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Capturing Real-Time Data in Disaster Response Logistics

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ABSTRACT: The volume, accuracy, accessibility and level of detail of near real-time data emerging from disaster-affected regions continue to significantly improve. Integration of dynamically evolving in-field data is an important, yet often overlooked, component of the humanitarian logistics models. In this paper, we present a framework for real-time humanitarian logistics data focused on use in mathematical modeling along with modeling implications of this framework. We also discuss how one might measure the attributes of the framework and describe the application of the presented framework to a case study of near real-time data collection in the days following the landfall of Typhoon Haiyan. We detail our first-hand experience of capturing data as the post-disaster response unfolds starting on November 10, 2013 until March 31, 2014 and assess the characteristics and evolution of data pertaining to humanitarian logistics modeling using the proposed framework. The presented logistical content analysis examines the availability of data and informs modelers about the current state of near real-time data. This analysis illustrates what data is available, how early it is available, and how data changes after the disaster. The study describes how our humanitarian logistics team approached the emergence of dynamic online data after the disaster and the challenges faced during the collection process, as well as recommendations to address these challenges in the future (when possible) from an academic humanitarian logistics perspective.

Keywords: Humanitarian logistics, real-time data, classification, logistical modeling, Typhoon Haiyan.

1. INTRODUCTION

Over the past two decades, the field of humanitarian logistics has progressed significantly, with a growing number of researchers and practitioners studying problems, such as relief distribution, post-disaster debris removal, and evacuation of affected populations. Much work within the academic community has focused on the development and application of operations research tools for humanitarian logistics (e.g., see recent surveys: Altay & Green, 2006; Ergun, Karakus, Keskinocak, Swann, & Villarreal, 2010; Kovács & Spens, 2007; De la Torre, Dolinskaya, & Smilowitz, 2010). As the ultimate goals and benefits of these efforts are to improve real-world applications, integration of in-field data is an important, yet often overlooked, component of such humanitarian logistics models. For example, in their recent review, Sangiamkul & Hillegersberg (2011) identify only two papers (Sheu, 2010; Yi & Özdamar, 2007) out of 30 surveyed that use real-time data in logistical modeling. In another survey, Ortuño et al. (2013) describe only two papers among 87 that integrate dynamically up-dated data. Finally, Özdamar & Ertem (2015) acknowledge three papers (Sheu, 2010; Yi & Özdamar, 2007; Huang et al., 2013) out of 110 studies mentioned in their review of humanitarian logistic models, solutions and technologies that capture such data. Outside these academic disciplines, extensive efforts have been made in information communication technology, especially in regard to the use of social media and crowdsourcing in disaster management At the same time, the volume, accuracy, accessibility and level of detail of near real-time data emerging from disaster-affected regions continue to significantly improve Considerable efforts are currently focused on the collection, aggregation and dissemination of field data, which, together with the help of the humanitarian logistics decision tools, have the potential to considerably impact relief efforts In this paper, we present a structure for analyzing humanitarian logistics data, explore the process of retrieving real post-disaster relief data from sources available online, and examine the data for the purpose of integrating data streams into response logistics models to facilitate future modeling.

We present a framework for evaluating real-time humanitarian logistics data focused on use in mathematical modeling. The framework reflects the integration of our recent experience of near real-time data collection, a survey of different communities producing data and disciplines using data, and a development of measures to evaluate the quality of data and applicability to other disasters for logistical modeling We also discuss how to measure the attributes of the framework and describe the application of this framework to a case study of near real-time data collection in the days following the landfall of Typhoon Haiyan. We detail our first-hand experience of capturing data as the post-disaster response unfolded, starting November 10, 2013 until March 31, 2014 and assess the characteristics and evolution of data pertaining to humanitarian logistics modeling. The case study, illustrating our information retrieval process, presents an example of the classification of data and data sources using the proposed framework. The logistical content analysis, using the available information following Typhoon Haiyan, examines the availability of data and informs modelers about the current state of near real-time data. This analysis illustrates what data is available, how early it is available, and how the data changes after the disaster. The study describes how our humanitarian logistics team approached the emergence of dynamic online data after the disaster and the challenges faced during the collection process, as well as recommendations to address these challenges in the future (when possible) from an academic humanitarian logistics perspective.

This study signifies the importance of an interdisciplinary team approach when exploring real-time humanitarian logistics data, its value and challenges. The retrieval of information needed for humanitarian logistics models and knowledge of in-field data collection and dissemination come from a unique collaboration between logistical researchers and humanitarian practitioners. This research shows that well-formed and growing relationships allow for parties to gain insights into each other's respective use of terminology and broader domains. Such insights may enable each party to alert the other about potential opportunities for exploration, such as the uniqueness of Typhoon Haiyan with regards to public data, while the modelers can inform the practitioners and the broader humanitarian response community about the needs for accessible field-appropriate data for the on-ground-personnel or agencies to aid in their operations.

The rest of the paper is organized as follows. The following section provides some background information, which includes a literature review of different communities involved in data generation, processing and dissemination, and a description of disciplines using humanitarian logistics data. Next, section a proposed framework for humanitarian logistics data with respect to humanitarian logistics modeling is presented with the focus on data quality and applicability measures, and the framework implications for mathematical modeling. An application of this framework to the recent Typhoon Haiyan is illustrated with a logistical content analysis and describes the lessons learned. This paper concludes with final remarks on scarcity of data and points up the need for humanitarian logistics models that integrates multidisciplinary work to validate the limited data.

2. DISASTER RESPONSE DATA STAKEHOLDERS

Multiple entities play a role in the evolution of post-disaster data via collection, processing or dissemination. Furthermore, various communities are the intended users and beneficiaries of this data. Understanding the roles and motivation of the key stakeholders is essential to analyzing the emergence of near real-time data following a disaster. In this section we describe the data-gathering communities and the disciplines using the data.

2.1 Data-gathering Communities

Altay and Labonte (2014) discuss the challenges of information management and coordination amongst intergovernmental organizations, such as OCHA, government and non-governmental organizations in the case of the Haiti response in 2010. The United Nations Foundation Disaster (2011) examines the future of information-sharing in humanitarian emergencies with a focus on volunteer and technical communities, such as OSM and Crisis Mappers (2014). The response to the Haiti earthquake highlights the disaster response operations where thousands of volunteers around the world collaborated around various information communication technologies to inform the public about the affected population. Grünewald and Binder (2010) analyze the humanitarian response following the Haiti earthquake and discuss the inter-agency real-time evaluation. They also provide the list of people consulted from different organizations from government, donor representatives, international NGOs, national NGOs and UN agencies. These studies provide a good starting point for the main stakeholders in data gathering.

We also survey a number of practitioners and responders involved with Typhoon Haiyan and other major responses (e.g., the earthquake in Haiti) through the pre-existing relationships of our team members with other humanitarian practitioners and responders. These surveys and relationships brought to our attention considerable amount of disaster relief operations relevant data and their sources. In addition, the on-ground personnel involved with major responses, including Typhoon Haiyan, assisted the team with assessing reliability and understanding the nature of the datasets and the data sources.

We first present the key players we observed in the data collection, processing and dissemination, motivated by the literature, survey of practitioners and our observations of publicly available online data and information sources between November 10, 2013 and March 31, 2014 following Typhoon Haiyan.

Large International Humanitarian Response Organizations

The United Nations Office of Coordination for Humanitarian Affairs (OCHA) aims to plays a critical role in “mobiliz[ing] and coordinat[ing] effective and principled humanitarian action in partnership with national and international actors in order to alleviate human suffering in disasters and emergencies” (OCHA, 2014e). In the immediate aftermath of a disaster, when OCHA receives an international call for providing assistance, it often sends United Nations Disaster Assessment and Coordination teams to provide an initial assessment of the situation (OCHA, 2014d). The information management activities within OCHA aim to support information collection and sharing needs of humanitarian actors to support coordination (OCHA, 2014c). In large disasters, responding organizations often coordinate in “clusters” based upon major sectoral activities, such as logistics, health and shelter. In such cases, the information collection, management and sharing are often targeted to the specific cluster’s activities. For example, in Typhoon Haiyan, specifically, OCHA facilitated the activities of 11 clusters (CCCM, 2014).

Information management activities at OCHA take advantage of different types of information in different phases of the response. According to OCHA’s description of its services, they aim to create and share information in media that are simple to understand and easily accessible. Datasets including common operational datasets, contact lists, and “who, what, where” data are also maintained and shared by this group. Shared documents in the form of portable data formats (PDF) reports and maps are frequently used .

Geographic information system (GIS) data plays a key role in OCHA's information management (IM) services. Recent collaborations with external organizations, including MapAction, Humanitarian OpenStreetMap Team (HOT) and GISCorps, have advanced the timely processing of map generation. These organizations sometimes leverage microtasking and crowdsourcing methods to process large amounts of geographic information from imagery datasets and non-traditional geographic sources (e.g., satellite imagery, photos).

National Government

After a disaster, the host government coordinates governmental departments and agencies, such as the department of health, department of defense and emergency management authority, for its disaster response. For example, in the case of Typhoon Haiyan, The National Disaster Risk Reduction & Management Council (NDRRMC), which functions under the Department of National Defense, managed gathering and reporting data (NDRRMC, 2014). In addition to NDRRMC, the Department of Social Welfare and Development (DSWD) played a crucial role in providing information about affected citizens (Presidential Management Staff, Presidential Communications Development, & Strategic Planning Office, 2014). A detailed description of these two government offices' role in Typhoon Haiyan with respect to data efforts is provided inthe Appendix

Digital Humanitarians

The Digital Humanitarian Network (DHN) is a consortium of volunteer and technical communities that "provide an interface between formal, professional humanitarian organizations and informal yet skilled-and-agile volunteer and technical networks" with the purpose "to leverage digital networks in support of 21st century humanitarian response" (DHN, "About", 2014). In the case of Typhoon Haiyan, OCHA activated DHN immediately after the disaster. According to media reference, this was the first time officials were appointed to coordinate the crowdsourced mapping efforts with volunteer groups (Butler, 2013) during the early stage of the response. Some of these volunteer groups include HOT, Standby Task Force and MapAction. The general role of HOT is to serve as a bridge between the OSM community and the traditional humanitarian relief organizations In the Philippines, there were more than 1000 OSM volunteers from 82 countries who provided maps to nongovernmental organizations, including Doctors without Borders (Butler, 2013) and the American Red Cross (OSM, "Typhoon Haiyan"). The Standby Task Force analyzed more than one million texts, tweets and other social media posts with the help of MicroMappers software, which uses machine-learning techniques to filter potentially relevant messages (Butler, 2013). MapAction, a longtime partner of OCHA, worked in the Philippines to generate more than a hundred files per day to be shared with the disaster relief community. With all these efforts, the data from Typhoon Haiyan is a notable example of the evolution of collaboration between digital humanitarian and response agencies, where access to information, collaboration and the next steps of information-sharing were pushed forward.

