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Muddling through troubled water: resilient performance of incident management teams during Hurricane Harvey

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Abstract

Modern communities face escalating threats from natural disasters. Thus, resilience of incident management teams (IMTs) during adverse events becomes crucial to protect lives and physical systems. However, prior studies have only partially highlighted factors related to IMT resilience. To provide a holistic understanding of resilience of the IMTs, this study conducted semi-structured interviews with 10 experienced IMT personnel during Hurricane Harvey. Thematic analysis revealed six characteristics of resilient IMTs during a hurricane event: i) establishing common operating picture, ii) adopting and adapting plans and protocols, iii) proactive, re-prioritizing, and unconventional decision-making, iv) enhancing resourcefulness and redundancy, v) learning for improved anticipation and response readiness, and vi) inter-organizational relationship to promote IMT functions. As an empirical investigation of resilience of the IMTs, the findings inform future endeavors for developing incident information technologies and strategies to harmonize pre-established plans with adaptive actions in the field, and fostering capabilities to learn from incidents.

Keywords

Resilience, emergency management, hurricane, joint cognitive system

Practitioner Summary

Resilient incident management teams establish a common operating picture; effectively adopt and adapt plans and protocols; make decisions in an unconventional and anticipatory fashion; constantly re-prioritize goals and tasks; enhance resourcefulness and redundancy; continuously learn skills for improved anticipation and response readiness; and exhibit good inter-organizational coordination and planning skills.

1. Introduction

Disasters caused by natural hazards continue to pose increasing risks to humanity. Yearly global economic losses due to natural disasters have escalated from \$14 billion in 1985 (adjusted for inflation) to over \$300 billion in 2017 (United Nations Office for Disaster Risk Reduction, 2019). In the U.S., there were 250 weather-related disasters with at least one billion dollars in damages between 1980 to 2019, among which tropical cyclones, including hurricanes were the costliest hazard accounting for 54% of total costs (National Oceanic and Atmospheric Administration, 2019). In particular, Hurricanes Harvey, Irma, and Maria, all of which occurred in 2017, resulted in a total loss of \$265 billion, equivalent to 1.4% of the annual U.S. GDP (United Nations Office for Disaster Risk Reduction, 2019).

At the onset of a large-scale disaster, incident management teams (IMTs) are assembled with the aim of responding to and recovering from adverse impacts of the incident. An IMT is an *ad hoc* multidisciplinary team with complementary expertise (e.g., firefighting, law enforcement, emergency medical service), operating in a collocated facility such as an incident command post (ICP) or emergency operations center (EOC). Depending on the size of an incident and the areas of jurisdictions, IMTs can be activated at different hierarchical levels of government (e.g., from municipal to national level) (Federal Emergency Management Agency, 2017).

IMTs have to cope with both external and internal challenges that typically arise during a disaster. External challenges to IMTs emanate from the unpredictable nature of disasters: sudden onset of emergency events, constantly and unexpectedly evolving conditions, severe disruptions to physical, social, and economic functions, and potential harms to the public and emergency responders (Perry, 2018). IMTs also face internal difficulties: limited resources (e.g., staff, supplies), inaccurate and incomplete incident information, high-stake decisions to be made under time pressure, and discrepancies between pre-established emergency management plans and their implementation (Kapucu & Garayev, 2011; Perry & Lindell, 2003).

Resilience, defined as a system's capability to adapt its functions to expected and unexpected disturbances, has emerged as a crucial concept of academic and practical inquiry to describe coping mechanisms during complex disaster management (Boin, Comfort, & Demchak, 2010; Hollnagel, Paries, Woods, & Wreathall, 2011). Research efforts for disaster resilience often pertain to a specific level of the incident management system hierarchy. First, research at a macro-level of the government hierarchy has highlighted issues associated with overarching incident management frameworks such as the National Incident Management System (NIMS) and the Incident Command System (ICS), and emphasized the scalability and adaptability of the frameworks (Bigley & Roberts, 2001; Chen, Sharman, Rao, & Upadhyaya, 2008; Harrald, 2006). Second, studies focusing on a micro-level of the hierarchy investigated individual responders' cognitive and behavioral traits such as improvisation with respect to roles, plans, tools, and facilities (Mendonça, Webb, Butts, & Brooks, 2014; Webb, 2004; Webb & Chevreau, 2006). Third, at a meso-level where a group of emergency personnel (formed as an IMT) becomes a primary unit of analysis, intra- and inter-team aspects of resilience in dealing with adverse incidents were examined in some studies. For example, collective sensemaking or common operating picture (COP), a shared understanding of ongoing situations among different organizations (Comfort, 2007), was identified as a key to maintaining resilience in the face of unexpected circumstances, not only within a team (Schraagen & van de Ven, 2011; Weick, 1993) but also across organizations (Wolbers & Boersma, 2013). Other highlighted aspects of resilience at the meso-level include coordinated decision-making within and across IMTs (Militello, Patterson, Bowman, & Wears, 2007; Smith & Dowell, 2000), role adaptation of team members and its trade-offs (Lundberg & Rankin, 2014), anticipatory and proactive actions (Furniss, Back, Blandford, Hildebrandt, & Broberg, 2011; Tveiten, Albrechtsen, Waero, & Wahl, 2012), and resourcefulness and rapidity in stabilizing disruptions (Kendra & Wachtendorf, 2003).

Despite the crucial role of the IMTs during a disaster, not much attention has been given to investigating meso-level IMTs compared to the micro- and macro-level incident management. More importantly, existing literature regarding IMTs tends to spotlight partial dimensions or enumerate related constructs associated with resilience (e.g., collective sensemaking, coordinated decision-making) in

isolation without understanding the relationship between such constructs or using a holistic systems approach to account for different layers of such a complex system.

Joint cognitive system (JCS) theory is one such approach that views resilience as one of the defining patterns of a cognitive system in which humans and technology function as a whole (Norros & Salo, 2009; Woods & Hollnagel, 2006). A JCS exhibits goal-oriented functions by planning and modifying its performance based on knowledge of itself and surrounding environments (Hollnagel & Woods, 1983)—a characterization that resembles the functioning of IMTs. While the JCS theory was applied to some complex system domains such as healthcare and process control, (Hegde et al., 2015; Inagaki, 2010; Lay, Branlat, & Woods, 2015; Thraen, Bair, Mullin, & Weir, 2012), little has been studied in the realm of incident management. Our previous work conceived a JCS model of the IMT (Son et al., 2018), reflecting the cyclic, adaptive process consisting of major cognitive phases of perceiving the situations, coordinated decision-making, adaptive control actions, and continuous feedback. The model represents the IMT's continual performance adjustment to bridge the gap between challenges rising from an incident and goals to be accomplished. Efforts to apply the JCS model of the IMT to describe a real-world incident, however, have so far been limited. From a methodological standpoint, many of the previous studies focusing on the IMT resilience (e.g., Gomes, Borges, Huber, & Carvalho, 2014; Lundberg & Rankin, 2014) were based on simulated environments (e.g., emergency exercise). To this end, the objective of this study was to address this gap by garnering practical insight of the JCS functions of an IMT—how it perceives conditions of itself and environments, adapts its decisions and actions to achieve high-level goals, and utilizes resources to realize the actions in the context of a recent disaster: Hurricane Harvey.

