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THE TOHOKU DISASTERS: CHIEF FINDINGS CONCERNING THE POST DISASTER HUMANITARIAN LOGISTICS RESPONSE

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ABSTRACT

This paper describes the preliminary findings of the research conducted by the authors on the humanitarian logistic efforts after the cascading disasters that descended on the Tohoku region after the Great East Japan Earthquake of March 11th, 2011. Using a combination of in depth interviews with participants in the relief efforts, meta analyses of news accounts, the authors identified a list of preliminary findings, policy implications and suggestions for improvement.

Keywords: humanitarian logistics, disaster response, Japan disaster.

INTRODUCTION

The extreme and sudden nature of disasters poses significant challenges to the organizations involved in the delivery of critical supplies to assist those impacted. This is because: (1) infrastructure and communication systems may have been impacted and unable to fully function; (2) large (and dynamic) volumes of critical supplies must be transported; (3) there is a short timeframe to respond and prevent loss of lives and property; and, (4) there is a huge amount of uncertainty about what is actually needed, where is it needed, and what is available at the site; among other complications (Holguín-Veras et al.,

2007). These characteristics set post-disaster humanitarian logistics (PD-HL) apart from both commercial logistics and the various forms of longer term humanitarian logistic endeavors, e.g., distribution of medicines in crisis regions, as they that take place in less chaotic environments. Most notably, PD-HL differs in terms of: (1) objectives pursued; (2) nature and origination of the commodity flows transported, (3) knowledge of demand, (4) decision making structure, (5) periodicity / volume of logistic activities, and (6) state of the supporting systems (e.g., transportation and communications). For more information see (Holguín-Veras et al., 2010). Unfortunately, the realities of PD-HL response are not yet well understood. The reasons for this are three-fold: (1) the relatively low occurrence of disasters; (2) the extremely small size of the professional and research PD-HL communities; and (3) the ephemeral nature of the operations and data. As a result of these factors, the level of knowledge about PD-HL possessed by outsiders to the response process is appallingly small. Adding to the problem, only a handful of the PD-HL cases have been systematically studied (e.g., Katrina, Port au Prince), mostly by team members. For that reason, the disaster research community is only starting to scratch the surface of such complex subject. In this context, the research discussed in the paper is important to the nascent field of PD-HL and disaster research because it provides evidence-based insight into actual/emerging PD-HL practices, and lessons that ought to be learned to update plans and response procedures.

The fundamental objectives of this paper are to: (1) discuss how the unique nature of the cascading disasters in the Tohoku region impacted the PD-HL response; (2) describe the PD-HL operations implemented to respond to the Tohoku disasters; (3) identify how the persistent nuclear threat impacted the overall PD-HL effort; (4) document lessons learned, both positive and negative; and (5) identify a set of policy recommendations to improve future disaster response. In identifying the lessons learned, the authors are fully aware that in disaster response, particularly after catastrophic events, it is not realistic to expect perfection as these operations take place in chaotic conditions. The main goal is to identify lessons that could be of benefit to future disaster response in order to preserve life and property. The paper summarizes the work of an international team that—with funding from the National Science Foundation (NSF) and the Japanese Science and Technology Agency (JST)—visited the Tohoku region. The data were collected using a multi-prong approach based on in depth interviews with participants in the relief efforts, the assembly of a comprehensive database of news articles and reports, and the creation of a timeline of relevant events. The interviews, conducted during several trips to the area, were with the Tohoku Regional Bureau of the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT); the prefectures of Miyagi, Iwate, and Fukushima; the cities of Ishinomaki and Kesennuma, and three large private companies (i.e., Yamato, Sagawa, and AEON), that were involved in the response. In all cases, the authors met with numerous staff members. To ensure anonymity, the names of the individuals that provided the information are omitted in the paper. Triangulation of the responses was conducted to mitigate the limitations inherent in relying on accounts and information provided by individuals that, for the most part, only had a partial view of the operations. The paper has four sections in addition to this introduction. Section 2 discusses the cascading disasters that precipitated the humanitarian crisis in Tohoku. Section 3 provides a system-level overview of disaster preparation and PD-HL response efforts.

Section 4 analyzes the lessons learned as described by the interviewees. And, Section 5 summarizes the chief findings and defines a set of policy recommendations.

THE CASCADING DISASTERS

On March 11th, 2011 a 9.0 earthquake struck 130 km East of the city of Sendai in the East Coast of the Island of Honshu, Japan. Lasting about five minutes, the earthquake—referred to as the "Great East Japan Earthquake"—produced a violent shaking that damaged an untold number of roads and buildings. Providing testimony of Japan's seismic design and construction practices, physical damage was kept to a minimum; and loss of lives by the earthquake was relatively low considering its intensity. However, the earthquake led to the temporary shutdown of ports, airports, subways, and rail systems throughout Japan (Journal of Commerce, 2011c). Immediately after the earthquake, tsunami alerts were issued throughout the Japanese East coast. The warnings predicted waves of 6-7 m height which, in most cases, would have been within the design range of the tsunami protection infrastructure. Local citizens, well trained after years of emergency drills, moved to higher ground following pre-established tsunami evacuation routes. Regrettably, anecdotal evidences point out that large numbers of people—with fresh memories of the false alarms of February 22nd and March 9th, 2011 (with a magnitude of 7.3) earthquakes—ignored the warnings. As expected, the waves struck the Eastern seaboard of Japan. Unfortunately, the waves were much higher than anticipated and tens of villages and cities and hundreds of small communities were hit by waves towering in excess of 12-16 m, with a reported maximum of 39 m in Northern Japan (NHK World News, 2011). There was also confusion about the arrival time of the tsunami waves, which may have led people to believe that the danger had passed when in fact, the tsunami was still on its way (NHK World News, 2011).

The Japanese people had been preparing for such a scenario for decades. Local governments had organized tens of thousands of evacuation drills throughout the country, and invested heavily on seismic resistant structures and tsunami protection infrastructure and systems. The latter includes a huge network of tidal gauges to collect real time wave height data, sophisticated information technology systems that process the wave height data and issue automatic warnings in case of danger, and an estimated 8,800 miles of seawalls and breakwaters to protect life and property (New York Times, 2011).

