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Social Science Considerations for Integrating Aviation Technology, Emergency Services, and Human Resilience

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Introduction

The purpose of this paper is to explore social science considerations of unmanned aerial systems (UAS) in disaster management. UAS have a range of innovative applications within the field of disaster response (Erdelj, Natalizio, Chowdhury, & Akyildiz, 2017). For instance, UAS can enhance situation awareness (Terzi, Anastasiou, Kolios, Panayiotou, & Theocharides, 2019), improve access to hazardous areas (Restas, 2015), transport information and supplies (Hildmann & Kovacs, 2019), and increase effectiveness across disaster phases (Alzahrani, Oubbati, Barnawi, Atiquzzaman, & Alghazzawi, 2020; Sakurai & Murayama, 2019). However, the implementation of UAS support depends upon numerous technical considerations, from UAS energy consumption and payload to network connectivity and security (Alzahrani et al., 2020). Existing literature addresses many disaster management needs, such as accessing dangerous areas (Hildmann & Kovacs, 2019), monitoring evolving situations (Ejaz, Ahmed, Mushtaq, & Ibnkahla, 2020), and facilitating information exchange (Busnel, Caillouet, & Coudert, 2019). See Table 1 for a summary of current applications of UAS according to different phases of disaster management.

Some of the unsolved barriers of UAS in disaster management are not technical in nature; they are social and human performance issues. For instance, teamwork concerns, such as poor communication, lack of coordination, and role ambiguity, are responsible for several difficulties in disaster management (Palttala, Boano, Lund, & Vos, 2012; Power, 2018), and sociotechnical issues contribute to significant challenges for UAS operation (Waraich, Mazzuchi, Sarkani, & Rico, 2013). The overlap of UAS challenges with these human resource challenges may exacerbate one another. As a result, it is unlikely that UAS will be capable of consistently and reliably contributing to disaster management efforts until scholars bring greater attention to social and human performance issues.

Until now, the attention of UAS in disaster management has focused primarily on the technological benefits and limitations. This paper provides an alternative, but equally important, view from the social sciences with the narrow focus on the community, emergency coordinators, and responders in disaster management. Specifically, we provide analysis, recommendations, and research questions for each phase of disaster management (Phillips, Neal, & Webb, 2017) to guide the future of applied research in the growing field of UAS technology. In doing so, we address the following research question: How do we best integrate UAS with disaster management considering the complexities of both applications?

Table 1

Summary of UAS Applications Across Disaster Management Phases

Phase	Phase Goals	Current UAS Applications
Mitigation	Reducing risks[1]; increasing structural resilience[2]	Mapping terrain[6-8] Structural inspection[6-8]
Preparedness	The conduct of activities to enhance response capabilities[3]	Monitor land, rivers, critical infrastructure[6-9] Pre-disaster supply delivery[6-8] Estimate safe evacuation routes[6, 10]
Response	Conducting immediate actions to save lives, stabilize environments, protect property[4]	Establish/support communication networks[6-10] Improve situational awareness[6-7] Search, detect, and track victims/survivors[6-10] Reach inaccessible areas[6, 8, 9] Guide teams by detecting & avoiding hazards[9, 11] Big Data collection & decision support[10, 12] Real-time monitoring [6, 9] Disaster-specific response tools[6-8, 10]
Recovery	Helping communities return to normal or improved levels[5]	Aerial mapping and evaluation of affected areas[7,9,10,12] Media coverage[12] Chronicling rebuilding efforts[12] Insurance claims and risk assessment[8]

Note. [1]Haddow, Bullock, & Coppola, 2011; [2]Bruijne, Boin, & Eeten, 2010; [3]Gillespie & Streeter, 1987; [4]Phillips et al., 2017; [5]McEntire, 2015; [6]Hildmann & Kovacs, 2019; [7]Erdelj et al., 2017; [8]American Red Cross and MEASURE, 2015; [9]Alzahrani et al., 2020; [10]Restas, 2015; [11]Terzi et al., 2019; [12]Ejaz et al., 2020

Mitigation Considerations: Foundation of Technology-Assisted Teamwork and Trust

The social considerations of using technology will be relevant for all teams who intend to integrate UAS with mitigation efforts. Advances in technology require its users to conceptualize individual UAVs in the broader UAS as teammates instead of tools (Jones, Mohan, Trainer, & Carter, 2020). Processes that are already difficult to optimize in human teams (e.g., trust, motivation, and freedom from conflict) can be even more challenging when technology, such as UAS, is involved (Jones et al., 2020). Recent experimental research, for instance, has indicated that humans report feeling a range of positive and negative emotions toward the thought of operating UAVs, and that these emotions influence their anticipated trust in and use of UAVs (Jensen et al., 2020).