2. Background

2.1. Incident management teams

When demands from an incident exceed a local jurisdiction's capacity, IMTs comprising staff from multiple agencies and organizations are established to supervise and support tactical activities in the field. The primary purpose of an IMT includes handling imminent hazardous situations and providing coordinated support to incident commanders, field responders, and other organizations. Generic functions of the IMT are defined by the U.S. Federal Emergency Management Agency (FEMA) to include: collecting, analyzing, and consolidating incident information; meeting resource needs by allocating and tracking them; and coordinating plans based on current status and future goals (Federal Emergency Management Agency, 2017).

Activities of the IMTs are guided by a coordinated and iterative *incident action planning* process that results in an Incident Action Plan (IAP). The incident action planning process is aimed at ensuring that day-to-day operations are aligned with incident objectives and conducted within available resources and financial capability (Federal Emergency Management Agency, 2012). To cover various facets of such activities, an IMT is generally composed of five sections: Command, Operations, Planning, Logistics, and Finance & Administration (F&A) as shown in **Fig. 1**. The Command Section is responsible for organizing the IMT and defining incident objectives and priorities. In addition, staff supporting incident commanders are responsible for providing information to the public and media, ensuring the safety of emergency personnel, and liaising with other agencies. The Operations Section directs on-scene tactical activities (e.g., search and rescue, evacuee transportation, debris removal) to attain the incident objectives established by the incident commanders. The Planning Section manages incident information including status of situations and resources, and is responsible for steering the incident action planning process used to sustain emergency operations. The Logistics Section provides services and supports including resources (e.g., food, facilities, supplies) to incident personnel. Lastly, the F&A Section handles financial

matters such as cost, compensation, and procurement (Federal Emergency Management Agency, 2017). As shown in **Fig. 1**, each section includes several functional units, divisions, or groups that work collaboratively to accomplish the section's goals.

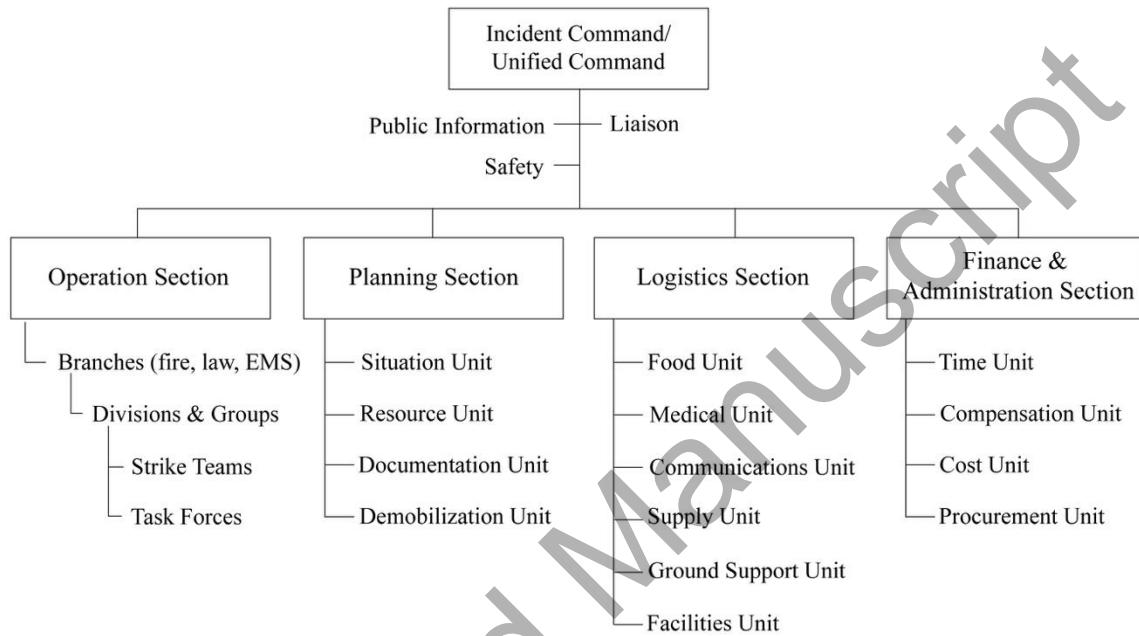


Fig. 1 An ICS-based organizational structure of an IMT (adapted from Federal Emergency Management Agency [2017])

From the onset of a large-scale emergency, IMTs are established in an ad hoc and flexible manner (Bigley & Roberts, 2001). The captain of a local emergency response organization (e.g., a fire chief) that first arrives to the scene serves as an initial Incident Commander. The initial Incident Commander then converts part of individuals in his/her organization into essential roles for the IMT such as Command Staff (e.g., Public Information Officer, Safety Officer, and Liaison Officer) and four section chiefs (i.e., Operations, Planning, Logistics, and F&A) based on their credentials and experience (Federal Emergency Management Agency, 2017). As the situation escalates, the initial Incident Commander may be replaced

with ones with higher ranks or positions, forming a unified command. Also, the structure of the IMT expands as incoming personnel from other agencies and organizations are assigned to other individual roles. As the emergency begins to subside and the activated roles are deemed no longer necessary, the individuals assigned to the roles return to their original organization (e.g., local fire or police departments).

The size of an IMT varies depending on the scope and severity of the emergency event. The minimum number of personnel for IMTs that deal with less severe incidents ranges from 12 to 15, mostly filling key staff (i.e., Command Staff) and section chiefs. For high-consequence events, a typical configuration of large IMTs involves over 40 personnel to incorporate more organizational elements (Federal Emergency Management Agency, 2019). In real-world incidents, multiple IMTs can be established with varied team sizes. During the Deepwater Horizon incident in 2010, for instance, one unified area command post and five incident command posts were set up near the Gulf Coast to coordinate on-scene oil spill response operations (National Oceanic and Atmospheric Administration, 2011). The largest IMT established at Houma, Louisiana had approximately 1,200 people at its peak, involving representatives from multiple federal, state, and local agencies (Briggs, Lundgren, Parker, & McMullin, 2013). Due to the diverse and ad hoc composition of IMTs, it is not uncommon that a majority of members of the teams have not worked together previously and may not work together in the future (Bigley & Roberts, 2001).