Operationally-focused Humanitarian Practitioners and Responders

Humanitarian practitioners and responders (both local and international) in affected regions are often among the most knowledgeable people about the changing post-disaster environment. They are frequently aware of information sources and datasets, sometimes generating data themselves, which may not only reflect the current context but also represent information and data used by organizations for planning and executing response activities. In our experience, the pre-existing relationship of our practitioner team member with other practitioners and responders has brought tremendous value to identifying and better understanding various information outlets and how they can be integrated in future logistical models using real-time data.

As information communication technology improves, connecting with responding humanitarian organizations, theoretically, is more feasible. However, developing trusting relationships and personal networks still requires years of engagement in working with people from various backgrounds, often having different short-term goals but with common overarching missions.

2.2 Disciplines Using Data

Current humanitarian logistics models aim to capture real-time data in order to improve their decision support tools. Here, we discuss how the data is used in these models and the assumptions the researchers make, especially in relation to the data availability. Various disciplines utilize humanitarian logistics data and impact the changes in data collection, processing and dissemination. Therefore, the role and purpose of each discipline as it relates to real-time data should be taken into account by the logistics modelers in order to better understand the data characteristics.

As modelers studying the real-time humanitarian logistics data focused on use in mathematical modeling ourselves, we naturally investigate the academic humanitarian logistics as one of the disciplines benefiting from data. The efforts on understanding data gathering communities (such as literature review and surveys) enlighten us about the other disciplines benefiting from humanitarian logistics data. Similarly, the work on digital humanitarians enables us to recognize the importance of information and communication technology for understanding the current status of the real-time data, its implications and challenges. Thus, in addition to the academic humanitarian logistics discipline, we also discuss the role humanitarian data plays for practitioners, the intended primary users of this data, and information and communication technology (ICT), the data collection, processing and communication facilitators.

Academic Humanitarian Logistics

We first describe the current efforts of humanitarian logistics models with real-time data. As mentioned previously, although the number of models related to humanitarian logistics is growing, models with real-time data are limited. We review those papers below.

Liu and Ye (2014) present a decision model for the allocation of relief resources in natural disasters using information updates. These updates predominantly contain information on disaster states (population transfer rates) and traffic conditions (road affected level). Authors suggest that this information can be obtained from the disaster database of governmental agencies, such as the National Oceanic and Atmospheric Administration (2013), the National Climatic Data Center, and the National Geo-physical Data Center, among others. Liu and Ye apply their model to the Wenchuan earthquake in China with data provided by China's National Committee on Disaster Reduction.

Sheu (2010) develops a dynamic relief-demand management model that forecasts the demand in real-time and dynamically allocates supplies based on those forecasts, as well as urgency and population vulnerability measures. The main components of the information used in the model are 1) time-varying ratio of the estimated number of trapped survivors relative to the local population; 2) population density associated with a given affected region; 3) proportion of frail population (e.g., children and the elderly) relative to the total number of population trapped; 4) time elapsed since the most recent relief arrival; and 5) level of building damage. Sheu uses the official statistics from the 921 earthquake (also known as the Jiji earthquake) special report from Taiwan to demonstrate the application of the developed model. The model contains the most detailed amount of data in comparison to other academic studies we have surveyed and is valuable for estimating regional level demand under dynamic information updates. The author also generates simulation data to replace the missing data points in an effort to tackle incomplete information.

Yi and Özdamar (2007) study a dynamic coordination problem of supply distribution and transfer of injured people. They apply their model to an earthquake scenario for Istanbul. The demand distribution (number of wounded people) and supply distribution (people, fleet composition, and total capacity transport) are provided for each time period. Researchers employ the widely used data from the Earthquake Engineering Department of Bogazici University (2002) for attrition numbers and possible structural damage to Istanbul, which are used to calculate the number of affected people. Information about permanent emergency units is gathered from local municipalities and the Turkish Medical Doctors Association. However, the information about the number and capacity of vehicles, the capacity of temporary emergency units, as well as how this information is updated are not explicitly provided.

Huang et al. (2013) study the impact of incorporating real-time data into disaster relief routing for search and rescue operations in the aftermath of the 2010 Haiti earthquake. They use OpenStreetMap (OSM) to obtain road and building data. They also extract demand information on collapsed structures and trapped persons using Mission 4636, a text-message communication initiative. This research provides insights into incorporating crowdsourced data into humanitarian logistics models.

In addition to the integration of data into logistical models, some researchers also study classification frameworks for humanitarian data. This work is discussed in more detail later (see Measures of Data

Quality and Applicability section) as it closely relates to our developed measures of data quality and applicability.

Humanitarian Practitioners

Humanitarian practitioners often rely on situational awareness to make critical decisions in difficult situations with limited resources and time. Mica Endsley (1988) defines situational awareness as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" The availability of timely and accurate data is critical to personnel making operational decisions. Therefore, there have been numerous and ongoing efforts to improve the collection, management and sharing of humanitarian data for humanitarian practitioners such as Humanitarian Data Exchange (HDX) (See Information and communication technology section below for more details).

There are also ongoing efforts among practitioners to build vocabulary standards for crisis management (Limbu, Wang, Kauppinen, & Ortmann, 2012). This is of particular interest to researchers, as we observe not only differences between researchers and practitioners in the terminology used, but even among various handbooks and guidelines intended for practitioners (World Food Programme [WFP], ""About""; Logistics Cluster, ""About""; WFP, ""Food Aid Information System""; Federal Emergency Management Agency [FEMA], 2010; FEMA, ""Data Feeds""; FEMA, ""FEMA''s International Programs""; Inter-Agency Standing Committee [IASC], 2012; IASC, 2010a; IASC, 2010b). For example, while humanitarian logistics researchers extensively use the term "supply", practitioners use "supply", "resources", "capacity", "stockpile" and "availability". Until these vocabulary standards are developed and implemented in the field, researchers should be aware of the various terms different data sources might use in the same context.

The role that data plays in humanitarian operations continues to change as data gathering, processing and sharing technologies evolve. Many humanitarian agencies actively acknowledge, assess and forecast the effects of the corresponding changes. The annual World Disaster Report 2013 from the International Federation of Red Cross and Red Crescent Societies (2013) "examines the profound impact of technological innovations on humanitarian action, how humanitarians employ technology in new and creative ways, and what risks and opportunities may emerge as a result of technological innovations" (2013). These and other similar reports can provide logistics models with insights into how data is perceived by the humanitarian practitioners discipline.

Information and Communication Technology (ICT)

Information and communication technology plays a critical role in facilitating data collection, processing and communication. From the academic perspective, with the ongoing evolution of these technologies, the studies that analyze their application to crisis and emergency management have also significantly expanded (Faria Cordeiro, Campos, & Silva Borges, 2014; Howden, 2009; Scott & Batchelor, 2013; Li, Li, Liu, Khan & Ghani, 2014; Dorasamy, Ramen, & Kaliannan, 2013; Palen et al., 2010). The majority of this research focuses on crowdsourcing and social media applications in disaster responses (Ashktorab, Brown, Nandi, & Culotta, 2014; Hester, Shaw, & Biewald, 2010; Imran, Elbassouni, Castillo, Diaz, & Meier, 2013; Manso & Manso, 2012; Munro, 2013; Ortmann, Limbu, Wang, & Kauppinen, 2011; Purohit, Castillo, Diaz, Sheth, & Meier, 2013; Sarcevic et al., 2012; Velev & Zlateva, 2012), with particular interest in Twitter (Munro, 2013). For example, Ashktorab et al. (2014) present a Twitter-mining tool to classify, cluster and extract tweets. The authors include the keywords processed in their study, such as "bridge", "intersection", "evacuation", "impact", "injured" and "damage", among others. The authors implement their algorithm to tweets collected from 12 different crises in the United States. Purohit et al. (2013) present machine-learning methods developed for social media specifically to identify needs (demands) and offers (supplies) to facilitate relief coordination, by matching the needs with offers, encompassing shelter, money, clothing, volunteer work, etc.

DeLone and McLean (1992) develop an information system success model with six interdependent success variables: system quality, information quality, use, user satisfaction, individual impact, and organizational impact. Over the years, this model has been extensively studied and improved (Petter, Delon, & McLean, 2008). DeLone and McLean (2003) later update their model with the following success variables: system quality, information quality, service quality, system use, user satisfaction, and net benefits. Each variable also has numerous dimensions. For example, relevance, understandability, accuracy, conciseness, completeness, currency, timeliness, and usability are provided for information quality, which are defined as the desirable characteristics of the system outputs such as reports and web pages. System quality is defined as the desirable characteristics of an information system and ease of use system flexibility, system reliability, and ease of learning, as well as system features of intuitiveness, sophistication, flexibility, and response times. Bharosa, Appelman, Zanten, and Zuurmond, (2009) examine information and system quality as requirements for information system success during disaster management. The researchers state that, although information quality requirements are very relevant for information system success during disaster management, they are very hard to measure. In the case of systems quality measurements, much of the effort is focused on the inter-operability and ease of use.

From the practitioner's perspective, ICT has improved data collection, processing and communication in recent decades. UN OCHA's (2002) Symposium on Best Practices in Humanitarian Information Exchange resulted in humanitarian information management principles as: accessibility, inclusiveness, inter-operability, accountability, verifiability, relevance, impartiality, humanity, timeliness and sustainability. In a later symposium, reliability, reciprocity, and confidentiality were added to the list (Haggarty & Naidoo, 2008). The ongoing Humanitarian Data Exchange (HDX) project, led by OCHA, aims to "make humanitarian data easily available and useful for decision-making," by bringing together multi-country, multi-sourced, curated data for analytical use through a single platform (OCHA, 2013c). As part of HDX project, Humanitarian Exchange Language (HXL) is intended to offer the standardization of humanitarian data (OCHA, 2013a). In order to further facilitate standardization, the HDX Quality Assurance Framework identifies five dimensions of quality as accuracy, timeliness, accessibility, interpretability and comparability (OCHA, 2014b). Logistics modelers can benefit and often directly utilize the data collection and processing tools developed by the ICT discipline.

