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Agility in Humanitarian Response Operations for Water Based Disasters

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ABSTRACT

The purpose of this paper is to explore relationships between two dimensional components of agility i.e. flexibility and responsiveness in humanitarian response operations with special reference to water based disasters such as cyclones and floods. Empirical data from four case-studies on cyclones and floods were collected to study and analyze humanitarian response operations. This includes data from 142 interviews, participant observation and documents obtained during field visits. The analysis revealed that supply chain visibility had a positive influence on both reactivity and volume flexibility. However, in-station last mile logistical capabilities mediated the relationship between reactivity and velocity of the supply chain. Delivery flexibility was observed to be dependent on reactivity. The results suggest that humanitarian organizations should focus on enhancing last mile delivery capabilities, communication and infrastructural resilience, and improve training of field forces for disaster-specific operations. Community involvement was observed to have a positive effect on response operations. This paper is the first to study agility of response operations for water based disasters. The insights will be useful for practitioners and researchers to build models that are more realistic. The theoretical contribution is the development of model capturing relationships between flexibility and responsiveness dimensions of supply chain agility.

Keyword(s): *Humanitarian response, supply chain agility, flexibility, responsiveness, water based disasters, case based research.*

1 INTRODUCTION

Research on disaster management and humanitarian operations has gained considerable traction over the last two decades. From a three-year moving average of 2.67 articles per year in top-tier journals in 2001, research output has risen to 33.67 articles per year in 2014 (Gupta *et al.*, 2016). Perhaps, this interest is a reflection of the relevance of the issue and its impact on businesses, people and society. A twenty-year study by Centre for Research on the Epidemiology of Disasters and United Nations Office for Disaster Risk Reduction (CRED, 2015) reports that water based disasters (storms and floods were the top two contributors) accounted for a majority 63% of recorded economic damage from all disasters during 1995-2015. Data from CRED's EM-DAT database indicates that in 2017 alone, floods and hurricanes together accounted for over 80% of damage caused by all types of disasters emanating from natural causes. Interestingly, people who were most affected by floods and hurricanes resided in island states or coastal regions in the equatorial belt. Evidence to this are floods and hurricanes in recent times that hit the Carolinas, Florida, Bahamas, Madagascar, Ethiopia, Peninsular India, the islands of Indonesia, South China and Japan. The National Oceanic and Atmospheric Administration (NOAA) predicts that the tropical cyclonic precipitation, and proportion of storms that will reach intensity levels of Category 4-5 hurricanes, is set to increase globally (Knutson *et al.*, 2019). However, academic literature on humanitarian response operations for water based disasters, such as hurricanes and floods is scarce. This lacuna in the understanding of response operations has real-life consequences.

Humanitarian response operations comprise of a set of activities that include: issuing early warnings, evacuation of people from disaster-prone areas, search and rescue operations for stranded, disabled or missing personnel, activating relief shelters for evacuees, distributing pre-positioned inventory to demand centers etc. These activities are to be carried out during the early stages of the crisis, often under severe time constraints. For example, for a hurricane, response operations usually start a few hours or days before actual landfall, with monitoring and assessment of the hurricane build-up, its trajectory, intensity and time of impact, and continues until the affected region weathers the storm. It may be noted that, the time-scope for response operations for such water based disasters is limited and span only a few hours or days during which there is a huge surge in demand for resources. This is different from post-disaster activities such as reconfiguration, reconstruction and recovery that extend over several months, or years (Balcik and Beamon, 2008). **Figure 1** depicts the temporal slot representing build-up to the response phase, within the larger setting of humanitarian operations.

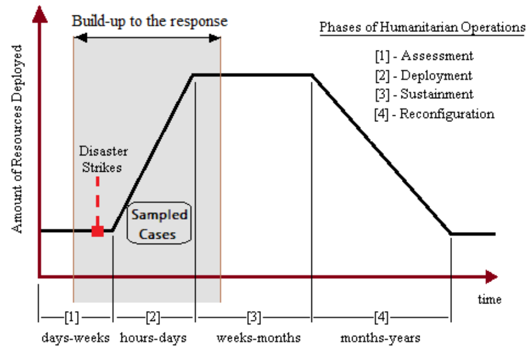

Figure 1 Temporal slot representing build-up to response phase

Hurricanes and floods occupy a unique position within the framework for classification of disasters (Apte *et al.*, 2016) in terms of operational complexity. As portrayed in **Figure 2**, hurricanes are classified as events with 'sudden onset' (Van Wassenhove, 2006) due to how quickly they evolve, and often affect many states covering dispersed coastal archipelagos and island territories. The difficulty in response to such events that are quick and dispersed is of the highest level (Apte *et al.*, 2016). Past research studies have observed that the performance of response operations has a bearing on the agility (Charles *et al.*, 2010; Dubey and Gunasekaran, 2016; Oluruntoba and Kovács, 2015; Dubey *et al.*, 2014) of humanitarian supply chains.

