

Towards Social Media Decision Support for Joined EMS and Crisis Logistics

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ABSTRACT

In this paper, we investigate how social media can be utilised to support the integration of emergency medical services (EMS) and crisis management activities. We explore the literature both on social media in crisis management and on EMS logistics to elaborate on their potential to support EMS logistics planning based on the experiences from crisis management. We then discuss how social media data can be used for tactical and strategic decision-making using location data to improve demand forecasting and planning for both routine emergencies and crises.

Keywords

Crisis Logistics, EMS Logistics, Social Media, Decision-Making.

INTRODUCTION

Recent statistics illustrate the continued relevance of research in crisis and disaster management. The United Nations Office for Disaster Risk Reduction finds that between 1998 and 2017, natural disasters caused 1.3 million fatalities and otherwise affected 4.4 million people (Wallemacq and House, 2018). While reports indicate an overall decline in the number of human-made catastrophes, the number of natural crises and disasters, such as hurricanes, wildfires, and earthquakes, continues to increase (Swiss Re Institute, 2018).

This sheds light on the crisis and humanitarian logistics required to attenuate the impacts of crisis events for people and communities that are affected (van Wassenhove, 2006). However, crisis and humanitarian supply chains, just like other systems involved in crisis response, often suffer from information flow impediments, including the unavailability and unreliability of information, with potentially serious implications for crisis response (Altay and Labonte, 2014; Day *et al.*, 2009; Maitland *et al.*, 2009). This is particularly evident when it comes to emergency medical services (EMS), which are expected to serve routine emergencies (e.g., traffic accidents and medical emergencies), but at the same time also to participate in crisis response activities.

In the crisis informatics field, the question of how information and communication technologies and particularly social media – Web 2.0 platforms such as content-sharing sites, microblogs, and online social networks that provide a forum for user-generated content and that are open to modification, participation, and collaboration by its users (Kaplan and Haenlein, 2010) – can assist in the coordination of crisis management efforts within and across different agencies has received much attention (Meum and Munkvold, 2013; Sarcevic *et al.*, 2012; Yates and Paquette, 2011). Taking up this question, we investigate how social media can specifically support the integration of routine EMS and crisis management activities.

Our research questions can be formulated as follows: *How can social media support decision-making in EMS logistics relating to crisis management activities? What is the potential of and opportunities for using social media as input for planning problems, and what are the limitations and risks?*

To answer these questions, we combine the existing literature on social media in crisis management and on EMS logistics. We draw on prior research on both crisis and humanitarian logistics, as both branches often face similar tasks and challenges (Zhang *et al.*, 2002). We then match the planning levels for EMS logistics with the crisis management phases to elaborate on the potential of social media to support EMS logistics planning based on the experiences from crisis management. We explain how social media data can be used at both the tactical and strategic decision levels – for example, using location data to improve demand forecasting and planning for both routine emergencies and crises.

The remainder of the paper is structured as follows. In the next section, we describe the research problem in detail. We then illustrate how social media might be used to support EMS and crisis logistics decision-making, considering operational as well as tactical and strategic decisions in crisis mitigation, preparedness, response, and recovery. Based on this, we present a use case for illustration and a research proposal at the strategic-tactical level. We conclude with a summary of our work and prospects for future research.

RESEARCH PROBLEM

Many different parties and service providers are needed to address a crisis event adequately, including EMS, firefighters, and police (van Borkulo *et al.*, 2005). The EMS system is designed to meet the requirements of everyday service, but also to be available during crises. Given that, it stands to reason that preparations for potential crises should take everyday EMS activities into account.

This is especially true for EMS logistics, which are an essential aspect of crisis management (Kovács and Spens, 2007). Decisions that relate to facility location, relief distribution, or casualty transportation – such as locating and relocating ambulances, setting up dispatching and routing policies, and coordinating with other actors involved in crisis management – are essential for dealing with a crisis (Caunhye *et al.*, 2012).

Thus, responding to a crisis inevitably requires EMS logistics planning, including decisions at the *operational, tactical, and strategic levels*, as Table 1 summarises (Reuter-Oppermann *et al.*, 2017).

