ON THE SELECTION OF FEMA'S TRANSPORTATION SERVICE PROVIDERS: HOW TO EMPLOY THE ANALYTICAL HIERARCHY AND NETWORK PROCESSESS TO MAKE GUIDED DECISIONS

Graduate Research Paper

Denver H. Barrows, Captain, USAF

AFIT-ENS-MS-20-S-036

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

ON THE SELECTION OF FEMA'S TRANSPORTATION SERVICE PROVIDERS: HOW TO EMPLOY THE ANALYTICAL HIERARCHY AND NETWORK PROCESSESS TO MAKE GUIDED DECISIONS

Graduate Research Paper

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics

Denver H. Barrows, B.A.

Captain, USAF

September 2020

ON THE SELECTION OF FEMA'S TRANSPORTATION SERVICE PROVIDERS: HOW TO EMPLOY THE ANALYTICAL HIERARCHY AND NETWORK PROCESSESS TO MAKE GUIDED DECISIONS

Denver H. Barrows, B.A.
Captain, USAF

Committee Membership:
Timothy W. Breitbach, PhD
Lieutenant Colonel, USAF

Abstract

Hurricane Maria caused massive supply chain disruptions in Puerto Rico. This was most evident in the middle mile, where humanitarian aid was supposed to move from federal staging areas to regional staging areas. As a result, more than 3 million Americans failed to receive the life-saving support they needed in a timely manner. The research uses this historical account and FEMA contracting documentation to develop a notional analysis evaluated with two methodologies to examine potential transportation service providers in the middle mile. The supplier selection question is framed as a multi-criteria decision-making problem where criteria are grouped through a socio-technical system lens and evaluated using Analytical Hierarchy and Network Processes in SuperDecisions. The research recommends this methodology and tool be employed as a standard process in FEMA's selection of transportation service providers in an effort to operationalize its culture of preparedness.

To all those working to respond when disaster strikes.

Acknowledgements

A heartfelt thanks to my research advisor for his immense patience, guidance, and encouragement throughout this work. I would also like to thank all of my AFIT instructors who tirelessly instructed students in the Distance Learning program. Lastly, thank you to those individuals associated with response organizations and previous researchers who helped guide the formation of this research question.

Table of Contents

	Page
Abstract	v
Acknowledgements	vii
Table of Contents	viii
List of Figures and Tables	ix
I. Introduction	1
Background	1
The U.S. Model for Responding to Natural Disasters	2
FEMA 2017 After Action Report and 2018-2022 Strategic Plan	3
Humanitarian Logistics	4
Research Question	5
II. Literature Review	7
Humanitarian Logistics	7
The Middle Mile and Transportation Service Providers	10
National Response Framework's Emergency Support Functions	11
Socio-Technical System Theory	12
Conclusion	13
III. Methodology	14
Validating the Analytical Hierarchy Process	15
Validating the Analytical Network Process	16
Criteria Identification, Development and Weighting	17
Alternative TSP Development	19
Developing the Baseline Analytical Hierarchy Process	20
Developing the Weighted Analytical Hierarchy Process	21
Developing the Analytical Network Process	24
Validating the Use of SuperDecisions	25
Conclusion and Limitations	26
IV. Results and Analysis	28
AHP Results	28
AHP Sensitivity Analysis	29
ANP Results	32
Conclusion	33
V. Conclusions and Recommendations	34
Recommendations for FEMA	34
Future Research	37
Limitations	38
Conclusion	39
Appendix A	40
Appendix B	41
Bibliography	42

List of Figures and Tables

Page

1. Figure 1: The Process of Humanitarian Logistics 5
2. Figure 2: Structural Difference Between Hierarchy and Network Processes 14
3. Figure 3: Hierarchy of TSP Selection Model based upon STS Perspective 19
4. Figure 4: TSP Comparisons with Respect to Cost 20
5. Figure 5: All Else Being Equal 21
6. Figure 6: Outcome with All Else Being Equal 21
7. Figure 7: Pairwise Comparison Scale for AHP Preferences 22
8. Figure 8: Variable Pairwise Comparison Judgement Matrix 22
9. Figure 9: Pairwise Comparison Matrix 23
10. Figure 10: Variables Weighted with STOS Inputs 23
11. Figure 11: Alternatives Pairwise Judgement Matrix 24
12. Figure 12: Notional TSPs 24
13. Figure 13: Variable Pairwise Judgement Matrix with Respect to TSP 1 25
14. Figure 14: Analytical Network Process 25
15. Figure 15: Outcome with Notional TSPs 29
16. Figure 16: Cost Sensitivity 30
17. Figure 17: Flexibility Sensitivity 31
18. Figure 18: Reliability Sensitivity 32
19. Figure 19: ANP Outcome 33

I. Introduction

Background

"Puerto Rico Aid is Trapped in Thousands of Shipping Containers" (Gillespie *et al*, 2017), "Snarled Distribution Networks Hamper Puerto Rico Relief" (JOC, 2017)", "Logistics Front and Center in the Puerto Rico Disasters; Who is to be Blamed?" (Atapattu, 2018), "FEMA was Sorely Unprepared for Puerto Rico Hurricane, Report Says" (Roble, 2018). These are just a few headlines that highlight the major gaps in relief efforts following Hurricane Maria in 2017. While many factors of the 2017 hurricane season contributed to these issues, the roughly 80% of unavailable commercially licensed drivers certainly didn't help either (Gillespie *et al*, 2017). Ultimately, as 3.3 million Americans struggled to recover from the devastation, 10,000 containers sat idle at the Port of San Juan awaiting middle mile movement (Gillespie *et al*, 2017). The errors of Hurricane Maria's response cannot be corrected, but there are takeaways that can improve the next response, especially as the scientific community warns of more hurricanes to come (Smith, 2020).

As scientists study natural disasters, they are continuing to become stronger and more frequent, and those locations historically affected will continue to be so on a much larger scale (Chinoy, 2018). While this is devastating news for people unable to relocate, it is an opportunity to focus on preparedness in key locations, namely those disconnected locations where response and recovery supply chains require a significant head start. As Michael Hart, the Federal Emergency Management Agency's (FEMA) Media Branch Chief said, "'as natural and man-made hazards become increasingly complex […], the need for forward-leaning action is greater than ever before'" (Eschner, 2018). This '"forward-leaning action'" has a financial incentive and in an effort to understand the economics of the "'culture of preparedness'", a FEMA-funded study found that for every $1 expensed by the U.S. government on mitigation efforts, roughly $6 were saved in future spending (Eschner, 2018).

The need for greater preparedness, and its associated cost savings, motivates this research to identify how the best transportation service provider (TSP) can be selected by FEMA for natural disaster response efforts, specifically in the middle mile of humanitarian supply chains. In order to do so, the background first introduces the model for natural disaster response in the United States. Next, it examines FEMA's 2017 After Action Report and its 2018-2022 Strategic Plan. These works position the need to identify a practice for TSP selection within the confines of FEMA's takeaways from a disaster-heavy 2017 and a strategic plan that seeks build a "culture of preparedness." Next, it covers the basics of humanitarian logistics.

The U.S. Model for Responding to Natural Disasters

The 1988 Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) was signed into law designing a system whereby natural disaster assistance could be provided by federal, state, and local government authorities (Stafford Act, 1988). The act developed a framework for a presidential emergency declaration and subsequent action through FEMA for coordinating relief responsibilities. It has been amended on three occasions under the Disaster Mitigation Act of 2000, the Pets Evacuation and Transportation Standards Act of 2006, and the Disaster Recovery Reform Act of 2018, and remains the foundational US federal policy for disaster relief.

While several titles are important for outlining relief roles, Title V1: Emergency Preparedness is the source for the authority and responsibilities of FEMA's Director. For the purpose of this research, it is important to take note of the definition of emergency preparedness under this section, which "means all those activities and measures designed or undertaken to prepare for or minimize the effects of a hazard upon the civilian population" (Stafford Act, 71). Even before hurricane response became a well-documented and researched arena, preparation was seen as a means of protecting those in a disaster's path. While specific types of "activities" and "measures" are not addressed in a prescriptive manner, framing disaster response in the eyes of a supply chain spurs certain actions to take place far before a storm hits. Many of these preparedness efforts failed to be adequately executed in the hurricane response of 2017, prompting key findings in FEMA's After-Action Report and the foundation for a new strategic plan.