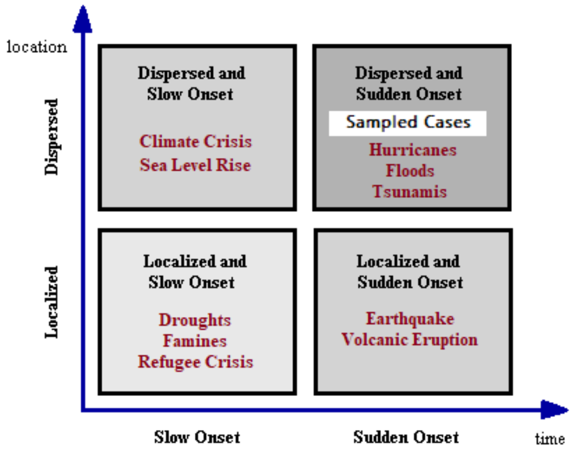

Figure 2 Classification of disasters

2 BACKGROUND AND THEORETICAL CONTEXT

Supply Chain agility (SCA) is a complex construct. Charles *et al.* (2010) defines the dimensions of SCA as: (1) *Flexibility* having components of volume, delivery, mix, and product, (2) *Responsiveness* having components of visibility, reactivity and velocity, and (3) *Effectiveness* having components of reliability and completeness. Past studies have showed flexibility (Scholten *et al.*, 2010; Beamon and Balcik, 2008) and responsiveness (Oloruntoba and Kovacs, 2015; Jahre and Fabbe-Costes, 2015) as two important contributors of agile capabilities of humanitarian supply chains. However, a proper deconstruction of the variables within these dimensions are important for the following reasons: First, from a theoretical standpoint, it is important to understand how these variables play a part in the humanitarian response phase. Do they interact with other variables within the construct of SCA? Or are the effects limited to within their individual dimensions? Secondly, we do not yet fully understand peculiarities of response phase of disaster management, which needs to be captured from real data (Gupta *et al.*, 2016). There is lack of understanding on how these SCA variables behave in light of real humanitarian response operations (Altay and Green, 2006; Van Wassenhove, 2006). Insights on this will help, for example, researchers to accurately define relationships, and develop more realistic mathematical models. Furthermore, what are the implications of SCA variables in operational terms? Which competencies of humanitarian organizations are affected, and what are its repercussions? In light of the above research gaps, we state our research questions:

- **RQ** [1] – How do variables within the dimensions of *flexibility* and *responsiveness* interact?
- **RQ** [2] – What are the practical implications of these interactions?

3 RESEARCH DESIGN

3.1 *Research Methodology*

We adopt case study and field research for our study. The reasons for this are twofold. First, a number of researchers (Glaser and Strauss, 1967; Meredith, 1998; Edmondson and McManus, 2007) suggest empirical case studies and field research as appropriate for theory extension, which fits our objective. Second, the underlying interactions between dimensions of flexibility and responsiveness during response operations, and the competencies required by humanitarian organizations for operational agility are not well understood due to lack of empirical evidence. Therefore, case study and field research offers a methodological fit (Eisenhardt, 1989; Yin, 2003; Fisher, 2007) for our study. Since the focus of our study is on the response phase of humanitarian operations, we define it as our unit of analysis.

3.2 *Theoretical Sampling*

The cases were chosen after careful consideration of the research context and unit of analysis being investigated. To study response operations that evolved quickly which affected widely dispersed geographies, we decided to examine operations during select cyclones and floods. *Cyclone Ockhi* was the pilot study which revealed peculiar characteristics of humanitarian response operations and the need for agile capabilities. This was from the author's direct experience during a field expedition to Lakshadweep islands with the Navy shortly after the response phase of Cyclone Ockhi in December 2017. This pilot set the tone for a detailed study. Further discussions with practitioners during HADR meetings and conferences validated this potential area of study. Drawing inspiration from ethnographic research (Van Maanen, 1988), we undertook three more case studies within the research frame of reference, capturing complexities of the underlying phenomena through thick case descriptions. The second and third cases, namely *Kerala Floods* 2018, and *Cyclone Fani* (Odisha) 2019 were from coastal states affected by cyclones/ floods, while the fourth case was on *Cyclone Pabuk* 2019 in Andaman and Nicobar Islands (A&N) in the Bay of Bengal. Another aspect of consideration was, while the latter two cases were perceived by experts as successful response operations, the first two cases were not, giving depth for cross-case comparisons, enabling relationship validation, and generalizability of theory. Recency of these cases were also considered, as respondents would find it easier to relate to these events from recent past. In preparation to the field visits, practical considerations included access (appointments) to relevant stakeholders from state and district administration, disaster response teams, fire and police departments, communications and transport systems, NGOs etc. operating at state, district and community level.

3.3 Type of Data Collected, Data Collection Methods and Procedures

Since the study was exploratory in nature, we collected qualitative open-ended data, primarily using semi-structured interviews (Edmonson and McManus, 2007) from all four case locations. We also used mixed methods (Spens and Kovács, 2012) approach to supplement the data for triangulation of evidence (Eisenhardt, 1989). This was through participant observation, field notes, documents and materials obtained from field site, and survey of disaster affected people. It may be noted that the additional evidence obtained differed for the four cases. For example, field notes and participant observation were used as additional data collection tools for *Cyclone Ockhi*. Vivid narrations were possible during to-and-fro 12-hour long boat trips with disaster response personnel to Lakshadweep islands. On another case, survey of 1997 households affected by *Kerala Floods* was facilitated by the municipal administration. In A&N, Standard Operating Procedure (SOP) and other documents were provided by Directorate of Disaster Management.

From December 2017 to Nov 2019, a total of 142 semi-structured individual interviews were conducted for four cases, namely Cyclone Ockhi [35 interviews], Kerala Floods [34 interviews], Cyclone Fani [43 interviews] and Cyclone Pabuk [30 interviews]. Appendix A shows the base questionnaire used for the interviews. Brief profile information of interviewees is included in Appendix B. On an average, an interview lasted about 45 minutes in duration. Multiple investigators including the author and project associates were involved in the interview process on a rotatory basis, asking questions and taking down notes for preparing interview transcripts. The research team followed strict protocols for data collection and storage recommended (Eisenhardt, 1989) such as: (1) following the 24-hour rule, compiling the interview notes within a day of the interview, (2) daily debrief sessions, and cross-referencing notes, and (3) refining the questions for next round of interviews. Finally, the transcripts were coded for thematic analysis, and the data was delineated into different levels and functions. This helped comparison of data, and also enabled analysis to proceed alongside data collection at the field, which benefited from adjustments gained through insights from ongoing parallel analysis.