In the Tohoku region—the one closest to the epicenter and the one most heavily impacted—the most critical pieces of infrastructure are the: Sendai Airport, Iwate-Hanamaki Airport, Port of Sendai-Shiogama, Port of Onahama, Tohoku Motorway, Joban Motorway, Sanriku Motorway, Routes 4, 6, and 45, the East-West arterials connecting the Tohoku Motorway to the coastal areas, the Tohoku Shinkansen (high-speed railway), the Fukushima Daiichi Nuclear Plant, and the Onagawa Nuclear Plant (Journal of Commerce, 2011f). In addition, there are hundreds of miles of populated areas in which both agriculture, industrial activity, and human habitation takes place.

Overall, the level of protection against tsunamis was uneven. In most of the populated areas, seawalls—not as effective as breakwaters and certainly much less effective than tsunami breakwaters—were the main form of protection. The airport at Sendai, located about one km from the coast behind a 4 m seawall, was deemed to be in a safe area (NHK World News,

2011). The Fukushima Daiichi Nuclear complex had a double layer of protection: the reactors had been located at the top of a 6 m bluff facing the sea and a small two-wing breakwater protected the facilities. In contrast, the Port of Sendai has two sets of breakwaters including a massive deep water tsunami breakwater located 3 km from the port. These critical facilities experienced different levels of damage. The airport, though flooded, did not experience irreparable damage, and was back in operation six days after the disaster (Washington Post, 2011). The port was in acceptable shape, though hundreds of containers were piled up by the waves requiring significant clean-up. More importantly, the piers were not damaged though gantry (ship) cranes needed repairs (a very different situation than what happened in Port au Prince, where both piers and cranes were completely destroyed by the earthquake, thus removing a crucial component of the logistic system). The port was opened to receive relief supplies on March 18th (Journal of Commerce, 2011h), to commercial domestic traffic on March 29th (Journal of Commerce, 2011f), and to international containers on June 9th, 2011 (Journal of Commerce, 2011b). Farther away from the epicenter, the Fukushima Daiichi nuclear complex did survive the earthquake, and went into the automatic shutdown established in emergency procedures. Unfortunately, the tsunami waves overtopped both the breakwater and the bluff, flooding the emergency generators that provided the electricity to run the water pumps needed to cool the nuclear reactors while the plant was not in operation (the generators had been located near sea level). The crisis that followed—that culminated with the release of radioactive material—impacted the response in rather dramatic ways as it deterred the convergence of volunteers and materials to the disaster site. As a result, local responders had to undertake the response without the assistance of the massive help that typically comes from the outside bringing manpower, equipment, supplies, and expertise. The deterrent effect of the nuclear crisis had on both people and material convergence sets the Tohoku disasters apart from the most recent events (one would need to go back to Chernobyl to find a precedent); as in most disasters once the physical phenomenon that produced them fades away, the response process can start in earnest.

Three specific features make the Tohoku disaster an event without precedents in recorded disaster history: (1) severity and pervasiveness of the danger, (2) geographic coverage with both widespread and localized damage, and (3) persistence over time. First, in terms of severity, the earthquake and tsunami are among the strongest on record, while the nuclear crisis is only topped by Chernobyl. Adding to the complexity, the pervasiveness of the (invisible) nuclear threat—and the fact that it conjures images from Hiroshima, Nagasaki, and Chernobyl—sent a powerful deterring signal to potential responders outside the area. Secondly, the disasters also impacted a large geographic area: the tsunami wiped out hundreds of square kilometers of coastal communities, while the nuclear crisis threatened the health of individuals and impacted environmental conditions within a large radius from the nuclear plants. A unique feature of the disasters was that the damage was both widespread and localized. It was widespread because it impacted large continuous urban areas, e.g., Ishinomaki, and it was localized as it destroyed numerous isolated communities leaving untouched communities nearby that were not on the path of the tsunami. Finally, the time-persistence of the nuclear crisis—which lasted months—and its impacts on the response may ultimately be the defining factor as it profoundly altered the flows of goods and the very essence of the PD-HL process, particularly in the Fukushima Prefecture.

Important to the purposes of this paper is that for some communities (e.g., Ishinomaki, Minami Sanriku) the Tohoku disaster was a catastrophic event, because: "…most or all of the community built structure is heavily impacted… [and] facilities and operational bases of most emergency organizations are themselves usually hit…"; "…local officials are unable to undertake their usual work role…"; "…help from nearby communities cannot be provided…"; "…most, if not all, of the everyday community functions are sharply and concurrently interrupted…"; "…the mass media system especially in recent times socially constructs catastrophes even more than they do disasters…"; "…mass out-migrations for protracted periods of time…"; and, because of the previous processes "…, the political arena becomes even more important…" (Quarantelli, 2006; Wachtendorf et al., 2010). As discussed in Holguín-Veras et al. (2012b), the catastrophic nature of the event has a profound and dramatic impact on PD-HL because of a number of interrelated effects. First and foremost, logistic activity in general is a socio-technical process in which a social network of individuals (e.g., shippers, carriers, receivers) organize technical activities such as routing and distribution, using supporting systems, e.g., transportation and communications. In this context, events that impact any of these components have the potential to produce massive disruption. Second, large portions (and, in some cases, all) of the inventories of supplies held by households and businesses in the impacted area are destroyed, which deprives the local communities of what otherwise would be readily available critical supplies. Third, the private sector supply chains that—in normal conditions bring all the supplies needed by the community—are severely disrupted (taking them weeks to recover) or completely destroyed. Fourth, the demand for supplies at the disaster area increases tremendously due to the combined needs of: survivors, the response process itself, and local stores that perceiving a business opportunity due to panic/precautionary buying on the part of individuals—mostly from the outside of the disaster area—increased the size of their orders above and beyond what is actually needed under normal conditions. The combined impacts on supply and demand leads to a situation in which the only practical alternative is to bring the supplies from the outside. This stands in contrast with smaller disasters where local inventories and existing supply chains are able to satisfy a significant portion of the needs. The failure to recognize this crucial difference, and prepare for it, had major impacts on the response as discussed next.

OVERVIEW OF PREPARATION AND RESPONSE EFFORTS

This section provides a general overview of both disaster preparation and the response, without discussing in great detail the efforts of specific agencies, local governments, and companies. In all cases, the discussions center on the PD-HL effort as other important aspects (e.g., search and rescue, medical logistics) are outside the scope of the paper.