2.2. Hurricane Harvey

Hurricane Harvey was a Category 4 tropical storm that made landfall over south-central Texas on August 25, 2017. The estimated total cost incurred by Harvey was \$125 billion, second only to Hurricane Katrina, which caused an approximate cost of \$161 billion (National Hurricane Center, 2018). Harvey did not follow typical patterns of a hurricane, which tends to weaken or dissipate in one to two days after landfall due to the loss of heat and humidity (Sampson, Jeffries, Chu, & Neumann, 1995). Unlike a traditional hurricane, Harvey moved extremely slowly after striking inland and re-emerged as a tropical storm while

stalling over the Texas Gulf coast, all of which resulted in tremendous amounts of rainfall (National Weather Service, 2018). Until it became a tropical depression, Harvey dropped record-setting rainfalls of more than 60 inches and caused an unprecedented flooding, affecting over 100,000 residential properties. The flood damage in the Greater Houston area was extremely serious with all 22 watersheds and many creeks and bayous in that area flooded. Although this region is accustomed to dealing with floods, given that the entire region (approximately 1,800 square miles) was experiencing severe flooding, emergency responders were soon overwhelmed with the large number of residents who had to leave their homes with little preparation or warning. Further, the temporary shelters that needed to be set up in the middle of the hurricane to accommodate the increased number of people who voluntarily evacuated or got rescued, were not reliably established (The Governor's Commission to Rebuild Texas, 2018). Such anomalous impacts of Harvey were dissimilar to previous storm and flooding events in Texas such as 2015 Memorial Day Flood and 2016 Tax Day Flood, which left localized damage for several hours, and thus allowed recovery operations to start swiftly (Harris County Office of Homeland Security and Emergency Management, 2016).

No large-scale mandatory or voluntary evacuation order was issued from the city of Houston. However, citizens in some limited surrounding areas were recommended to evacuate voluntarily. In several surrounding cities and counties, however, mandatory evacuations were ordered (Sebastian et al., 2017). As a result, nearly 780,000 residents evacuated their homes and more than 42,000 were accommodated in 692 shelters temporarily. First responders from local, state, and federal agencies rescued over 122,000 people and over 5,000 pets (Texas Commission on Environmental Quality, 2018). Over time, Harvey caused 68 direct fatalities, the largest number from a tropical storm since 1919 (Zelinsky & Blake, 2018). Due to the unanticipated impacts from Harvey, recovery activities (e.g., removing debris, insuring health) were initiated and sustained while the immediate response (e.g., search and rescue) was being operative (The Governor's Commission to Rebuild Texas, 2018). In response to and recovery from Hurricane Harvey, several IMTs were formed to manage and coordinate the response and recovery efforts at the municipal, county, or state level.

3. Method

3.1. Research sites

Six IMTs at state, county, or municipal levels in Texas that served a primary role during Hurricane Harvey were chosen as the sites for the current research (**Table 1**). The jurisdictions covered by the IMTs experienced high emergency response demands that resulted from Harvey. The size of the IMTs varied, ranging from about 10 to over 700 members when fully utilized. City-level IMTs had only essential roles such as the Incident Commander and Command Staff with multiple roles being covered by the same personnel. County-level IMTs fully incorporated the ICS structure as they involved representatives from individual municipalities, state agencies, and non-profit organizations (e.g., Red Cross). IMTs at the state-level covered specialized areas of operations (e.g., search and rescue, mass care and human services) across the state, and thus activated the largest number of personnel. While most of the IMTs' capacity was utilized during Hurricane Harvey, such large IMTs generally deal with other types of public safety events, sometimes in parallel, such as large-scale fire and explosion, mass shooting, and incidents during major sports (e.g., Super Bowl, World Series).

Table 1. Research sites involved in this study

Site No.	IMT level	Approximate No. of staff if activated	Primary emergency functions
S01	County	100	All-purpose
S02	State	720	Search and rescue
S03	State	500	Mass care and human services
S04	County	50	All-purpose
S05	City	15	All-purpose
S06	City	10	All-purpose

3.2. Data collection

In order to elicit a comprehensive understanding of resilient performance of the IMTs, semi-structured interviews were conducted with 10 government emergency personnel (nine males and one female) who

were deployed to the IMTs during Harvey. The average age of the interviewees was 51.6 years ($SD=9.5$, $MIN=35$, $MAX=63$), and the average overall length of their career in emergency services was 20.8 years ($SD=6.9$, $MIN=13$, $MAX=32$). Interviews took place in the interviewee's office or their preferred location between February and July of 2018. No one refused to participate or dropped out during the interview. To account for multifaceted aspects of the IMTs, the interviewees were recruited from different organizations and areas of specialization by utilizing purposive and snowballing sampling strategies (Creswell & Poth, 2017), based on the initial email contact by a collaborator (JBM) who was a subject matter expert in the emergency management field. Criteria used to choose an interviewee were: i) whether the person worked as an incident commander or key staff at IMTs, not as a field responder, and ii) whether the person was deployed in immediate response to Hurricane Harvey, not in the long-term recovery phase. The interviewees' areas of expertise based on their past experience and roles during Harvey are presented in **Table 2**. Interviewers had no previous familiarity with the participants and participants were not familiar with the specific goals of the research project.

Table 2. Interviewees' areas of expertise

Interviewee No.	Site No.	Command	Operations	Planning	Logistics	F&A
H01	S01	✓	✓	✓	✓	✓
H02	S02		✓	✓		
H03	S01				✓	✓
H04	S01		✓	✓		
H05	S02	✓	✓			
H06	S03		✓	✓	✓	
H07	S04	✓	✓			
H08	S04	✓		✓	✓	✓
H09	S05	✓		✓		
H10	S06	✓		✓	✓	✓

Two faculty members at a tier-1 research university (FS and SCP) and a postdoctoral fellow (TN) knowledgeable in the incident management domain and qualitative study methods served as the primary interviewers during each interview and were supported by two Ph.D. students (CS and JM) for note-

taking, audio-recoding, and probing questions when further clarification was needed. Interviewers discussed saturation during post-interview briefings.

The interviews were guided by a set of questions concerning the constituent aspects of the JCS framework of resilience. **Table 3** presents major aspects of the JCS framework and some examples of the associated questions used in the interviews. In some cases, new questions were asked based on emergent findings as the conversation progressed.

Table 3. Questions used in semi-structured interviews

Aspect	Related questions
Personal and organizational context	<ul style="list-style-type: none">• What was your role in response to Harvey?• Can you describe organizational structure and composition of the IMT you worked at?
Challenges and successes during the incident	<ul style="list-style-type: none">• What were the major challenges of Harvey that you had not expected or experienced from previous incidents?• How did you overcome such challenges?
Goals of IMTs	<ul style="list-style-type: none">• What were the major goals that you tried to achieve during Harvey and how did you accomplish those goals?
Functions of IMTs	<ul style="list-style-type: none">• How did you make sense of evolving situations during Harvey?• What key decisions did you make to solve problems in Harvey and how?• Can you tell us about procedures, plans, or guidelines you used in response to Harvey?• How did you utilize resources to perform response actions?

Interviews took on average 1.2 hours. After acquiring informed consent, the interviewer first asked for a brief professional career history and roles that the interviewee carried out during Harvey. Based on the interviewee's initial answer, the interviewer asked the next questions deemed relevant. The audio-recordings were first transcribed by an artificial intelligence-based transcription service (Temi, 2018), and then manually corrected by the first author (CS). The study followed a research protocol approved by the Institutional Review Board.