Table 1: Overview of EMS logistics

Planning level	Time horizon	EMS planning problems
Strategic	Yearly or longer	Locating bases Determining the number of ambulances Hiring crew Long-term demand forecast
Tactical	Weekly or monthly	Locating ambulances Staff scheduling Scheduling emergency medical physicians
Operational	Daily	Relocating ambulances Assigning ambulances to calls Daily demand forecast Patient transport scheduling Handling unavailability of staff and vehicles

At the strategic level, much research on EMS logistics has focused on models and approaches for locating bases. Once opened, a base typically is in use for several years or even decades. Decisions about acquiring new ambulances are often made annually, but once purchased ambulances are expected to be in use for many years. However, as ambulances can be transferred easily between base locations, decisions on where to put them are made at the tactical level. Similarly, the schedules of emergency medical physicians, who are a constituent part of the EMS systems of several European countries, are determined tactically. At the operational level, planning addresses relocating and dispatching ambulances, as well as scheduling patient transports (Reuter-Oppermann *et al.*, 2017). EMS logistics decisions are thus an essential prerequisite of crisis management as they determine what resources can be mobilised when a crisis occurs (Bui *et al.*, 2000).

EMS logistics activities can be assigned to the four stages of crisis management (Altay and Green III, 2006; Galindo and Batta, 2013). They include: *crisis mitigation* and *crisis preparedness* activities aimed at preventing the occurrence of a crisis, limiting its impacts, and providing resources to respond to an event before it takes place; *crisis response* activities intended to minimise its acute impacts; and *crisis recovery* activities in the post-event stage, such as rebuilding physical infrastructures (Lindell, 2013).

The literature on EMS logistics in crisis mitigation and recovery has focused mainly on strategic decision-making, whereas the tactical and operational levels are considered more often in the context of crisis preparedness and response operations (Leiras *et al.*, 2014). In the pre-event stages, recruiting and training personnel, prepositioning ambulances and emergency supplies, and setting up long-term working relationships with other crisis responders is essential (Altay and Green III, 2006; Bui *et al.*, 2000; Goldschmidt and Kumar, 2016). During crisis response, EMS logistics often serve operational tasks, such as evacuating threatened populations, opening shelters, and providing mass emergency medical care (Altay and Green III, 2006). During crisis recovery, the focus of EMS logistics is on the tactical reduction of resources (Pettit and Beresford, 2005), but operational tasks, such as providing sustained mass care, and strategic activities surrounding the adjustment of existing tools and procedures are addressed as well (Altay and Green III, 2006; Bui *et al.*, 2000).

Demand prediction is a major challenge for EMS logistics in crisis management (Kovács and Spens, 2009). While rare, crisis are potentially catastrophic events associated with a high degree of uncertainty of occurrence, which means that the potential for crisis planning is limited (Boin and McConnell, 2007). Despite the occasional nature of events, sufficient EMS resources such as ambulances and paramedics must be available immediately at the onset of a crisis. This need competes with the fact that it is not feasible to install more resources than necessary for everyday service provision due to high cost pressures in many healthcare systems. Furthermore, even during a crisis, routine emergencies (e.g., traffic accidents and medical emergencies) still need to be served by EMS. It is thus unsurprising that the integration of EMS logistics and other systems is considered a prime challenge of crisis management (Gupta *et al.*, 2016).

To ensure the functionality of the crisis response system when it is needed, an efficient flow of information to and among all actors before, during, and after an event is essential (Day *et al.*, 2009; Maitland *et al.*, 2009). At the strategic level, incident data from previous years is a main input for EMS logistics planning and demand forecasting (e.g., of the expected locations and times of future emergencies [Ingolffson, 2013]). In addition, demographic information such as the number and ages of inhabitants in a district and the distribution of schools, nursing homes, and production sites can be taken into account. At the operational level, weather and current traffic are further data points. Beyond these inputs, social media and other sources of big data are expected to facilitate demand forecasting (Starr and van Wassenhove, 2014).

USING SOCIAL MEDIA TO SUPPORT EMS AND CRISIS LOGISTICS DECISION-MAKING

Prior research on social media in crisis management has emphasised the capability of platforms such as Facebook and Twitter to enhance decision-makers' *situational awareness*: by monitoring social media, they can learn about crisis events, including the location and extent of a hazard, newly developing threats and security risks, and the needs of affected communities (Eismann *et al.*, 2018). In addition, social media can assist decision-makers in obtaining contextual background knowledge to complement information from other sources. Thus, social media can support decision-makers in developing an overview of a crisis situation and establishing a sense of context (Ludwig *et al.*, 2015; Tapia and Moore, 2014).

