicals and research have mainly focused on very specific problems and "literature is significantly limited" (Siebert and Venkatasubramanian 2015 p. 140). Considering these aspects, there is a lack of general overview on how data is managed during a firefighting operation and on what trends and challenges emerged in the past years. It is also unclear, how different jurisdictions adapt to data management innovations. Two countries that adapt very differently to advances in the firefighting sector are Germany and the Netherlands. Germany has problems with adapting innovation (Weidinger et al. 2018 p. 688), especially in rural areas (Müller 2009 p. 81), while the Netherlands have many factors that stimulate high innovation (Nijenhuis and Borninkhof 2015 p. 23). In this article, the current challenges and trends of data management for firefighting in Germany and the Netherlands should be examined (research objective).

To accomplish this overall research objective, the following three sub-objectives have been achieved:

(1) A database and keyword literature search were conducted to identify current pivotal challenges and trends in firefighting which can differ from those that are occurring in practice.
(2) To see how these trends and challenges are adopted in the Netherlands and Germany or whether there are even new trends and challenges in practice, two additional interviews were held with firefighting experts from Germany and the Netherlands.
(3) The literature research was then subjected to a "reality check". The results of the expert interviews

(i.e. the local challenges and trends) were contrasted with the general results from the literature search. Through that, it should be made apparent what trends are popular in the literature but have not made the transition to practice yet and what challenges are currently the focus in each country respectively.

METHODOLOGY

Methodologically, this work is structured in two parts. To identify current trends and challenges, a systematic literature review was carried out. Then, the results of the literature review were juxtaposed with the situation in Germany and the Netherlands by means of expert interviews.

The literature research was based on the systematic literature review process of VOM BROCKE ET AL. (2009). First, a database search was carried out within the Scopus database. Scopus is the biggest database of peer-reviewed titles. To search for literature, the database was first queried with the keyword term *ALL (fire AND fighting AND (trend OR challenge) AND data AND management AND (germany OR netherlands))*. To be able to create an overview of modern challenges and trends, only sources which have been published from 2016 to 2018 were considered initially. The 270 resulting articles (initial hits) were checked for relevance by title evaluation and all but 34 articles were discarded, because they were deemed irrelevant (e.g. medicine, arts etc.). A subsequent abstract evaluation led to 13 relevant hits which were thoroughly analyzed by a full text review. Lastly, the literature research was supported by an internet search of relevant online sources. This was especially crucial for examining what the current state of these trends is, as they were often rapidly changing or were discontinued (e.g. Twitcident: http://www.wis.ewi.tudelft.nl/twitcident/).

The general trends and challenges which have been identified in the literature research were then compared to their local counterparts in Germany and the Netherlands. To do that, two 30- to 45-minute-long interviews were conducted with local experts from the respective country. The interviews were carried out in four steps (Flick 2002 p. 294f.): 1) The interviewer obtained general knowledge of the topic and phrased appropriate questions. 2) The interviewer contacted the appropriate interviewee with the topic. 3) The interview was conducted and recorded. 4) The interview recordings were analyzed, generalized and compared with the results from the literature.

The German expert is head of a department in a big federal firefighting institute and thus a specialist on German firefighting. The department is responsible for crisis management and research and the expert has deep research knowledge, as well as extensive field experience.

The Dutch expert is a firefighter and a CEO of an enterprise that offers data solutions for fire services. He also holds a guest research position at a university in the Netherlands with the research topics emergency response and knowledge management.

THEORETICAL BACKGROUND

To get an understanding on how firefighting works in general and how Germany and the Netherlands operate on a national and local level, some basic processes are introduced to the reader.

Firefighting and Data Management Need

To fight fires a firefighting operation is generally divided into four steps:

(1) Prevention

(2) Preparation

(3) Fire response management

(4) Recovery

This work focuses on the response phase of a firefighting operation (i.e. fire response management).

Due to the complex nature of firefighting, the operators must collect and manage a lot of data throughout these steps. These data can be structured in a lot of different formats (e.g. climate data, time series data, geographic data, textual data). Often the format is proprietary to its private or public organization (Zlatanova et al. 2010). This causes problems when data needs to be harmonized or shared across organizations.