3.3. Data analysis

A thematic analysis method (Braun & Clarke, 2006) was used to identify patterns or themes relevant to resilience of the IMTs during Harvey. While some *a priori* themes were reflected on the interview

questions, coding of the data was conducted in different inductive and deductive phases (Creswell & Poth, 2017). Initial coding was done by the first author (CS) focusing on what the data evinced, being mindful of minimizing theoretical preconceptions. The initial inductive codes were then presented to other authors and the codes were revised, discarded, and regrouped into themes based on existing theories of resilience via multiple discussions. Also, the codes and the themes were continuously adjusted based on the constant comparative method with which data of a similar concept were grouped together during the course of analysis (Corbin & Strauss, 2015). Several themes emerged deductively that represent core aspects of resilience of IMTs. In order to facilitate the analytic efforts, MAXQDA® (Version 18.0.7; VERBI Software, 2018), qualitative data analysis software, was used.

4. Results

The identified themes and subthemes are presented in **Table 4**. First, analysis of the data identified general themes regarding challenges the IMTs encountered and goals the IMTs strove to achieve during Harvey. Second, in the course of filling the gap between the challenges and the goals, the IMTs were found to exhibit six resilient behaviors: i) establishing common operating picture (COP), ii) adopting and adapting plans and protocols, iii) proactive, re-prioritizing, and unconventional decision-making, iv) enhancing resourcefulness and redundancy, v) learning for improved anticipation and resource preparedness, and vi) the inter-organizational relationship, which emerged as an important factor that facilitated the resilience functions of the IMTs as multiple organizations and other agencies coordinated and collaborated during Harvey.

Table 4. High-level categories and themes of resilience of the IMTs

General Themes	Subthemes
Challenges during the incident	Unexpected patterns of Harvey Massive demands for response activities
Incident response goals	Life safety Incident stabilization
Resilience Themes	Subthemes
Establishing common operating picture (COP)	COP as an integrated snapshot of evolving situations COP as distributed awareness among IMTs COP established via joint information platform COP as a basis for decision-making in IMTs Trustworthiness of inputs to COP
Adopting and adapting plans and protocols	Adapting to ad hoc plans under changing situations Flexibility of operating protocols Advantages and disadvantages of following plans and protocols
Proactive, re-prioritizing, and unconventional decision-making	Proactive decisions Dynamic re-prioritizing decisions Unconventional decisions Trade-off of decision-making
Enhancing resourcefulness and redundancy	Strengthening resourcefulness Increasing technical redundancy
Learning for improved anticipation and resource preparedness	Learning for informed anticipation Lessons reflected on resource preparedness
Inter-organizational relationship to promote IMT functions	Facilitating COP of IMTs Promoting pre-incident planning among IMTs Coordinating decision-making between IMTs Enabling resourcefulness of IMTs

4.1. Challenges and goals of IMTs during Hurricane Harvey

4.1.1. Unexpected impact of Harvey and massive response demands

Unlike other tropical storms that affected the U.S., response to Harvey faced unique challenges. Interviewees (9/10) indicated that Harvey had an unusual movement pattern as hurricanes affecting south-central Texas typically make landfall and dissipate or head northward, but Harvey reconstituted while staying along the Gulf Coast, and as a result it dropped an unprecedented amount of rainfall. Due to the unusually severe consequences, the IMTs confronted massive demands for response activities such as evacuation, search and rescue, and mutual aids for additional resources.

“[A similar] one that happened was the 9-1-1. It got to the point where calls were going on hold and then it went out over the radio waves that 9-1-1 crashed and everybody was panicking with what we did.” (H03)

“[Search and rescue demands were so high that an adjacent city] actually asked for help. [The adjacent city] never wanted help from us. We have literally been on the outskirts of [the adjacent city] multiple times for flooding and there’s been no request for assistance from our resources.” (H05)

4.1.2. Goals in the incident response

In the face of unanticipated challenges from Harvey, IMTs set goals that guided their operational and tactical activities. Major goals of IMTs that the majority of interviewees (8/10) stated include *LIPS*, or Life safety, Incident stabilization, Property protection, and Societal restoration. However, not all the goals of the IMTs carried the same weight. Among others, the highest priority was given to life safety such as preventing loss of life and addressing immediate threats to the safety of the public and emergency responders. During Harvey, evacuating vulnerable populations such as residents in nursing homes and treating dialysis patients were notable examples of context-specific objectives. The second priority was placed on incident stabilization aimed at keeping the incident from expanding and getting affected populations back into a new normal state of living, albeit in a diminished state. Additionally, the interviewees emphasized the time-sensitivity of attaining such goals.

“Our priority is LIPS, right? Life safety, incident stabilization, property protection, and societal restoration. So, ‘L’ is first. ‘L’ is always first. And that’s how we drive our priorities. [...] Again, going back to the life safety, time is a key.” (H07)

“In emergency management, our goal is to get back to a new state of normal. How do I get on my community back to where it was as a whole?” (H01)

4.2. Establishing common operating picture (COP)

Interviewees commonly claimed that COP was the *sine qua non* in sustaining incident management, serving as the basis for decision making and other several critical purposes in the IMTs. We identified three major interpretations of COP: an integrated understanding of changing situations; distributed awareness depending on IMT's scope of work; and a joint information platform.

4.2.1. COP as an integrated snapshot of evolving situations

Most participants (8/10) stressed the importance of establishing and updating COP since situations surrounding Harvey changed relentlessly and a multitude of emergency operations occurred simultaneously. As a *common* picture of the evolving and complex situations, the COP served as an integrated snapshot of multiple facets of incident management such as on-scene tactical activities, weather forecast, status of infrastructure and allocated resources. In particular, the interviewees emphasized that the COP should be a real-time reflection of the evolving situation rather than an information repository.

"So, the way I see common operating picture is not really stating like information warehouse, but I guess it is constantly updated [or] should be updated. And how do you manage that? How do you deal with discontinuity of this common operating picture? That's the thing. It's a different snapshot every two minutes," (H10)

"All of the partners in the room enter information into our portal, which goes to the situation unit. [...] Here's what we have. Here's what we're doing. Here's what we know. What we call a SWEAT report, which is Security, Water, Energy, Accessibility, Telecommunications. So, that gives me a snapshot. [...] Now I can have a snapshot of a jurisdiction and know now who's in trouble." (H01)

4.2.2. COP as distributed awareness among IMTs

In contrast to the commonality of the COP, some (5/10) expressed an opposing view that the COP was distributed and diverged among the IMTs depending on jurisdictional boundaries or organizational responsibilities. In other words, the COP meant an *uncommon* operating picture that spotlighted an individual IMT's scope of interest.