3.4 Data Analysis Methods

From the interview transcripts and secondary data collected following the research protocol, we compared case data to uncover relationships within cases, and its replicability across cases. For example, using thematic analysis of recurring words such as "cyclone forecast", "evacuation", "public transport", "rented vehicles" etc. observed in the transcripts, we delineated events, and build the process of response operations. The data collected also formed the basis of each of the case descriptions. Further, we compared the emergent patterns observed across cases for replicability of logic. This analysis led us to inductively develop our provisional propositions (Eisenhardt, 1989) on interrelationships between SCA variables and its operational implications. In order to validate and iteratively refine our propositions, we went back to reconfirm it with case data. We took feedback from experts for external validation, by presenting our propositions at HADR meetings and conferences.

4 BRIEF CASE DESCRIPTIONS

In this section, we present four case studies in brief: (1) Cyclone Ockhi at Lakshadweep Islands in 2017, (2) Kerala Floods in 2018, (3) Cyclone Fani at Odisha in 2019, (4) Cyclone Pabuk at A&N in 2019. Part of the operations during Kerala Floods, in particular that at a distribution center, was developed as a teaching case (John *et al.*, 2020), and is available from the author(s).

4.1 Cyclone Ockhi

Cyclone Ockhi was a Category III hurricane that caused devastating impact in South-West India, Sri Lanka and Maldives during December 2017. In its early stages, it was ill-defined and categorized as a poorly organized disturbance near Sri Lanka. The Meteorological Department predicted heavy rains, but did not issue a cyclonic warning, citing insufficient data. This ambiguity led to no clear instruction disseminated to the public early on. Logistical assets were also not pre-positioned for response operations in these areas due to lack of precedence of a cyclone during this time of the year. However, the cyclone subsequently gained intensity and tracked in the north-west direction towards Lakshadweep islands. It was only then that the Meteorological Department issued cyclone warnings with instructions to evacuate coastal zones, and advising fishermen at sea to return to safety.

In the search and rescue operations that ensued, the disaster management forces along with the navy, and private organizations such as Red Cross Society evacuated around 2500 people along the coast to safe shelters, and rescued over 400 fishermen who were stranded in the outer seas.

Response operations at Lakshadweep islands, which are spread around 200 to 400 kilometers away from the west coast of mainland India was particularly difficult. First, access to the islands was limited for evacuation operations. Due to the cyclone that was at large, vessels from the mainland suffered time delays. Second, communication within the islands was disrupted. Only one telecom provider was functioning, with limited network and connectivity. Third, the in-station field personnel located in the islands, trained to handle such scenarios during the time-critical response phase were inadequate. Fourth, inadequacy of cyclone resilient infrastructure to act as distribution centers slowed down the pace at which volume of relief supplies could be built-up for distribution locally.

From a supply chain and logistics standpoint, covering the demand requirements in the islands in time was constrained. One, there was the problem of pre-stocking food supplies in islands for local distribution due to poor forecasting of requirements, and dependence from mainland. Second, the supplies from the mainland were severely delayed due to vessel re-routings that was necessitated from port cities as far as Mumbai, raising issues on fleet management, coordination and risk assessment. Third, the issue of last-mile connectivity in the islands crippled the relief supply chain. The 36 islands in Lakshadweep were coral-atolls with shallow drafts for inter-island navigation. Large vessels could not approach many of these islands, and supply of relief materials to demand points were depended on in-station fleet of smaller boats with low draft requirements, that could only cover the last mile of delivery. Inadequacy of smaller boats for last mile connectivity affected timely delivery to different islands in the prescribed time windows.

4.2 Kerala Floods

The Kerala Floods in August 2018, was the most severe of all floods in the past century that affected the southern Indian coastal state of Kerala. In the first week of August 2018, the Indian Meteorological Department (IMD) had issued warning of excessive rainfalls in Kerala from 9 to 15 August. However, based on historical trends, state officials were expecting a tapering of the southwest monsoon in the month of August 2018. In anticipation of requirements during the dry spell, water was not released early on from major dam reservoirs which were almost full. In the second week of August, the events that unfolded contrasted with historical trends. The state received 3.5 times more rainfall than normal. The transmission of IMD's forecast to general public was limited. The state had also not prepared for this scenario.

With incessant rains, rising flood water levels in several parts of the state and amid fears of water spilling over dam reservoirs that were almost full, shutters of 34 major dams in Kerala were opened, resulting in a state-wide deluge that claimed 483 lives. The flood response operations were delayed. Several thousand households, particularly in coastal low lying regions, voluntarily attempted to move to relief centers, only when they observed the water levels rising to unmanageable levels. Some of them who did not move out, remained trapped in higher floors of buildings for 1-2 days, running out of provisions. Of 1997 households surveyed in Paravur region that were affected by floods, only 53% of respondents reported of having received assistance for early evacuation. Real time information about inundation scenario from flash floods in many regions were not available, as inundation maps were not ready, and inundation sensors were not installed at demarcated spots for monitoring.

Logistics and connectivity to demand centers were serious issues: One, hub-to-hub transport for relief supplies from neighboring states were limited to certain routes, due to flooding. Inter-district road access was also restricted. Two, the state had no helicopters for evacuation and air drops of relief supplies. The deployment of 40 choppers made available by central government suffered time lag on arrival. Three, the last mile connectivity to local communities were cut off in several districts. The capacity of helicopters to reach all these demand centers was limited. Nonetheless, the involvement of fishermen community in the response operations was a positive. They deployed about 650 boats to participate in the rescue and relief operations in inundated districts of the state. Volunteers from youth organizations and NGOs, in coordination with state agencies, devised ad hoc mechanisms using technology, social media and the internet, to estimate and track the relief supply requirements at different locations.