3. FRAMEWORK FOR ANALYZING REAL-TIME LOGISTICS DATA FOR MATHEMATICAL MODELING

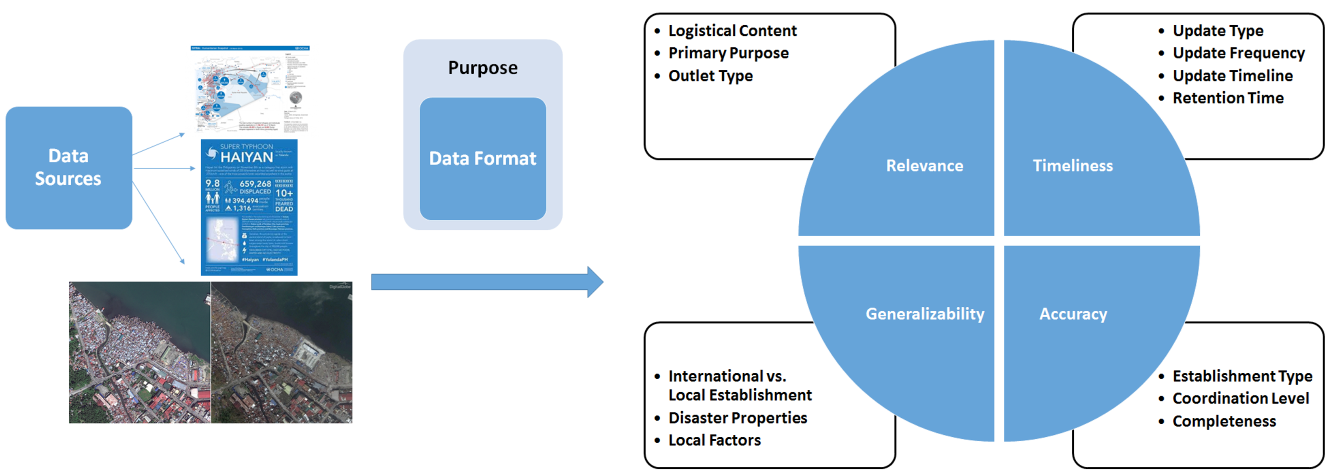
This section presents the framework for analyzing real-time post-disaster data, specifically focusing on the measures that describe the quality of data and data sources, as well as their applicability to different disasters for logistics modeling to learn from past disasters. Information during the aftermath of a disaster can more frequently be found on websites and is often shared via listservs and emails. Each disaster context will vary in the degree of online information access for several reasons, such as: the type of disaster (e.g., disasters with predictable timing and location, such as hurricanes, versus disasters with unpredictable timing, such as earthquakes), availability of information technology, and level of involvement of host nations and their national and local governments. In order to better assess the quality of numerous information sources that emerge after a given disaster and their applicability to other disasters, we classify the outlets and data provided from these outlets based on a number of measures relevant to the focus of this study. We first determine broad areas of quality and applicability measures, which help us understand humanitarian logistics focused real-time data and their indication for modeling. We then introduce attributes of data and data sources to explain each measure in detail and discuss the implications of the presented attributes and measures for disaster response logistics models. Finally, we address how to measure the attributes of the proposed framework.

3.1 Measures of Data Quality and Applicability

In order to develop the framework, we first review the data standards and literature from the disciplines described earlier in the disciplines using data, as well as survey our practitioner contacts for their input. Based on our previous modeling experiences and observations from the data and data sources over time, we identify four fundamental questions about the data and data sources, which lead us to the measures in the framework. These questions are: what data is available (relevance), when data is available (timeliness), where data is available and to what degree data represents the surrounding environment (generalizability), and the degree to which the data reflects the true environment (accuracy). We believe these four categories emphasize the critical characteristics that describe the quality of data and data sources and their applicability to different disasters for logistical modeling. As a result, we propose the following four measures: 1) relevance, 2) timeliness, 3) generalizability, and 4) accuracy. Similar to measures, we survey the literature and practitioners to identify attributes that sufficiently represent each measure and their implications for logistical modeling. The attributes are described in this section in detail. Figure 1 outlines our developed framework for analyzing real-time logistics data for the purpose of use in mathematical modeling. Following a disaster, as the data starts to become available, the data user evaluates it based on his or her purpose (e.g., research, situational awareness and decision- making on the ground). As a result, the importance of overall quality measures and the level of their applicability depend on the purpose of the data user; thus we span these measures around the user's purpose. The data format is highly correlated with the purpose of the research team and refers to the format of the files that data or the information relevant to our humanitarian logistics modeling focus is represented. Day, Junglas, and Silva, (2009) and Altay and Labonte (2014) stress inconsistent information and data formats as one of the information flow impediments that impact decision-making and coordination in the humanitarian response. The data is available in many formats from portable data formats (PDF) to keyhole markup language (KML) and Microsoft Word Documents (.doc).

The data format plays a critical role in the accessibility of data and smooth integration of data into models. Many of the available files identified in our case study (see sectionFramework Application: Typhoon Haiyan Case Study) depict humanitarian logistics information, such as roads and hospitals, yet frequently only in static formats. Optimal data formats for integration with logistics models are editable documents and dataset file types. For example, PDF maps often contain a great amount of information about the severity of damage in an area; however, due to their format limitations, it is hard to access information about road structure. Many released reports do not contain easily or quickly transferable numerical data. KML files and shape (SHP) files might contain the relevant data for testing models, however not in an immediately accessible manner, often requiring file conversions and format manipulations. On the other hand, even after these files are converted, discrepancies may exist between the content. Two different sources converted through the same online SHP to comma separated value (CSV) formatter (Geodata Converter, 2014) can return different marking systems, e.g., XY coordinates vs. "osm_id," as location indicators. This variation may be problematic for analysis, since it might require multiple infrastructure information sources. On the other hand, some sources contain Microsoft Excel data spreadsheets, and classification in this data simplifies the identification process of sources with promising data for the purpose of logistics models.

Figure 1. Data Analysis Framework: Applicability Measures and Related Attributes



Next, we describe the measures and attributes used in our framework based on their utility for logistical modeling and potential challenges. We should note that, while some attributes might refer to multiple measures (e.g., the classification category primary purpose might infer about the relevance and generalizability), some attributes can be related (e.g., local factors and disaster properties).

Relevance

Relevance is determined by whether the data meets the needs of its users The relevance of the data obtained from the data streams refer to the degree to which the data meets the current and future needs of the data required for logistical modeling. For our framework, we identify the following measures that represent relevance.

Logistical Content

Humanitarian and relief organizations constantly collect, process and disseminate immense amounts of information in a broad range of settings and applications. Our work and this specific paper focuses on humanitarian logistic operations in post-disaster settings, such as on-the-ground operations immediately following natural or man-made disasters (e.g., immediate medical assistance or search and rescue operations). Thus, our first step consists of identifying specific types of information relevant to humanitarian logistics. The data is divided into the following categories: demand, supply and infrastructure. These categories are similar to those used in the literature (Ergun et al., 2010a; Tatham & Spens, 2011).

– Demand: Effective and efficient relief efforts require the identification of the location, quantity and types of supplies needed within the affected region. Demand in these settings can correspond to needed physical goods, such as food, medication or shelter, as well as needed services, such as medical assistance, rescue, and telecommunication.

– Supply: Information about relief supplies that are pre-existing or gathered after a disaster, transportation vehicles and expert or key personnel (e.g., see (OCHA, 2013b) for examples specific to Typhoon Haiyan) is another important component for the relief efforts.

– Infrastructure: In order to facilitate distribution of supplies to demand, we need to have knowledge of the infrastructure (e.g., roads, airports, seaports and their post-disaster conditions). While this critical component can be highly uncertain, there is great potential benefit from accurate and timely data from the field.

Primary Purpose

Primary purpose indicates the focus of the information posted in the outlet and/or role of the organization providing the information. Some of the examples are initial assessment, evacuation and providing maps. The primary purpose of the data outlet or organization might help researchers search for relevant information for their models. For example, if a researcher is working on search and rescue operations, it might be easier for him or her to start from an outlet that is focused on initial damage assessments. More specifically, in the case of Typhoon Haiyan, a researcher can begin his or her analysis from CEMS, NDRRMC and OpenStreetMap (see Table 2for the primary purpose of surveyed information outlets in this study).

Outlet Type

Outlet type identifies the ownership of information, as observed in our study. We distinguish between two types of information outlets: original information outlets and aggregator information outlets. Original information outlets refer to organizational websites that primarily provide information and data, either collected by that organization or transform the data for their specific response purposes. We use the term aggregator for outlets that predominantly disseminate information collected by various other sources.

Outlet type classification can be helpful for practitioners and researchers for the following reasons. Original information outlets might be a good choice to look at when a researcher or practitioner is searching for a certain type and/or format of information, such as maps or reports about damaged areas. In this case, researchers or practitioners might need to search for several original information outlets to find particular data or accumulate a series of different information pieces. Aggregator information outlets generally compile information about supply, demand and/or infrastructure from assorted outlets. Thus, a researcher might want to start his or her initial search from these sources.

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Timeliness

The timeliness of data refers to time dimensions of the collected, analyzed and disseminated data. Timeliness is deemed by many users as generally the most important characteristic of data (Teran, 2014). Humanitarian data should be collected, analyzed and disseminated efficiently, and must be kept up to date (OCHA, 2002). Timeliness is also defined as the delay between when the data is collected and when data becomes available and accessible . Timeliness is a crucial measure for modelers as it highly impacts the types of the models they can feasibly implement.

Data Update Type (new update/incremental vs. overwrite)

Data update type represents the method by which the status updates are provided after the initial file upload. Incremental updates suggest that the new information is described in a new file or new field. On the other hand, overwrite updates indicate that the additional information is appended to the existing file containing the original information.

Practitioners and researchers may have different needs with respect to data updates. While practitioners may seek the most current data with cumulative statistics for operational decision-making during a certain disaster, logistics modelers often prefer to see the evolution of the post-disaster data. As a result, while an overwrite update may be preferable for practitioners, it is not desirable for humanitarian logistics researchers who focus on adaptive modeling. Modelers generally find the piecewise information about additional available roads or estimated needs (e.g., refugee camp population requiring food assistance from WFP) at a location more useful. Update type also provides important implications for the prioritization of the data collection process for research purposes. Sources such as OpenStreetMap may have openly available data that archives the prospective near real-time updates of roads, which can be retrieved later on, while other map sources that have overwrite updates should be monitored frequently to capture the evolution of data over time.

Update Frequency

Update frequency represents the frequency with which data is updated. Update frequency can be by minute, hour, day or other. Due to the nature of humanitarian operations and impact of time in the output, the humanitarian community benefits from data being updated timely and frequently.

Update frequency may have a large influence on modeling decisions. In our case study (see Table 2), many organizations that share data sources appear to update and upload their datasets daily and frequently post new content data related to logistics. This may influence the model type and the inclusion of the dynamic information into the models. For example, as the frequency of the information increases, a researcher might prefer dynamic programming to multi-stage optimization for modeling.

Data Update Timeline and Retention Time

While both data update timeline and retention time are associated with the time perspective of data, update timeline refers to the timeline from the initial time data starts to be uploaded until the last time data is uploaded. On the other hand, retention time captures the last time when the data will be available for public use. In other words, update timeline describes when files are updated on the website, e.g., from November 1, 2014 to December 15, 2014. Retention time is for how long that data will stay up on the website, e.g., the data can be accessed for another year after it has been uploaded. Retention time is also often associated with the establishment type of the information outlet, which is discussed later.