Overview of Disaster Preparation Efforts

The public sector interviewees reported having taking numerous steps to enhance disaster response. In all cases, prefectures and cities had response plans that outlined in some detail the actions they were expected to take in case of a disaster. However, all the interviewees

said that these plans were not followed, for the simple reason that they only considered a small disaster and not a catastrophe as the one they faced. Moreover, the respondents indicated that—with perfect hindsight—PD-HL was not adequately discussed in the response plans: in some cases it was not mentioned at all; in another "…it was just one line in the plan…" (Iwate Prefecture), and in three cases (Miyagi, Iwate, and Fukushima prefectures) was limited to identifying a handful of distribution centers or DCs, (Holguín-Veras et al., 2011d; Holguín-Veras et al., 2011b; Taniguchi et al., 2011a; Taniguchi et al., 2011b; Taniguchi et al., 2011c). Quite tellingly, none of the plans considered in adequate detail the local distribution, and how the manpower and assets required for the entire operation would be secured. As a staff of a company said: "…they were assuming that 'somebody else' would take care of the distribution of relief supplies…" (Holguín-Veras et al., 2011a). As a result and not surprisingly, PD-HL did not figure prominently in the training exercises annually conducted by local governments. The respondents could only recall two cases (Fukushima Prefecture and Ishinomaki City) with a PD-HL component, albeit small ones. In one of them, the exercise consisted of transporting supplies from the outside of the region to a DC inside the area. The other involved transporting cargo from a shopping mall to a single Refuge Center (RC), which was deemed by participants as "...simplistic…". Reflecting on the experience that they went through, a staff member at Fukushima Prefecture indicated that "…a quality exercise would have been very helpful…" (Taniguchi et al., 2011c). The lack of complex and realistic exercises involving local distribution prevented the agencies from appreciating the complexity associated with the challenge they would face in March 11th, 2011. In their favor, most of the agencies and local governments had signed cooperation agreements with potential private sector partners. In the case of the MLIT, the agreements were with construction companies for debris removal, construction work (Taniguchi et al., 2011d). In the case of prefectures and cities, the typical agreement was with the Japanese Trucking Association (JTA) for the transportation of supplies from the outside of the disaster area to the DCs operated by these governments (though some prefectures, e.g., Miyagi, reported having agreements with construction companies). Unanimously, the transportation agreements were deemed "…too general…" by interviewees (Holguín-Veras et al., 2011a; Holguín-Veras et al., 2011d; Taniguchi et al., 2011a; Taniguchi et al., 2011c) as they did not specify crucial details such as who would organize the local population, who will be the public sector person in charge of PD-HL, where the RCs would be located, how many people would be expected at each RC, who would be in charge of the local distribution of the relief aid, how much and what type of cargo would be transported, among other key operational details. Not recognizing the complexity and magnitude of the challenge associated with local distribution would have dramatic consequences. Moreover, the lack of established relationships between government authorities and transport and logistics companies—particularly local ones—hindered an efficient response. Only one prefecture (Fukushima) had an agreement with a local trucking organization (Taniguchi et al., 2011c), which seems to have worked well as the local truckers assumed from the start (though it was not explicit in the agreement) that they would take care of the local distribution. This agreement with local truckers provided the prefecture with speedy access to local assets and knowhow where and when relief supplies were needed the most.

In terms of the structure of the PD-HL networks, the disaster plans typically defined a three echelon network with the DCs managed by the prefectures at the top, a middle layer with DCs operated by the cities, and Refuge Centers (RCs) at the bottom. Implicit in this structure was the assumption that the cities would be able to undertake the PD-HL work at their DCs and RCs; and that, as a result, the role of the prefectures would be to ensure a suitable flow of supplies from their DCs to the DCs operated by the cities. Unfortunately, such assumption was not valid as the ability of the cities (which have been destroyed by the tsunami) to man, organize, and orchestrate the operations at DCs and RCs was severely hampered. This, in turn, forced the prefectures to undertake major components of the local distribution, which was a task for which they were not prepared nor they had the physical resources to operate. Thus, the disaster plans were not followed. In the chaos that ensued, some goods went directly to the city DCs, and even others to the RCs, making difficult to coordinate deliveries and conduct any form of centralized management and control. Over time, most prefectures and cities evolved towards a structure in which some of the DCs operated as warehouses of non/low-priority supplies; while others operated as DCs. In this way, depending on the type of cargo the vehicles were sent to one or the other. In other cases, non/low-priority supplies were allowed to unload at the busiest DCs complicating operations tremendously as these locations were already congested, and had limited manpower to unload, sort, store, and manage such cargo.

All the prefectures (i.e., Miyagi, Iwate, and Fukushima) and one city (Ishinomaki) indicated that they had prepositioned critical supplies (e.g., blankets, meals ready to eat, water) (Holguín-Veras et al., 2011d; Taniguchi et al., 2011b). Unfortunately, they all indicated that the prepositioned amounts "…were not enough…", which ultimately would come to haunt them as there were major delays in starting the local distribution. The companies interviewed did have inventories of food, water, and other supplies intended for their normal business operations which were used during the immediate response (Holguín-Veras et al., 2011a). The companies also had contingency plans to deal with minor emergencies and interruptions, e.g., a blackout of limited duration.

Overview of the Disaster Response

This section discusses the most salient events concerning the PD-HL response to the Tohoku disasters. To facilitate understanding of the complex response that followed, a timeline with milestones is shown in Table I. The most striking aspects of the table are the breadth of the disaster impacts that impacted all modes of transportation both in and outside the disaster area; and the time persistent effects produced by the nuclear crisis, which hampered the response for an extended period of time.