"There's no such thing as a common operating picture. They're uncommon operate pictures, right? So, I have my own common operating picture that I use for my team. Somebody else has their own common operating picture. Those two are not common!" (H05)

"[EMS] also wants to know the common operating picture of the hospitals, which are working with the EMS so that they know where to take patients. Military doesn't care. My county attorney doesn't care. Right? [...] They're looking at that snapshot on that dashboard that's important to them." (H01)

4.2.3. COP as a joint information platform

Given the concept of COP as a shared but distributed awareness of changing situations, all the interviewees treated joint information platforms as the COP itself. The IMTs utilized different platforms to incorporate inputs from multiple sources into the COP via the IAPs or computer-aided applications (e.g., WebEOC¹, GeoSuite²). However, some of the interviewees commented on limitations of the computerized application interface designs which often suffer from low usability and traceability.

"That incident action plan is your common operating picture. [...] it actually had an assignment list where everybody was, the communications plan or a medical plan, hazmat plan, [...], the safety

¹ Internet-based software used to support the information and resource management among multiple agencies.

² A web-based system that enables real-time collection and sharing of incident response using geospatial interface.

message, our air operations summary, what air frames do we have out there? Who do they belong to? Where were they stationed?" (H02)

"[A computerized application] is intended to be a common operating picture here. If ten of us were having the same conversation via text messaging and I needed you to recall some bit of data, it would require you to physically read through each one of those until you find the information. That's what [the application] is. And what we're trying to transition to is a picture worth a thousand words." (H04)

4.2.4. COP serving as a basis for decision-making in IMTs

While the COP was largely responsible for the IMT's common understanding of ongoing situations, half of the interviewees (5/10) also implied that the COP informed decisions for operational and tactical actions made in the IMTs. Specifically, the COP helped the IMTs make decisions regarding evacuation route, location of shelters, and allocation of necessary resources.

"Here's the downstream application. We're going to flood 2,000 homes. It's going to happen within the next two hours. Alright. Call [a neighboring city]. Talk to them. 'Hey guys, flood control says we've got a huge problem. You want to keep them in place? Do you want to evacuate anybody?', 'Got any functional and access needs of population that might be in that area?'" (H01)

4.2.5. Trustworthiness of inputs to COP

Many (8/10) questioned the trustworthiness of information put into the COP. According to the participants, information to establish the COP often comes from multiple sources in parallel, and during Harvey, those inputs were often based on rumors (e.g., breached levee, dead bodies), inflated through

social media, or on suppositions not validated against ground truth via field responders or trusted informants from federal agencies and private partners.

“Nothing you hear is right. Everything that comes in has got a little bit of a thread on it and you got to figure out what ‘right’ looks like.” (H05)

“I would have to bed more people. I have to feed over more people and then it wouldn’t happen. In three hours, 150 people would show up but you get like ten. Right? And I mean that happened pretty consistently.” (H06)

4.3. Adopting and adapting plans and protocols

4.3.1. Adapting to ad hoc plans under changing situations

Due to volatile conditions surrounding Harvey, incident objectives had to be updated accordingly. This dynamic shift in demands required the IMTs to not only *adopt* pre-established emergency operations plans and protocols but also *adapt* the plans to the new situation. In other words, according to the interviewees, the IMTs espoused a formal incident action planning process put in place to promote continuous adjustment of high-level objectives and associated strategies. Nonetheless, the IMTs claimed being successful in adapting to *ad hoc* tactical plans when situations at hand were inimical to the execution of the original plans. One noteworthy example was a change in one of the IMTs’ food distribution plan that shifted points of distribution from fixed locations to first responders on the move, accounting for civilians’ limited mobility during Harvey.

“I made a decision that we weren’t going to do that [referring to the distribution plan]. We had to change it after the event. We changed it to the first contact. [...] So, we called the first contact and I gave food and water to every first responder. [...] I wanted them to be able to hand them [citizens]

food and water. So, we created a new process within the point of distribution plan that we had not done before, but we adapted.” (H01)

4.3.2. Flexibility of operating protocols

Recognizing the needs for adaptation due to unpredictable environments, some (4/10) highlighted the flexibility of the incident management protocols to be a convenient factor. For example, the flexible nature of the Incident Command System (ICS) and National Incident Management System (NIMS) was praised for being adaptable to different hazards and sizes of an incident.

“The best part about the ICS is [the ease of] changing plans ... [are there] two people at that desk or is there 12 today? It doesn't matter. It's expandable and contractible based on the incident.” (H01)

4.3.3. Advantages and disadvantages of following plans and protocols

Most of the interviewees (9/10) pointed out tension between complying with and departing from plans and protocols. On one hand, advantages of following plans and protocols include synchronizing operational tempo, maintaining unified knowledge among the IMT personnel, and minimizing surprising actions. On the other hand, the interviewees commented that they had to depart from the plans or protocols to deal with imminent threats, deficient resources, and situations in the field that did not correspond to the plans.

“They follow the normal planning ‘P’. We go through the [same] cycle each day. We have our meetings. We go through the briefings in all the next operational periods. They were 12-hour operational periods. They followed it exactly. They would write it out so everybody knew that they were on the same page.” (H03)

"I can plan ahead for the next day, but I am flooded. I can't get any more resources. So, what's the point of having 215 [an ICS form for planning resources]? I mean, what's the point of doing some of that planning if you can't get those resources to fulfill that plan." (H07)

4.4. Proactive, re-prioritizing, and unconventional decision-making

4.4.1. Proactive decisions

According to the interviewees, the tracking of future impacts of a hurricane is relatively easier than other abrupt disasters such as earthquakes. Based on previous operations for tropical storms and hurricanes, the IMTs were able to make proactive decisions before Harvey caused actual impacts. One proactive decision commonly made in the IMTs was to pre-position necessary resources to anticipated areas even when such actions were not requested.

"I'm sitting here looking and going, 'Okay. We're getting all this rain over here. I need to start. I know you have fire chief. You haven't asked for resources.' Let me send you resources because I know what the water's about to do. So, let me pre-position them before I can't get them to you." (H05)

4.4.2. Dynamic re-prioritizing decisions

In a broad sense, impacts from Harvey (e.g., its path, wind, and precipitation) were forecasted by responsible agencies in the U.S. (e.g., National Weather Service). Nevertheless, unpredicted situations that arose from local levels required the IMTs to allocate limited resources to those impacted with the highest priority. This meant making difficult calls to delay responses to lower priority entities. Such dynamic re-prioritization decisions were especially evident in search and rescue operations where limited resources had to be allocated to those under more critical states such as nursing home residents and patients with life-threatening conditions.

“We got somebody with heart conditions. So that's where you really had to make that hard decision and as painful as it was...we had to prioritize who has high, medium and low risk. And those are the ones having to prioritize.” (H09)

4.4.3. Unconventional decisions

In cases where pre-established operating plans were rendered inoperable due to overwhelming demands, innovative decisions were attempted in the IMTs. Although response activities were largely driven by the incident action planning process, the IMTs took advantage of unconventional decisions. The one that many interviewees (7/10) highlighted was a decision to allow civilians including Cajun Navy to engage in search and rescue using their own assets (e.g., boats, high-water vehicles). Other unconventional practices identified from our study include using food trucks to feed members of the IMTs, conducting aerial evacuation from an isolated island to another big city, and launching civilians’ boats at flooded highways.