The distribution of relief materials from Distribution Centers (DC) to demand points were fraught with challenges. While DCs in major cities could be activated quickly based on the disaster response plan, scaling up volume within a short time was a problem. Volunteers with prior experience of working in a DC during such situations (for example, during the Chennai Floods in 2015), and with knowledge of operations of cross-dock led the efforts. But they had to handhold untrained volunteers during the crisis, and onboard them for ongoing operations to meet the output demanded from the DC. This involved covering different activities in the DC 24x7, such as unloading, picking and sorting, packaging, load-out, and shipping. On the demand side of logistics, intermodal transfer was often required as trucks couldn't access inundated zones. Also, in flooded regions, many DCs connected by road network couldn't be operationalized. Delay in assessing logistical requirements, and lag in deployment of helicopters and boats for last mile connect, led to temporary inventory buildup in certain locations, while other regions faced scarcity of supplies.

4.3 Cyclone Fani

Cyclone Fani in May 2019, was the strongest Category-4 cyclone that hit Odisha since the super-cyclone in 1999 that had caused over 10000 casualties. *Fani* began as a depression during the last week of April 2019, on the west side of Sumatra, and intensified into a Category IV cyclone by 2nd May. During this buildup, IMD issued progressive warnings, signaling yellow, orange and red alerts, which were received and acted on by humanitarian response force.

According to state officials, "Information about the trajectory, timing and intensity of landfall was disseminated to people in the affected regions at least 2-3 days prior to occurrence, through national television and radio broadcasts." Text messages, public announcement systems and sirens were also used for transmitting information. Fishermen were prohibited from venturing into the sea. 45 police platoons, 23 National Disaster Response Force (NDRF) teams, 9 Odisha Disaster Rapid Action Force (ODRAF) teams, 52 Fire Service Units, 50 Public Work Department (PWD) teams with 300 vehicles, 450 JCB excavators and heavy machinery, 25 rural development teams and 45 medical teams where pre-positioned in state for the disaster response effort. The cyclone was predicted to make landfall at the city of Puri. The district administration evacuated about 65% of the residents in Puri, particularly in the low lying regions that were vulnerable to flooding, at least a day before cyclone *Fani* made landfall. The field forces moved residents to shelter homes in hinterland regions with adequate protection.

The evacuation in Puri was performed in a coordinated manner led by the district administration using a fleet of vehicles from three different sources: (1) Government owned vehicles such as jeeps, trucks and other vehicles earmarked for evacuation purposes, (2) Vehicles requisitioned by the district administration from state transport departments in nearby districts, to meet possible surge in demand for mass evacuation in a short time span,

(3) Private vehicles hired by the government, based on agreements made to meet the logistics requirements during response phase. Ships and aircrafts were pre-positioned by the navy in the nearby Vishakhapatanam and Arakkonom bases for rescue and relief operations. The state government also readied 300 motor boats and 2 helicopters at field stations to meet the logistical requirements in coastal areas.

Tourists who were in Puri region during that time were offered options to relocate to alternate tourist destinations, or to return to the safety of their homes. Patient loads in hospitals were reconfigured. According to the Chief Medical Officer at the District Hospital in Puri, “Only critical patients were retained at the hospital, and others were discharged to accommodate emergencies during cyclone. Medics were posted to shelter homes to attend to accidents and emergencies, and to administer preventive healthcare measures.”

According to the Nodal Medical Officer for *Cyclone Fani*, drugs, pharma and other medical supplies were adequately pre-stocked for a period of 7 days. Emergency diesel generator sets and fuel were stocked, anticipating possible power failure during and in the aftermath of the cyclone.

At 8.45 am on May 3rd, *Cyclone Fani* made landfall in Puri, with wind speed estimated to be 200+ km/h. The cyclone lasted for about 3 hours, and then waned in intensity as it moved onto land. Residents were strictly instructed to stay indoors in cyclone-resistant shelter homes during the period. The government had set up 60 shelter homes for housing the people evacuated from Puri in earmarked schools, auditoriums and community halls that functioned for 7 days. “Free kitchens” for providing cooked food were set up by the district administration for a period of 15 days. The government also supplied free ration of 50 kg rice and 3000 rupees as immediate financial support for households in the lower socio-economic strata that were affected.

4.4 Cyclone Pabuk

Cyclone Pabuk was a tropical storm that hit A&N in January 2019. It originated in the South China sea on 1st January 2019, and was designated by IMD as one of the earliest forming cyclones in the Northern Indian Ocean basin during a calendar year. As *Pabuk* tracked westwards, Disaster Management Authority (DMA), the nodal agency, monitored and issued alerts based on information converged from multiple sources such as IMD, Joint Typhoon Warning Center (JTWC), and Indian National Center for Ocean Information Services (INCOIS). Upon official confirmation of the impending cyclone from IMD on 4th January 2019, DMA activated humanitarian response operations for *Cyclone Pabuk*. Mobile alerts were sent to public through state-owned communications partner BSNL. The information transmitted included speed of cyclone, time of landfall and tentative location. On 4th January, two teams of 52nd battalion from Arakonnam were deployed at A&N by NDRF to meet exigencies.

The response teams included personnel from A&N Administration, Police Force, Fire & Rescue Services, Public Works Department (PWD), Motor Transport Department (MTD), Directorate of Shipping Services (DSS), Health Department etc. These response teams used to meet at least 3-4 times a year for simulated response drills to build competencies related to SOP. For the humanitarian response during *Pabuk*, the DMA and A&N administration officials centrally coordinated with response team leaders in 40 island locations, from the Control Room at Port Blair through a network of 40 satellite phones. The Fire Department and PWD stationed machinery and equipment for response operations at designated zones. The police force led the evacuation operations in high risk zones, low lying areas and isolated islands. For this, they requisitioned transport from MTD and DSS. A fleet of 284 vehicles that consisted of 52-seater long chassis buses, 42-seater mini buses, and 32-seater small vans were kept on standby by MTD for deployment in larger islands. The DSS redeployed its fleet of boats used for regular ferry transport for evacuation operations. The fleet also included 9 landing crafts which could dock on beaches and island territories with no jetty facilities. Logistics, particularly last mile delivery in Andaman Islands was perceived by officials to be adequately backed up with the in-station fleet of boats, vehicles and helicopters. Deep draft zones around Andaman Islands enable larger vessels to approach the region.