FEMA 2017 After Action Report and 2018-2022 Strategic Plan

FEMA's response operations in 2017 were supposed to be well-integrated and coordinated, but the reality was far different. A review of the 2017 Hurricane Season After-Action Report shows that FEMA played a supporting role responding to hurricanes in Florida and Texas, but led efforts in logistics coordination in Puerto Rico. Infrastructure and transportation constraints forced FEMA to "lead the entire logistics supply chain" for Puerto Rico and featured conflict in prioritizing resources, distributing aid and tracking its progress as well as delays in the contracting process (FEMA 2017 After Action Report). These are key responsibilities that strategic doctrine requires FEMA to assume in the case of a completely debilitated system, the likes of which were evident in Puerto Rico (National Response Framework, 2019).

Hurricanes Harvey, Irma, and Maria demonstrated the vulnerabilities posed by multi-location island disaster, and in response FEMA developed the 2018-2022 Strategic Plan set to "build a culture of preparedness" (Strategic Plan, 7). Focusing on preparedness and integration highlighted that "while FEMA has significantly increased its logistics capabilities since 2015, the 2017 hurricane season and wildfires demonstrated that additional people, processes, doctrine, and contracted services are needed to effectively move resources from point of origin to disaster survivors during large-scale incidents" (Strategic Plan, 25). These details reveal an internal interest to pursue efforts that can expedite humanitarian aid and alleviate constraints in executing components of the humanitarian supply chain. Both the after-action report and the strategic plan demonstrate an opportunity in the logistics domain to be better prepared when disaster strikes. This research takes this opportunity to introduce the TSP selection as a traditional supplier selection question, framed with a glimpse into the realities of Hurricane Maria.

Humanitarian Logistics

Hierarchically, humanitarian logistics oversees transportation elements within a disaster relief supply chain. Humanitarian logistics is defined as:

> The process of planning, implementing and controlling the efficient, cost effective flow and storage of goods and materials as well as related information from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people. The function encompasses a range of activities, including preparedness, planning, procurement, transport, warehousing, tracking and tracing, customs and clearance' (Tomasini *et al*, 2009).

The academic literature discusses a variety of components as it tackles the definition of humanitarian logistics. While all combine traditional logistics components of a commercial supply chain, this particular definition drives home the idea of "alleviating the suffering of vulnerable people" through activities and measures like "preparedness, planning […and] transport". These elements tie closely to work that FEMA must do by virtue of federal law, and what it strives to do as evidenced in its Strategic Plan. But, these words are easier said (or written) than done. In figure 1 the intricacies of humanitarian logistics are mapped with flows of financial value, material, and information. Understandably, the implications of efforts in the disaster area have significant impact on the lives of the beneficiaries. Therefore, having knowledge of important variables at play and potential transportation providers is key to partnering with those who are best positioned to do the work of material flow when responding to a natural disaster.

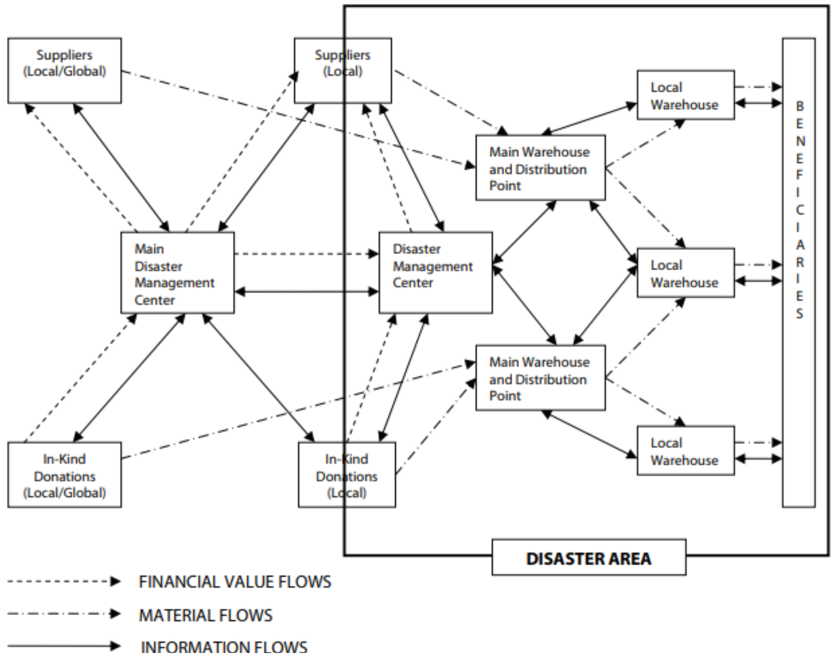

Figure 1: The Process of Humanitarian Logistics (The Humanitarian Relief Chain, 2011)

Research Question

Humanitarian aid stockpiled in the Port of San Juan and elsewhere throughout Puerto Rico at a time when it desperately needed to be distributed. The stockpiling of aid was caused by an unprepared middle mile and a destroyed infrastructure impeding much of the initial efforts to move relief supplies to regional staging areas in Puerto Rico. Middle mile trouble is not often seen when FEMA is responding to natural disasters in the continental United States, but when it is required to assume responsibilities for a multi-modal operation in island states and territories, logistics become inherently more complicated. But, knowing that national policy drives FEMA to organize this element of the supply chain presents an opportunity. It gives researchers the chance to present tactical ways to execute their "culture of preparedness". Building from this knowledge, this research seeks to offer FEMA a notional analysis and theoretical methodology to select TSPs and focuses our question: how can FEMA select the best transportation service provider (TSP) in preparation for disaster response?

Answering this research question will help prepare FEMA for future response and recovery efforts. Also, its applicability is not limited to island state and territory efforts, even if it finds its motivation from Puerto Rico and Hurricane Maria in 2017. At the halfway point in FEMA's 2018-2022 Strategic Plan, this research provides a necessary and adaptable way to implement strategy by employing two multi-criteria decision-making analysis techniques chosen to answer the research question. In order to inform these models, the analysis uses a socio-technical system framework to categorize FEMA's Standard Tender of Service (STOS) document (its chief document used in selecting TSPs). Then, the model uses a weighting system to provide a notional analysis of variables and alternative TSPs. These steps find an academic foundation in the literature review, are explained in the methodology, and interpreted in the analysis. Ultimately, the conclusion provides recommendations for FEMA to employ this methodology in their own practice and future research areas that can contribute to the continuing conversation on humanitarian supply chains.

II. Literature Review

The literature review first explains humanitarian logistics by discussing its similarities and differences from the private sector. Then, it highlights opportunities where humanitarian response organizations can apply tactics from their commercial counterparts. After discussing those opportunities, it examines the middle mile in supply chains and how transportation service providers fit movement requirements in that segment. Next, it details the two Emergency Support Functions from the National Response Framework that place responsibility for logistics in the middle mile on FEMA. Lastly, it focuses on socio-technical system (STS) theory and its ability to organize systems. Of note, this review will often use Logistics Service Provider (LSP) in its discussion because of the presence in academic literature. It is an extension and interchangeable with the Transportation Service Provider (TSP) designation FEMA employs.

Humanitarian Logistics

From the 1950s until the mid 2010s, natural disasters have increased by more than ten-times per year (Cozzolione *et al*, 2017). The increase in disasters has come with an increase in cost as well, most notably in the 2010s, where twice the number of billion-dollar disasters compared to the 2000s occurred in the United States (Smith, 2020). In particular, 2017 marked the costliest year ever when 16 separate billion-dollar events totaled more than $300 billion. In fact, the response to Hurricane Maria alone cost $90 billion (Chinoy, 2018). The upwards trend is only expected to continue with some forecasts estimating a five-fold increase in disasters in the next 50 years (Thomas and Kopczak, 2005).