“I think Harvey took thinking outside the box to a totally new level [...] [A jurisdiction’s chief official] made the decision to basically say, ‘We can’t handle this. We need to ask for citizens to bring in their boats.’ I think that was probably the number one decision that saved more lives than anything else, to speak openly. It’s not in the book. It’s not in the ICS program. We need to do something. And it worked out. There were no known injuries or fatalities [of citizens rescuing others], which is unbelievable.” (H03)

“We had sought to do air evacuation where we can push people to Galveston from the shelters that could then be flown to Dallas. That was the first time that’s ever been done because they couldn’t go north by bus.” (H08)

4.4.4. Trade-offs in decision-making

Notwithstanding the benefits of re-prioritized and unconventional decisions, decisions that forgo one value over others entail trade-offs. For instance, by involving civil resources in the government-led search and rescue activities, the IMTs had to lower the rigor of command and control and sought to mediate the coordination among civilian helpers. One interview also mentioned that civilians' involvement in the search and rescue, in fact, resulted in duplicate efforts of the IMT personnel and field responders.

"It wasn't command and control. [...] Inevitably, those civilians were going to go out and try to help their neighbors. [...] We're trying to manage that, just coordinate it, right? Very loosely." (H04)

4.5. Enhancing resourcefulness and redundancy

4.5.1. Strengthening resourcefulness

Given the quantity and quality of resources not commensurate with demands brought by Harvey, the IMTs had to strengthen their resourcefulness, an ability to promptly devise means for sustaining their operations. A common resourceful action that the IMTs practiced was mobilizing resources in an unusual fashion. For example, the IMTs designated local schools as a shelter, utilized web-based documentation application (e.g., Google Docs, SharePoint) for information sharing, used a commercial real estate website (e.g., Zillow) for locating those who needed be rescued, and took advantages of local restaurants (e.g., Waffle House) and recreational merchandise retailers (e.g., Bass Pro Shop) to meet the needs of feeding and rescue activities. Such resourceful activities were epitomized in the establishment of the largest shelter at a football stadium in a short amount of time.

“We added the ISD [independent school district] onto [the planning process] because the schools ended up being a big part of the sheltering by itself. [...] It became an impromptu shelter or a refuge.”
(H07)

“We're just getting the whole thing set up and it was unbelievable to see the logistics. When I got down there, there were already tractor trailers coming in with water and food, and COTS [commercial-off-the-shelf products]. And there were literally a thousand youths from this organization setting stuff up. [...] I've never seen it. It was unbelievable at 10:00 that evening, they took their first person, then it was 18 hours after the request went out and we had a full-blown shelter.” (H03)

4.5.2. Increasing technical redundancy

In addition to the resourceful actions, some interviewees (6/10) stressed technical redundancy when a primary resource or an operating system had malfunctioned and thus needed to be substituted readily. The interviewees also expressed their doubt on the reliability of modern technologies (e.g., telecommunication, computer-aided software) and emphasized the importance of sustaining operational activities under deteriorated conditions. Indeed, one IMT during Harvey leaned on sticky notes to maintain resource status that was usually kept via standard forms (e.g., ICS 219 T-Card). The redundancy among technical resources were also found in the use of telecommunication methods such as text message, cell phone call, email, and radio since each provided distinct advantages and disadvantages. Interviewees especially preferred emails and text messages to convey much richer information (e.g., photos) to multiple recipients in a prompt manner.

“We are as redundant as possible. But what happens if we're the target of a bomb and we can't operate in this facility. [...] Do I have electricity? Do I have the resources in order to boot it all up?

“Maybe, maybe not. But if we don’t, can you do your job with a chief tablet and pencil because that’s what you have to be able to fall back to? If we don’t train to that level, we will fail.” (H01)

4.6. Learning for improved anticipation and response readiness

A majority of interviewees (7/10) emphasized that lessons learned from previous incidents played a key role in increasing the knowledge base for anticipatory actions and resource preparedness pertaining to the IMTs’ response to Harvey. The interviewees also implied the importance of learning lessons not only from rarely occurring catastrophic disasters, but also recurrent local incidents.

4.6.1. Learning for improved anticipation

The IMTs took advantage of past experience and lessons learned in order to recognize their vulnerabilities and to more accurately anticipate ensuing situations. For example, the IMTs were able to predict which areas would be likely to be flooded and what types of resources (e.g., rescue boats) would be needed based on their knowledge regarding geography around the area and historical flooding patterns. Furthermore, one interviewee stated that such lessons were utilized in choosing the location of the IMT facility such that it had a minimal impact from floods.

“It’s easy to say when this part floods, I know how many resources I need. [...] When the Sabine river floods, we know exactly what it’s gonna do. You gotta get a boat load of people out there quickly because you’re going to need that many resources out there. So as soon as we saw what the storm started to do, we realized you’re going to get cut off.” (H05)

4.6.2. Lessons reflected on resource preparedness

Another area in which the IMTs utilized lessons from past incidents was their resource preparedness and technological capabilities. For example, the quantity of water rescue assets was increased and a county-

wide resource management system was initiated in the aftermath of two consecutive large-scale flooding events in southeastern Texas. Also, lessons used to enhance the resource readiness in the IMTs were not only derived from local incidents but also other incidents. As an example, the IMTs took benefits from mobile cell towers on wheels during Harvey based on lessons from cellular network disruptions during Hurricane Sandy in 2012.

“So, what we did following the 2015 and 2016 floods was we actually created a database of all of the county-based water rescue assets. [...] On Wednesday [a week before landfall], we started making phone calls. ‘Is the piece of equipment operational and is it staffed and will you respond if we need it? Okay. So, if a department over here needed more boats, could I reach over to this department here to go there?’ So, we had outlined all that data out.” (H04)

“So, we had two buses brought in. Two mobile networks were brought in. Both parked trucks right next to us. So, this time we took care of that. When I was in Sandy, [it] was a different ball of wax. We couldn’t text. We couldn’t use radios. We had to do face-to-face because the tower has originally got knocked out by the storm.” (H06)

4.7. Inter-organizational relationship to promote IMT functions

Most of the interviewees (8/10) indicated the importance of the inter-organizational relationship among the IMTs since it supported different aspects of resilient functions of the IMTs. As Harvey imposed demands that exceeded one jurisdiction’s response capacity, coordination among multiple agencies including the IMTs was found to be essential to attaining their goals.

“[Our jurisdiction] is unique because we have 34 cities, 57 fire departments, over 125 law enforcement partners that have jurisdictional authority within [the jurisdiction]. So, we try to build those relationships, build those partnerships in order to meet the mission of getting to a new state of

normal, based on the risk and the threat that has occurred as quickly and effectively as possible.”

(H01)

4.7.1. Facilitating COP of IMTs

The relationship between IMTs and other organizations was considered a basis for the establishment of accurate and updated COP because it depended upon external partners as well as internal sources. In particular, interviewees (5/10) claimed the important role the Liaison Officer plays in the inter-agency communication.