Because community safety can be vulnerable to critical infrastructure breakdown (Boin & McConnell, 2007), we argue that there is a delicate balance of trust versus mistrust when relying on technology to enhance the safety and resilience of critical infrastructure. For example, too *little* trust in UAS as members of the team can lead to mitigation efforts that fail to fully rely on the benefits of the technology. On the other hand, too *much* emphasis on trust in UAS teammates may lead to blindly following a UAS despite errors or to the anthropomorphizing of UAVs, leading to efforts to reduce their chances of damage—thereby compromising the safety of human teammates instead (Jones et al., 2020). While manned unmanned teams (MUM-Ts, e.g., helicopter pilots using semiautonomous UAVs during flight) and other human-technology teamwork considerations, such as the reduced ability to develop a shared sense of identity or shared knowledge structures, have been examined (Jones et al., 2020), questions remain about the ways UAS will influence teamwork in disaster mitigation (Table 2). Future research will need to identify the "sweet spot" of trust in UAS for mitigation efforts so that disaster management personnel will feel confident that UAS represent efficacious tools.

Recommendation 1: Disaster mitigation efforts must balance teamwork issues such as trust in UAS technology.

Preparation Considerations: Team Development and Training

Social science considerations become increasingly salient during the preparation and response phases because they typically require coordinated efforts of multiple personnel teams representing multiple organizations. Each team works to meet its internal organizational goals (e.g., fire fighters working toward broader fire department goals) as well as the overarching disaster management goals, which are specific to a particular disaster in question and may or may not overlap with broader organizational goals of each team. As a result, conflict may arise between activities of teams representing multiple organizations who are called to work together to prepare for disasters. Another word for this team of teams is a *multiteam system* (MTS), which is an especially useful structures for organizing teamwork in complex, dynamic, and ambiguous contexts (Shuffler & Carter, 2018). MTSs are comprised of multiple distinct teams (i.e., component teams) that work together to achieve superordinate system goals (Mathieu, Marks, & Zaccaro, 2001). For example, in a disaster preparation context, this may involve teams from multiple organizations (e.g, fire, law enforcement, non-profits) working together to evacuate citizens. However, due to their complexity and the dynamic situations in which they operate, MTSs may experience numerous challenges that hinder the achievement of overarching goals, including inadequate communication, coordination, training, and boundary spanning (i.e., mechanisms of facilitating communication and coordination across component teams) between component teams (Shuffler & Carter, 2018).

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Integrating UAS in planning requires an established team trained in UAS operations and communication for efficient flow of information from the operator(s) to the incident command. Such information flow requires effective coordination between UAS team(s) and incident command; proper planning and training are critical to eliminate barriers in each step of the operation (Rimstad, Njå, Rake, & Braut, 2014). Planning and training of response strategies are needed to effectively execute response strategies. Therefore, MTS training during preparation will facilitate MTS execution during response (Uitdewilligen & Waller, 2012). In general, a disaster MTS should be strategically designed to facilitate cross-team collaboration and communication (Shuffler & Carter, 2018). This involves the identification of each component team (e.g., fire department, police department, emergency medical services, UAS), their specific roles, and the type of training needed to ensure the full MTS is prepared to respond to disaster situations.

Integrating UAS in disaster management will require individuals and teams to learn a new set of skills. Therefore, UAS roles must be first strategically selected based on the demands of the situation and integrated into the overall disaster management MTS. Second, MTS training must occur *with* UAS to establish shared mental models of what work needs to be done, what the UAS capabilities are, and what everyone's role is throughout disaster management processes (Jones et al., 2020). Further, MTS preparedness training should incorporate all component teams within the MTS in cross-training, so each component team is aware of the various teamwork and taskwork skills and processes that occur within and between teams. If personnel are not prepared to handle the integration of UAS, disaster management organizations will not see the return on their investment (Bisbey, Traylor, & Salas, 2020).

Recommendation 2: Preparedness training curricula must involve the full disaster MTS in cross-training to operationalize UAS as a component team and build a shared identity.

Response Considerations: Communication and Coordination

Psychosocial considerations of UAS integration, such as MTS dynamics, have not been given sufficient attention in the response phase of disaster management. Preliminary work has suggested that trust established among team members before a disaster facilitates effective collaboration during response (Chang & Trainor, 2018). Indeed, much of the relevance of social science considerations to disaster response involves laying groundwork during the preparedness phase, so that response activities are well-coordinated and executed effectively. Effective coordination and communication rely on trust and a shared MTS identity (Shuffler & Carter, 2018) that must be established in training and emphasized during response activities. UAS operators should be included in all strategic decisions and meetings that occur during response. During response efforts, there should be no questions or surprises related to the limitations of UAS capabilities; uncertainty regarding the quality of information provided by UAS may make it less likely for responders to intend to use it in future disaster response activities (Nicolaou & McKnight, 2006).