The evacuated people were moved to earmarked shelters in higher terrains in larger islands. These shelters were either school buildings or hurricane resilient buildings erected by PWD for the purpose. ‘*Apada Mitra*’ – a Volunteer Disaster Response Force developed over the years by DMA coordinated community level activities by deploying a group of 200 trained volunteers at each *taluk* (district zone) level during response phase. The safe shelters were supplied food, clothes and other requirements by the civil supplies department. Inventories were pre-stocked in the island to handle emergency demand requirement of provisions up to 2-3 weeks. According to Chief Medical Officer at GB Pant Hospital, Port Blair, stocks of medicines for preventive, clinical and emergency care could meet requirements up to 3 months. In the case of *Pabuk*, extended supplies were not required as the intensity of cyclone waned on day two and dissipated by 7th January 2019. There were no casualties reported in A&N.

4.5 Comparison of Cases

The four cases were structured along key attributes for cross-case analysis. The high-level data on each case is presented in the beginning of **Table 1**. In terms of severity, *Cyclone Fani* was extremely severe, followed by *Ockhi* and *Kerala Floods*, whereas *Cyclone Pabuk* was a moderate tropical storm. It may be noted from the case data that while the economic damage corresponds to the severity of the disasters, the consequent casualties do not. *Cyclone Ockhi* and *Kerala Floods* had 4-times or more fatalities than *Cyclone Fani* which was of much higher severity.

Table 1 Classification of disasters

Key Attributes	***Cyclone Ockhi***	***Kerala Floods***	***Cyclone Fani***	***Cyclone Pabuk***
Location	Lakshadweep	Kerala	Odisha	Andaman
Geography	Island territory	Coastal region	Coastal region	Island territory
Event Magnitude	Very Severe	Severe	Extremely Severe	Moderate
Casualties	> 245	483	64	-
Total Econ. Loss	$ 5 bn.	$ 5.3 bn.	$ 8 bn.	$ 0.15 bn.
Info. System				
Early Warning	Not Effective	Overlooked	Available	Available
Info Details	Fair	Fair	Good	Very Good
Multi-Source (DM)	No	No	Yes	Yes
Trans. Effectiveness	Low	Moderate	High	Moderate
Assets for EHO				
Com-sys Resilience	Low	Moderate	Moderate	High
In-Station Fleet	Inadequate	Moderate	High	High
DC Facility Readiness	Inactive	Partially Active	Active	Active
Safe Shelter Readiness	Low	Moderate	High	High
Logistics				
Hub Dependency	High (mainland)	Moderate	Moderate	Moderate
Hub Transport	Very difficult	Difficult	Moderate	Very difficult
In-station Fleet	Low	Low	High	Very High
Fleet Ownership	Military	Govt. + Private	Govt. + Contracted	Govt. + Military
Last Mile Connect	Weak	Moderate	Strong	Strong
Evacuation				
Primary Mode(s)	Air, Water	Air, Water, Road	Air, Water, Road	Road, Water
Operated by	Govt., Military	Mil., Communities	Govt., Military	Govt., Mil., Comm.
Effectiveness	Low	Moderate	High	High
Field Force				
Competency	Cat-1	Cat-1	Cat. 3-4	Cat. 4
Response Op. Training	Low	Low	High	Very High

5 RESEARCH FINDINGS AND DEVELOPMENT OF PROPOSITIONS

The first research question aims to study the interactions between variables within flexibility and responsiveness dimensions. For this, we delineate the components within these dimensions. Visibility is a component in the responsiveness dimension. Barratt and Oke (2007) defines *visibility* as "the extent to which actors within a supply chain have access to or share information which they consider as key or useful to their operations". The supply chain *visibility* (Francis, 2008) includes the ability to know the identity, location and status of entities transiting the supply chain. Based on the coded transcripts, we captured interview comments on visibility to ascertain relationship with other components (variables).

According to a fire-station officer, "During a cyclone, communication infrastructure is vital to first responders for access to information about events. Resilience of our communication handsets and network infrastructure affects our ability to pass information to intra and inter-departmental stakeholders." Furthermore, the ability to collaborate between stakeholders (Scholten and Schilder, 2015) is dependent on the integration of information system. An officer from the naval meteorology commented, "… distributing logistical assets is based on needs at different locations. Availability of integrated information systems effects our ability to evaluate supply-demand gaps and deploy logistics for humanitarian response." The Assistant Director of Fisheries department at A&N observed, "…our ability to minimize causalities is based on the strength of our communications network. We insist on VHF systems for mechanized fishing boats for better tracking, as well as for search and rescue operations."

A conversation with a senior district administration official on evacuation operations revealed, "… our evaluation of alternative evacuation plans depends on information about inundation in different localities and its demographics. This information is crucial for needs assessment such as fleet composition, size, routing alternatives etc." Statements from multiple response units supports positive impact of *visibility* on *reactivity* (Kisperska-Moron and Swierczek, 2009) which represents ability to evaluate and take needs into account quickly. Visibility is bi-directional and also affects the people to be evacuated. According to a Senior Manager at BSNL, "Based on directions of DMA, we send early warnings through text to almost 70% of the population, who are our subscribers in the region. This helps communities access information on cyclone landfall, and organize themselves for evacuation." During Kerala Floods, we obtained direct evidence from a cross-dock, where *visibility* issues due to failure in communication networks led to demand-supply mismatch, as needs could not be accurately assessed for certain regions that were cut off by inundation. Therefore, we propose:

- P_1: Supply chain *visibility* is positively associated with *reactivity*

Reactive capability, wherein one can quickly assess requirements on the field, stems from different origins. According to coordinator of a distribution center setup during Kerala floods of 2018, "Many of our senior volunteers have gone through a learning curve. They have past experience of handling relief distribution operations during Chennai Floods. Their ability to assess different types of demands from relief camps are better, and they train new volunteers on-the-job to operate the cross-dock." An official of DMA in A&N observed, "Since the Tsunami that hit us in 2005, we periodically conducted mock-drills and unannounced simulation exercises to build competence to face real decision-making scenarios. Our field forces and logistics are largely local, and not dependent on deployment from mainland. This gives us the advantage of knowing the local terrain, topography and features unique to the islands." The Director of Shipping Services at A&N added, "This training is not limited to response units, but also given to our family members in the islands. Schools conduct special drills for kids to know what to do during response phase. This increases community involvement."