Table I – Timeline of events concerning PD-HL

Date	**Description**
3/11/2011	Great East Japan Earthquake and tsunami
	Ports, airports, highways shutdown
	Container shipping traffic stopped
	Train service suspended in Tokyo
3/12/2011	Tokyo trains to resume service
	Japanese government sends aircraft and ships

	11 out 16 East-West arterials opened
	Prefectures start receiving supplies
3/13/2011	SDF ready to mobilize 50,000 troops
	Nine expressways close, hundreds of flights canceled
3/14/2011	Ports of Tokyo, Yokohama; Tokyo airports open
3/15/2011	Lack of relief supplies reported
	Shipping companies announce efforts to help
	Yamato starts bringing supplies on volunteer basis
3/16/2011	Express carriers restore service (UPS, FedEx, DHL)
	Passenger airlines cancel flights to Tokyo
	Shortages of critical supplies reported
	Destruction of production bases described
3/17/2011	Shipping lines start to cut down service due to nuclear crisis
	Shift to air transportation noticed
	Hardships in shelters described
	Yamato approaches government to offer help
	Sendai airport opens
3/18/2011	Port of Sendai opens to relief supplies
	Ships advised to stay clear of Fukushima
	Ocean carriers cancel some services
	Humanitarian crisis increases, only a trickle of supplies
	Government criticized for lack of help
	SDF announces that will distribute supplies
	Trucking associations offer help, refused for lack of fuel
	Sagawa approaches government to offer help
3/19/2011	South Korea will donate 6,000 blankets
	Volunteers start work
	Sagawa starts operations in Ishinomaki and Onagawa
3/21/2011	110,000 blankets donated so far
	Yamato resumes operations DC to DC
3/22/2011	Oil tankers arrive at Port of Sendai
	Carrier offers free transport
3/23/2011	Oil tanker arrives at Port of Hachinobe
	Sagawa starts operations in Higashi Matsushima
3/24/2011	All ports and airports open
	Yamato starts operations in Minami Sanriku and Kesennuma
	Tohoku Motorway opens access to Fukushima Prefecture
3/25/2011	Carrier suspends calls to Tokyo and Yokohama
	Carrier resumes service to Nagoya
	Yamato resumes business/home deliveries outside disaster area
3/29/2011	Carrier turned away from China
	91% of infrastructure related requests fulfilled
	Port of Sendai opens to commercial domestic traffic
4/6/2011	Supplies reported no matching the needs of survivors
4/9/2011	Yamato starts getting paid
	Sagawa starts getting paid
4/12/2011	Trucks able to travel to Fukushima (air lift ends)
Mid-April	Private sector supply chains re-established in Kesennuma

As expected in catastrophic events, both public and private sector representatives reported major impacts on their operations (Holguín-Veras et al., 2011b; Holguín-Veras et al., 2011d;

Taniguchi et al., 2011a; Taniguchi et al., 2011c; Taniguchi et al., 2011b; Taniguchi et al., 2011d). In some cases, public sector staff were killed, injured or missing, and key components of the response system were destroyed. Topping this list is the hospital at Minami-Sanriku, which was hit by tsunami waves so high that only the individuals that made it to the roof (of a four story building) survived. In all cases, the disaster led to the collapse of power and communication systems, major interruptions of private sector supply chains, and extreme shortages of fuel (in some cases because there was no fuel at all, in others because there was no power to extract fuel from underground tanks). However, in contrast with Haiti—where the earthquake killed or injured the leadership of the key local institutions expected to lead the response (Holguín-Veras et al., 2012a)— in most of the cases the local leadership survived, led the response, and provided visible links to the outside help, which helped the response. There were exceptions such as the city of Otsushi, where town leaders gathered to coordinate the response, and died when the waves overtopped the seawall; and Minami Sanriku, where the senior leaders were killed by massive tsunami waves (Holguín-Veras et al., 2011a).

The companies interviewed were also impacted. In the case of the trucking companies 6 out of 69 DCs in Miyagi Prefecture (Yamato), and 3 out of 43 DCs in the entire Tohoku region (Sagawa) were damaged or destroyed (Holguín-Veras et al., 2011a). In addition, two DCs and a shopping mall operated by AEON were damaged, and its main DC in Tohoku was without power for a week (Holguín-Veras et al., 2011c). AEON reported a surge in demand—double than in normal conditions—for food and water, which was attributed to panic/precautionary buying as people—even those in areas that had not suffered major damage—rushed to purchase critical supplies (Holguín-Veras et al., 2011c). Thus numerous retail stores—sensing a business opportunity—increased the sizes of their orders to take advantage of the situation. This proved to be a major challenge as the main DC in Tohoku was working at 75% of capacity, and the staff had no experience on how to deal with this unforeseen situation. As soon as they organized themselves, the agencies, prefectures, and cities tried to assess the impacts on their jurisdictions.

The MLIT and one of the prefecture (Miyagi) used helicopters and planes to get an initial sense of the conditions of roads and critical infrastructure (Holguín-Veras et al., 2011d; Taniguchi et al., 2011d). The MLIT reported making good use of the 1,800 Closed Circuit Television Cameras (CCTVs) part of their state of the art Disaster Control Room (DCR) in Sendai City. The DCR has a disaster mode feature—automatically engaged when a warning is received from the national government—that focuses the CCTVs on pre-defined critical infrastructure (e.g., bridges, tunnels), and enabled the MLIT staff to get a sense of infrastructure conditions at key locations. The DCR is also a multi-agency coordination hub, e.g., it has a permanent representative of the SDF, and it is designed to be self-sufficient as it is equipped with emergency generators, food, fuel, and water for a week. One of the cities (Ishinomaki), could not use the helicopters and planes maintained by a local detachment of the Self Defense Force (SDF) because they were destroyed by the tsunami waves (the pilots did not take off once tsunami warnings were issued as it was recommended in the disaster protocols) (Taniguchi et al., 2011b). In contrast to the MLIT and Miyagi Prefecture—which were able to use planes and helicopters—most agencies did not have a good idea about the physical damage, and impacts on the population. An additional complicating matter was that

the subsidence of the ground—in some cases 1.0 m—led to flooding in high tide that reduced the effectiveness of air inspections, which had to be repeated (Holguín-Veras et al., 2011b). Following established procedures, the SDF controlled access to the disaster area (none of the interviewees were involved in access control). The interviewees reported that in the first phase, only emergency vehicles were allowed into the disaster area; in the second phase, delivery trucks were granted access; and that finally, all restrictions were lifted. Some respondents indicated that unscrupulous individuals falsely reported transporting supplies to gain entrance to the area and/or to avoid paying the tolls at the Tohoku Motorway, which had waived the tolls for vehicles involved in relief efforts.