Firefighting in Germany

Who is responsible for firefighting and emergency situations in Germany is organized very differently depending on the local jurisdiction. Responsibility for firefighting is delegated from the state to the cities and counties and thus firefighting institutions are independent from each other and very heterogeneous. Thus, small fires are fought by autonomous fire departments and fires who span multiple regions and cause a lot of damage are fought through a staff organization consisting of multiple local authorities. This tactical-operational staff organization is generally defined in the FwDV 100 ("Feuerwehr-Dienstvorschrift 100") which has been established in Germany in 1999 (Lamers 2016 p. 84). It is important to note that this regulation is not legally binding on a national scale and it is up to the federal states to adapt it in their laws. The defined management staff organization comprises a leader who supervises the staff that is divided into six different areas and additional external consultants (Figure 1). The areas are human resources (S1), location (S2), mission (S3), supply (S4), public relations (S5) and information and communication (S6) (Lamers 2016 p. 85f.).

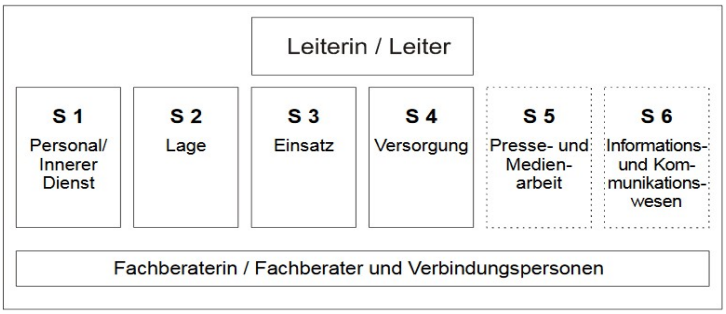

Figure 1. Management staff defined by FwDV 100

Between these specialist areas exists a need for the exchange of information and data, so that they can work together as effective and efficient as possible. LAMERS (2016 p. 88) identified four edges between the different areas, where a close collaboration - and thus a heavy data exchange - is necessary:

(1) S3 and S2 for mission judgment.
(2) S1 and S3 for the reorder of human resources.
(3) S1 and S3 for the management of emergency staging areas.
(4) S4 and S1 for the resupply mission.

Firefighting in the Netherlands

Firefighting in the Netherlands is organized completely different to Germany. The Dutch fire service is a centralized syndicate of all fire brigades of the nation. The brigades are all subordinate to a board of fire chiefs ("Raad van Brandweercommandanten"). In total, the board comprises 25 fire chiefs, one for each safety region ("Veiligheidsregio's") of the Netherlands (Boersma et al. 2012 p. 13). The board has an executive committee, one chairman and six program heads. The program heads are responsible for the following six areas of the national fire service program ("Landelijk Programma Brandweerzorg"):

(1) Risk control and fire-safe living.
(2) Incident control.
(3) Skills and knowledge.
(4) Crisis management.
(5) Information management.
(6) People and business operations.

As many topics are important for each fire department (response times, wide-spread fires in nature or general business management), they are dealt with at a national level. Of course, regional differences are considered (Brandweer Nederland 2015). Work of the programs is carried out in networks and research groups consisting of firefighters under supervision of the central office of the Netherlands Fire Service. Due to this centralized government mode, all safety regions have adopted the so-called netcentric method when working together. This method enables standardized communication between the different partners (Instituut Fysieke Veiligheid 2018). It becomes obvious that the centralized Dutch organization of the fire service is in stark contrast with the federal, decentralized German fire service.

RESULTS

The majority of the results were not exclusive to Germany and the Netherlands. Because of that, the results of the literature are juxtaposed with the results of the expert interviews, which in turn are restrictively focused on the local situation.