We argue that social media can be considered *emergency response information systems* that enable EMS planners to collect information related to a crisis event (Turoff, 2002). In the following, we illustrate the promises and limitations of social media to enhance the flow of crisis-related information. Our assumption is that by supporting EMS planners in managing (i.e., collecting, processing, and sharing) information, social media can also enhance the integration of EMS logistics into crisis mitigation, preparedness, response, and recovery efforts (Maitland *et al.*, 2009; Saab *et al.*, 2008). Our argument is based on the premise that increased access to situational information can assist decision-makers in recognising decision problems (Bui *et al.*, 2000), while at the same time the actual relevance and meaning of this information depends on *environmental constraints*, such as the extent of situational uncertainty, complexity, and time pressure (Kapucu and Garayev, 2011), as well as the *time horizon* of a decision (Iakovou *et al.*, 1994).

Using Social Media to Support Operational EMS and Crisis Logistics Decision-Making

Operational EMS and crisis logistics decisions are often about routine tasks, such as the inspection and inventory of resources, but also include less-structured problems, such as monitoring potential information sources and coordinating assistance planning (Bui *et al.*, 2000). A key issue with such short-term decision-making is the lack of lead-time before decisions are made. *Timely access to relevant information* is generally not considered a problem for well-structured tasks (Thompson *et al.*, 2006), but operational decisions made during crisis response are known to suffer from a lack of timely and locally specific information, which cannot be provided by established sources of information because of the immediacy and unexpectedness of events and the lack or outage of local contacts and infrastructure (St. Denis *et al.*, 2014; van Gorp *et al.*, 2015). Yet under conditions of high situational complexity and uncertainty, decision-makers' need to consider a greater variety of

sources that provide general background information increases (Vakkari, 1999). By providing them with access to large amounts of near real-time information, social media can help fill these information gaps (Ludwig *et al.*, 2015; Sarcevic *et al.*, 2012; Tapia and Moore, 2014).

In addition, the *accuracy and representativeness of information* is essential for addressing short-term problems, which means that the evaluation and verification of data are major issues in decision-making (Fisher and Kingma, 2001; Thompson *et al.*, 2006). Using information from social media requires assessing the relevance and accuracy of that information under conditions of information overload and scarcity of time and other resources (Ludwig *et al.*, 2015). Moreover, operational – rather than strategic and tactical – crisis-response decisions are associated with high criticality, which means that trustworthiness of data is essential. Decision-makers may not, therefore, rely on available information to make decisions that have the potential to save or lose lives or that involve allocation of scarce resources, such as assigning vehicles and personnel for search and rescue operations. The findings of prior research suggest that social media data are usually at least triangulated with information from other, presumably more reliable sources (Tapia and Moore, 2014).

As regards operational decision-making, we observe that information from social media is likely of limited value for routine decision tasks for which alternative sources of relevant and high-quality information are available. For particularly urgent tasks, however, information overload and limited reliability of information can be problematic.

Using Social Media to Support Tactical and Strategic EMS and Crisis Logistics Decision-Making

Tactical and strategic EMS logistics decisions are most relevant during the pre- and post-event stages of a crisis, given that the acute impact phase of such events rarely lasts longer than a few days (Kumar and Havey, 2013) and decision-makers typically prefer making medium- and long-term decisions well in advance of a potential crisis (Danielsson and Ohlsson, 1999).

It is useful to distinguish between crises with a sudden onset, such as terrorist attacks, and events with a slow onset, such as droughts (Kumar and Havey, 2013): Whereas crisis preparedness is basically precluded for sudden-onset events, slow-onset events can be mitigated in the abstract and effective preparation is possible. In both cases, decisions made weeks or months before an event are likely to have ripple effects on crisis response activities because both the availability EMS capabilities and the flexibility of the EMS logistics system depend on prior planning (Thompson *et al.*, 2006).

Problems of timeliness and availability of relevant information are less severe at the strategic and tactical levels because a more extensive search for and vetting of potential information sources is feasible. Nonetheless, we find that there are still limitations to using social media to support medium- and long-term decision-making, as crisis planning involves many tasks that are well-specified in advance, such as defining roles and responsibilities and allocating materials and equipment, as well as activities that are restricted by organisational routines (Boin and McConnell, 2007).