Recommendation 3: Disaster response MTSs must prioritize the development of communication and coordination structures that incorporate UAS personnel in decision-making processes.

Response Considerations: Responder Health

A major consideration of the integration of UAS into disaster recovery is the performance and well-being of disaster responders. Critically, first responders are already at risk of myriad negative health effects due to the stress of the job (Guilaran, de Terte, Kaniasty, & Stephens, 2018). There are stressors that are unique to the disaster response environment, such as time

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pressure, complex decision-making, environmental hazards, fatigue, interpersonal interactions, and task novelty (Paton & Flin, 1999) that contribute to challenges among disaster response teams over time. There are also stressors unique to UAS operation, including cognitive demands and need for vigilance, ergonomic design, visual strain, and the demand of performing tasks vicariously through UAVs (Armour & Ross, 2017). Stressors similar to both environments include long hours, shift work, under-staffing, fatigue, and a highly variable workload. More research is needed to examine the impact of work environments in which these stressors interact.

Recommendation 4: Stressors unique to UAS operation in disasters need to be better understood in the context of existing effects of work stress on disaster worker performance and well-being.

Recovery Considerations: Public Trust

When a disaster occurs, dissemination of information becomes central to government, organizations, and emergency response systems (Coombs, 2010). Populations impacted by disaster also seek information so they can become oriented, make informed decisions, and regain reality (Ball-Rokeach & Jung, 2009). Yet, the majority of crisis communication research focuses on offering information that strategically protects organizations and governments (Coombs, 2010). Because population reliance on technology for recovery decisions continues to increase (Pew Research Center, 2019)—and UAS constitute one potential form of technology that provides information—future research must consider the ways that disaster-impacted populations use UAS in their recovery efforts.

While employing UAS offers effective coverage strategies, public concerns about UAS flying overhead, or the impact of public beliefs on their trust in UAS information, are just starting to be understood. These concerns include lacking regulations, safety in poor weather, endurance, noise (Watkins et al., 2020), general privacy, and concern over military and terrorist activity (Clothier, Greer, Greer, & Mehta, 2015). Aydin (2019) suggests that while UAS can be employed to effectively mitigate risk through developing crisis and disaster response procedures, the public needs to be better informed about their specific capacities that can be helpful in these situations. Otherwise, they may be resistant to accepting their help for recovery efforts.

Recommendation 5: As crisis communication affects disaster-impacted communities, populations must be able to leverage UAS as a mechanism for, and not a barrier against, recovery.

Direction for Future Research

Integrating UAS in emergencies creates human factor issues that contribute to a high rate of mishaps (Waraich et al., 2013), and disaster management suffers from communication and coordination breakdowns (Bharosa, Lee, & Janssen, 2010). It is unknown what will happen when these challenges are combined. Therefore, future research should focus on improving the integration of the UAS component team with existing disaster management MTSs. Table 2 highlights five research questions among the phases of disaster. These research questions take a unique position regarding social science and will need to be answered before UAS and disaster management harmonization can be achieved.

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Table 2

UAS-Disaster Management Integration Research Questions

Phase	Recommendations	Research Questions
Mitigation	Disaster mitigation efforts must balance teamwork issues such as trust in UAS technology.	What will effective teamwork look like for disaster mitigation teams with UAS team members?
Preparation	Preparedness training curricula must involve the full disaster MTS in cross-training to operationalize UAS as a component team and build a shared identity.	Should first responders be trained to operate UAS, or should UAS operators be trained to respond to disasters?
Response	A. Disaster response MTSs must prioritize the development of communication and coordination structures that incorporate UAS personnel in decision-making processes. B. Stressors unique to UAS operation in disasters need to be better understood in the context of existing effects of work stress on disaster worker performance and well-being.	A. What breakdowns in communication and coordination between UAS and human component teams are most likely? B. What are the predictors of fatigue and burnout among disaster response UAS operators?
Recovery	As crisis communication affects disaster-impacted communities, populations must be able to leverage UAS as a mechanism for, and not a barrier against, recovery.	What strategies of communication about UAS to the public generate the greatest trust in the application of UAS to recovery efforts?

Conclusion

The involvement of UAS in disasters will grow as technology increases capacity, becomes more efficient, and costs less. However, social science hurdles are critical to overcome to gain full potential of UAS in disaster management. Emergency managers may begin to adopt these recommendations in their training and planning goals. At the same time, researchers can explore the questions presented herein that will later enhance the practical recommendations. The implications of these considerations include the development and evaluation of best practices for training response MTSs with UAS component teams, strategies to ensure the well-being of all disaster response team members, and strategies to communicate UAS involvement with the public. The UAS and disaster management domains will be able to best work together by acknowledging these social science considerations.

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