As stated before, timeliness is generally one of the most important measures of data and it has several implications for modelers. Different update timelines might express different values to various types of modeling purposes. The first available post-disaster data is crucial, especially when one wants to find as much information as possible to understand the immediate context and link information with high-priority humanitarian logistics activities within a certain period after the disaster. For example, the data available during the golden time (first few days after the disaster) is vital for models focused on search and rescue operations (Huang et al., 2013). As the initial few days pass after the disaster, the information about the supplies (which team is where with how much medical or other supplies) becomes widely available. This information provides a basis for the relief-distribution modeling. Additionally, longer timelines imply more data for the modelers and this allows them to conduct more comprehensive analysis for test case generations of past disasters.

Similar to update type, retention time might also impact and aid in enhancing the data collection process. Longer retention times enable researchers to access time-sensitive critical information. Postponing the collection of data that remains well after its posting date may allow for greater time spent on more volatile sources.

Generalizability

The generalizability measure in this framework indicates the applicability of the information obtained from the data resources of a particular disaster to other disasters for preparedness, analysis, lessons learned and evaluation. We determine an establishment's local versus global designation, disaster properties and local factors as key indicators of generalizability. Generalizability facilitates modelers to learn from previous disasters to improve the preparedness and response to future disasters.

Local/ National vs. Global/International

This classification addresses whether the information source is administered by an international organization or a local government/organization where the disaster occurs. It signifies the level of involvement from local government in the disaster response operations.

Local/national versus international data ownership might inform about the generalizability of this data and analysis for future disasters. For example, the level of involvement from the local government for the post-disaster response can be included in the discussion of different disaster comparisons. Similarly, depending on the disaster type, pre-disaster evacuation efforts of the local/national government can be a critical factor when comparing different disasters and making inference from them.

Disaster Properties

As the name suggests, this attribute describes the main characteristics of a disaster. Tatham et al. (2013) develop a 13-parameter framework that captures the factors impacting logistical preparedness and response. A significant part of the classification categories from Tatham L'Hermitte, Spens, and Kovács's framework, such as the time available for action (disaster onset), disaster size, magnitude of impact, duration of time and environmental factors (such as the topography or weather conditions of the affected area) are related to disaster characteristics used in our framework.

Disaster characteristics can educate modelers about decision-making in different stages of the disaster cycle. For example, a sudden-onset disaster with predictable timing, such as Typhoon Haiyan, can help modelers and practitioners on the ground to improve the prepositioning strategy to save as many lives as possible. In addition, disasters with predictable timing impact the level of information available in the response phase by advance notice, which can impact the specific characteristics of the model and model validation.

Local Factors

The World Bank Logistics Performance Index (LPI) measures the "friendliness" of a country based on six factors: customs, infrastructure, services quality, timeliness, international shipments and tracking/ tracing (Arvis, Saslavsky, Ojala, & Shepherd, 2014). Tatham et al. (2013) suggest the Logistics Performance Index as one of the four factors impacting the logistical preparation and response. While LPI focuses on factors that impact logistical performance directly such as infrastructure, local factors refer to metrics for local environment. L'Hermitte, Bowles, and Tatham (2013) present a classification model of disasters from a humanitarian logistics perspective. Their model composes the time and space components of the disasters and five external situational factors of the disaster environment. The external factors stated in the paper are the government situational factors, the socioeconomic situational factors, the infrastructure situational factors, the environmental situational factors, and the conflict environment. Five external situational factors of the disaster environment of L'Hermitte et al.'s work (2013) and some of the categories from Tatham et al's 13-parameter framework such as the geographic context, population density, per capital GDP, and potential for the reoccurence of the disaster in the same area are examples of local factors. Another local factor is the language of the local environment, as in the case of the 2010 Haiti earthquake (United Nations Foundation, 2011) .

According to existing studies (e.g., (Vaillancourt, 2013)), as the value of LPI increases, the expected number of affected people generally decreases. Logistics modelers can benefit from this information when estimating service demand for a given region.

Using a country's LPI value, modelers can evaluate applicability of the available data from one country to another. Furthermore, higher LPI scores usually correspond to less restriction from the government (Haavisto, 2014) on relief response operations, corresponding to another generalizibility measure of the data.

Geographical context of the local area where a disaster takes place might also provide multiple insights for modeling. For example, the Philippines being a combination of islands implies routing decisions using different modes of transportation, as well as the coordination of relief items among islands. Furthermore, whether or not a given island is the hub for relief operations can also impact the routing decisions. Another local factor, disaster reoccurrence probability, can provide useful information to logistics modelers at various stages of the disaster management cycle. For example, Ergun, Stamm, Keskinocak, and Swann (2010) describe numerous efforts of Waffle House Restaurants to effectively respond to hurricanes in southeast US. These efforts include equipment prepositioning, special menus and advanced personnel scheduling. Similar strategies can improve disaster management in areas that are prone to storms such as the Philippines.

Accuracy

Multiple researchers discuss data accuracy directly or using related terms, such as reliability, verifiability and accountability (OCHA, 2002; Haggarty & Naidoo, 2008; OCHA, 2013a; OCHA, 2013b; Galton & Worboys, 2011; Day, Junglas, & Silvas, 2009; Altay & Labonte, 2014; DeLone & McLean, 2003). According to the Humanitarian Data Exchange Quality Assurance Framework, the accuracy of the data is defined as "the degree to which the information correctly describes the phenomenon it was designed to measure" Synthesizing the definitions from these resources, we define accuracy as the measure that represents the reliability and the credibility of the information obtained from the data streams and data sources.

DeLone and McLean (2003) emphasize accuracy in their information success model. For example, accuracy-related terms appear in systems quality as "system reliability", in information quality as "accuracy", "conciseness" and "completeness", and in service quality as "accuracy" and "reliability". Day et al. (2009) state that self-reported information like shelter registration is generally unreliable. Altay and Labonte (2014) assess unreliability as an information impediment for decision-making and provide several sources of unreliable information examples from the case of the earthquake in Haiti in 2010, such as crowdsourced data. They also note that, rather than waiting for the perfect information, practitioners should utilize the available information and make sure coordination is stressed in the information-sharing. From a modeler's perspective, accuracy implies various assumptions about the available information, as well as the unknown data.

Establishment Type

Establishment type denotes whether the placement of the data (e.g., website or repository) was established specifically and solely for the purpose of a specific disaster or maintains data across multiple disasters. We use establishment type to separate data sources into two categories: multiple disaster and disaster specific. Multiple disaster sources correspond to organizations and websites involved with data on disasters prior to a given disaster, often retaining data from such disasters. Such sources or repositories usually retain data for multiple disasters after the relief operations are completed, e.g., ReliefWeb. Disaster-specific sources generally provide information during relief operations of a specific disaster and may become unavailable shortly afterwards.

Establishment type can often inform researchers and practitioners about reliability, completeness and accuracy of information since it often relates to the structure of the organization that maintains the information outlet. Multiple disaster data sources may possess additional verification processes, which may increase their reliability. However, these data sources (e.g., PDF maps) rarely contain the raw pre-processed data. In contrast, based upon our specific case study experience, we observe that disaster-specific sources may directly post datasets without progressing through a verification process, or may not fully share the verification process with the public. They may also lack the level of reliability and trust in comparison to sources established for previous disasters. Regardless of the situation, connecting with practitioners at appropriate times might assist in further understanding how and whether data is verified. It may also open up opportunities to explore datasets in pre-filtered formats, reliable short-term sources, or data sources more relevant to practitioners. However, datasets may not necessarily be complete or entirely accurate, requiring data fusion or synthesis of various datasets together to achieve logistics modeling requirements. The resultant fused datasets will need to be reassessed for applicability for effective on-the-ground operations.

Coordination Level

This attribute represents the level of coordination among different communities during a disaster response. It might indicate various types of collaboration, such as coordination between different relief agencies and coordination between local and international governing bodies. The concept of coordination through subgroups introduced by Jahre and Jensen (2010) aims to organize humanitarian help in a number of different areas by predefined management. Jahre and Jensen (2010) discuss the importance of the balance between horizontal and vertical coordination in any period of disaster management. Additionally, the authors mention the role of logistics cluster, one of the 11 OCHA formed clusters, on information management and the challenges of coordinating the information.

One key component to a successful coordination is the exchange of information, which in return results in additional information generation (e.g., cluster reports to be shared with participants). In addition, the involvement of various parties in the combined mission improves data accuracy as information is validated by the distinct participants. Moreover, similar to the establishment's international versus local designation, the level of cooperation of the local government with international communities in the disaster response efforts impacts the evolution of available data.

Completeness

Completeness represents whether there is missing information or not. Examples of incomplete information might be in regards to the status of certain roads or damage level of buildings.

Missing data raises questions regarding the accuracy of information to be used in the logistical models and forces modelers to account for the incomplete information. For example, when road status information is not provided, the modeler needs to make assumptions about that information. In order to account for the inaccurate and incomplete information, uncertainty factors should be included in the models.

Assessment of Framework Attributes

Table 1 provides an example of a metric that might be used to assess and categorize each framework attribute developed above, as well as sample metric categories for illustration purposes. Some of these attributes and the metrics have been previously introduced in existing literature, in which case we include the appropriate references in the last column of Table 1. As discussed by Bharosa et al. (2009), some parameters, such as relevance, accuracy, and timeliness that signify information quality, are often hard to measure during disaster management. Thus, what we provide in Table 1 is just one set of examples to measure the attributes, and there might be many other ways to measure each of them. For example, in addition to the sample metric provided in Table 1, it is possible to measure the coordination level using the number of agencies sharing resources or presence and the role of a single agency during a disaster such as local government.