Beyond that, evidence suggests that social media can provide decision-makers with *intelligence that is not available from other sources*, such as notifications about emerging security threats, newly developing crises, and other emergent conditions on the ground that could affect the safety of people and materials. If thoroughly vetted, such information can be useful for the tactical deployment of personnel and the location or relocation of vehicles and supplies, route choices, as well as strategic investment decisions regarding bases, local infrastructure, and alliances with other actors (Tapia and Moore, 2014). Furthermore, the literature suggests that information from social media can assist in long-term tasks aimed at increasing organisational and community resilience, such as reputation and community management (Anson *et al.*, 2017).

However, ambiguities in the interpretation of available information can hinder decision-makers from arriving at correct and consistent interpretations of a problem (Kowalski-Traklofer *et al.*, 2003). As the consequences of tactical and strategic decisions might not be observed until the actual occurrence of a crisis, which could be much later, this issue is particularly problematic for medium- and long-term EMS logistics decisions (Helsloot, 2005). Thus, reliability and especially the *accuracy, completeness, and consistency of available information* remain essential (Fisher and Kingma, 2001).

Overall, we are cautiously optimistic regarding the potential of social media to support EMS and crisis logistics integration in the medium and long runs. While many routine tasks might still not benefit from the additional information, social media can be used to obtain intelligence not available from other sources and to increase organisational and community resilience through timely engagement. The need for cross-validation is evident; the literature suggests that this can be done due to the extended planning horizon and the possibility to rely on crowdsourcing and interactive approaches to information collection and validation (Mehta *et al.*, 2017).

Summary

Figure 1 summarises our conclusions. Overall, it is unlikely for medium- and long-term decisions to be made while situational uncertainty and time pressure are high (Kumar and Havey, 2013). Due to the significant long-term impacts of such decisions, social media also do not recommend themselves as sources of information in such cases, given that baseline quality criteria might not be met and time pressures impede thorough validation of information.

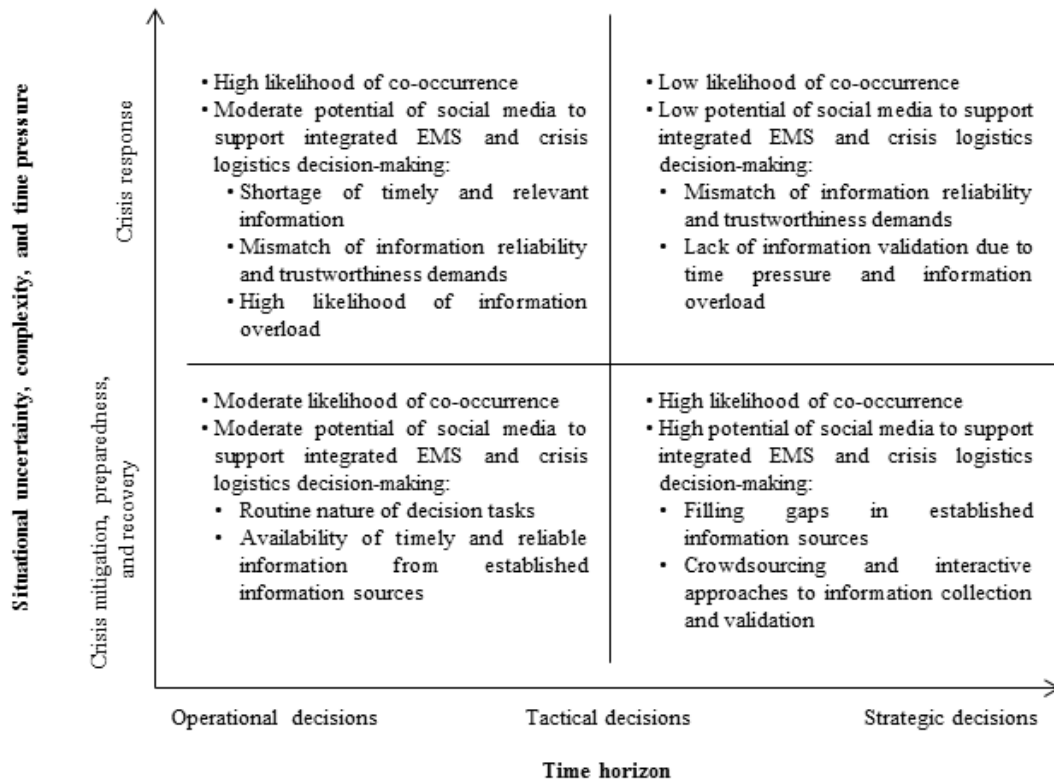


Figure 1 Potential of social media to support integrated EMS and crisis logistics decision-making

The less acute stages of a crisis are more similar to non-crisis EMS logistics (Holguín-Veras *et al.*, 2012). Based on the research literature, we conclude that operational decisions before or after the crisis impact phase are often subject to established EMS routines and can be made using regular sources of information, which diminishes the potential of social media to contribute to these tasks.