Current Challenges

GRASSO ET AL. (2018 p. 625) name "trans-boundary cartographic data harmonization and management for environmental protection and common policies" as big challenges in firefighting operations. The lack of cartographic data is especially critical for widespread fires and access to geographic data is often only possible by accessing different interfaces and thus data of different formats. Because there are different cartographic platforms, so-called geographic information systems (GIS), they are often hard to access in a standardized way, due to their different meta data. Also, integrated into an emergency response system, they often tend to focus only on specific and few parts of the firefighting operation steps, such as command and control (response) or simulation (preparedness).

In city scale scenarios, fires more often occur at places that are more populated (Song et al. 2017 p. 834). Experts are lacking a tool to accurately predict fires, because the explanatory variables that facilitate fires (such as average ground temperature, humidity, etc.) are not collected. This is due to three challenges: 1) the explanatory variables are not recorded in a system, 2) the systems are proprietary, and the data are not stored in an open format and 3) it is unknown how to use these big data to predict fires.

Also, there exist data which are commonly and openly available, but whose potential has yet to be discovered and used. In crisis situations, social media can be a resource of unexplored capabilities. People share their evacuation plans (Chaniotakis et al. 2017) or share information about damages and casualties. This could be used to improve evacuation efforts or to assess incidents by damage, casualties or risk. Again, practitioners are unsure on how to cope with the huge amount of data that is generated by social media sites. Twitter users, for instance, produce over 500 million tweets in a single day and these tweets are polluted with spam, typos and slang (Weiler et al. 2017 p. 329), thus making it hard to extract useful structured data that can be connected to a fire emergency.

Data generation is not a problem anymore as most people carry around GPS ready devices who can put out a lot of geographical information on the go and geographic information technology is more sophisticated than ever. However, consolidating this information into a central knowledge base is still a challenge. GRANELL AND OSTERMANN (2016 p. 231f.) examined volunteered geographic information and geo-social media and concluded that the building of canonical bodies of knowledge has not happened yet, as most studies focus on the challenges and potential of data handling. This stage comprises steps such as merging of data sources, cleaning, annotating, filling missing values and filtering which must be done before an actual analysis of the data at hand can be carried out. Another necessity of canonical bodies is the usage of a shared terminology. For instance, if a dispatch center registers a medium-sized fire it must be known by each participating fire department, what resources to allocate to a fire and therefore it must be known what medium exactly means. An integrated data management for firefighting situations that includes heterogeneous knowledge bases is therefore still out of reach in research, as well as practice.

All challenges are grouped by some general categories and presented in Table 1.

Table 1. Results of the literature review: Challenges

Challenges
Cartographic data harmonization (Grasso et al. 2018)
IS standardization (Granell and Ostermann 2016; Steinhäusler, Friedrich Hällström et al. 2018; Steinhäusler et al. 2018)
Information from unstructured data (Chaniotakis et al. 2017; Weiler et al. 2017)
Creation of canonical bodies of knowledge (Granell and Ostermann 2016)
Creating data-driven firefighting support (Song et al. 2017)

Current Trends

There are some trends that directly tackle previously mentioned challenges. For instance, to harmonize data and establish common policies, a European directive, called information for spatial information in Europe (INSPIRE: https://inspire.ec.europa.eu/), has been setup (Grasso et al. 2018 p. 625). INSPIRE is an initiative of the European parliament and aims at establishing a central GIS. It forces all European countries to 1) standardize their data and

create conform meta data and 2) publish their spatial information over network services. It is in place since 2007 and should be fully implemented in 2021, thus making it at a big current trend in data management for firefighting. GRASSO ET AL. additionally propose a method to design and implement a GIS that fulfills the standards of INSPIRE. The proposed GIS comprises the three major object categories command, land and event which are represented in an INSPIRE-compliant UML model (Grasso et al. 2018 p. 629). For the implementation open source software is used, because it facilitates interoperability through open formats.