“Once I had a liaison officer in [a jurisdiction’s IMT], I started getting good information from [the jurisdiction]. But remember we don’t work on a direct dial. [...] I just happened to get a call from the emergency manager for [another jurisdiction] that got my number from probably one of my guys.”

(H05)

4.7.2. Promoting pre-incident planning among IMTs

The partnership between neighboring jurisdictions was important in pre-incident planning. Some interviewees (3/10) stressed the benefits of collaborative planning before Harvey such as reduced stress and opportunities to initiate mutual agreement and to discuss strategic matters in a preemptive manner. Especially, one of the interviewees addressed that a face-to-face visit to a nursing home helped build the relationship and establish the emergency plans for the nursing home, a high-priority facility during Harvey.

“I’ve been having to build all those relationships, to get people in the room to have those conversations, and to work on the plans so that we can go forward and not have to make those

decisions during periods of stress instead of being able to do them during a blue sky day when there's no stress or less stress. And the strategic stuff that we can do ahead of time." (H10)

4.7.3. Coordinating decision-making between IMTs

The relationship between the IMTs played a crucial role in making decisions that affected neighboring jurisdictions during Harvey. Decisions regarding the issuance of ground and aerial evacuation, among others, were predicated upon the pre-established relationship among response agencies. As seen in the establishment of COP, the Liaison Officer facilitated decision-making that took place between the IMTs in terms of reallocation of ambulances from one jurisdiction to another, for instance.

"We have a handshake agreement. [...] Typically, if we're going to call for evacuation, we need to let them [other adjacent jurisdictions] know and they'll give us time to get the county clear before they call for an evacuation because we're closest to the dangers." (H10)

"We had one liaison that worked for a bunch of weeks. She was really good. She's been out there a lot so she was the one that made decisions or suggested the ambulance trade-off. [...] They speak for us because they know our capabilities." (H06)

4.7.4. Enabling resourcefulness of IMTs

We also found that multi-agency coordination was a critical factor to boost resourcefulness of the IMTs. Some interviewees (6/10) pointed out formal mutual aid systems such as FEMA Emergency Management Assistant Compact (EMAC) and Interstate Emergency Response Support Plan (IERSPP) designed to legalize state-to-state assistance. Nevertheless, the IMTs that responded to Harvey also counted upon relationships with local and community partners in satisfying the needs for resources (e.g., volunteers, food, water, and fuel).

“During Hurricane Harvey, we made sure that there were no boundaries. You know, jurisdiction lines pretty much got washed away. Community effort is a lesson learned. The FEMA model calls to have to be community-oriented. And it's very true because we were not able to get the State resources.” (H09)

“The kind of frugal innovation comes in whether it be human resources or food resources or water resources, relationships are very important. Our logistics section chief has the keys to pretty much three of the supermarkets here. So, we would never have an issue.” (H09)

5. Discussion

5.1. Resilient behaviors of IMTs during Harvey

The main purpose of this study was to draw a holistic picture of resilience of IMTs during a catastrophic incident. As illustrated in **Fig. 2**, the findings presented in this paper show what challenges the IMTs faced, what goals they sought to accomplish and how the IMTs muddled through unprecedented situations by exerting essential functions of a JCS: establishing and updating COP, balancing between adopting and adapting plans and protocols, making proactive, re-prioritizing, and unconventional decisions to remain functional, fostering resourcefulness and redundancy with limited resources, and learning for anticipatory knowledge and improving resource readiness. Moreover, our study suggests that the relationship between IMTs and other organizations promoted some aspects of the resilient functions.

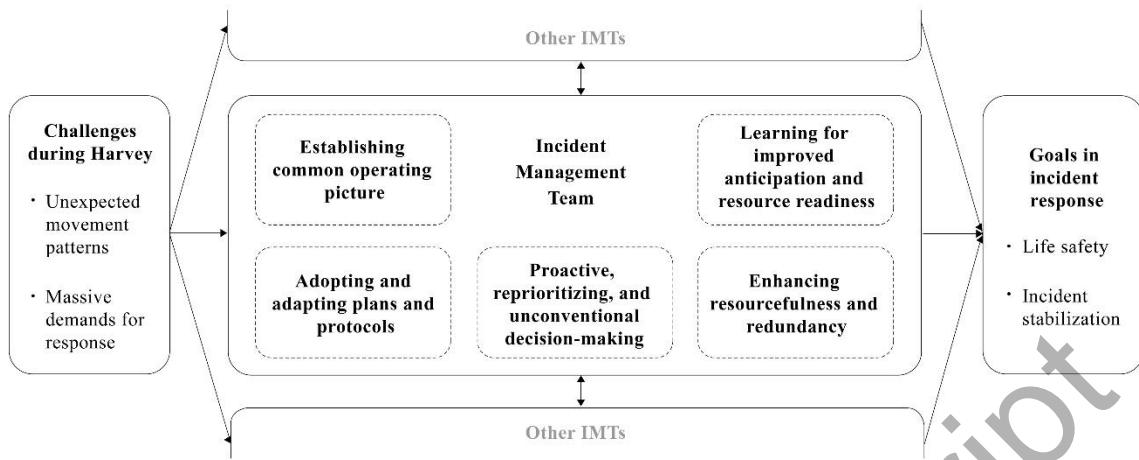


Fig. 2 A thematic map of resilient IMTs during a disaster: To overcome the challenges imposed by Harvey and achieve the goals in incident response, the characteristics of a resilient IMT were found necessary.

First, our findings support three major characteristics of COP in the context of incident management:

i) an integrated operating picture, ii) a distributed awareness, and iii) a joint information platform. In line with a general meaning of the term, *common*, the COP for the IMTs during Harvey meant a global, consolidated awareness of the ongoing operations (McMaster & Baber, 2012). From shared mental model theory (Cannon-Bowers, Salas, & Converse, 1993), the COP of the IMTs can be regarded as a team's shared understanding of what response activities to carry out, how team members function as a team, and what information (e.g., resource status) to collect and disseminate. As a complementary concept, the COP also existed as multiple divergent, thus *uncommon*, representations depending on the responsible areas of individual IMTs (Luokkala & Virrantaus, 2014). The concept of uncommon COP supports the idea of transactive memory system (Lewis, 2003) in that the overall picture of an emergency operation can be better established through communication between members or IMTs with specialized and credible knowledge of their respective roles and responsibilities. To facilitate *shared yet distributed* awareness of the IMT operations, the COP served as a joint platform or a trading zone where incident information is exchanged (Baber, Stanton, Atkinson, McMaster, & Houghton, 2013; Comfort, 2007; Wolbers & Boersma, 2013). However, recurrent challenges in integrating different components of the information and problems associated with information integration technologies (Militello et al., 2007; Scholl, Ballard,

Carnes, Herman, & Parker, 2017) also emerged during Harvey, which warrant future endeavors to improve the design of COP applications.