We believe, however, that both tactical and strategic EMS logistics decision-making can benefit from incorporating social media, especially during crisis mitigation, preparedness, and recovery. Although the need to cross-validate information is evident for medium- and long-term decisions, too, the environmental conditions allow for more rigorous data collection and verification using more time-consuming methods. In particular, social media can support decisions that are not overly regulated by organisational norms and routines, such as those regarding investments in infrastructures, personnel, and networks of responders and potentially affected communities.

Contrary to our insights, prior research on social media in EMS and crisis and humanitarian logistics has mostly focused on operational decisions made in the response phase (Kirac and Milburn, 2018). Therefore, we suggest a use case for illustration and a research design to investigate further how social media can enhance EMS and crisis logistics integration based on strategic and tactical decisions, especially in mitigating and preparing for a sudden crisis event.

RESEARCH SCENARIO

Although prior literature has mostly focused on the use of social media for operational decision-making during crisis response, our insights demonstrate that it can also be used for tactical and strategic planning problems. On

the strategic level, decisions regarding where EMS ambulance and bases should be located are frequently investigated. In line with earlier approaches (van Essen *et al.*, 2013), we consider the planning problem of locating ambulances and bases both strategically and tactically.

Locating ambulances and bases serves several objectives that may, depending on the decisions made, lead to outcomes that are at odds with one another. These include, for example, maximising the coverage of the region or population, minimising driving times to emergency calls, maximising response time fulfilment, minimising costs for installing ambulances and bases, and maximising the survival probability of patients in case of an emergency (Reuter-Oppermann *et al.*, 2017). When deciding on locations for ambulances and bases, it is typical to take only everyday EMS demand into account (Steins *et al.*, 2019). Crisis mitigation and preparedness activities thus must be handled separately, using the locations of EMS vehicles as input. Nevertheless, these EMS decisions are likely to have ripple effects on how a crisis is dealt with in the acute response phase, which means that it is most promising to investigate the potential effects of integrating novel sources of information for integrated EMS and crisis logistics decision-making prior to an event. Our research proposal thus aims at integrating EMS and crisis logistics planning by considering the potential of information from social media to facilitate strategic and tactical decision-making in crisis mitigation and preparedness.

The research question of the proposed study is: *How does integrating social media into tactical and strategic EMS logistics decision-making for base and ambulance locations influence crisis response?*

The expected demand is the most important input parameter for this planning problem. Unfortunately, the occurrence of future emergencies is, by nature, uncertain. Based on historical data on the times and locations of past emergencies, future demands can be predicted with a certain probability using statistical and machine learning techniques (Steins *et al.*, 2019). Predictions could also benefit, potentially highly, from integrating novel sources of (big) data and information, such as social media (Starr and van Wassenhove, 2014).

The assumption is that significantly improved predictions cannot be obtained using currently available data; additional data are necessary for that (Steins *et al.*, 2019). It is obvious that emergencies can occur only where there are people, but it is not easy to determine with certainty where they may be at any given time of a given day. Census data can provide a zone's population, but we cannot know for certain when people are actually at home. We do not know generally where individuals within a population work, when they work, and where they spend their free time. We also do not have anywhere near precise knowledge about how many people go to shopping areas, city centres, and other public or private facilities, which routes they take, and which means of transportation they rely on. The planning problem is aggravated when having to account for a sudden crisis event, such as a terrorist attack or a major fire. In such cases, ambulances that would otherwise serve routine emergencies (e.g., traffic accidents, medical emergencies, and patient transport) are needed to respond to the events.

Social media can help EMS planners approach this challenge, using, for instance, location data from posts and tweets collected in advance (Hasan *et al.*, 2013), which could be beneficial in better estimating the actual number of people in an area for different months, weekdays, and also times of day. Combined with the actual number of emergencies in a zone and data obtained from other information sources, such as the density of active mobile phones in an area, such information could be used to estimate the relationship between the number of emergencies and the location of people to arrive at better forecasts of emergency events. Furthermore, social media data collected during a crisis event (de Longueville *et al.*, 2009), along with potentially available data from historical events in the same region, could be integrated into crisis mitigation and preparedness planning for future events.