Another EU-wide initiative is SAYSO. SAYSO has been initiated in mid of 2017 and should be completed in 2019. It stands for standardization of situational awareness systems to strengthen operations in civil protection and strives to accomplish two deliverables which are relevant to data management. The first deliverable is the specification of open data format standards for crisis management organizations and includes digital map formats, geospatial data, meteorological data, media streaming and many more (Steinhäusler, Friedrich Hällström et al. 2018). The second deliverable is a specification of a multi-stakeholder standardized situational awareness system which is based on requirements of crisis managers, international surveys and several expert meetings (Steinhäusler et al. 2018). When adopted in the future, SAYSO will be a big milestone towards data management standardization in firefighting.

Another trend in the times of big data is the data-driven prediction of fires. Today, researchers have tools of the domain of artificial intelligence at hand which could help to improve prediction. It was mentioned earlier that often data are not recorded sufficiently. Especially data on fire occurrence at the city scale are scarce and site-specific. To tackle this problem, SONG ET AL. (2017) present an econometric model and a random decision forest algorithm which use several variables to predict fires on the scale of Hefei City, a city located in China with a population of almost eight million. The methods work on a reduced set of variables such as elevation, slope and average temperatures. While this study delivered promising results, the research was only done in a case study and its main limitation is that better predictions still rely on an integrated information system (IS) that can deliver a multitude of explanatory variables in real-time (Song et al. 2017 p. 836).

In contrast to data which are not accessible, there is also a lot of data which are available, but whose potential has not been recognized. Through social media, the decision process of people in evacuation situations can be analyzed and used to improve in such conditions. CHANIOTAKIS ET AL. (2017) examined Twitter data from an evacuation in Oroville, USA and created a model that uses historical data to predict the behavior of evacuated people. Twitcident is another online data mining tool that allows to filter tweets related to incidents. The tweets can be filtered by region or topic and can be used to assess damage, casualties and many more. WEILER ET AL. (Weiler et al. 2017 p. 836) proposed an experimental analysis on event detection techniques. Event detection techniques try to extract events (i.e. real-world occurrences that take place in a geographical location over a certain period) out of unstructured data. The analysis should give researchers and practitioners the possibility to choose the best algorithm to extract event data based on their preferred properties such as precision, recall, memory usage or run-time performance.

Another trend tries to answer the challenge of insufficient canonical bodies of consolidated knowledge laid out by GRANELL AND OSTERMANN (Granell and Ostermann 2016 p. 231f.). One example are different definitions of the same term between two different organizations, e.g. our medium-sized fire example from the previous section. To solve this issue, Firebrary (http://www.firebrary.com/) was developed to provide a data dictionary for common terms for the Dutch services. Firebrary uses the SKOS-XL standard to provide open access to people and software (Spaling et al. 2018 p. 122).

Again, all trends are grouped by some general categories and summarized in Table 2.

Table 2. Results of the literature review: Trends

Trends
INSPIRE (Grasso et al. 2018), Digital plan (Weidinger et al. 2018), OpenFireMap, Fireboard
SAYSO (Steinhäusler, Friedrich Hällström et al. 2018; Steinhäusler et al. 2018), Firebrary (Spaling et al. 2018), on-site IS (Weidinger et al. 2018)
Twitter model (Chaniotakis et al. 2017), twitcident, event detection (Weiler et al. 2017)
Firebrary (Spaling et al. 2018)
Econometric model (Song et al. 2017)

Expert Interview: The Situation in Germany

The expert interview with the German expert yielded the following results. If not indicated differently, the source of information is the expert interview.