Not widely reported in the media is that the PD-HL operations had a very inauspicious start. To start with, prefectures and cities—which had not even identified PD-HL as a critical function in their disaster plans—made no provisions for it. Most likely influenced by their experience with small disasters in which PD-HL is of secondary importance, they failed to recognize that catastrophic events require complex PD-HL operations in which most of the relief supplies have be transported from the outside. Moreover, as hundreds of thousands of individuals needed critical supplies, PD-HL became a monumental challenge for which they were not ready. As a result, for at least the first six days of the crisis hundreds of thousands of survivors did not receive relief supplies (Daily Yumiuri, 2011; Sakurai, 2011). This prompted heavy criticism of the official response, which was accused of ignoring the plight of the survivors: a member of the Democratic Party of Japan said, "…The prime minister and Mr. Edano [Chief Cabinet Secretary] are focusing too much on the accidents at the nuclear reactors, and not caring enough about the evacuees…" (Daily Yumiuri, 2011). In response, in day seven of the crisis, the SDF announced that it will distribute relief supplies to the pockets of individuals that survived the disaster (Daily Yumiuri, 2011). The crisis would have been much worse, if not by the admirable community spirit of the Japanese that led them to share the supplies they had with their neighbors, as corroborated by the first author in Higashi-Matsushima (Holguín-Veras, 2011). In spite of that, the human suffering due to the lack of critical supplies was significant, though it did not lead to widespread riots. However, looting of warehouses in the Watanoha district of Ishinomaki and the robbery of a bank were reported to the authors (Holguín-Veras et al., 2011a). At this juncture, everything seemed to indicate that—with the SDF strained to the limit—and the normal private sector supply chains severed, that a huge humanitarian crisis was unavoidable. Fortunately, fate intervened in the form of a handful of trucking/distribution companies (e.g., Yamato, Sagawa, Nittsu, and Akado) that—because of their role in the food and retail sectors—were in a position to know that the private sector supply chains had been severely disrupted, and that the public sector was not ready to fill the gap. They recognized that a huge humanitarian crisis was looming and that without their intervention things would get much worse. Independently of each other, they approached local officials during the period March 15th-19th and took the unprecedented step of volunteering to do local deliveries of relief aid (Holguín-Veras et al., 2011a). In the two cases interviewed for this paper (i.e., Yamato and Sagawa), the companies paid for the full costs of the local distribution (and the initial wave of supplies that they distributed) during the first week, and continued doing volunteer work for almost a month of PD-HL operations, in entire cities (Holguín-Veras et al., 2011a). Without their timely intervention—and the assets, expertise, and supplies they brought with them—the situation

in Tohoku would have taken the path of Haiti, where the lack of help from the local business class contributed to a crisis of huge proportions (Holguín-Veras et al., 2012a). Ironically, many other trucking associations and companies volunteered their services, though their offers were rejected because the government could not guarantee the fuel for the return trips (Daily Yumiuri, 2011). Although it is not the objective here to second guess decisions made in the midst of chaotic field conditions, it is important to highlight that using SDF's assets to transport fuel to the disaster area would have enabled the government to accept the help from the private sector, thus expediting the relief effort. This point was made by an anonymous source that told the Japanese media that "Giving these firms preferential access to fuel would be one way to help us get more aid on the road to Tohoku,"…"There isn't a lack of supplies." (Daily Yumiuri, 2011).

The volunteer companies did not have an easy time as they faced numerous challenges, notwithstanding their high level of professionalism, experience, and the fact that one of them (Sagawa) "…learned from the 1995 Kobe earthquake experience...". In most cases it took the companies more than a week to start distributing supplies to the RCs, which began during the period March 19th-25th, 2011. The staff reported being shocked and overwhelmed by the complexity and magnitude of the challenge. Unanimously, they complained about: not having a good idea about the actual needs at the RCs, not knowing the conditions of roads and bridges, the lack of a single person in command of the PD-HL effort, and above all, of the challenge of doing local deliveries in a disaster zone. In their own words: "…transporting to DCs was easy…", while "…transporting to RCs was very difficult…" (Holguín-Veras et al., 2011a). The experience of these world class companies clearly show that the local distribution of critical supplies cannot be taken for granted; and that the response plans for catastrophic events must seriously take into account, and prepare for, such challenging effort.

An even more complex scenario was presented to the leaders of Fukushima Prefecture as the nuclear crisis had a major impact on both the response and the local population. First, it deterred the flow of volunteers and supplies to areas within a large radius around the nuclear plants due to concerns of radiation exposure. This led to a situation in which local responders were left to their own devices and the help they could get from the overextended SDF. Although the authors could not find hard data to assess the extent of the problem, there is substantial evidence that illustrates that the nuclear crisis had a significant deterrence effect. For instance, in the days after the crisis started airlines canceled numerous flights to Northern Japan and Tokyo (Journal of Commerce, 2011a), major shipping companies rerouted their ship schedules to avoid nuclear contamination (Journal of Commerce, 2011g; Journal of Commerce, 2011e; Journal of Commerce, 2011d), and even the U.S. Navy ships pulled out of the area due to the radiation risk (Reuters, 2011). However, in contrast to other areas where infrastructure had been devastated, most roads were passable. In this context, the Fukushima Prefecture was having a very difficult time mounting the relief effort because they also had to contend with the impacts of the nuclear crisis (Taniguchi et al., 2011c). The most significant of the impacts on the PD-HL effort was that countless truckers decided to stay away from the entire prefecture thus reducing the flow of supplies, similar to what was observed after Hurricane Katrina when truckers abandoned the relief effort upon hearing that a second hurricane was coming (Holguín-Veras et al., 2007). Although there are no data, the

prefecture staff indicated that "…a large number…" of truckers simply unloaded their cargo at the border of Fukushima Prefecture (e.g., Koriyama) or simply parked the trucks and left, even though the destinations were well outside the exclusion zone. Of great significance was the case of 36 fuel tankers that—at the height of the crisis—were left about 50 km from their destination, which required sending drivers to retrieve the trucks and their critical cargo (Taniguchi et al., 2011c).