As the costs associated with natural disasters have increased, so has research into how humanitarian response organizations can develop best practices in supply chain management (Leiras *et al*, 2013). Notably, efforts examining logistics have become an area of focus as they “directly affect the ability of humanitarian organizations to respond to disasters and improve their overall effectiveness” (Leiras *et al*, 2013). Other academics have named logistics as the costliest component of a humanitarian supply chain and the difference between a win or loss in a response scenario (Van Wassnehove, 2006). However, this component stands in contrast to its commercial counterpart because of its unpredictability, suddenness, resource scarcity and high stakes (Balcik and Beamon, 2008). Ultimately, when responding to natural disaster, it is the unknown that logistics must be prepared for (Van Wassenhove, 2006).

Historically, unknowns in private sector supply chains have driven analysis aimed at mitigating future issues. But, until recently, little of this has taken place in the humanitarian sector (Van Wassenhove, 2006). As a result, massive inefficiencies in response efforts have put relief organizations about 15 years behind the private sector in developing efficient supply chains (Van Wassenhove, 2006). However, even though relief organizations are behind, they can still apply tools and methods from business logistics in disaster relief (Kovacs and Spens, 2007).

The idea of adapting tools and methods from business logistics is a topic explored frequently in the literature (Vega and Roussat, 2015). Pettit and Beresford (2009) discuss the basic activities executed in humanitarian supply chains and their similarity to private sector supply chains. Operating under this premise, they find that there are commercial critical success factors that increase efficiency in humanitarian supply chains (Pettit and Beresford, 2009). Swanson and Smith (2013) suggest areas where response organizations can learn from and implement commercial practices in order to increase their overall effectiveness. And, Schulz and Heigh (2009) note that storage and transportation are specific areas where experience from the private sector can be applied by humanitarian organizations in a successful manner.

In large part, the above functions are often outsourced in commercial supply chains and have "proven to be an effective strategy helping logistics service users (LSUs) to achieve competitive advantages, improve customers' service-levels and reduce overall logistics costs" (Boyson *et al*, 2009). Given the prospect of reduced cost (logistics accounts for 80% of relief costs) and improved customer service, one might assume specific and well-established roles for logistics service providers have been created (Abidi *et al*, 2015). But, the academic literature demonstrates otherwise. Even with its colossal presence, little work has studied the specific areas where outsourced logistics can be optimized (Vega and Roussat, 2015).

The lack of role assignment seems to be a basis for the next gap in humanitarian logistics research – logistics service provider selection – where established criteria for selecting LSPs is absent (Baharmand *et al*, 2015). While this is well studied in the private sector, "no explicit effort has been done to identify factors in selecting a right CLSP for disaster relief" (Kim *et al*, 2018). That was until Kim *et al* (2018) presented the question: "how can HROs select the most appropriate CLSP for disaster preparation?" Since humanitarian supply chains more closely resemble their commercial peers in the preparedness stage, research into this area offers direct applicability of methods and tools used in the private sector (Tomasini and Van Wassenhove, 2009). Additionally, presenting logistics as a front and center initiative in the preparedness stage allows for agreements and movement lanes to be in place once disaster strikes, accelerating aid to those in need (Van Wassenhove, 2006). Based upon the literature, approaching LSP selection in the preparedness stage could address two major areas seen in humanitarian supply chains – the cost of logistics and the delays associated with moving goods from federal to regional staging areas (the middle mile). Additionally, it could work to mitigate some of the inherent unknowns that exist so prevalently in humanitarian logistics.

The Middle Mile and Transportation Service Providers

In industry, optimizing supply chains is always top of mind. In the case of the retail industry, the inefficiencies of transporting between distribution centers and retailers has come to be one of the most expensive parts of the supply chain and is dubbed the middle mile (Beechman, 2020). While the middle mile has been studied less than the first and last mile in supply chains, its increasingly become a focus for technology disrupters (Advanced Training System, 2020). For giants like Walmart, emerging technology from external vendors is regularly introduced to research best practices for bridging this gap (Bloomberg News, 2019). Academics and businesspersons alike agree, there is opportunity for external logistics service providers to work successfully in the middle mile (Sigala and Wakolbinger, 2018).

Sigala and Wakolibinger (2018) identify where commercial logistics service providers can be best used in humanitarian supply chains in their research. It points to the many segments of transportation required to move relief from a storage facility to a beneficiary and how commercial partners are best positioned to accomplish this task. While their work designates middle mile movement as the "local" component of the supply chain, it is referencing that key leg from federal staging areas to regional staging areas (in the case of FEMA). Other researchers have also segmented movement requirements in response scenarios with similar descriptions of middle-mile requirements (Leiras *et al*, 2013). Ultimately, these requirements drive transportation to be the most commonly outsourced activity in humanitarian supply chains, particularly in the challenging middle mile (Bealt *et al*, 2016; Vega and Roussat, 2015).

With this knowledge, researchers have seen that response organizations that establish expectations for transportation service providers in the preparedness stage of disaster relief are more successful (Rodriguez-Espindola *et al*, 2018). Defining roles and specified selection criteria can help avoid distribution delays and transportation liabilities in the middle mile of humanitarian supply chains (Baharmand *et al*, 2017). Ultimately, researchers have found that those response efforts most focused on logistics and transportation are overwhelmingly more successful in distributing aid to those in need (Van Wassenhove, 2006).

National Response Framework's Emergency Response Functions

At the core of executing the National Response Framework in the United States are the tasks outlined as Emergency Support Functions, which allows resources to be coordinated and structured following an event. According to FEMA, ESFs allow for the organization, management and delivery of core capabilities (National Response Framework, 2019). Of the 15 ESFs, ESF#1 Transportation and ESF#7 Logistics, are most relevant.

ESF#1 Transportation is owned by the Department of Transportation and its purpose is to provide "support by assisting local, state, tribal, territorial, insular area, and Federal governmental entities, voluntary organizations, nongovernmental organizations, and the private sector in the management of transportation systems" (ESF#1 Annex, 1). While ESF#1 clearly states it has no responsibility for the movement of goods, alternatives must be identified when existing systems are inaccessible or overwhelmed. While the private sector is identified as the lead for the "rapid restoration of transportation-related services" (ESF#1 Annex 2), there is no backup if the private sector is unable to perform the task, placing that responsibility solely on the government.

ESF#7 Logistics coordinators are the General Services Administration and Department of Homeland Security (FEMA) who should integrate "logistics planning and support for timely and efficient delivery of supplies, equipment, services and facilities" (ESF#7 Annex, 1). Its scope includes all traditional logistics components in a supply chain, with a specific emphasis on managing an operation that provides supplies to those in need (ESF#7 Annex, 1). ESF#7 partners with local governments in order to assess logistics resources, detect areas of weakness, and mitigate risks. ESF#7 works with private sector associates and NGOs in coordinating the details of logistics providers and movements. Lastly ESF#7 provides an adaptable capacity that integrates stakeholders and drives the movement of materials to victims. According to the Annex's listing of primary agency ownership, these capabilities are overseen by FEMA.

Socio-Technical System Theory

Kim *et al*'s (2018) logistics service provider selection research employs a socio-technical system (STS) perspective to organize the larger system of humanitarian supply chains. STS theory is rooted in post-World War II Britain and has been used in a variety of settings to study organizations and the interaction of three systems – the social, technical and environmental – in its operation (Long, 2013). The theory was developed to define interrelatedness amongst these three components (Trist and Bamforth, 1951) and it creates a framework for analyzing how factors affect organizational outcomes (Emery, 1959). Future efforts built upon this initial theory and framework for integration and optimization in large systems (Trist *et al*, 1963). The technical component includes tools and techniques employed to provide a service to a customer; the social takes on the human side of the organization, paying attention to the relationships, behaviors and norms in the system; and, the social and technical play out in the environmental arena, containing them both by including segments of government, economic, and transportation (Pasmore, 1988).