Table 1. Assessment of Framework Attributes

Framework Measure	**Attribute**	**Metric Example**	**Sample Metric Categories**	**Reference**
Relevance	Logistical Content	number of logistical content categories that the data source cover	a) infrastructure b) demand c) supply d) all	Ergun et al. (2010a)
	Primary Purpose	main focus as described in mission statement	a) (initial) post disaster assessment, damaged infrastructure b) relief aid c) coordination d) all	
	Outlet Type	percentage of the content that is originally prepared by the data source	a) < 20% (aggregator) b) 20-50% (mixed) c) >50% (original)	

Timeliness	Update Type	number of previous versions of the file stored	a) 1 (overwrite) b) >1 (incremental)	
	Update Frequency	average time between two consecutive updates	a) hourly b) daily c) weekly d) monthly e) one time	OCHA (2002)
	Update Timeline	average time between the first and last update	a) > 1 year b > 3 months c) >1 month d) > 1 week	
	Retention Time	average time the information is kept by the data source	a) > 5 years b) > 3 years c) > 1 year d) < 1 year	
Generalizability	International vs. Local Establishment	percentage of funding available from local government	a) < 50 (local) b) > 50 (international)	
	Disaster Properties	number of people impacted	a) > 1,000,000 b) > 10,000 c) > 1000 d) > 100	Tatham et al. (2013)
	Local Factors	LPI score	a) > 4 b) >3.5 c) >3 d) <3	Tatham et al. (2013)
Accuracy	Establishment Type	total number of disasters involved	a) 1 (disaster-specific) b) >1 (multiple - disaster)	
	Coordination Level	average number of agencies listed in the reports	a) 1 b) >5 c) >10 d) > 20	Jahre and Jensen (2010)
	Completeness	percentage of the attributes tagged or have information about	a) > 20% b) > 10% c) > 5% d) < 5%	DeLone and McLean (2003)

4. FRAMEWORK APPLICATION: TYPHOON HAIYAN CASE STUDY

To illustrate the application of the framework presented above, we focus on a specific disaster response, Typhoon Haiyan, as the case study for investigating the role, value and limitations of integrating new information streams for logistical modeling during the aftermath of a disaster. On November 8, 2013, Typhoon Haiyan, named as Typhoon Yolanda, the strongest storm recorded at landfall (Open Street Map [OSM}, "Typhoon Haiyan", 2013) and one of the strongest tropical cyclones in recorded history (National Oceanic and Atmospheric Administration, 2013), hit the Philippines and resulted in catastrophic damage throughout the country. As of April 7, 2014, 6,300 individuals were reported dead, 28,689 injured, and 1,061 are still missing according to the National Disaster Risk Reduction and Management Council (NDRRMC) (Government of the Philippines, 2014). Both the Philippines government and international humanitarian organizations started their preparedness activities as early as November 7, 2013 and began response activities immediately following the fall.

Typhoon Haiyan represents an evolution of disaster response in which the emergence and growth of data during relief operations brought new opportunities for addressing humanitarian challenges. Multiple factors played a role in the generation of this outstanding level of information, including local factors, the nature of the disaster and efforts of OCHA and the availability of data from the Philippines government responding entities. More specifically, the Philippines benefited from advanced information communications technology and widespread media and organizational coverage within the country in the disaster response efforts.

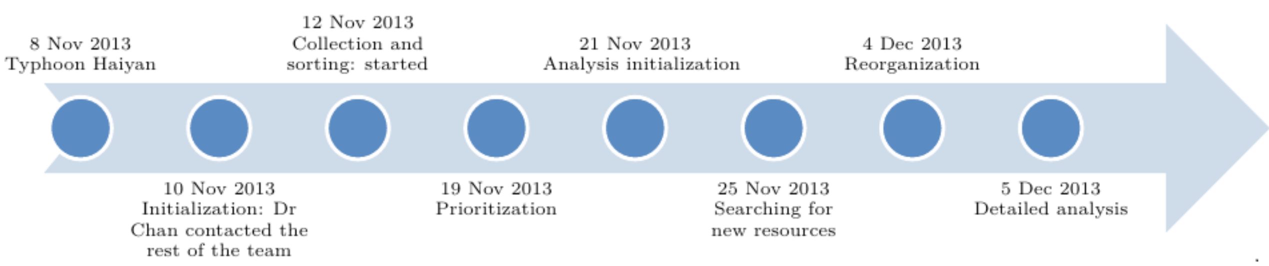
As this research is carried out by an English-speaking team, the synergy between information and data predominantly shared in the English language provides us an opportunity to pursue this case study. In addition, the Typhoon Haiyan post-disaster environment was permissive with respect to information-sharing across stakeholders; unlike conflict-driven, complex humanitarian crises where repressive environments often restrict information-sharing, especially through public online sources. Typhoon Haiyan is a sudden-onset disaster with relatively predictable timing and location, which made it possible for the advance staging of volunteers. OCHA's call for digital volunteer support through the Digital Humanitarian Network prior to the typhoon activated volunteers around the world to participate in collecting and processing information (OCHA, 2013d). In addition, the growth of digital humanitarians or "crisis mappers" has expanded nontraditional data streams during recent crises (Haiti earthquake, Pakistan, Chile, Christchurch, Bhopa, super-storm Sandy, etc.), often in online formats and frequently available to the public.

In this section, we first present the timeline of events following Typhoon Haiyan for the case study. Next, we examine the data sources and provide the classification of the data and data sources based on the framework developed in Section 3. We provide a brief logistical content analysis to assess the available information for logistical models. Finally, we present lessons learned from this case study.

4.1 Information and Data Retrieval

This section highlights the chain of events describing our information retrieval process. Figure 2 illustrates the information and data retrieval epochs of this study.

Figure 2. Information and Data Retrieval Epochs



Initialization

Shortly after November 8, 2013, when Typhoon Haiyan moved into the central Philippines region, one of our team members, who is an active researcher and practitioner in the humanitarian technologies community, began receiving numerous email communications from the crisis mappers network These emails contained publicly available website links to information sources pertaining to Typhoon Haiyan. This network is also linked to other digital humanitarian groups that were being activated by the Digital Humanitarian Network, including the Standby Task Force, Humanitarian OpenStreetMap Team, GISCorps, HumanityRoad, Info4Disaster, MapAction, Translators without Borders, Statistics without Borders and other members of the Digital Humanitarian Network (DHN, "Super Typhoon Haiyan") .

Collection and sorting

The team recruited an undergraduate research assistant to collect data beginning on November 12, 2013, starting with the resources identified in initial emails. As a first step, we iteratively devised a sorting scheme for data intake. After teasing out the emails relevant to the typhoon, our initial approach in the first days, between November 12, 2013 and November 19, 2013 was to continuously download from the data sources identified on those websites, such as Logistics Cluster and Copernicus Emergency Management Service (CEMS), with the goal of capturing the temporal aspect of the available data. The potential relevance for each data source was assessed using the accompanying description of the data. However, since time constraints and our advancing knowledge of humanitarian information sources did not allow for a complete understanding of each dataset at the time of retrieval, we continued to download from as many of these sources as we could find, in the hopes that each of those sources might contain desired information.

Prioritization

After one week of sorting data, around November 19, 2013, we realized that the volume, both in number and size, of data was overwhelming. For example, the Humanitarian Response had over a hundred new files (Humanitarian Response, 2014c) and OpenStreetMap had several gigabits of data (OSM, "Index of Haiyan". The magnitude of the data created a need to balance the trade-off between processing the known data sources and searching for new sources. After the initial few days of collecting a breadth of data, we attempted to focus on understanding the content of the resources, especially with respect to their logistical content. For almost a week, we focused on differentiating between logistical content, storing and archiving current data according to its content type.

Searching for new sources

As time passed, around November 25, 2013, we continued to search for new data sources. The sources from the email lists served as a starting point, and allowed for retrieval from some important sources earlier than otherwise possible. However, finding new sources required other methods, such as subscriptions to appropriate newsletters and mailing lists, and manual internet searches. Yet, even with these methods as aids to supplement the manual search for sources, we were not able to identify all additional sources, particularly those not openly shared on the internet. This illustrates the challenge to discover the relevant sources far enough to reduce lost data and the limits of remote research activities that explore field operations. Within this particular case study, many relevant sources, e.g., the OSM repository specific to Typhoon Haiyan, were further researched by our team over one month later, despite HOT and the American Red Cross activities commencing very early in the response, around November 8, 2013.

Reorganization

With the addition of new resources, the team acquired significant information and continued content differentiation, storing and archiving. On December 4, 2013, the team noticed the duplication of resources and decided to reorganize the list of them. At this point, the team discontinued downloading from repeating outlets.

Analysis

The team started the analysis of downloaded data on November 21, 2013, which consisted of the initial assessment of the data content, especially the logistical content discussed in measures of data quality and applicability section While the team worked on analysis and data collection in parallel after this point, the detailed analysis of data sources classifications began on December 5, 2013.

4.2 Data and Data Sources Classification

In this section, we implement the framework proposed in the study to the data obtained from Typhoon Haiyan. We begin with the detailed description of the studied data outlets (see Appendix for details). The information posted at the outlets, generally in their "about us" and data pages are analyzed based on their relevance to humanitarian logistics models during the timeline of the study, between November 10, 2013 and March 31, 2014. In developing measures of data quality and applicability we identify two types of information outlets: information aggregation sites and organization or sector specific data repositories (original, in other words, primary outlets). However, this dichotomy may not necessarily be entirely distinct, as some organization-focused sources will also include some data collected from other groups; for example, MapAction takes advantage of data from NDRRMC to generate some of the maps. Thus, one might expect to categorize MapAction as an aggregator. Also, there might be more information outlets providing information after Typhoon Haiyan. This classification includes analysis of a subset of available resources. Table 2 comprises a subset of the proposed classification categories such as outlet type, primary purpose and logistical content as they apply to the studied data sources.

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Table 2. Classification of Information Data Files Collected by Our Team
(see Section 3 for details on classification categories and Appendix for description of sources)

Source Name	Outlet Type	Primary Purpose Posted Related to HL Models	Logistical Content	Main Downloaded File Type(s)	Update Frequency Observed in Timeline	Update Type Observed	Establishment	Update Timeline	International / Local
APAN	aggregator	user-uploaded files	all	mixed	varies	new	disaster-specific	11/12/13 - *present**	international
Copernicus EMS	primary	initial post-disaster assessment	infrastructure	SHP	daily	new	multiple disasters	11/12/13 - 11/18/13	international
DSWD	primary	evacuation	supply, demand	PDF	every few days	new	multiple disasters	11/09/13 - 12/12/13	local
Google Crisis Maps	aggregator	facility placement and damage assessment	infrastructure	KML	unknown	overwrite	multiple disasters	11/08/13 - 11/26/13	international
Humanitarian Response	aggregator	satellite imagery	all	mixed	daily	new	multiple disasters	11/12/13 - *present**	international
IFRC	aggregator	displacement	all	PDF	daily	new	disaster-specific	11/10/13 - *present**	international
Logistics Cluster	primary	coordination and resource aggregation	infrastructure	PDF	almost daily	new	multiple disasters	11/12/13 - *present**	international
LogIK	primary	relief aid	supply	XLSX	daily	overwrite	multiple disasters	unknown	international
MapAction	primary	disaster-response maps	all	PDF	daily	new	multiple disasters	11/12/13 - *present**	international
NDRRMC	primary	facility operations and damage assessment	All	PDF	daily	new	multiple disasters	11/08/13 - *present**	local
OSM (repository)	primary	user-mapped damage, damaged infrastructure	infrastructure	SHP, OSM	daily	overwrite	multiple disasters	11/08/13 - *present**	international
Reliefweb	aggregator	aggregates various sources	all	mixed	daily	new	multiple disasters	11/08/13 - *present**	international
UNITAR - UNOSAT	primary	initial post disaster assessment	infrastructure	PDF	daily	new	multiple disasters	11/12/13 - 11/20/13	international
VISOV	primary	user-mapped damage	infrastructure	CSV	daily	new	disaster-specific	11/09/13 - *present**	international

∗ Timeline of the reported team's actions is between November 10, 2013 and March 31, 2014. As of March 31, 2014, the updates are still being posted.