Further complicating the matter, the nuclear crisis led to a situation in which almost all supplies had to be transported by plane to the Fukushima Airport. This was because: (1) of the inability of using highway transport because of potentially long exposures (the closing of the Tohoku Motorway until March 24th led to great uncertainty about travel times in the network); and, (2) planes have relatively short exposure times as they could quickly enter and leave the area. At the beginning, only official planes were allowed to land as there were no resources to sort donations. Planes were the main form of transportation until April 12th, 2001 when highways were finally opened. The PD-HL operations were further complicated by the orders issued by the Japanese government to minimize nuclear exposure. As a result, large segments of the population had to relocate elsewhere, while others were asked to stay indoors (including areas that had been impacted by the earthquake and tsunami). The Fukushima prefecture staff reported that, in spite that the national government had instituted a 20 km exclusion zone with a mandatory evacuation, and another zone between 20-30 km where people could leave but not return, many individuals stayed on both. For that reason, the prefecture asked Tokyo Electric Power and SDF to distribute supplies on their behalf. The suffering of those that stayed behind is dramatically illustrated in the video uploaded to the Internet by the mayor of Minami-Soma (Sakurai, 2011). In the video, he discusses in agonizing details how the nuclear crisis both forced the survivors indoor, and prevented the arrival of the volunteers and supplies they needed. Pleading for volunteers willing to "…act at their own risk…" that "…could bring in petrol (so that they could leave)…", he described their plight. He implied that large numbers of residents stayed indoors to reduce the risk of nuclear contamination; could not leave because of lack of fuel and vehicles and the impassable roads; and were not receiving the supplies needed.

The Tohoku experience yet again demonstrated the problems caused by excessive donations of non/low priority goods. This phenomenon, i.e., material convergence (Fritz and Mathewson, 1957), has been identified in all large disasters and has been labeled as a "…second tier disaster…" (Newsweek, 2002). The convergence of non/low-priority goods is extremely problematic as it arrives in very large volumes, at a time at which the responders are busy with other more important activities, disrupting operations. The trucking companies interviewed—which were responsible for the operations of the DCs and had to deal with the problem—estimated that between 50% and 70% of the cargo handled was not needed at all and should not have been sent there (Holguín-Veras et al., 2011a; Jaller, 2011). This is consistent with the literature on the subject that suggest 60% (Fritz and Mathewson, 1957), and with the observations of the authors on the Katrina and Haiti disasters (Holguín-Veras et al., 2007; Jaller, 2011; Holguín-Veras et al., 2012a). The amount of resources required to manage this humongous and uncoordinated flow of goods is significant. As an illustration, when the authors visited the Iwate Industry and Culture Convention Center in Iwate Prefecture, one third of the staff at this large facility were sorting the unnecessary clothing

that had been donated (20 out of 60 workers) that was occupying about 40%-50% of the floor space. The consensus was that blankets, clothing (both used and new), and water were the top three non/low priority supplies. The case of blankets (and water) is illustrative of the dynamic nature of priorities as during the first week of the response they were high-priority because of the prevailing cold weather. However, as the weather warmed up, blankets ceased to be high-priority and became a nuisance as hundreds of thousands of them from prefectures in Japan, and countries like Canada (25,000 blankets) and South Korea (6,000 blankets) descended on Tohoku (Kyodo News, 2011a; Kyodo News, 2011b) producing major complications on the response.

LESSONS LEARNED

The interviews conducted with the participants in PD-HL efforts concluded with questions about lessons learned, and what they would advise others or would do differently based on the experience they gained. Their answers are summarized in Table II, which shows that the responses are dominated by the perceived inadequacy of the disaster plans, and the importance of putting in place a number of steps to improve communication, coordination, and efficiency of the overall response.

Table II – Lessons learned as stated by the interviewees

	Key lessons learned:	**What to do differently, advise to others:**
MLIT	Reality is more difficult than what described in the disaster plan. Planning for larger disasters is extremely important.	Communications with local MLIT offices should have been better.
Miyagi Prefecture	The response required resources that they did not have. Better communication equipment and helicopters were needed. The importance to have strong linkages between municipalities and prefecture. Biggest challenge: perishables and isolated towns.	To provide subsidies to municipalities so that they purchase satellite phones.
Iwate Prefecture	The importance of: (1) adjusting to conditions, e.g., allowing the person in charge of a DC to decide without consulting superiors worked well; (2) establishing a relationship with logistic companies before the disaster, too difficult to do it after; (3) unified command at DCs, e.g., having two groups doing distribution and inventory management caused problems; and, (4) having female teams to asses needs of female IDPs (men-only had lots of problems).	There should be only one person in charge of humanitarian logistics, with the power and financial resources to do what is needed. One important thing that the national government should do is to help pay for the expenses. Create female teams to assess the needs of women.
Fukushima Prefecture	The importance of: (1) using the right type of trucks (2 trucks are the best); (2) providing psychological assistance to IDPs; (3) using helicopters for search and rescue, and transporting supplies to inaccessible places; and, (4) responding within 3-7 days. Google Earth and ITS-Japan helped with satellite pictures and information about road conditions.	Recognize the importance of evacuation and provision of information. Assess bridge conditions with inspectors. Take advantage of satellite imaging to assess infrastructure conditions. Try to get satellite pictures sooner.

Kesennuma City	Everything. Disaster plan did not work because it assumed that only part of the city would be damaged (the entire city was destroyed). The basic assumption was wrong. The importance of satellite phones. Did not have the equipment, electricity, phones. Had to do basic things: receiving, storage, distribution by hand.	Emphasize humanitarian logistics, which is not considered in disaster planning.
Yamato	Gap between demand and supply dynamically changed. Government must have closed it sooner. Clothing donations were a problem (too difficult to match to survivors). The level of priority of supplies changes with time.	To prepare good response plans. To find ways to accurately estimate the needs based on lifestyle and community habits. Government should engage the private sector sooner.
Sagawa	Lack of planning for private-public work led to problems. Military forces collaborated really well. SDF did not collaborate well with cities, though it did a very good job in delivering supplies to isolated places. The difficulty of local distribution: "…long haul was OK, but distribution from DC to RCs was very difficult, we need more planning and coordination…"	To put someone in control, "…nobody in control of who delivers to the people in need…" Improve agreements between prefectures and JTA so that they include local distribution. Need to reduce the excessive reliance on SDF which only delivers basic supplies and has a lot of problems because their vehicles (mostly troop carriers) are not designed for logistic duties.
AEON	The need for emergency generators. That they could work without computers, power, and modern technology. Experience with other modes (before: only rail and trucking; after: water transport), thinking to send containers by water. The importance of setting up a command center quickly, and prepare rations for IDPs.	They would try to have control on the total flow of cargo. Store owners ordered supplies without considering the entire picture. Install emergency generators.