In the academic literature, the conventional wisdom is that "whenever there are people, working together in a system with technology, in an environment that provides resources the system needs, there is the possibility of adapting STS thinking" (Passmore, 1988, p. 155). In supply chain studies, STS theory has been applied regularly across topics of logistics, supplier integration, and complexity (Closs *et al*, 2008, Hadid *et al*, 2016, Kull *et al*, 2013). The foundation of applicability validates the underlying framework used to present the seminal work on LSP selection in humanitarian supply chains by Kim *et al* (2018), where they apply the STS framework in a supplier selection problem. They organize the selection of LSPs based upon the STS framework as it best captures the necessary partnerships and components of disaster relief (Kim *et al*, 2018). Their selection criteria are substantiated by STS theory and categorized into three dimensions: economic, technical, and social. Since the economic dimension is a core component of the environmental dimension, that title is used instead as it best captures the factors contributing to an overall decision (Kim *et al*, 2018). Ultimately, application of the STS theory in a supplier selection decision by Kim *et al* (2018) provides the academic validation for the approach taken by this research in organizing FEMA's selection criteria document.

Conclusion

This literature review provides the foundation for how this research answers the question: how can FEMA select the best transportation service provider (TSP) in preparation for disaster response on islands? By understanding the academic background on humanitarian logistics, it is clear there is room for commercial practices to be applied to the private sector. Specifically, using outsourced transportation in the middle mile of a disaster relief supply chain produces more successful outcomes of aid distribution. National doctrine and operationalized support functions lay much of this authority for response and relief logistics and transportation in the hands of FEMA, which should drive the organization to prepare an approach to selecting TSPs. Kim *et al*'s (2018) work is the first example of how to answer that question with an STS framework and is the theoretical basis for the approach of this research.

II. Methodology

The research arranges TSP selection for FEMA middle-mile movements as a multi-criteria decision-making (MCDM) question. Analytical Hierarchy Process (AHP) is the most frequently used technique in answering these questions, especially in the transportation arena (Mardani *et al*, 2015). Another common tool is Analytical Network Process (ANP) which differs from AHP by considering interdependence amongst variables; it has been used to answer the question of supplier selection by several researchers (Gencer and Gurpinar, 2006). As both are common techniques, the paper will work through AHP and ANP analysis while explaining variation in outcomes. These processes are outlined in Figure 2 and validated in subsequent sections.

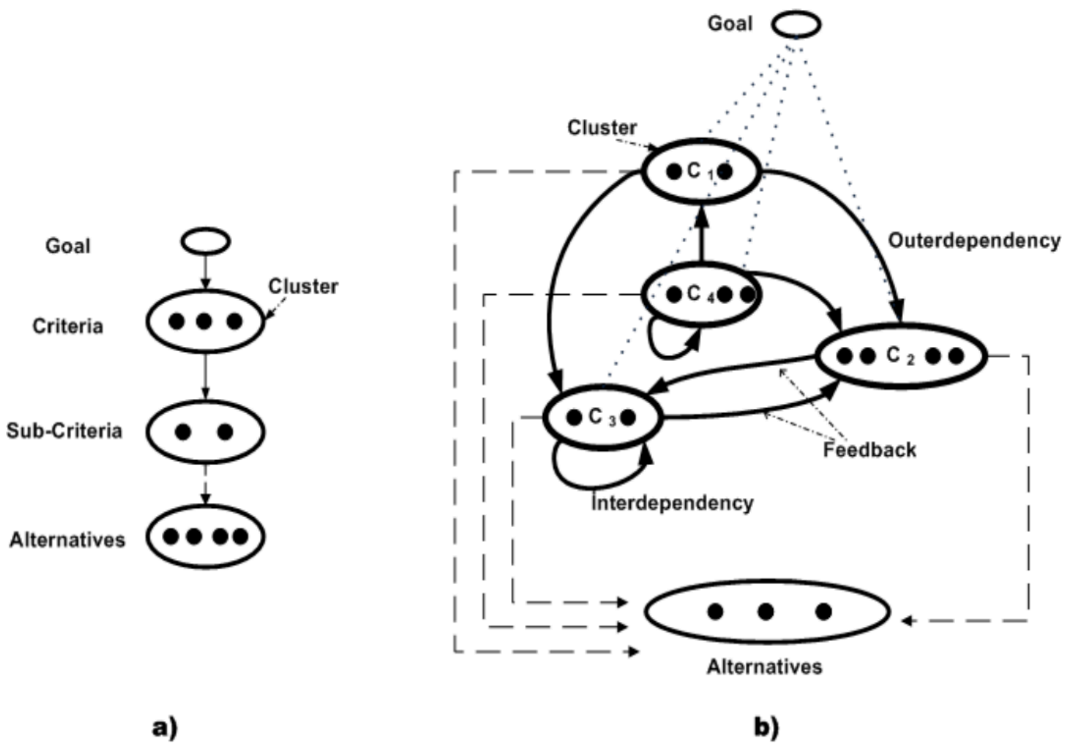

Figure 2: Structural Difference Between Hierarchy (a) and Network (b) Processes (Gorener, 2012, 197)

The analysis uses academic literature, federal contracting documentation, and historical accounts of middle-mile transportation troubles in response to the 2017 Hurricane Maria in Puerto Rico to identify the variables, TSPs, and weighting system developed for the hierarchy and network. Given that the analysis is notional, assumptions, limitations, and intended application are discussed throughout the following sections. Ultimately, the methodology demonstrates the answer to the research question and a theoretical example of how FEMA can employ the two techniques when selecting TSPs.

Validating the Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) was developed by Thomas Saaty in order to introduce a logical process in decision-making with multiple criteria and alternatives (Mardani *et al*, 2015). Saaty's (1980) work found that it is hard for humans to assign weights to different criteria in a decision-making process when the number of criteria is high. However, it is much easier to determine importance between criteria when those options are presented in a pairwise manner. AHP is a process that uses human judgement in pairwise comparisons among criteria to derive the weights then assigned in decision making (Saaty, 1980). To demonstrate, instead of directly assigning weights to some hypothetical criteria *a*, *b*, *c*, the human labeler can judge that "a is preferred to b twice, and b to c three times, but a is preferred to c only five times" (Saaty, 2001). Humans tend to be inconsistent when dealing with intangibles (as in the case above) and AHP corrects for these inconsistencies in human logic by finding the principle relationship implied by the human labeler in judgement ranking (Saaty, 1980).

Since it is easily adapted to multiple scenarios, AHP has been used to answer MCDM questions in a variety of industries (Ho, 2007). Mardani *et al* (2015) found that it is the most commonly used technique in evaluating transportation-related MCDM questions. Their rigorous review of 89 transportation system academic articles found that roughly 20% of the research focused on performance evaluation and over 25% of the work was evaluated using an AHP approach (Mardani *et al*, 2015). Among the 25% of AHP-analyzed questions, Rezaei *et al* (2014) assessed supplier selection in the airline industry and Chou *et al* (2011) classified assurance and reliability as critical factors in performance evaluations. The frequency of supplier selection and performance factor research was significant in the review. Ultimately, Mardani *et al*'s (2015) work concludes that AHP is most widespread because of its theoretical basis and straightforward application. The thorough review substantiates the application of AHP in answering this research question on FEMA's TSP selection decision.

Validating the Analytical Network Process

Saaty's work continued with the introduction of Analytical Network Process (ANP), which considers interdependence amongst dimensions, criteria, and alternatives (Saaty, 1996). Since interdependence and influence amongst clusters cannot be evaluated in a strict hierarchy, a network approach was developed to account for connections (Gencer and Gurpinar, 2006). In these situations, ANP delivers a framework for decisions without making assumptions about independence, both between and within levels of the structure. In order to do so, ANP poses questions about criteria importance relative to the alternatives being considered (Saaty, 1996). Much of the research heeds that advice of Saaty (1996) when he suggested that ANP be used when dependence among alternatives or criteria exist.

Given that context, ANP has become a particularly valuable practice for selecting suppliers as connectivity between and within criteria and alternatives exist and can be modeled through network nodes and arcs. A pictorial representation of this interaction is seen in Figure 2. Gencer and Gurpinar (2006) do just that when working to solve a supplier selection question in an electronic firm in their research. They draw a distinction between the historical approach to supplier selection, rooted exclusively in financial-based decision making, with a more modern approach that evaluates relationships and the total cost of ownership with a vendor decision (Gencer and Gurpinar, 2006). FEMA's TSP selection process mirrors the decision Gencer and Gurpinar (2006) are solving in their research and validates the approach to solving this question.