The recording of the first response in an emergency in Germany is sophisticated. A caller is referred to a control center in which an employee poses structured questions. The answer is put into an IS and subordinate questions are posed until the dispatcher can conclude a so-called alarm key word, a single word that describes type and magnitude of the fire. If agreed, the caller can be located over the mobile network. The gathered information is forwarded to the responsible fire department and resources are allocated depending on the alarm key word (this is defined in the "Alarm- und Ausrückeordnung"). While data of the call is stored in a control center system, the smaller fire departments often have a non-compatible IT infrastructure and thus, the information is printed on an "Alarmdepesche". The "Alarmdepesche" contains information about the route to the operation site, water supply and the caller. For special sites, construction blue prints and maps are stored in paper format at the local fire department. It is rare that a fire department has fully digitized this process, but this is likely to change in the future. A first example is the FIRE application of the department in Berlin where the "Alarmdepesche" is fully substituted by an IS on a tablet (Bäker 2018 p. 479f.). Additionally, the FIRE App is equipped with a hazardous substance database, rescue data sheets and a fire wiki (Bäker 2018 p. 482f.). A similar system has been deployed in Saxony (FwA - "Feuerwehrapp"). The app comprises four modules: a map module with hydrants and water sources, rescue data sheets, a hazardous material information module and a respiratory protection module (Heyne 2018 p. 492f.). More prominent than a digitized "Alarmdepesche" is the automatic transmission of the route into the navigation systems of the fire trucks which is implemented almost everywhere. However, during the actual firefighting almost no IT is used (an exception is the respiratory protection module of the Saxon "Feuerwehrapp"). Afterwards, the operation is documented in an IS.

As identified in the general challenges and trends, GIS are very topical. Due to the independently acting federal states and local fire departments, there are multiple geodatabases. For instance: There exists an ALKIS geo database for Lower Saxony which can be integrated easily with generic interfaces (Dunkel 2018 p. 134), but this is a solution on federal state scale. DUNKEL suggests that all future applications should be encoded in the DIN 14095 standard to increase interoperability on a nation-wide level (Dunkel 2018 p. 140). BERNSDORF identifies four challenges of the usage of geo information for firefighting in Germany: internet connectivity, data actuality, training of executives and operability of these complex systems (Bernsdorf 2018 p. 155f.).

The biggest challenge in the process is the standardization between the local institutions. Due to the independent and autonomous nature of the fire departments, there is a big heterogeneity in IS. HEYNE sees the usage of proprietary systems as the biggest inhibitor of a dissemination of successful software (2018 p. 499). Unfortunately, there is no binding regulation on systems standardization in Germany and a new regulation is costly for the administration of the federal state, due to the "Konnexitätsprinzip", i.e. the state must carry the costs for tasks which it imposes. Control centers of different jurisdictions use proprietary systems. North Rhine-Westphalia alone consists of 52 autonomous control centers. Some federal states have already consolidated their control centers (e.g. Hesse and Bavaria). Additionally, the alarm key words are only standardized within a county. A country-wide glossary or general semantics do not exist. This is especially critical for fires which span multiple regions.

For such fires, a crisis staff must be established and here, the problem of standardization is even more critical. The go-to data management device is still e-mail and telephone communication, as no integrated software solution is implemented. There are some efforts to offer central data management tools. North Rhine-Westphalia has a database where resources such as water reserves are stored ("Informationssystem Gefahrenabwehr NRW"). There is also an EU wide project for the standardization of situational awareness tools (project SAYSO, mentioned earlier). Still, crisis management is relying on traditional methods for communication which partially exists since multiple decades (e.g. paper message and radio). Rarely, more advanced technologies such as fax or scans are used. The whole procedure is slow and full of misunderstandings.

All in all, politics, federalism and the decentralization of responsibilities to the local authorities are the main reasons for the non-standardization of data management for firefighting in Germany and this is one of the biggest challenges.

Expert Interview: The Situation in the Netherlands

Because of their safety-regional structure, the Netherlands are not as federal as Germany and thus systems standardization is much less of a problem. The safety regions are not centrally governed; their geographical borders are defined by law, but their mode of operation is autonomous. Still, there is a nationally standardized radio communication system and a central national dispatch system, which are standardized even across the autonomous safety regions. Only some systems, such as human resource management systems, are procured locally.

The expert sees the biggest challenge in data management in the qualification of the fire fighters. When fire fighters are employed, they are tested on practical skills, rarely are they tested on IT competence or trained while on the job. Of course, this stems from firefighting requiring a whole different set of base qualifications.

Another challenge is the inertia of the fire service as a governmental institution. For the innovation of legacy information or data management technologies within the institutions, a complex procurement process needs to be initiated because investments are often very big. Due to the complexity of the procurement that is often subsidized with only small budgets, innovation is very tedious.