CHIEF FINDINGS AND POLICY IMPLICATIONS

The experiences of the participants in the response to the Tohoku disaster provide important lessons for disaster preparation and response. This section summarizes the key lessons, and puts forward a set of policy recommendations. To facilitate the analyses, the key lessons have been summarized as follows:

(i) The disaster plans, particularly at the prefecture and city levels, failed to consider and prepare for worst case scenarios as they only focused on the small events that they could handle on their own. This proved to be inadequate. In this context, it is crucial to issue guidelines that require disaster response plans consider a wide range of scenarios, and particularly large catastrophic events spanning over multiple jurisdictions.

(ii) Not having disaster plans that, in detail, considered PD-HL operations hampered public sector response as local officials had to confront the crisis without any guidance about how to proceed. Thus, it is important to develop specific and detailed disaster plans for mid/large cities. The plans ought to discuss in detail location of DCs

and RC, alternative arrangements in case that some of these facilities are damaged, staffing arrangements, role of prepositioned supplies, and the like.

(iii) The lack of designated local leader with primary responsibility for coordination of the PD-HL and with strong linkages to the logistic industry produced numerous problems. As a result, companies and individuals interesting in supporting the relief operations did not know whom to contact to offer help and coordinate efforts. Thus, it is important to have visible and competent points of contact that could become the coordinating hub of the PD-HL effort.

(iv) The private sector in the construction, transportation, and retail sectors played a key role as they brought to bear expertise and assets that benefited the response. However, the participation of transportation companies was improvised, unanticipated, and at times refused. This stresses the need for a framework that allows the efficient integration of the private sector, and by extension community groups and local social networks that could help in the response.

(v) The most challenging part of the entire PD-HL process was the local distribution. For that reason, disaster planning must undertake the necessary steps so that relief agencies, private sector, local social networks, and community groups are prepared to deal with the challenge. As the experience of Haiti shows (Holguín-Veras et al., 2012a), the integration of the local communities to the effort could play a fundamentally important role as in most disasters they are the only ones that could provide the manpower and local knowledge needed to man the points of distribution .

(vi) The lack of training and realistic exercises on PD-HL significantly diminished the effectiveness of the public sector response to the disaster. It is very telling that, among the 60 individuals that participated in the interviews conducted, only about ten had experience in commercial logistics, and that none of them had any previous exposure to PD-HL. This highlights the need to significantly increase the institutional capacity of disaster response agencies on PD-HL.

(vii) The unavailability of technologies and systems to quickly assess the conditions of the transportation network and other critical infrastructures hampered the response. This highlights the need for integrated systems that combine satellite imagery, remote sensing, and geographic information systems to provide local responders with an assessment of infrastructure conditions. These systems must be complemented with proper communication, computer, and backup systems, and the assets needed to do local inspections.

(viii) The lack of efficient communications with the field was a negative factor that difficult the assessment of needs. For that reason, ensuring good communication should be a key priority to ensure a timely assessment of the needs on the ground. This may requires prepositioning of either satellite phones, or priority phones with preferential access to bandwidth, at strategic locations—together with appropriate

charging mechanisms, e.g., small generators with a supply of fuel—so that they could be quickly deployed and used for extended periods of time.

(ix) The bulk of the relief supplies had to be transported from the outside of the impacted area, as expected in the response to catastrophic events. This is because private sector supply chains are severely disrupted, significant portions of the local inventories at household and businesses are destroyed, there are significant increases in demand for supplies, and transportation networks are impacted. Moreover, since the evidence from both Japan and Haiti (Holguín-Veras et al., 2012a) indicate that private sector supply chains started to become functional about two weeks after the disaster took place, it is important to preposition supplies in the vicinity of mid/large metropolitan areas so that they become the first wave of resources to reach the impacted area.

(x) Lack of fuel for the return trips prevented the volunteer participation of numerous trucking companies during the initial days of the crisis. The importance of fuel is difficult to overstate, as without it the PD-HL effort collapses. For that reason, disaster response plans must make specific provisions to ensure that an adequate supply of fuel is available at the disaster site so that it could be shared with the companies participating in the PD-HL process.

(xi) The large flow of non/low priority donations created numerous problems as they consumed significant amounts of resources, were not needed, and arrived at a time at which there were more important activities to undertake.

(xii) Precautionary/opportunistic buying by individuals outside the disaster area aggravated the PD-HL challenge. Although it is natural for individuals living close a disaster to buy critical supplies out of concern for shortages, such purchases prevent the use of these supplies for the benefit of the survivors in the disaster area, and the overall research effort.

The findings summarized in this section provide the basis for the identification of a number of policy recommendations that, in the opinion of the authors, could play a key role in improving PD-HL response to future events. A central element of these recommendations is the goal of ensuring scalability of the PD-HL operations as this may be the only way to ensure robustness of the disaster response plans. These recommendations are discussed next.

Recommendation #1: Integrate civic society in disaster preparation and response efforts. As outlined in findings (i) thru (vi), many of the problems encounters in the PD-HL response were the result of the lack of familiarity with the unique demands that a catastrophic event would impose on the PD-HL efforts. This insight, together with the analyses of the factors that explain the performance of the construction sector response, suggests the convenience of integrating key representatives of the civic society and the commercial logistic industry—and particularly those involved in the distribution of food, water, medicines, and other supplies likely to become critical after a disaster—to help lead the local PD-HL effort. As part of this concept, a committee of representatives of disaster response agencies, key private sector companies, trade associations, community groups, churches,