Criteria Identification, Development, and Weighting

FEMA's Standard Tender of Service (STOS) describes variables used for selection and performance evaluation of TSPs. Initially, the academic literature was used to frame an analysis of the STOS by keying in on the STS framework inherently developed in the FEMA document. The STS framework hones in on the environmental, technical and social interaction in organizational outcomes and the academic literature substantiates the application of the STS framework to supplier-related decisions (Kull *et al*, 2013). Like Kim *et al* (2018), this research concludes that the environmental designation would be more appropriately labeled as economic. Since the economic domain is a sub-section of the environmental dimension, this decision was substantiated by existing academic content (Kim *et al*, 2018). With that framework validated, variables were assembled from the STOS and assigned to the STS dimensions. FEMA's STOS explains 23 variables that were narrowed into seven groups for consideration based upon the STS dimensions. These seven factors largely mirrored those found in the existing academic literature (Kim *et al*, 2018).

Since FEMA's STOS does not assign an explicit list of variables nor an associated weighting system to their TSP selection process, the academic literature and STS framework is used as a theoretical base to list variables from the document as well as notional weighting factors. The STOS outlines the award process by first explaining the rate cycle, provider insurance minimums, and other non-negotiable requirements to be eligible for FEMA transportation routes. Once a potential provider meets those requirements, their information is stored in the Logistics Supply Chain Management Systems (LSCMS) and pulled when transportation is required. Those initial results are ranked from least expensive to most expensive and, ultimately, TSPs are selected based upon the Best Value for the Government. In addition to cost, the STOS mentions 22 other variables that could be considered when evaluating TSPs. As discussed, the theoretical framework validates a smaller number of variables by grouping those with similar objectives (Kim *et al*, 2018). Those seven variables are weighted based upon the frequency with which they were discussed in the STOS (and can be referenced in Appendix B).

Since cost is the initial consideration, it received the greatest weight in the analysis. Additional weighting was assigned based upon how many of the original 23 factors were categorized into a specific criterion. For example, the literature considers reliability often in supplier selection decisions (Chou *et al*, 2012). After analyzing the STOS, it became clear that reliability was an important factor in selecting TSPs. While it was not specifically called reliability, the variables listed discussed commitment, unwarranted withdrawal from shipments, and past performance. Based upon the academic literature's definition of reliability (Chou *et al*, 2012), these variables were categorized under that title and grouped in the STS social dimension given their focus on relationships and business norms. Eight of the original 23 variables were considered reliability factors in the social dimension based upon the STS framework. The grouping of verbatim variables, and their associated groupings, are listed in Appendix A and B.

This methodology was used to identify, classify, weight and substantiate the other five variables seen in FEMA's STOS. Those variables can be seen in Figure 3 below and are quoted and grouped in Appendix A and B as well.

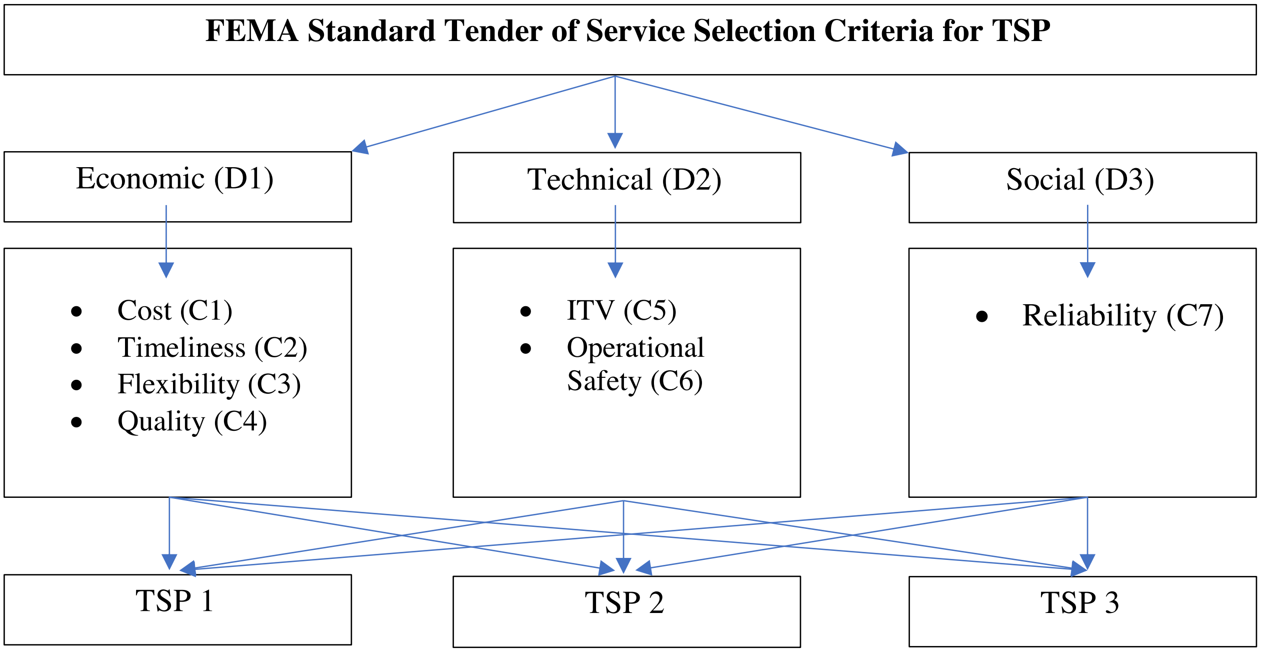

Figure 3: Hierarchy of TSP Selection Model based upon STS Perspective

Alternative TSP Development

Notional supply chain components regularly inform academic research (Chatterjee and Layton, 2020). This research takes a similar approach when developing the TSP alternatives used in the analysis. While there is limited specific knowledge of potential ground TSPs in Puerto Rico, reasonable knowledge of ocean TSPs moving between the United States and Puerto Rico exists (Green, 2019). In supply chains, regardless of the mode of transportation, similar criteria are considered and evaluated when selecting TSPs and grading their performance (Kim *et al*, 2018; Chou *et al*, 2011). Therefore, that knowledge of ocean TSPs is used to inform the TSPs developed in this research.

Since Green (2019) provides numerous metrics about TSPs Crowley, Tote, and Trailer Bridge, this research developed three notional TSPs for its analysis. TSP 1 is built as the most cost-effective alternative, TSP 2 the most reliable and timely, and TSP 3 as the most flexible. These variables are the most highly considered in FEMA's STOS and receive strong consideration in the academic research as well (Kim *et al*, 2018; Chou *et al*, 2011). As a result of the academic literature, this analysis links reliability with timeliness in order to represent a TSP alternative that occupies a market segment with a different set of credentials than those strictly cost-based. Given the similar evaluations of quality, ITV, and safety in FEMA's STOS, those variables are treated equally among the three alternatives. In order to present three competitive alternatives, the notional TSPs are matched closely against each other.

In Figure 4, this qualitative description is seen in quantitative form. The 1-9 scale employed in the analysis (and described in subsequent sections) pits each alternative as a level of importance decision relative to the other. In this case with respect to cost, TSP 1 is "equally to moderately more important" than TSP 2, TSP 1 is "moderately more important than" TSP 3, and TSP 2 is "equally to moderately more important" than TSP 3.