Second, an attitude towards balancing between adopting formal plans and adapting from them appears to be a key to remaining functional under unpredictable conditions during a disaster. While acknowledging the advantages of a formal incident action planning process such as the Incident Command System, our findings on the benefits of adjusting the plans support viewing plans and protocols as resources for situated actions rather than as prescriptive, ‘one-and-done’ rules (Wears & Hunte, 2017). In this regard, future studies should focus on harmonizing two seemingly conflicting perspectives (e.g., developing directive but flexible emergency management plans). In a similar sense, our study captured the advantages of proactive and unconventional decisions that helped the IMTs better respond to the overwhelming challenges. Particularly, such decisions exemplify transformative adaptations commonly seen in extreme conditions (Son, Sasangohar, Rao, Larsen, & Neville, 2019). Nonetheless, ways to address the trade-offs resulting from the unconventional decisions in incident management should be further examined in future research.

Third, the current study proposes that resilience of the IMTs also depends on how the IMT becomes resourceful and the technical systems redundant. As highlighted in other studies (Kendra & Wachtendorf, 2003; Zobel, 2011), the IMT’s attempts to promptly devise resources and operate under substitutive, degraded environments during Harvey are noteworthy. Considering that such endeavors were impromptu rather than planned, a question to be answered is how to incorporate ideas from the improvised actions (e.g., the use of web-based information sharing applications) during Harvey into pre-incident planning and existing emergency operation protocols.

Fourth, our study recognizes the importance of learning from past incidents in promoting different resilient functions (Hollnagel, 2011). We found that learning facilitates other aspects of the IMTs’ behaviors, playing an especially crucial role in the anticipation of adverse event scenarios and in improving resource readiness. It is noteworthy that the lessons that benefitted the IMTs were learned from not only large-scale crises but also small- to mid-scale local incidents, the latter being more frequent than

the former. Such finding indicates that resilient performance of the IMTs can be nurtured via continuous cycles of learning from both few-and-far-between catastrophes and routine successful emergency operations. In that vein, to our knowledge, this paper is the first attempt at documenting the resilient behavior exhibited by IMTs during the response to a major disaster and can inform proactive anticipatory efforts to mitigate the impact of future incidents.

Lastly, our findings indicate that resilience in the IMTs is exhibited at both the macro- and micro-level of the incident management system as well as coordinated efforts between the two. In relation to the macro-level (e.g., federal), the flexibility and adaptability of incident management policies such as NIMS and ICS (Bigley & Roberts, 2001; Harrald, 2006) has been substantiated through the very users (e.g., emergency managers)' recent implementation during Harvey. With respect to the micro-level (e.g., on-scene activities), team efforts to adapt the use of incident resources further suggest that the adaptive and improvisational behaviors of individual responders (Mendonça et al., 2014; Webb & Chevreau, 2006) could be extended to a team setting.

5.2. Contextual meaning of JCS in the IMT environment

In addition to investigating resilience of an IMT from a holistic viewpoint, this study elicits anecdotal insights for better understanding of the JCS model of the IMT in a real-world disaster context. In line with the cognitive systems theory (Hollnagel & Woods, 1983, 2005), this paper describes how the IMT plans and changes its actions to reach goals based on a current understanding of surrounding situations, supporting the proposition that the IMT acts as a JCS (Son et al., 2018). More importantly, basic elements of the JCS model (i.e., collective perception of information, coordinated decision-making, taking adaptive actions) were further embodied into context-specific instances applicable to a hurricane event. Our study suggests that maintaining the COP is considered as the IMT's effortful action as a JCS to have a shared understanding of changing situations. Based on the COP, the IMT's operational and tactical decisions were made in an ad hoc manner in addition to a formal incident action planning process. This paper highlights the impromptu decisions such as involving citizens in search and rescue operations. This paper

also presents multiple examples of the IMT's adaptive actions in implementing decisions made in the midst of Harvey. For instance, the IMTs utilized commercial facilities and services, and civilian resources in order to support search and rescue, and sheltering operations.

The essential functions of the IMTs during Harvey identified in our study are in agreement with fundamental abilities of the JCS (i.e., monitor, anticipate, respond, and learn) (Hollnagel, 2011). For instance, maintaining the COP in the IMT may be equated with the JCS's ability to monitor. Furthermore, several themes pertaining to the IMT's anticipatory behavior (e.g., pre-positioning resources), adaptive and resourceful actions, and an attitude of learning to improve its response capacity may resemble the JCS's abilities to anticipate, respond, and learn. In a similar sense, the characteristics of resilient IMTs during Harvey are in line with adaptive team performance processes (Burke, Stagl, Salas, Pierce, & Kendall, 2006; Zajac, Gregory, Bedwell, Kramer, & Salas, 2014), in that the IMTs adjusted their operations by assessing evolving situations and operational status (i.e., COP), formulating and executing incident action plans, and reflecting lessons from past storm and flood events on their current capabilities. While it is worthwhile to investigate interdependent relationships between resilience functions and between team adaptation processes, such investigation exceeds the scope of the current study. Therefore, future endeavors to examine how the essential functions and processes of the IMTs influence each other are greatly recommended. Furthermore, as indicated in the team adaptation literature (Maynard, Kennedy, & Sommer, 2015), we also recommend future studies to examine how the functions and processes of resilient IMTs influence the team performance outcomes (e.g., populations and areas affected, team members' affective reaction) and are influenced by team inputs (e.g., similarity of member's skills and knowledge, organizational structure).

5.3. Limitations of the current study

Several limitations of our study need to be stated. First, a relatively small number of interviewees were recruited in the study. While involving more participants in the interview was desirable, it was difficult to gain access to a larger number of IMT personnel due to the *ad hoc* nature of the organizations. In addition,

there was a limited pool of emergency personnel who were deployed to the IMTs compared to the populous field responders, given the hierarchical structure of the incident management system. Despite the small sample, interviewees had broad and lengthy experience in the IMT operations, and the analysis of themes was considered to reach a point of saturation. Second, findings of this study are predicated on settings in the U.S., for example, a hurricane that hit south-central U.S. and incident management protocols (e.g., NIMS, ICS) commonly mandated across the U.S. Therefore, results specific to this context may not be generalizable to other countries or states having dissimilar disaster management frameworks, although the advocacy for such protocols is growing worldwide (Jensen & Thompson, 2016).

6. Conclusion

This paper presents a holistic view towards resilience of IMTs during a large-scale incident through a thematic analysis informed by theories of resilience engineering and joint cognitive system. Based on subject matter experts' recent experience during Hurricane Harvey, this paper documents characteristic functions that make the IMTs able to plan and modify their activities to remain resilient when confronted with unforeseen challenges. While Harvey offered an opportunity to inspect 'markers of resilience' of a system (Woods & Cook, 2005), our investigation of the IMTs leaves several areas of vulnerability to remediate in future studies: developing information management technologies that better maintain common operating picture, reconciling formal incident management planning with goal-seeking, adaptive actions in the field, and capturing opportunities to learn from routine emergency operations before waiting for a catastrophic disaster to occur.

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Declaration of Interest

The authors have no interests to declare with respect to the study.

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