It is notable that while IS standardization is a smaller issue than in Germany, the creation of a canonical body of knowledge and shared semantics is very important in the Netherlands. To allow effective communication between different firefighting departments, there must be a taxonomy of firefighting terminology and information architecture of the IT systems must be improved. A notable endeavor to do this is Firebrary, a data dictionary for common terms for the Dutch service which was introduced earlier.

Also, the expert mentions that "the road to AI leads through IA [information architecture]". This means that first, the data in the systems must be harmonized, before it can be used for artificial intelligence, due to its data-driven nature. The Netherlands also employed first trials with artificial intelligence. While artificial intelligence is not used for predicting fires, it showed very promising results when fighting a fire and looking for similar environments or buildings to gather helpful information. Another data-driven firefighting support tool is RESC Info Insight that allows to combine forensic research data, internal statistical data and publicly available data to gain additional insights (https://netage.nl/resc-info-insight/).

All in all, the Netherlands are also concerned with some more traditional challenges such as building of canonical bodies of knowledge, as well as more advanced technologies, such as data-driven firefighting support.

DISCUSSION

To get a concluding overview on which challenges were identified and which trends are answering these challenges, Table 3. **Challenges and trends of data management in firefighting**

Challenge	Trend
Literature Review / International	
Challenge	**Trend**
Literature Review / International	
Cartographic data harmonization (Grasso et al. 2018)	INSPIRE (Grasso et al. 2018), Digital plan (Weidinger et al. 2018), OpenFireMap, Fireboard
IS standardization (Granell and Ostermann 2016; Steinhäusler, Friedrich Hällström et al. 2018; Steinhäusler et al. 2018)	SAYSO (Steinhäusler, Friedrich Hällström et al. 2018; Steinhäusler et al. 2018), Firebrary (Spaling et al. 2018), on-site IS (Weidinger et al. 2018)
Information from unstructured data (Chaniotakis et al. 2017; Weiler et al. 2017)	Twitter model (Chaniotakis et al. 2017), twitcident, event detection (Weiler et al. 2017)
Creation of canonical bodies of knowledge (Granell and Ostermann 2016)	Firebrary (Spaling et al. 2018)
Creating data-driven firefighting support (Song et al. 2017)	Econometric model (Song et al. 2017)
Germany	
Cartographic data harmonization (Bernsdorf 2018)	Feuerwehrapp (Heyne 2018), ALKIS (Dunkel 2018)
IS standardization (Heyne 2018)	FIRE App (Bäker 2018), Feuerwehrapp (Heyne 2018), SAYSO
Netherlands	
Lack of IT qualifications	none
Governmental innovation inertia	none
Canonical bodies of knowledge	Firebrary (Spaling et al. 2018)
Data-driven firefighting support	Artificial intelligence for similar fire environments, RESC Info Insight

Cartographic data harmonization (Grasso et al. 2018)	INSPIRE (Grasso et al. 2018), Digital plan (Weidinger et al. 2018), OpenFireMap, Fireboard
IS standardization (Granell and Ostermann 2016; Steinhäusler, Friedrich Hällström et al. 2018; Steinhäusler et al. 2018)	SAYSO (Steinhäusler, Friedrich Hällström et al. 2018; Steinhäusler et al. 2018), Firebrary (Spaling et al. 2018), on-site IS (Weidinger et al. 2018)
Information from unstructured data (Chaniotakis et al. 2017; Weiler et al. 2017)	Twitter model (Chaniotakis et al. 2017), twitcident, event detection (Weiler et al. 2017)
Creation of canonical bodies of knowledge (Granell and Ostermann 2016)	Firebrary (Spaling et al. 2018)
Creating data-driven firefighting support (Song et al. 2017)	Econometric model (Song et al. 2017)
Germany	
Cartographic data harmonization (Bernsdorf 2018)	Feuerwehrapp (Heyne 2018), ALKIS (Dunkel 2018)
IS standardization (Heyne 2018)	FIRE App (Bäker 2018), Feuerwehrapp (Heyne 2018), SAYSO
Netherlands	
Lack of IT qualifications	none
Governmental innovation inertia	none
Canonical bodies of knowledge	Firebrary (Spaling et al. 2018)
Data-driven firefighting support	Artificial intelligence for similar fire environments, RESC Info Insight

Table 3 is presented. The table visualizes the results of the previous sections. To do that in a simple manner, categories of challenges were formed and one or multiple challenges were grouped by these categories.