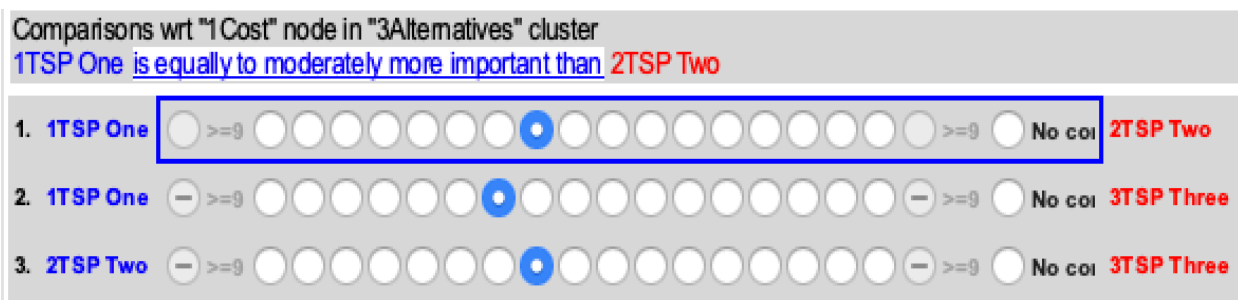

Figure 4: TSP Comparisons with Respect to Cost

Developing the Baseline Analytical Hierarchy Process

When treated equally, the weights of each variable are seen in Figure 5. This figure is built to demonstrate the breakdown of the matrix pairwise comparisons. In pairwise comparisons, each variable is a priority of the goal. These priorities are absolute numbers between zero and one, similar to probabilities. By definition, one priority is valued at 1.000. In the case of a decision amongst alternatives with one priority, that alone will be the determinative factor. In the case of multiples, in total, the priorities must equal 1.000. In the case of this baseline demonstration, there are seven variables considered and weighted equally. In mathematical terms their values are determined by simple division:

$$1.000 \div 7 = 0.142857$$

and seen in the Goal column of Figure 5. Since the variables are weighted equally and the alternatives (TSPs) evaluated as equals amongst those variables, each TSP receives an equal endorsement (ideals value) for selection (in Figure 6). While this is an unlikely scenario, it provides the baseline for further analysis.

Clusters	Nodes	1Goal
1TSP Selection	1Goal	0.000000
2Criteria	1Cost	0.142857
	2Timeliness	0.142857
	3Flexibility	0.142857
	4Quality	0.142857
	5ITV	0.142857
	6Safety	0.142857
	7Reliability	0.142857

Figure 5: All Else Being Equal

Name	Graphic	Ideals	Normals	Raw
1TSP One		1.000000	0.333333	0.166667
2TSP Two		1.000000	0.333333	0.166667
3TSP Three		1.000000	0.333333	0.166667

Figure 6: Outcome with All Else Being Equal

Developing the Weighted Analytical Hierarchy Process

The remainder of the work considers FEMA's STOS. As discussed above, analysis of the STOS provides a grouping and associated priority for each variable assessed in the selection process (seen in Appendix B). Given that each priority must add to 1.000, 21 comparisons take place in order to produce the values below, which combine to equal 1.000. These comparisons pit one criterion against the other and assigns a numerical value on the 1-9 scale used in AHP. This preference judgement and corresponding numerical value is seen in Figure 7. These numerical preferences are applied in the matrix in Figure 8 where each variable is compared to the other using the AHP scale. The blue arrows indicate an importance level in favor of the blue-colored criteria while the red arrow indicates the opposite. For example, when cost is compared to timeliness, it receives a 3 or "moderately important" score. When deciding about alternatives, the cost variable is 3 times more important than the timeliness variable.

Judgement of Preference	Numerical Rating
Equally important	1
Equally to moderately	2
Moderately important	3
Moderately to strongly	4
Strongly important	5
Strongly to very strongly	6
Very strongly important	7
Very strongly to extremely	8
Extremely important	9

Figure 7: Pairwise Comparison Scale for AHP Preferences

Goal	Timeliness	Flexibility	Quality	ITV	Safety	Reliability
Cost	← 3	← 4	← 4	← 5	← 5	← 2
Timeliness		← 2	← 2	← 3	← 3	↑ 3
Flexibility			← 1	← 2	← 2	↑ 4
Quality				← 2	← 2	↑ 4
ITV					← 1	↑ 5
Safety						↑ 5

Figure 8: Variable Pairwise Judgement Matrix

With this information, the matrix in Figure 9 is constructed. The values across the diagonal are all 1 because they are a comparison of the same variable. The lower triangular matrix is filled with the inverse of the judgements seen in Figure 8, given that the comparison applies in the opposite direction.

$$
\begin{array}{c|cccc}
K & A_1 & A_2 & \cdots & A_n \\
\hline
A_1 & 1 & a_{12} & \cdots & a_{1n} \\
A_2 & 1/a_{12} & 1 & \cdots & a_{2n} \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
A_n & 1/a_{1n} & 1/a_{2n} & \cdots & 1
\end{array}
$$

Figure 9: Pairwise Comparison Matrix (Selection of Wastewater Treatment Process Based on Analytical Hierarchy Process and Fuzzy Analytical Hierarchy Process Methods)

Next, each criteria's role in the final decision is determined by evaluating the priority vector (eigenvector). In order to approximate this value, the columns are normalized to add up to 1.000 and then the rows are summed to arrive at the corresponding weights seen in Figure 10.

Clusters	Nodes	1Goal
1TSP Selection	1Goal	0.000000
2Criteria	1Cost	0.336851
	2Timeliness	0.132341
	3Flexibility	0.080039
	4Quality	0.080039
	5ITV	0.047993
	6Safety	0.047993
	7Reliability	0.274743

Figure 10: Variables Weighted with STOS Inputs

Figure 11 applies the same methodology discussed above to the alternatives. For example, the importance of cost is pairwise compared between TSP 1 and TSP 2, TSP 1 and TSP3, and TSP 2 and TSP 3. As discussed, TSP 1 is built as the most cost-effective alternative, TSP 2 the most reliable and timely, and TSP 3 as the most flexible. The notional alternatives are built based upon previous research (Green, 2019) and provide a notional example of alternatives FEMA may decide between when selecting the best TSP. After completing the pairwise comparisons for the other six variables and conducting the matrix calculations described above, the weights for each TSP relative to the criteria are seen in Figure 12.

Goal	TSP 2	TSP 3
TSP 1	← 2	← 3
TSP 2		← 2

Figure 11: Alternatives Pairwise Judgement Matrix

Clusters	Nodes	1Goal	1Cost	2Timeliness	3Flexibility	4Quality	5ITV	6Safety	7Reliability	1TSP One	2TSP Two	3TSP Three
1TSP Selection	1Goal	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2Criteria	1Cost	0.336851	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	2Timeliness	0.132341	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	3Flexibility	0.080039	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	4Quality	0.080039	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	5ITV	0.047993	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	6Safety	0.047993	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	7Reliability	0.274743	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3Alternatives	1TSP One	0.000000	0.539615	0.296961	0.296961	0.333333	0.333333	0.333333	0.163424	0.000000	0.000000	0.000000
	2TSP Two	0.000000	0.296961	0.539615	0.163424	0.333333	0.333333	0.333333	0.539615	0.000000	0.000000	0.000000
	3TSP Three	0.000000	0.163424	0.163424	0.539615	0.333333	0.333333	0.333333	0.296961	0.000000	0.000000	0.000000

Figure 12: Notional TSPs

Developing the Analytical Network Process

Much of the ANP construction is built upon the foundation of the AHP approach discussed above. The additional step takes place when criteria are pairwise compared with respect to a particular TSP. An additional 63 pairwise comparisons take place in order to assess the interdependence in the network. The exact same variable weighting method and TSP profiles are used in this section where TSP 1 is built as the most cost-conscious, TSP 2 has the most reliable and timely, and TSP 3 as the most flexible.

In approaching the additional questions, only the TSP's priority criteria are evaluated as more important than the other criteria. In Figure 13, this can be seen for TSP 1. Presumably, additional TSP data points in an actual decision allow for more accurate pairwise comparisons, but for the purpose of this notional analysis, only the TSP's most attractive variables are considered in the pairwise comparisons. Similar approaches are taken for TSP 2 and TSP 3. Additionally, the Goal node is removed in the ANP processes as it is not a place where measures of interdependence can be made.

	Timeliness	Flexibility	Quality	ITV	Safety	Reliability
Cost	← 3	← 4	← 5	← 6	← 6	← 2
Timeliness		← 1	← 1	← 1	← 1	← 1
Flexibility			← 1	← 1	← 1	← 1
Quality				← 1	← 1	← 1
ITV					← 1	← 1
Safety						← 1

Figure 13: Variable Pairwise Judgement Matrix with Respect to TSP 1

The matrix process, priority vector, and normalization take place for these additional pairwise comparisons to produce the values in Figure 14.