and any other group that could contribute a large social network, would be trained and certified as PD-HL area leaders, and charged with orchestrating the effort in case of a disaster. In essence, these representatives of the civic society would become part of a reserve of post-disaster logisticians that would be called into action if the need arise. It is important to mention that this concept is similar to the standard practice in other areas, e.g., medical teams, in which the need to incorporate specialized help from the outside has long been recognized. In this context, the incorporation of outside groups and expertise would complement the public sector effort in notable ways because it will: (1) enable logistic professionals with deep knowledge of local conditions to lead the effort; (2) ensure access to the regional private sector logistic networks that extend beyond the jurisdiction of the public sector agency; (3) contribute to the effort strong connections to the rest of the private sector expanding the potential pool of assets available; (4) provide the logistic effort with access to the existing social networks of volunteers that are likely to prove influential in community organizing efforts, and local distribution of critical supplies. The latter will address one of the major challenges in PD-HL as organizing the population, splitting and distributing rations, and other related tasks require a significant amount of power (Holguín-Veras et al., 2012a). To this effect, the authors' recommendation is to proactively engage local churches, community groups and the like so that they become the backbone of the local distribution effort (Holguín-Veras et al., 2012a). Achieving this could open the door to new paradigms of disaster response through better integration of efforts. Moreover, the incorporation of broad sections of the civil society as part of the disaster planning process would allow them to contribute ideas, and know what may be expected from them in the case of a disaster.

Recommendation #2: Design plans for a wide range of events. One of the key lessons from the Tohoku experience is that the scalability of a response function cannot be taken for granted. Thus, the key to robust design of disaster plans is to ensure that the plans are able to function well in a wide range of conditions. To ensure that a given operation is scalable, disaster planners must assess the wide range of needs (from small disasters to large catastrophes) and design scalable design response operations, i.e., that could satisfy the needs by simply adjusting upwards or downwards the amount of input resources to provide the supply of goods and services needed at the site. The dual effort of careful studying the wide range of needs, and designing the corresponding response functions in a way that could be seamlessly expanded or contracted to meet the needs in the ground will ensure that the same template of action be used in a wide range of scenarios. Taken together, these recommendations could significantly increase robustness and flexibility of disaster response plans.

Recommendation #3: Design plans for easy integration of outside help. The complexity and magnitude of the PD-HL, particularly the ones after large disasters and catastrophes, clearly suggests the need to engage all segments of society in the response as this is the only way to minimize human suffering. However, doing so requires considerable planning to avoid duplication of efforts, interference, and all the other problems that arise from lack of coordination; as well as the establishment of clear priorities that ensure maximum effectiveness of the delivery of aid. Achieving this requires, in addition of coordination, a reasonable subdivision of the tasks to be performed, and a minimum level of standardization of individual assignments so that there is common agreement what needs to be done. In the PD-HL case, this may require subdividing a large urban area into smaller districts to be assigned to the different groups; as well as minimum training to ensure that all involved do their jobs reasonably well.

Recommendation #4: Train potential participants in PD-HL. It is important to recognize that PD-HL is a highly technical and complex activity. It stands to reason that if large private

companies employ teams of professionals to organize their routine logistic activities, the more complex PD-HL efforts which have a direct impact of human suffering should be granted equal or higher professional status. To this effect, a significant effort should be undertaken to enhance the technical capabilities of all individuals expected to be involved in a PD-HL effort. As part of this, it is important to: train all potential participants, including private sector logisticians, on the basics of PD-HL operations. This must include: use of standards of humanitarian aid, proper procedures to control material convergence, modeling demand needs after disasters, estimating impacts on physical infrastructure and provision of alternative means of transport, use of different communication technologies in order to avoid information loss, team building and stress management trainings. And to conduct exercises, both real and simulated (table top), so that all participants develop a sense about what may be expected in a real life scenario.

Recommendation #5: Preposition critical supplies and equipment. As amply illustrated in this paper, an established in Holguín-Veras et al. (2012b), in the aftermath of a large disaster or a catastrophe it is not realistic to expect that local responders and resources could provide a meaningful first wave of resources to help survivors. This is the net result of the likely destruction of local inventories and logistic assets, the huge increases in local needs, and that the minimal inventories that characterize modern supply chains cannot be counted to be enough to satisfy the emergent needs (Holguín-Veras et al., 2012b). The fundamental implication is that the bulk of the critical supplies needed must be brought from the outside of the disaster area. There are two potential sources for such supplies: (1) supplies stored by private sector operators in regional distribution centers and warehouses; and (2) emergency stocks of critical supplies maintained by disaster response agencies. In cases, where there is a regional inventory of critical supplies and equipment that is not likely to be destroyed by a large catastrophic event, such supplies could be counted to be part of the first wave of resources reaching the site, as long as they are located in relatively close proximity to the urban area in question. However, this would require the establishment of contractual agreements with the corresponding private sector operators to ensure that the cargo could be requisitioned in case of need. In situations where no such regional distribution networks exist, or when the amount of cargo is not enough to provide a first wave of resources, the only alternative is to rely on prepositioning of critical supplies by disaster response agencies. It is important to stress that it is not advisable to rely on local inventories of critical supplies and equipment as these are susceptible of damage and destruction by the event. The cases of Haiti and Japan made this point abundantly clear.

Recommendation #6: Control material convergence and precautionary/opportunistic buying. The research reported in this paper, yet again, highlighted the problems created by the non/low priority component of the material convergence generated by a disaster; and the necessity to implement proactive procedures to dampen precautionary/opportunistic buying. In terms of material convergence, it is important to: (1) ensure that proper control procedures are in place to allow only high priority supplies to enter the disaster area, divert low priority supplies to secondary DCs in the outskirt of the impacted areas, and refuse/destroy non priority supplies; (2) implement proactive donation management plans that: provide potential donors with guidelines about what and when to donate; (3) engage the media so that they convey a realistic representation of needs; and (4) use information systems to try to match needs on the ground to potential donations (Jaller, 2011; Holguín-Veras et al., 2012b). Disaster response agencies must also take steps to ensure that precautionary/opportunistic buying of critical supplies does not deplete stocks of critical supplies in the vicinity of the disaster area, which are the supplies best positioned—for reasons of proximity—to be the first wave of resources reaching the site. Thus, it is important to control such buying as much as possible so that these supplies are available for the benefit of survivors. To this effect, it is

important to: establish agreements with key private sector vendors to allow the immediate requisition of the critical supplies they may have in stock, educate the population about the need to avoid buying in excess of needs, engage the private sector so that they help steer supplies to the disaster area, put in place rationing schemes until the situation stabilizes, among other potential demand management measures.

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