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Copernicus EMS	primary	initial post disaster assessment	infrastructure	SHP	daily	new	multiple disasters	11/12/13 - 11/18/13	international
DSWD	primary	evacuation	supply, demand	PDF	every few days	new	multiple disasters	11/09/13 - 12/12/13	local
Google Crisis Maps	aggregator	facility placement and damage assessment	infrastructure	KML	unknown	overwrite	multiple disasters	11/08/13 - 11/26/13	international
Humanitarian Response	aggregator	satellite imagery	all	mixed	daily	new	multiple disasters	11/12/13 - *present**	international
IFRC	aggregator	displacement	all	PDF	daily	new	disaster-specific	11/10/13 - *present**	international
Logistics Cluster	primary	coordination and resource aggregation	infrastructure	PDF	almost daily	new	multiple disasters	11/12/13 - *present**	international
LogIK	primary	relief aid	supply	XLSX	daily	overwrite	multiple disasters	unknown	international
MapAction	primary	disaster response maps	all	PDF	daily	new	multiple disasters	11/12/13 - *present**	international
NDRRMC	primary	facility Operations and Damage Assessment	All	PDF	daily	new	multiple disasters	11/08/13 - *present**	local
OSM (repository)	primary	user-mapped damage, damaged infrastructure	infrastructure	SHP, OSM	daily	overwrite	multiple disasters	11/08/13 - *present**	international
Reliefweb	aggregator	aggregates various sources	all	mixed	daily	new	multiple disasters	11/08/13 - *present**	international
UNITAR - UNOSAT	primary	initial post disaster assessment	infrastructure	PDF	daily	new	multiple disasters	11/12/13 - 11/20/13	international
VISOV	primary	user-mapped damage	infrastructure	CSV	daily	new	disaster-specific	11/09/13 - *present**	international

∗ Timeline of the reported team's actions is between November 10, 2013 and March 31, 2014. As of March 31, 2014, the updates are still being posted.

4.2 Logistical Content Data Availability Analysis

In this section, we examine the availability of logistical content information following the days after Typhoon Haiyan. As discussed in disciplines using data section there are differences in the terminology used by researchers and practitioners. In order to find the relevant information (e.g., demand and infrastructure) to integrate into models, academic researchers should first learn about these differences. For example, in the case of Typhoon Haiyan, while searching for relevant information, we establish a set of key search terms that are used to identify the potential data sources within our compiled database that contain information about service demand and infrastructure. We use sources from different disciplines described in Section to help us build the list of these search terms. Then, using this list, we examine the data gathered from sources such as OpenStreetMap, Logistics Cluster, NDRRMC, and Copernicus Emergency Management Service (CEMS) for availability of the logistical content (see Table 2 for logistical contents and the Appendix for description of these data sources). The filtered data is then analyzed to identify the specific content they contain in relation to the kind of information needed for logistical models. For example, we want to know the level of damage each road link sustained, its post-disaster status and location of potential beneficiaries of medical and rescue services.

In the analysis of data availability for road damage, we look specifically at the data for Tacloban City, which is expected to have more data in comparison to more rural areas (DHN, 2014b). The number of roads labeled with some level of damage and the total number of roads recorded are compiled for each day between November 7, 2013 and November 28, 2013 using OSM and CEMS. However, even by November 28, 2013, only approximately 5% of the road links among these data sources are labeled to contain at least some level of damage. This result demonstrates how limited logistics data is for modeling following a disaster.

As an example, Table 3 shows the details about the information provided by NDRRMC regarding the road and port status between November 7, 2013 and November 13, 2013 in its situation reports. Regarding road status, the reports include information about the name of the road, status (not passable or passable) and additional comments (why it is not passable or status of ongoing clearance operations). The reports before November 8, 2013 12:00 pm do not include road status information. The information provided in the reports is cumulative; in other words, a road that was previously identified as impassable is kept in the following reports until November 13, 2013. As of November 13, 2013 6:00 pm all roads that were previously affected are stated to be passable and road status information is not included in the following situational reports. In the entire Philippines area, the reports include at most only 18 roads. The airport information consists of the name of the suspended airports as well as cancelled flight information. Data related to sea ports include the name of the port and number of strandees by type (passengers, vessels, rolling cargoes and motor banca boats).

Table 3. Road and Port Status Information Update after Typhoon Haiyan between 11/8/2013 and 11/13/2013 in NDRMMC Situational Reports

Update Date	Update Time	Number of Roads with Status Information	Number of Roads Reported Not Passable	Number of Suspended Airports	Number of Sea Ports with Strandees
11/8/2013	12:00 PM	5	5	5	12
11/8/2013	6:00 PM	5	5	13	15
11/9/2013	6:00 AM	5	5	13	20
11/9/2013	6:00 PM	13	13	4	4
11/10/2013	6:00 AM	18	18	4	3
11/10/2013	7:00 PM	18	3	4	0
11/11/2013	6:00 AM	18	3	4	0
11/12/2013	10:00 AM	18	3	4	0
11/12/2013	10:00 PM	18	3	4	0
11/13/2013	7:00 AM	18	2	0	0
11/13/2013	10:00 PM	18	0	0	0

In order to obtain service demand information for logistical models, we also examine the available building data, which might provide information about the individuals either trapped under collapsed structures or displaced persons due to loss of property. The building damage reports vary by different data sources. Table 4 contains a sample of information from the NDRRMC reports on the number of damaged buildings (totally or partially damaged), deaths, injured, and missing individuals, affected families and persons, and stranded individuals between November 8, 2013 and November 13, 2013. These numbers are aggregated for the entire Philippines.

Table 4. Demand Information Update after Typhoon Haiyan between 11/8/2013 and 11/13/2013 from NDRMMC Situational Reports

Update Date	Number of Damaged Houses	Number of Total Damage	Number of Partial Damage	Number of Deaths	Number of Injured	Number of Missing	Number of Affected/ Pre-Emptively Evacuated Families	Number of Affected/ Pre-emptively Evacuated Persons
11/8/2013							26675	125604
11/8/2013				3	7		151910	748572
11/9/2013				4	7	4	161973	792018
11/9/2013	3438	2055	1383	138	14	4	944597	4282636
11/10/2013	3480	2071	1409	151	23	5	982252	4459468
11/10/2013	19651	13191	6360	229	48	28	2055630	9497847
11/11/2013	23190	13473	9717	255	71	38	2095262	9679059
11/12/2013	41176	21230	19946	1774	2487	82	1387446	6937229
11/12/2013	149015	79726	69289	1798	2582	82	1387446	6937229
11/13/2013	149756	80047	69709	1833	2623	84	1387446	6937229
11/13/2013	188225	95359	92886	2344	3804	79	1730005	8012671

For more detailed building data analysis, we next focus on five cities: Tacloban City, Guiuan, Palo, Ormoc and Cebu. Notably within three of these cities (Tacloban City, Guiuan and Palo), the percentage of buildings with "collapse" or "damage" indicators range between 40% and 60% by November 20, 2014. This analysis is conducted by using OpenStreetMap and CEMS. Table 5 shows the total number of buildings and number of damaged or collapsed buildings for each city between November 8, 2013 and November 20, 2013. The information about building damage appears to be delayed in these sources in comparison to NDRRMC reports. Even in Tacloban City, the damage information starts on November 14, 2013. This is another example of limited information immediately after disaster, especially for search and rescue purposes.

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Table 5. Demand Information Update after Typhoon Haiyan between 11/8/2013 and 11/20/2013 in OpenStreetMap and CEMS

Date	Tacloban City		Palo		Guiuan		Ormoc		Cebu	
	Total Number of Buildings	Total Number of Collapse/ Damage	Total Number of Buildings	Total Number of Collapse / Damage	Total Number of Buildings	Total Number of Collapse / Damage	Total Number of Buildings	Total Number of Collapse / Damage	Total Number of Buildings	Total Number of Collapse / Damage
11/8/2013	2967	0	65	0	0	0	327	0	327	0
11/9/2013	15456	0	469	0	2	0	327	0	327	0
11/10/2013	24468	0	1649	0	28	0	327	0	327	0
11/11/2013	30278	0	2942	0	1585	0	327	0	327	0
11/12/2013	35786	0	3579	0	2262	0	328	0	327	0
11/13/2013	38722	0	3746	0	2277	0	328	0	327	0
11/14/2013	55374	14808	5432	1604	2294	0	329	0	2087	0
11/15/2013	65579	23242	8422	3934	2308	0	337	0	5999	0
11/16/2013	71338	28409	10465	5975	2308	0	337	0	6111	0
11/17/2013	75781	32738	11009	6519	2309	0	350	0	6111	0
11/18/2013	76045	32937	11010	6520	2309	0	350	0	6111	0
11/19/2013	76132	32992	11010	6520	4248	1890	350	0	6112	0
11/20/2013	76133	32993	11010	6520	4343	1963	350	0	6112	0

We next examine the available data for supply information. For illustration purposes, we examine two pieces of supply information. Table 6 depicts the number of vehicles available each day throughout November, beginning on November 11, 2013 from UN OCHA's Logistics Information About In-Kind Relief Aid (LogIK) records. The table includes the number of vehicles decided by certain dates and their status categories (i.e., dispatched, committed, delivered) as of December 8, 2013.

Table 6. Vehicle Information Update after Typhoon Haiyan between 11/8/2013 and 11/13/2013 from LogIK Entries

Date	Number of Vehicles Dispatched	Number of Vehicles Committed	Number of Vehicles Delivered by	Total Number of Vehicles
11/11/2013	1	4	13	18
11/12/2013	2	6	18	26
11/13/2013	3	9	33	45
11/14/2013	4	10	48	62
11/15/2013	4	11	54	69
11/16/2013	4	13	55	72
11/17/2013	4	15	60	79
11/18/2013	4	15	63	82
11/19/2013	5	15	68	88
11/20/2013	5	15	80	100
11/21/2013	5	16	83	104
11/22/2013	5	20	85	110
11/23/2013	5	20	85	110

11/24/2013	5	20	86	111
11/25/2013	5	20	86	111
11/26/2013	5	20	88	113
11/27/2013	5	20	90	115
11/28/2013	5	20	90	115
11/29/2013	5	20	90	115
11/30/2013	5	20	90	115

In addition to vehicle information, we also explore data about the medical teams from WHO Health Cluster Reports. The PDF maps show the total number of foreign medical teams divided by city and origin of the medical team, starting November 15, 2013. Table 7 shows the number of foreign medical teams and their operational status. In this context, operational teams refer to medical teams that are actually seeing patients. Similar to infrastructure information, updates on the medical teams are very scarce.