Clusters	Nodes	1Cost	2Timeliness	3Flexibility	4Quality	5ITV	6Safety	7Reliability	1TSP One	2TSP Two	3TSP Three
2Criteria	1Cost	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.409051	0.084059	0.115360
	2Timeliness	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.102162	0.213227	0.106942
	3Flexibility	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.097374	0.093267	0.359191
	4Quality	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.094501	0.093267	0.102733
	5ITV	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.092586	0.081557	0.100208
	6Safety	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.092586	0.081557	0.100208
	7Reliability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.111739	0.353066	0.115360
3Alternatives	1TSP One	0.539615	0.296961	0.296961	0.333333	0.333333	0.333333	0.163424	0.000000	0.000000	0.000000
	2TSP Two	0.296961	0.539615	0.163424	0.333333	0.333333	0.333333	0.539615	0.000000	0.000000	0.000000
	3TSP Three	0.163424	0.163424	0.539615	0.333333	0.333333	0.333333	0.296961	0.000000	0.000000	0.000000

Figure 14: Analytical Network Process

Validating the Use of SuperDecisions

While there are a variety of software programs that can be used to evaluate supplier selection decisions from an MCDM perspective, SuperDecisions was the tool used for this research. It was developed by Dr. Thomas Saaty and implements the AHP and ANP techniques in a straightforward manner. Further review of MCDM research questions analyzed with AHP and

ANP techniques indicated SuperDecisions was a reliable tool for the topic. Elkhayat *et al* (2020) used the AHP tool to answer a question about construction in their research. Baldemir *et al* (2013) used its ANP approach to analyze an environmentally friendly decision in cities. Nematkhah *et al* (2017) used its ANP functionality to answer a manufacturing question. Gencer and Gurpinar (2006) endorse its application to supplier selection questions in their research even though they use MS Excel as their analysis tool. Ultimately, the decision to employ SuperDecisions was supported by a robust list of academic articles seeking similar answers to this research.

Methodological Limitations

Given that there is no formal weighting system applied to FEMA's STOS, the research uses a notional weighting system rooted in a theoretically-based reading of the federal contracting document. STS theory is applied to the STOS in order to collect variables into the three dimensions considered in the decision-making process. Then, the 23 variables are further concentrated into 7 variables whose nomenclature and definitions are found in the academic literature. The weighting system assigned to these seven variables are based upon the number of original 23 variables found in their domain. This limits the applicability of the research because it assumes a level of importance for each variable that may not necessarily be true. However, FEMA's Transportation Program office confirmed that there is no internal mathematical formula used when selecting a TSP and that a number of factors are considered depending on the needs of the particular move. Therefore, this approach leans on academic literature to develop a notional level of importance. While this internal process limits this research's ability to provide a specific formula for TSP selection, it can provide a specific methodology, validated with a notional analysis, for analyzing alternatives.

FEMA's caveat that much of their decision depends on the needs of a particular move lends credibility to the decision to use historical evidence from the response to Hurricane Maria in Puerto Rico (2017). According to FEMA's own After-Action Report written in 2018, the complexities of responding to Hurricane Maria amidst a tumultuous hurricane season throughout the Caribbean and Continental United States made for a never before seen response effort. AHP and ANP analysis can accommodate for this level of complexity when working through a decision. Its limitation may be its direct transferability to more straightforward scenarios, namely ground transportation in the Continental United States. However, by developing a more complex hierarchy and network, the efforts could be adapted to simpler transportation requirements when necessary.

Based upon previous research and interviews following Hurricane Maria (Green, 2019), the alternative TSPs were built for the model. In large part, the lack of substantial data depicting the ground transportation arena in Puerto Rico will limit the immediate applicability of the model to a TSP selection scenario. However, as Kim *et al* (2019) recommend, serious investment into understanding the TSP landscape in the response region is critical to sound supplier selection. Given that FEMA operates an internal Logistics Supply Chain Management Systems (LSCMS), having a through depiction of potential suppliers, not just rate-based profiles, will assist in executing these selection action in real-world scenarios.

IV. Results and Analysis

The results section presents the preferred alternative given the inputs. Ultimately, in both the hierarchy and network processes, the analysis aims to demonstrate a data-driven approach to factor evaluation in the pairwise comparisons. Since the data is used for a notional analysis, and a methodological approach to answering the research question, the results present a theoretical scenario with contributions from FEMA's STOS, academic literature, and Hurricane Maria research. The baseline results develop an important foundation for the remainder of the analysis, where situational differences in response scenarios could changes the TSP selected. Since no disaster response is the same, the analysis demonstrates the effects of weighting variables differently.

AHP Results

The outcomes of the STOS-based variable weighting and notional TSPs is demonstrated in Figure 13 where TSP 2 is the preferred alternative. In our constructed scenario, the preferred option is the TSP that can provide the greatest reliability and timeliness in addition to solid performance among the other highly rated variables. Of note, reliability and timeliness, when linked in a single alternative and evaluated against the most heavily considered variable (cost), are more determinative for selection. While cost is the most heavily weighted variables, it cannot be the only variables dictating a selection. In some cases, low cost could be a proxy for poor quality and reduced reliability while in others, high cost could really mean immense flexibility and strict timeliness. Ultimately, FEMA's STOS identifies multiple criteria because it contributes to the most informed selection of alternatives.

Given our notional information, the below outcomes provide more information than a simple selection. By presenting a "Normals" values as well, the results identify a ratio of movement requirements that can be granted to a specific alternative. In this case, TSP 1 should be allocated approximately 35% of the requirements, TSP 2 39%, and TSP 3 26%. This dispersal of movement requirements provides two advantages. First, it is a risk management strategy. In the case of Hurricane Maria, massive amounts of cargo sat in the Port of San Juan (Gillespie *et al*, 2017). If a selection scenario determined that, based upon the "Ideals" scores, that all movement requirements must be directed to a single alternative, an extraordinary amount of pressure and risk falls on a single partner. For situations like Hurricane Maria, this could mean even more cargo sits idle waiting to be moved to citizens in need. However, by allocating movement requirements based upon the "Normals" score, if a single TSP is unable to perform, all movement requirements are not completely halter, thereby reducing the enterprise-wide risk. Secondly, as FEMA hopes to introduce new TSPs, "Normals" values can provide a reasonable allocation of movement requirements to acquire initial performance metrics and reduce the overall risk of welcoming a newcomer. This topic will be discussed in the recommendations section as well.

Name	Graphic	Ideals	Normals
1TSP One		0.890045	0.348413
2TSP Two		1.000000	0.391456
3TSP Three		0.664522	0.260131

Figure 15: Outcome with Notional TSPs

AHP Sensitivity Analysis

Given that this research is notional, it is important this analysis spends time evaluating sensitivity. Sensitivity is defined as how priorities of the alternatives change as criterion importance are varied (SuperDecisions). Throughout this section, the sensitivity analysis demonstrates that no single variable has universal dominance in dictating alternative outcome. For example, in Figures 8, cost is portrayed on the x-axis and preferred alternative on the y-axis. The vertical dotted line indicates a point of rank reversal, where cost's weight increases to a level of importance that subsequently causes a change in preferred alternative (TSP). While the profile of cost remains the same in the figure, as its level of importance increases or decreases, the rank of the TSP changes.

Based on the STOS, cost is the most heavily weighted variable at 0.33 (seen in Figure 10). Based upon the pairwise comparisons, it drives a cost-conscious TSP 1 to a second place standing amongst the alternatives. But, when cost's weight increases 0.10 to 0.43, as seen Figure 15, TSP 1 becomes the top-ranked alternative. This example is important for several reasons. First, in the case FEMA must make a cost-conscious decision amongst relatively similar alternatives, it can employ a higher weight on the cost variable to determine the appropriate outcome. Moreover, it can understand and mathematically portray the situations in which reliance on cost could cause degradation in other key TSP profiles, namely reliability and flexibility. Since the analysis is notional, and the research a methodological approach to answering the research question, this is critical information for FEMA. Ultimately, once the models are built, sensitivity knowledge can allow for situation-specific adaptation.