Contrasting evidence on reactive capability was observed during Cyclone Ockhi and Kerala Floods. According to a Naval Officer, "We have never seen a cyclone [Ockhi] in recent past at this scale on the west coast, which is not prone to it. We had to re-route ships from other ports to handle logistical requirements." Direct observations showed delays from ad hoc re-routing. A Kerala Police officer commented, "[Operations during Kerala floods] … was a challenging task for us. We saw this disaster for the first time. A different type of training is required… we also have shortage of staff, materials and vehicles". According to the Deputy Superintendent of Police in Puri, "We have one of the largest locally trained reserve force - ODRAF (Odisha Disaster Rapid Action Force) in the country. Investment in training and logistics have reaped dividends. We have come a long way since super-cyclone of 1999." On the other hand, a community leader involved in Kerala Floods response commented, "We have no helicopters or boats for the response required for this type of calamity. Our police force has limited capabilities. If our local fishermen communities had not taken out their boats for rescue operations in hinterlands, there would have been many more causalities. The logistical support from central government came in late". The ability to actually cover the needs on the ground, otherwise known as *velocity* (Christopher *et al.*, 2004) of supply chain was observed to be positively associated with *reactivity*. However, reactivity per say did not imply that the actual needs on the ground were covered; it was subject to availability of logistical assets locally, particularly for the last mile coverage. Therefore, we propose:

- P_2: In-station logistics mediate the relationship between *reactivity* and *velocity*

According to the Deputy District Collector of Puri, "Agreements for contracting private vehicles locally from private players were already made to meet the anticipated surge in logistical demand during response phase. Logistics are key to taking action on ground". It was observed during Kerala Floods that the type for logistics available for last mile delivery was crucial; for example, small motor boats or canoes could be put to use for relief efforts when other transport modes failed. Evidence from *Cylone Fani* and *Cyclone Pabuk* indicate an optimal fleet mix comprising smaller boats, amphibious crafts for last mile transport, and choppers for air support positively influenced evacuation operations. The relationships proposed between components of responsiveness dimension is depicted in **Figure 3**.

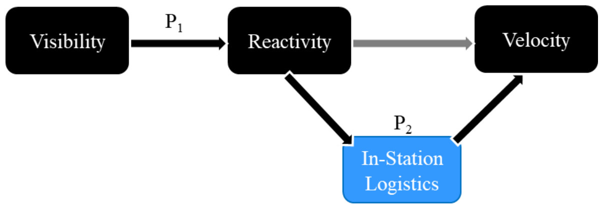

Figure 3 Proposed relationships between components of responsiveness dimension

Volume flexibility represents the ability to quickly ramp up volumes, and can be measured by a combination of metrics capturing changes possible to supplier lead times and options available within supply contracts (Narasimhan and Das, 1999), number of global suppliers and components purchased per suppliers (Kekre *et al.*, 1995), range of order sizes from suppliers, end users supported by each distribution facility, adequacy of storage capacity, and delivery capacity (Sethi and Sethi, 1990). According to a coordinator of a distribution center, "… network disruption in hub-to-hub transport often means having to resort to alternate suppliers to meet demand. Preparation in this regard, in terms of multi-supplier agreements provides backup during transportation network failures. During Kerala Floods, access to suppliers along the eastern boundary of the state were cut off; the volume requirement of relief materials was met by coordinating with suppliers from the northern side."

A naval officer involved in the humanitarian response operations at Lakshadweep island commented, "A large facility may be constructed and available, but that doesn't mean it has operational readiness. Real-time visibility of prepositioned stocks, logistical access, monitoring of operations in the DC etc. are crucial". According to a medical officer at GB Pant Hospital at A&N, "Being able to track different stock items, and position supplies locally for a 3-month period enables us meet spikes in demand. Our dependence on mainland supplies in the short term is reduced." The district administration of Puri in their response report stated, "…357 cyclone shelters were setup in different safe zones. Linking up with suppliers with depth of scale and variety of stock items ensured availability of stocks to the cyclone shelters." According to a rest-house manager at Puri, "…with an integrated communications system between relief camps and suppliers such as Food Corporation of India, we can prevent shortages and reduce demand-supply gaps. But the system should be robust." Therefore, we propose:

- P_3: Supply chain *visibility* has a positive effect on *volume flexibility*

Slack (2005) defines delivery flexibility as the ability to change planned or assumed delivery dates. This capability may be ascertained using metrics such as number of storage/ distribution facilities, user orders that can be fulfilled from alternate facilities, number and type of different delivery modes, and changes possible in delivery lead times (Sethi and Sethi, 1990). However, empirical evidence from case data suggests that this capability is not only depended on physical assets. For instance, according to an NGO volunteer, "During Kerala floods, despite last mile logistics available in certain zones, relief supplies reached the end user with significant delays. Supply stocks lay piled up in railway stations, waiting to be picked. This shows problems in organizing logistics." A similar view was echoed by a representative of Odisha Weaver's Association who volunteered for response operations, "We had adequate volume of stocks. But we need to improve the distribution mechanism. How to route vehicles in the shortest possible time? How to make adjustments between drivers to deliver goods to different relief camps? This needs specific skills." The ability to evaluate and quickly take needs into account were observed to have a positive impact on delivery flexibility. According to a police officer, "… fishermen are routinely exposed to high risk environment and can quickly make adjustments and course corrections. During Kerala floods, delivery of supplies in southern districts were made by several teams of fishermen working in coordination, and displayed better judgement on how to distribute the materials. Our coastal police force doesn't necessarily have the skillsets for making such decisions." According to a senior Naval officer, "… [during cyclone Ockhi], delivery schedules were often dynamic with changing requirements at shelter homes in different islands. Keeping the right mix of fleet and optimizing transport for distribution is a challenge." A DC coordinator commented, "… [during Kerala Floods], when our logistics are handled by volunteers from retail firms, with knowledge of logistics such as for home deliveries, our delivery performance is better. But personnel with such skills are not easy to come by during the crisis situation." Therefore, we propose:

- P_4: *Reactivity* is positively associated with *delivery flexibility*

As shown in **Figure 4**, P_3 and P_4 link responsiveness and flexibility dimensions of SCA.

6 DISCUSSION, CONCLUDING REMARKS AND FUTURE RESEARCH DIRECTIONS

While the propositions developed in the previous section aims to understand theoretical relationships between components under the flexibility and responsiveness dimensions of SCA, humanitarian organizations would certainly be interested in its practical implications. This is because, albeit investments in infrastructure, logistics, technology, competency building etc. will be essential to strengthen the individual components of agility, the performance of humanitarian response operations may be limited by the strength of the interactions between these components, as observed from empirical evidence described in the previous sections. For example, the ability to evaluate requirements at relief camps was dependent on bi-directional information exchange capabilities even during a disruptive cyclone. Similarly, dynamic vehicle-routing capabilities including multi-modal transfers effected flexibility demanded on delivery of relief material. **Table 2** summarizes the implications with respect to each of these interactions.

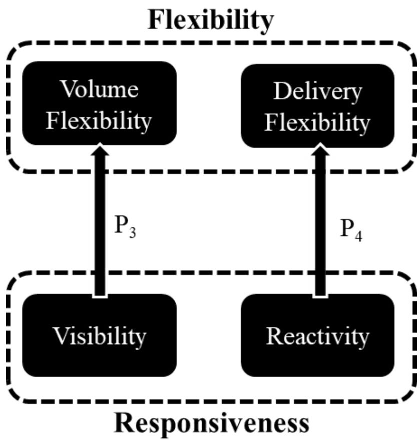

Figure 4 Proposed relationships between flexibility and responsiveness dimensions

Table 2 Implications of inter-dependencies in SCA construct

Comp. A => Component B		Practical Implications
Visibility	*Reactivity*	▪ Resilience of communication devices and networks ▪ Integrated communications network between stakeholders
Visibility	*Volume Flexibility*	▪ Real-time access to DC operations and inventory metrics ▪ Multi-supplier networks setup to absorb demand surges
Reactivity	*Velocity*	▪ Response fleet to be positioned in situ before landfall ▪ Pre-planned agreements on logistics with local org.(s) ▪ Unique modes of transport required for last mile logistics
Reactivity	*Delivery Flexibility*	▪ Training for organizing humanitarian response fleet ▪ Skills for distribution (last mile) in high risk environment ▪ System controls for delivery transfers during distribution

It may be noted that while this study was exploratory in nature, and attempted to understand the components of agility and its interactions within the phenomenology of humanitarian response operations during cyclones and floods in islands and coastal regions, future studies need to be conducted to test and validate these propositions. It is therefore important to conduct future research, using other techniques such as the survey method to confirm these findings.

Another observation from our study was that for certain components of agility, there wasn't sufficient evidence to justify its contribution to humanitarian response operations. For example, *product flexibility* that represents the ability to introduce new products was not observed to be critical, unlike in commercial supply chains (Charles *et al.*, 2010). The essential relief materials like food, medicines, clothes etc. remained similar across cases sampled for humanitarian response operations. It was noted that while *mix-flexibility* (Slack, 2005) which is the ability to change the range of products made or delivered, was found important, such as for distribution of materials to relief camps with different needs during Kerala Floods, we could not find any evidence of linkages with other SCA components that were generalizable across cases. Future studies may explore the effects of these components of agility on humanitarian response operations.

While this study is a first of its kind – studying humanitarian response operations of water based disasters and identifying interactions between components of SCA, it certainly has some limitations, with scope for improvements in future studies in closely related areas. One, the dimension of *effectiveness* with components of reliability and completeness is not included in the scope of this study. Second, the data for this paper was collected from the subcontinent. While cases described in this paper involved multiple organizations such as the government, NGOs and private organizations, their power allocations and roles could vary in other systems with structural differences, such as when private organizations have larger roles in decentralized systems (Besiou *et al.*, 2014). Future studies should be undertaken to study agility in different systems, the effect of power allocation, and involvement of multiple organizations such as private companies and communities in the disaster response phase.

In the broader context of humanitarian response operations, the effect of agility is not limited to cyclones and floods alone. While humanitarian response to cyclones and floods in dispersed regions (refer **Figure 2**) has its unique set of challenges, agility is also critical for response to events that are sudden and more localized. This may be observed during disasters from natural causes vis-à-vis earthquakes (Kokaji and Kainuma, 2018), volcanic eruptions, or accidents such as chemical explosions or fire (Das *et al.*, 2021). While extant research covers mathematical modeling techniques for network design, optimal location selection for facilities etc. (Barsing *et al.*, 2018) which are important for agility, future research may leverage from using data from social media, imagery from satellite data etc. independently or in combination to improve visibility, enabling interventions using data analytics tools to improve reactivity, and other techniques that can enhance of agility of humanitarian supply chain in different phases of preparation, response, and recovery. From our review of literature, we observe that disasters are studied, modeled and analyzed independently. However, natural phenomena pose an evolving research gap on humanitarian response when multiple disasters occur simultaneously, such as a hurricane or earthquake during a pandemic. While the response protocols for a region facing one type of disaster at a time may have been developed, solutions for response to simultaneous events using modeling, simulation or other techniques are ripe for research. Data collection is a challenge, especially during the response phase when researchers face the dilemma of observing or contributing to the response. Developing synergies with humanitarian organizations for setting up or advancing systems for response and observation, and analyzing data in real-time or retrospectively will facilitate future research on time-critical response phase of humanitarian operations.