POTENTIAL STUDY DESIGN

Our aim is to investigate how using location data from social media for strategic and tactical decision-making regarding the location of ambulances and bases influences crisis response activities. In particular, we want to investigate its effects on the estimated distances and driving times to expected emergency calls during a sudden crisis event (e.g., a terrorist attack) in a given zone.

We adopt a qualitative research approach based on the critical incident technique, which is a flexible method for investigating goal-directed behaviour in specific types of situations (Flanagan, 1954). Initially, a set of vignettes of the research scenario outlined in the previous section will be compiled. The vignettes will provide descriptions of the situation (i.e., responding to emergency calls during a sudden crisis event in a given zone) and the general aim of activity in that situation (i.e., minimising expected driving times and distances to emergency calls during crisis response). Using a vignette-based approach allows us to gain an in-depth understanding of the cognitive processes that guide respondents' decisions (Jenkins *et al.*, 2010).

We intend to compile a set of three vignettes to illustrate the critical incident. The first vignette will present the problem of locating ambulances and bases based on established data inputs, such as census and demographic data, historical incident data, and outputs of frequently used decision-support systems (Ingolffson, 2013). It will contain a description of the underlying planning problem in a fictive response zone, enriched by materials that further illustrate the zone, especially maps of the area, potential vehicle locations, and data inputs. The second vignette will introduce simulated location data from social media for the respective area to complement the first vignette by additional data input. The third vignette will enrich the scenario by the occurrence of a sudden crisis event. Again, supplementary materials to indicate the location and magnitude of the event will be displayed.

We then plan to use the vignettes to conduct semi-structured, qualitative, face-to-face interviews with EMS planners from rescue operation centres in Germany. All interviewees will be presented the vignettes in the order delineated above. For each vignette, interviewees will be asked to describe how they perceive the situation, how they would respond to it to achieve the stated aims, and what criteria would be relevant to their decision-making (Flanagan, 1954). Interviews will be recorded and transcribed to identify emergent themes, using the constant comparative method (Boeije, 2002). The number of interviewees is to be determined based on the theoretical saturation in an iterative data collection and analysis process (Bowen, 2008). To ensure the credibility and trustworthiness of results, the scenarios and vignettes will be discussed with at least two experienced EMS planners in advance. The outcomes of the study will be validated through discussions with domain experts and participant cross-checking (Butterfield *et al.*, 2005).

The results of the proposed study will demonstrate the potential of social media to support integrated EMS and crisis logistics decision-making in the tactical and strategic domain, which can serve as an input for future model development and testing.

CONCLUSION

Our goal is to evaluate the potential of social media as a complementary source of information to assist in the integration of EMS and crisis logistics decision-making. In this paper, we have investigated what prior research on social media in crisis management reveals about their capabilities to enhance the integration of EMS and crisis logistics. We find that social media are most likely to assist in that task for tactical and strategic decision-making – for instance, determining the location of ambulances and bases. The outcomes of these decisions can be used, in turn, as input in crisis mitigation and preparedness.

Based on our findings, we propose a research scenario and a potential study design to investigate how social media can be used to enhance tactical and strategic EMS logistics decision-making, and the implications of using social media in the pre-crisis stage for achieving crisis response outcomes. In our research proposal, we compare the outcomes of tactical and strategic ambulance and base location planning using established information sources (e.g., census and demographic data, historical incident data, and outputs of existing decision-support systems) with location data obtained from social media. We rely on vignette-based qualitative interviews using simulated data and a fictive area of operations in which a sudden crisis event (e.g., a terrorist attack) is imagined to take place. Apart from the potential of social media to support EMS and crisis management integration, the outcomes of the proposed study will also shed light on the limitations and trade-offs of social media with respect to information collection, forecasting, and (automated) information processing.

Future research might expand this approach by collecting social media data for a specific EMS region that can be used to update the expected demand for future EMS. Furthermore, decision models that take such data into account for strategic and tactical planning problems, such as locating ambulances and bases, or for operational tasks such as dispatching and relocating ambulances and scheduling patient transports to, from, or between hospitals, can be developed and integrated into decision-support tools for EMS planning based on the prospective results of our work.

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