Table 7. Medical Team Information Update after Typhoon Haiyan between 11/15/2013 and 11/30/2013 from WHO Health Cluster Reports

Date	Standby in country / without destination (out-of country)	At Destination (not registered)	Operational teams (not registered)	Left Deployment (not registered)
11/15/13	6(0)	12(0)	10(0)	0
11/17/13	1(4)	14(0)	9 (0)	0
11/20/13	5(3)	10(0)	22 (0)	0
11/22/13	1(6)	2(0)	42 (0)	0
11/26/13	2(6)	0(2)	41(10)	1(1)
11/30/13	0(5)	0(2)	39(11)	6(3)

4.3 Lessons Learned: Challenges Faced During the Collection Process and Potential Solutions

This case study enables us to better understand the current situation of real-time data, how data evolves, and to what extent real-time data is available. We believe that this valuable experience will inform and aid modelers in building improved models. This section describes the challenges faced during our study, and recommendations for how these challenges can be addressed in the future (when possible) from an academic humanitarian logistics perspective.

Time-sensitive information

As information evolves after a disaster, some sources that commonly recur during separate disaster relief efforts do not retain their data for long periods of time. This generally depends on the establishment type and update type of the information outlet. Investigating retention time and update type of information outlets before the onset of a disaster can aid in gathering time-sensitive information. For instance, collection and analysis of data from resources that have the tendency to retain their files longer can be postponed to later times depending on the ultimate goals of the data. If a researcher focuses on modeling the initial few days of the disaster, this approach might not work. However, if a researcher wants to model a later period, postponing collection of retained files can be beneficial, thus avoiding the trade-off between collection of time-sensitive information and the prioritization of analysis. Additionally, the format of the time-sensitive information provided by an outlet tends to be similar for each disaster. Familiarity with the data format can ease the data collection process. Moreover, some outlets, such as OSM, benefit from specifically searching for a separate repository that might be linked to their wiki webpage. Accessing those repositories in the early days of the disaster response supports the smooth collection of time-sensitive data.

Delays

The data on collapsed and damaged buildings did not begin to appear in Palo and Tacloban City until November 14, 2013, and in Guiuan until November 19, 2013. Depending on the main objectives of the humanitarian agencies using the data, those dates might be too late. For example, from the perspective of search and rescue operations, receiving information three days after a disaster may seem too late to assist most of the people trapped under buildings. However, people who were stranded but not directly impacted by the collapsed structures would likely still be alive during that particular time frame and could benefit from relief supplies.

Data explosion and information overload

With the emergence of technology and increasing number of humanitarian organizations, the amount of information available after a disaster is accelerating From the perspective of a humanitarian logistics research team, it is challenging to account for this information load in a timely manner. One major factor is a limited research workforce. The limited human resource capacity for information processing is a shared challenge across the humanitarian ecosystem and acutely experienced by field practitioners. The evolution and success of many digital humanitarian efforts is the harnessing of remote workforces, often through crowdsourcing and microtasking efforts. Based on this case study and our team's experience, a possible solution for this issue is to recruit additional help in the data collection process whenever possible. Exploring collaborative opportunities with research teams and potentially practitioners to build a feasible and appropriate workforce to identify, filter, assign and prioritize humanitarian logistics datasets for modeling purposes may be a long-term goal. In the short term, future efforts might consist of two groups working in tandem on the data retrieval: one searching for new sources and initializing their retrieval, while the other investigates whether to continue retrieving data from the identified sources or not.

Duplication

Further complications arose when we observed that several data sources were reposting data from other sources; for example, the NDRRMC situation reports were placed on both ReliefWeb.int and the NDRRMC site, in the case of Typhoon Haiyan. Additionally, many updating files with recent timestamps appeared to be identical to older versions of the files. Recognizing the overlapping data segments between primary information outlets and aggregator information outlets early is a key point for researchers. Furthermore, prior information about the expected update timeline and primary purpose of the information outlets can help resolve these issues. For example, if an information outlet is only focused on initial damage assessment, a researcher might stop downloading from this outlet a few weeks after a disaster to prevent any possible duplication.

Relevance

Some of the data retrieved was not as relevant to humanitarian logistics models as originally hoped. Identifying logistical content of an information outlet and prioritizing these outlets might be helpful in organizing the data collection process in the future. For example, seeking out resources, such as OSM and the Logistics Cluster, earlier in future disasters would be valuable, since the coordinates used in OSM provide information about the damaged structures. Additionally, collaborating with and supporting these organizations before disasters strike would help researchers to understand data relevance more clearly.

Compatibility

Even assuming file compatibility, problems might exist between perceptions of the sources and how the sources are developed. For example, when one data source is developed by people on the ground, and another source is developed by digital humanitarian mappers, conflicting information would have to have a system for prioritization. Such a system would also require the differentiation of information obtained from mappers versus on field personnel. Furthermore, the particular mapping techniques of various sources may differ. One information source may mark a singular section as damaged or impassable, whereas another source might tag the entire street. This discrepancy can cause major differences in routing decisions and make it challenging to combine multiple resources to build a larger database.

Availability

Our data analysis shows that there is only information for 5% of the roads that indicate some sort of damage to the road structure. This low level of information in the case of a high-impact disaster, with a high level of media coverage and a large amount of data tracking efforts within the first few weeks of the typhoon, shows that the available information is not enough to integrate real-time data into models without putting efforts into adding accuracy measures and finding missing data. On the other hand, 60% of the available building damage information also requires validity checks for source data.

The availability of data across regions change. Some locations receive more attention than others. In particular with the building data, Palo, Tacloban City, and Guiuan appear to receive more mapping than Ormoc or Cebu City. While some of this can be attributed to proximity to the storm at the peak intensity, looking at displacements suggests that more people were affected in Cebu and Iloilo than Guiuan, yet these regions were less mapped (Protection Cluster, 2013). Some of these variations in coverage may be due to the focus and collaboration of mapping activities with the online communities such as OSM, and need to be further explored. We also observe that most of the damage indicated by the data was for roads along the coast. A possible explanation of this phenomena might be the presence of multiple medical teams close to the coast (World Health Organization, 2013), as well as UN On-Site Operations Coordination Centers having predominant locations along the coast (MapAction, 2013a). In addition, digital humanitarians assisting with updating maps might more easily distinguish damage to a larger coastal road than to more crowded neighborhood streets.

We recognize that numerous pieces of data from aggregator outlets have citations to their primary information sources. However, availability of the underlying raw data is frequently limited for a number of reasons. In addition, multiple primary information outlets share PDF maps, yet the detailed information about the infrastructure damage is challenging to obtain since the original core datasets from the primary source are infrequently cited or made available. This results in information loss.

Technological Status of Disaster-Affected Regions

The pre- and post-disaster states of the communication system play a significant role in the opportunities, limitations and gaps of the available data. No matter how technologically advanced a particular geographic area may be, gaps in telecommunication coverage in the post-disaster setting are often present. Significant communication problems arose due to the destruction of power and communication lines in the Philippines soon after Typhoon Haiyan (Palatino, 2013). Over a month after the onset, connecting with field teams within specific regions on a daily basis presented significant challenges, as exemplified by "a survey undertaken in the affected community in Guiuan, which reconfirmed the need for clearer and more frequent communication between aid partners and affected communities" (OCHA, 2014). Recognizing the damage sustained by regional communication systems can help researchers understand the information flow and better explain missing data (completeness) for specific geographic regions and time periods. Absence of information flow from an area can also serve as a signal of significant damage and imply increased needs for humanitarian relief (i.e., demand).

5. CONCLUSION

This study introduces a framework for real-time humanitarian logistics data focused on use in mathematical models. We define a set of measures to assess the quality of the data and their applicability to different disasters. Additionally, we provide modeling implications of data based on the proposed framework and discuss how to measure the attributes listed in the framework. We then apply this framework to the data collected from Typhoon Haiyan and present an example of data sources classification based on proposed measures. We also provide an analysis of the data focused on the logistical content to inform modelers about the availability of logistical data, at least in the case of Typhoon Haiyan. The study describes how our humanitarian logistics team approached the emergence of data after the disaster and the challenges faced during the collection process, as well as our observations.

The study shows that, even with accumulating information from different resources, real-time logistical information is very scarce. The analysis demonstrates that only 5% of the infrastructure in Tacloban City has damage information. The number would be much less for other cities that did not receive as much attention as Tacloban City. We encourage researchers to design appropriate models that consider this issue. The framework and its application illustrate what data is available to the team, when data is available, and how data changes after the disaster. It also provides direction about which data sources to search for a particular purpose after a disaster which would be beneficial in future disasters.

The information and observations included in this study are based only on one disaster, Typhoon Haiyan. Future experiences might differ based on multiple factors, such as the disaster type (e.g., complex emergency, man-made disaster), ICT environment, and involvement of organizations and affected populations. The information outlets described and analyzed in this work constitute only a subset of the available resources and focus on those with an English content and online availability. The description of organizations and digital humanitarian groups involved in information management and data sharing is based upon a growing knowledge of our research team and one that is a work in progress. Furthermore, the classification provided in this paper is only one of the many possible ways, where other researchers might approach the same data differently. The development of parameters to measure the attributes of the framework is in its early stages. More work needs to be done to improve the measurement structure and customize it for specific purposes.

To the best of our knowledge, this is the first study conducted by humanitarian logistics researchers focusing on the real-time data collection process in a post-disaster setting. It also presents a unique team approach that combines the expertise of both humanitarian logistics researchers and a researcher with humanitarian practitioner experience. The data retrieval and aggregation process described in this paper would not have been possible to carry out in a timely fashion without the pre-existing relationships between researchers and humanitarian practitioners. Through comprehensive mathematical models built specifically for the emerging data sources, researchers can identify the most valuable and promising data for the purpose of more efficient humanitarian logistics operations, and ways to integrate this data into a decision-making process. Ideally, validated humanitarian logistic models developed based on near real-time data shared by humanitarian agencies should undergo a series of iterative processes with practitioners to translate logistic models into relevant tools for field logisticians and agencies to assist in their operational activities. The study enlightens researchers about the availability of real-time data and its challenges. Additionally, it provides a ground work for the integration of real-time data into logistical models.

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Appendix

A.1 Original Information Outlets

Logistics Cluster

Logistics Cluster, created by OCHA, aids the cooperation of groups of humanitarian organizations. World Food Programme (WFP, 2014a) is the lead agency as appointed by the IASC (WFP, UNICEF & Ministry of Foreign Affairs, Netherlands, 2012). Common types of datasets are maps, meeting minutes, and situation updates. Logistics Cluster maintains maps that detail infrastructure data such as operations access constraints and general operations. The meeting minutes from the Coordination – Roads Transport – Sea and Rivers Transport Group include information about the road conditions. These almost daily meeting notes start from November 11, 2013. The situation updates also provide information about various types of transportation channel availability including the overland transport. These updates start on November 14, 2013, with limited data about the road conditions. Most of Logistics Cluster's files found during the case study comprise of portable data formats (PDF).