The results from the literature review (international) were diverse and range from more traditional challenges,

Table 3. Challenges and trends of data management in firefighting

such as geo-data and IS harmonization and standardization to more innovative trends. When looking at the more innovative trends such as information gathering from twitter data or econometric fire prediction, it becomes apparent that these were not implemented through persisting and sustainable solutions, but through pioneering case study research. This is a small hint that these trends might not have made the transition to practice yet. On the plus side, there is no international category of challenges which is not addressed by at least one trend.

On the German side, challenges and trends look completely different. Information gathering from unstructured data and data-driven firefighting support are not addressed at all. The more traditional topics such as cartographic data and IS standardization are currently under heavy implementation. Because these topics take a lot of effort and are often a prerequisite for more advanced technology, current practice in Germany will probably take some time to fully adopt them. Due to Germany's federal nature, it will take some more years, before the more pioneering technologies will be integrated.

In the Netherlands, cartographic data and IS standardization are not a current challenge, because the Netherlands employ an integrated IT infrastructure within their safety regions. Canonical bodies of knowledge and a taxonomy are very important and already tackled by some approaches. The Netherlands additionally touched some areas which are currently unreachable for Germany. These comprise data-driven approaches. The Netherlands have also some more advanced challenges, that have not been answered, such as lack of qualifications and governmental innovation inertia. These two categories were not even recognized by the literature review. This may potentially be, because the used key words were focused on information systems research, while the two problems should be viewed through the lens of organization science.

CONCLUSION

Some unique revelations could be made through the combination of a literature review and interviews with local firefighting experts.

All in all, one can say that most of the current challenges are answered by at least one trend. Still, the situation of Germany and the Netherlands could not look more different, which is an interesting finding as both countries are alike in many other areas. While the former is determined by its federal political system, it cannot yet adopt newer technologies, because the basis of IS standardization is missing. It will take some more years (or even decades) for Germany to adopt newer trends and even then, the solutions will be pushed by single local fire departments instead of being established on a national scale. These phenomena are almost non-existent in the Netherlands, due to their centrally regimented safety regions, and more progressive trends emerged in the last couple of years. It is notable that challenges of the Netherlands are not only limited to the domain of information systems, but also organization science, and thus an interdisciplinary approach, that cannot be achieved by technological advances alone, is required to solve them.

For further research, some improvements can be made. The keywords could be extended to conduct an exhaustive literature review in future work. The authors also suggest, that the scope of the literature review should be extended to include literature from organization science which was not possible with the used key words. Additionally, it must be questioned whether a structured literature is the right means to identify (local) trends and challenges. Because much information is intangible and not accessible in research databases, more experts must be interviewed to get a more comprehensive and objective overview. This also increase the objectivity of the expert judgements. Additionally, the work is very descriptive, a structured comparison of countries could lead to learnings one country could gain from another country, thus making the research more prescriptive.

These limitations therefore address some gaps that must be bridged. For future research the authors recommend following research agenda which is concluded from the results and limitations:

(1) Standardized IT infrastructure in Germany.

(2) Lack of qualifications in the Netherlands.

(3) Governmental innovation inertia in the Netherlands.

(4) Practical applicability of information retrieval from unstructured data.

(5) Prescriptive analysis of practices to facilitate the adaption to challenges and adoption to trends.

To determine what happens with data management in the near future is dependent on how technology advances further and even more dependent on how the political systems in Germany and the Netherlands will facilitate innovation in the area of firefighting. One thing is sure, for the coming decades it will be a topic of high interest and constant change.

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