APPENDIX A – BASE QUESTIONNAIRE USED FOR SEMI-STRUCTURED INTERVIEWS

I. Event Description

- Can you describe the recent cyclone/ flood that affected your area?
- What were the actions taken during the early phase of the operations?
- How were you / your organization involved?

II. Information Management

- Did you receive early warning signal?
- How long before landfall did you receive the warning?
- What were the sources / channels or through which early warning was disseminated?
- Was the early warning effective? Did it reach the end user?
- What were the details your received as part of the early warning?

III. Evacuation and Logistics

- Can you describe the evacuation process? How was it carried out? Localities evacuated?
- What was the transportation mechanism? Type of vehicles used?
- Were there enough number of vehicles? Who owned / operated these vehicles?
- Were government vehicles sufficient for evacuation? Were additional vehicles / private arrangements needed?
- Were there any partnership agreements for evacuation operations

IV. Shelter Homes & Distribution Mechanism

- Where were the evacuated people sheltered? How was setting up of shelter homes decided?
- What were the supplies provided as part of relief requirements for shelter homes?
- How was the distribution of supplies done?
- Were there any problems in stock levels, inventory management and distribution process?
- What were the level of preparedness for emergency items such as medical supplies, health & sanitation kits?

V. Systemic Competencies

- How was the communications visibility (information access & sharing between stakeholders) during disaster?
- Was it possible to accurately evaluate the needs during disaster?
- How did you manage the volume requirements, and delivery of relief materials during response phase?
- Were there any challenges for last mile delivery? Or ramping up volume of relief material?

APPENDIX B – BRIEF PROFILE OF INTERVIEWEES

Cyclone Ockhi (Lakshadweep) – 35 Interviews					Kerala Floods – 34 Interviews				
#	Interviewee - Organization	SL	ML	JL	#	Interviewee - Organization	SL	ML	JL
1	Naval Officer	3	8	1	1	Community Leaders		8	
2	Communications Engineer			1	2	Doordarshan (National TV)			1
3	Engineer - Logistics			1	3	Fire & Rescue Department		3	2
4	Deepwater Divers			2	4	Hospital Administration	2	3	
5	Island – Resident Volunteers			2	5	Police Department	2	2	1
6	Army Medic			2	6	Meteorological Department	1		
7	Laboratory Specialist			1	7	Educational Institution		1	
8	NDRF Officer			2	8	District Administration	1	1	2
9	Meteorological Department			2	9	NGO	1		1
10	Fire & Rescue Department		1		10	Distribution center Coordinator	2		
11	Coastal Police		1						
12	Coast Guard Officer			1					
13	Navy Meteorology Dept.			1					
14	NGO Coordinator		1						
15	Govt. Hospital Admin.		1						
16	Drone Service Provider		1						
17	Pvt. Meteorological Agency		1						
18	State Informatics Center		1						
19	Civil Surgeon	1							
Cyclone Fani (Odisha) – 43 Interviews					Cyclone Pabuk (Andaman) – 30 Interviews				
#	Interviewee - Organization	SL	ML	JL	#	Interviewee - Organization	SL	ML	JL
1	District Administration	2	1		1	Disaster Management Authority		2	
2	Police Department	3	1	4	2	Police Department	1	1	
3	Private Transport Agency		4		3	Communications Officer	2	1	
4	Odisha Tourism Dept.		1		4	Tourism Department		3	
5	All India Radio	1			5	Public Works Department		3	
6	Doordarshan (National TV)		1		6	Motor Transport Department	3		
7	Odisha Weavers Asso.		1		7	Electricity Dept. (Utilities)		2	
8	Railway Station Officer		1		8	Ambulatory Services		1	
9	Railway Police			2	9	Doctors / Hospital Managers	1		
10	Doctors / Hospital Admin	2	3		10	Fisheries Dept.	1		
11	Fire Station		2		11	Mercantile Marine Dept.	1		
12	Community Parish Priest	1			12	District Control Room		1	
13	Hotel / Rest-House Manager	1	3		13	Harbor Works Dept.		1	
Cyclone Fani (Odisha) – 43 Interviews [contd.]					Cyclone Pabuk (Andaman) – 30 Interviews [contd.]				
#	Interviewee - Organization	SL	ML	JL	#	Interviewee - Organization	SL	ML	JL
14	Communications Officer		1		14	Hotel & Transport Agency		1	1
15	Driver			1	15	Fire Station	1	1	1
16	IT Professional		1		16	Directorate (Shipping Services)	1		
17	Retail Business		3						
18	Medical Store / Pharmacist	1	2						

Note: The aggregated list of persons interviewed for the research study is represented in the table above, categorized on the basis of the organization they represent and their position in the organization [SL – Sr. Level, ML – Middle Level, JL – Operational or Junior Level].

- What was the size and type of vehicles available in the locally positioned fleet?

VI. Partnerships and Training

- What is the type and level of disaster that you / your organization can handle?
- Do you have any partnerships with stakeholders (government, NGOs, private org., community volunteers)?
- What is your preparation and training to respond to disasters? How do you organize it?

- What are the different skills required to respond to different types and intensities of disasters?
- Do you have a mechanism to measure and differentiate the skills required response operations?
- Can you reflect on the assessment and response operations during the recent cyclone/ flood?
- How would you evaluate the operations? What are the areas for improvement?

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