LogIK

LogIK, or Logistics Information about In-Kind Relief, is a global online database maintained by OCHA (LogIK, 2014a). LogIK provides detailed reports in PDF or XLS format of supply operations, with three categories of data: relief items, transports and contributions. The database reflects reported international/regional humanitarian contributions of relief items. Within these categories, LogIK offers information such as supplier information, destination, and quantity (Logik, 2014b). Specifically, the relief items section includes data about donated item types (e.g., blankets, tents and emergency kits), quantity, senders and other. The contributions section provides the decision date and dollar value of the contributions. The transport section contains information about vehicles provided from different organizations by air, road and sea. This information source may be of higher reliability because its source data originates from donors affiliated with the United Nations Office (UN). The information in LogIK is updated daily.

HOT

The Humanitarian OpenStreetMap Team (HOT) is a volunteer-based community formed within the larger OpenStreetMap community that has emerged as a pivotal provider and platform for data in humanitarian operations by providing open source data The data placed into OSM by volunteers continues to increase its scope and accuracy with rising numbers of users verifying information in more locations. OSM furthermore contributes to the large growth in information in post-disaster operations by frequently updating geographic data, sometimes every minute (OSM, "Typhoon Haiyan"). OpenStreetMap globe data takes several gigabytes, so specific repositories exist for disasters such as Haiyan (OSM, 2014a). While the "history" feature of the OSM helps to see the previous actions, space limitations tend to prompt these repositories to update at longer intervals and not retain many previous updates. The initial OSM updates for Typhoon Haiyan date back to November 7, 2013 since the HOT team was called by OCHA to start mapping the region a day before the typhoon touchdown The basic street maps of the cities of Port-Au-Prince and Carrefour provided by OpenStreetMap (2014b) in about 48 hours following the previous crises were claimed to be the best available maps , "Some editing stats".

MapAction

MapAction is a non-governmental organization that produces maps for the humanitarian crisis. From November 13, 2013 to January 17, 2014, they provided maps in JPEG and PDF formats of affected areas, along with information on the populations, road conditions, coordination (cluster activities by location), shelters and others. The main type of MapAction maps seem to be "Who, What, Where" maps that exhibit the locations of organizations. MapAction compiles data from several sources such as OCHA and NDRRMC for different cities, and each map is accompanied by a summary. A lag appears to exist between the report date and the update time; however, MapAction directs its users to Humanitarian Response (2014a) Philippines portal for primary MapAction maps (MapAction, 2014). Similar to OSM, MapAction was also present in the Philippines before the typhoon hit (MapAction, 2013b).

Copernicus EMS

CEMS (Copernicus Emergency Management System, 2014b), maintained by the European Commission, "monitors and forecasts the state of the environment on land, sea and in the atmosphere, in order to support climate change mitigation and adaptation strategies, the efficient management of emergency situations and the improvement of the security of every citizen" The website appears to present these maps, which seem to run between November 9, 2013 to November 18, 2013, in numerous formats and resolutions for over a year after the disaster (CEMS, 2014a). Moreover, while CEMS is claimed to have published some of the best pre- and post-event analysis images in the first 36 hours of the Haiyan's landfall , the website appears to make only a few updates publicly once the initial assessment occurs.

ESRI

Environmental Systems Research Institute (ESRI) holds data from the US Government on infrastructural damage. The ESRI Disaster Response Program supports organizations responding to disaster. They provide "software, data coordination, technical support, and other GIS assistance to organizations" (DHN, 2014a). In this case study, similar to CEMS, these files appear to consist of initial damage assessments. They supported the Typhoon Haiyan response by providing an ESRI platform for publicly licensed imagery after the event, and have supported other disasters (ESRI, 2014a). ESRI was one of the organizations that responded to the OCHA call for volunteers as part of the DHN. After Typhoon Haiyan, ESRI collaborated with the digital volunteer mapping groups such as Standby Taskforce and GISCorps to process social media reports and provide interactive maps (ESRI, 2014b). The website also provides maps from other groups such as MapAction and OSM. The Haiyan maps start from November 8, 2013 and were last updated on November 25, 2013 (as of March 2014).

UNITAR - UNOSAT

United Nations Institute for Training and Research's (UNITAR) Operational Satellite Applications Programme (UNOSAT) is a satellite program that provides "solutions to relief and development organizations within and outside the UN system to help make a difference in critical areas such as humanitarian relief" (UNITAR, 2013). The satellite images appear to allow digital mapping volunteers to contribute to changing sources, such as OSM, and often remain available for several years. Daily maps illustrating brief overviews of satellite-detected areas of destroyed and possibly damaged structures of different areas of Philippines are provided from November 11, 2013 to November 20, 2013. While the first few are presented only in PDF format, the rest are also offered in Shapefile and ESRI's geodatabase format.

VISOV

The goal of Volontaires Internationaux en Soutien aux Opérations Virtuelles (2014a) or International Volunteers in Support of Virtual Operations (VISOV) "is to help coordinate disaster responses with those of emergency organizations (formal or humanitarian) via digital spaces on which they organize and communicate" (VISOV, 2014c). VISOV appears to openly share and maintain its datasets on the website, possibly due to its intention to "become a tool in the hands of local communities" These datasets contain relevant tweets and map tags to estimate the road damage and relief progression VISOV datasets in particular include information such as the type of damage, description of the damage, geographical location, and time of notification. The data is available in the comma separated value (CSV) and keyhole markup language (KML) format from November 11, 2013 to December 3, 2013.

NDRRMC

NDRRMC, a governmental agency of the Philippines, develops detailed situation reports used by many mapping efforts and other situational reports

(NDRRMC, 2014). These PDF reports include information about situation overviews, causalities, affected populations, damaged houses, status of roads and bridges, standees, prepositioned and deployed assets/resources, cost of assistance, cost of damages, status of lifelines (both power and network outage), and emergency management. The status of the roads and bridges demonstrates the damaged areas, declares if the roads are passable and adds remarks such as closing reasons or efforts made to make the roads passable. The level of detail includes even missing persons' names, as well as the coordination efforts (involvement of different governmental and international agencies and humanitarian groups). These reports were initiated immediately after Haiyan on November 8, 2013. NDRRMC retains the situational reports during the recovery operations and appears to archive a large number of files.

DSWD

The Department of Social Welfare and Development (DSWD) appears to play a similar role to NDRRMC. However, it seems to focus on breaking down the information on citizens by geographic regions, as well as statuses within each region such as the number of families in each evacuation center (DSWD, 2014). For the Typhoon Haiyan, DSWD frequently publishes effect, service and intervention reports from November 8, 2013 to December 12, 2013. Viewing previous disasters suggests that DSWD also retains its reports for several months after the onset of the disaster.

A.2 Information Aggregation Outlets

Humanitarian Response

Humanitarian Response, maintained by OCHA, "aims to be the central website for Information Management tools and services" It appears to compile files from OCHA sectors (Logistics Cluster, Education Cluster, Protection Cluster, etc.), and other groups such as the Canadian Red Cross, Logistics Cluster, MapAction and OSM. The Humanitarian Response website possesses a large number of files, retaining information from several past operations. The outlet provides numerous file filters such as content and data source, and within each filter, multiple items may be selected. Humanitarian Response also maintains a registry of common operational datasets and fundamental operational datasets that often contains files with numerical data, which it claims "should represent the best available datasets for each theme" (Humanitarian Response, 2014b). The relevant data starts from as early as the moment Typhoon Haiyan hit, and new information is still being uploaded months after the event.

ReliefWeb

As with Humanitarian Response, OCHA maintains the ReliefWeb website. ReliefWeb appears to differ from Humanitarian Response in that it provides files, from situation reports to maps, from a broad range of sources and topics, not focusing on information management to the extent that Humanitarian Response does. ReliefWeb may be effective for identifying primary sources, since it "collects, updates and analyzes from more than 4,000 global information sources" (ReliefWeb, 2014). Alternatively, ReliefWeb may help narrow which sources' files do not need to be captured right away since it appears to contain most of the files from each source and retains them long after relief operations. The OCHA-sourced information about Typhoon Haiyan is directly linked to the ReliefWeb website on the OCHA website. The ReliefWeb page for Typhoon Haiyan was activated on November 8, 2013 and different updates are still being uploaded, as of March 2014.

APAN

All Partners Access Network (APAN) functions similarly to ReliefWeb and Humanitarian Response, but differs mainly in that users upload the files themselves and that the specific page for Typhoon Haiyan is reactionary (APAN, 2013). User uploaded files allow for the identification of reactionary sources that may be overlooked in the expansive collection of ReliefWeb and Humanitarian Response sources. However, user uploading tends to lack consistency in uploading files from any given primary source, so using APAN as a data retrieval site may be problematic. In contrast, users may sometimes upload files not on a given website but derived from nonpublic datasets, e.g., insurance industry datasets. APAN amalgamates maps, briefs, reports from a variety of different organizations, agencies and groups from November 10, 2013 to January 7, 2014. The community for Typhoon Haiyan provides a link to an ESRI map (APAN, 2014).

Red Crescent Societies (BRC, ARC)

The Red Crescent Societies do not appear to put out files as an overarching system of organizations; rather some individual Red Cross societies may choose to do so on their own. In this case, a collaboration between the American Red Cross and British Red Cross (Red Cross, 2014) makes available numerous maps throughout the disaster recovery efforts using various data sources. Since the map files specify what data sources each map employs, they may be used to locate the primary sources that contain the desired raw data. Moreover, the maps seem to specify the exact file, e.g., report number, from the source, allowing for direct retrieval of specific data. The Red Cross also provides reports about damage assessments, affected people, shelter, etc. They collect information from a variety of resources, such as OSM, UNITAR-UNOSAT, and ReliefWeb.

Google Crisis Maps

Google Crisis Maps, one of the tools of Google Crises Response Group crowdsources data not only within its self-produced facility locations files, but also provides options to access files from sources such as Waze, a traffic mapping application, and CNES/Astrium, which provides satellite imagery (Google Crisis Maps, 2014). In particular, the self-produced map from Google Crisis Maps plays a role as infrastructure data. However, the facilities that Google Crisis Maps display appear to remain relatively constant at each map, so frequent downloads may not be necessary depending on the goals. The map shows damaged areas, their severity, evacuation centers, and relief drop zone areas. When color coding the damaged areas, the map shows the data as aggregated chunks. However, it is not always clear if this means that the roads to those areas or the roads within that area are closed or not; and more detailed explanation about classification of damages might be useful.