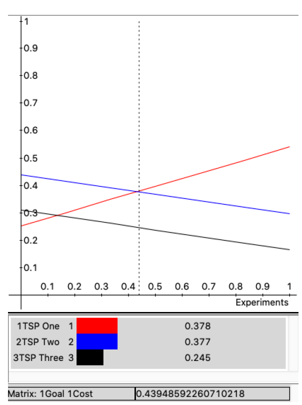

Figure 16: Cost Sensitivity

In responding to events like Hurricane Maria on island states or territories, flexibility may be the most important variable to be considered when selecting an alternative. Based upon the analysis of the STOS, flexibility is the fourth-most valued variable (seen in Figure 10). However, more flexible commercial partners could be critical when responding to specific events. In this analysis TSP 3 is built as the most flexible alternative. When the decision maker weights flexibility at approximately four-times more important than it is in the baseline analysis (0.33 as opposed to 0.08), a rank reversal takes place where TSP 3 becomes the preferred alternative. Understandably, this increase in weight will reduce the importance of variables like cost. It's likely that a very flexible TSP also happens to be the costliest. But, in a dire situation like Hurricane Maria, where immense flexibility is required to move aid from federal staging areas to regional staging areas, this may be a determinative criterion for FEMA when selecting the best TSP.

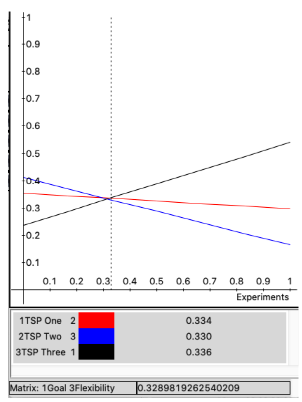

Figure 17: Flexibility Sensitivity

Natural disasters often strike the same area on a regular basis (Chinoy, 2018). In these situations, FEMA generally has a strong idea of the environment in which they will need to operate and the requirements to do so. In order to execute required movement, it would make sense to select the alternative that is the most reliable. In this analysis TSP 2 is built for this use case. The sensitivity analysis in Figure 17 indicates that when reliability is weighted at approximately 0.184, TSP 2 becomes the preferred alternative. The additional priority given to TSP 2's timeliness certainly accounts for a slightly lower overall weight driving the initial rank reversal. However, it is used to demonstrate a common situation in which FEMA operates and can be modified for different situations

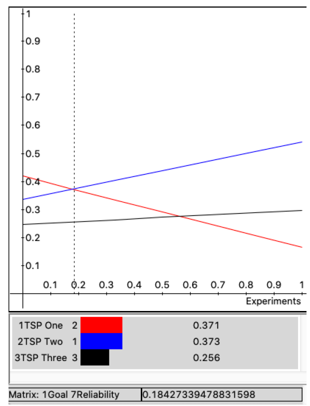

Figure 18: Reliability Sensitivity

Ultimately, sensitivity of a given variable can be evaluated like the three demonstrated above. With this notional analysis, FEMA has a methodology that can be employed and adapted for certain scenarios in order to operationalize their culture of preparedness.

ANP Results

Figure 14 demonstrates the outcomes of the network analysis. While the TSP 2, TSP 1, TSP 3 "Ideals" value, or sole selection decision remains the same, the "Normals" values are quite different from the AHP results. The most notable change in "Normals" values is seen in TSP 3, with an increase of over 0.04. In a situation where FEMA is allocating movement priorities based upon this methodology, TSP 3 would receive an additional 4% of the movements if shared amongst alternatives.

In the AHP discussion above, the research analyzes sensitivity of specific criteria and how it impacts the "Ideals" value. ANP considers this in its analysis through a study of interdependence. So, if FEMA can acquire more flexibility from TSP 3 with additional cost, the human labeler can quantify this situation in the pairwise comparison and it will be accounted for in the selection of a single TSP or distribution of movement requirements amongst TSPs. Also, ANP can allow the criteria to be affected by the potential alternatives. So, in the case each alternative is priced similarly, the importance of cost as a decision criterion could be changed. For FEMA, knowledge of the network analysis process could provide for those situations where nuance is critical and the decision matrix is less hierarchical. While the goal of this research is not to compare AHP and ANP, the analysis demonstrate how interdependence can play into the final result and or allocation of movement amongst alternatives.

Name	Graphic	Ideals	Normals
1TSP One		0.894387	0.328798
2TSP Two		1.000000	0.367624
3TSP Three		0.825783	0.303578

Figure 19: ANP Outcome

Results Conclusion

With this notional analysis, FEMA has a methodology to employ and adapt for certain situations in order to operationalize their "culture of preparedness." Both AHP and ANP provide approaches to evaluating criteria and alternatives. While the SuperDecisions results provide the single best alternative given the framework, it also offers a distributed decision by employing the "Normals" scores. This benefits a government organization that is often required by law to allocate its contracts among different alternatives. Ultimately, armed with two frameworks for multi-criteria decision making and knowledge of how criteria sensitivity affects outcome, FEMA can enter preparedness conversations with a methodology to select the best TSP.

V. Conclusion and Recommendations

This research uses a notional analysis to execute FEMA's practice of selecting the best TSP. The background and literature orient the problem and the academic framework used to organize the data for the notional analysis. SuperDecisions uses these inputs to conclude which notional TSP is best positioned given the criteria. In answering this research question, this theoretical example provides a methodology for use when posed with a selection decision and these recommendations present the necessary insights for FEMA to proceed.

Recommendation for FEMA

Employ a Weighting System through AHP and/or ANP that can be Adapted to Various Scenarios

Supplier selection has become an increasingly complex question in supply chain management. While much of the early research into this question centered around evaluating alternatives based upon cost, recent academic literature recognizes the importance of additional variables in the selection process (Gencer and Gurpinar, 2006). For FEMA, cost is the first metric evaluated when deciding amongst alternatives and drives the initial ranking of TSPs from least to most expensive. And, while there are other variables considered in their overall decision, there is no comprehensive formula used to evaluate variables for selection or distribution of movement requirements. In order to make the most informed decision, adapted to specific situations, it is imperative that FEMA treat TSP selection as a multi-criteria decision-making problem and employ a weighting mechanism in their process.

There are a variety of techniques that can be used to answer MCDM problems, but in questions similar to this research question, AHP and ANP methodologies are used most frequently (Kim *et al*, 2019). Both approaches provide a mechanism for organizing the decision FEMA must make when selecting a TSP. By using a codified pairwise comparison technique, additional variables can be considered against one another in the pairwise process. Further pairwise comparisons can take place between alternatives as well. Initially, this methodology can be used to create the weights for criteria simply by using the 1-9 scale in AHP/ANP. Over time, after collecting information on how the model's recommendations execute movement requirements, explicit weights can be assigned for the criteria under consideration in the STOS itself. If that is not the desired outcome, pairwise comparisons can be completed for each decision at hand and specially curated for individual responses. Ultimately, by assigning values to each variable under consideration, and using AHP/ANP to pool those values in a matrix process, FEMA can apply a scientific procedure to their TSP selection process.

The selection outputs can be viewed from a variety of different angles: selecting a single TSP, distributing movement requirements amongst TSPs, and even providing an opportunity for new TSPs. These outcomes further indicate the applicability and usefulness of the AHP/ANP process. Not only is it a scientific procedure for selection, it is a risk management and new vendor opportunity tool. The issues and intricacies of Hurricane Maria demonstrate the need to have a well-distributed allocation of movement providers as an operational strategy. If FEMA selected a single TSP for middle mile movement in Puerto Rico, and that TSP was completely inoperable, even more containers would have set idle at the Port of San Juan. By distributing movement requirements amongst alternatives according to AHP/ANP outcomes, FEMA is issuing an inherently flexible plan, already accounting for some level of unexpectedness in their response scenario. Also, it is likely that FEMA would need to account for government contracting provisions, including first-time TSPs. In these situations, FEMA can look to AHP/ANP methodologies to distribute movements and then use a baseline percentage for new providers. In this research, reducing allocation by 3% across each TSP, could provide a new TSP 9% of the movement requirements.

Record and Store TSP Performance Profiles

In the analysis, notional TSPs are developed based upon historical research of logistics providers. This provides the basis for evaluating alternative TSPs against the variables at play in the decision process. In order for FEMA to make the best decision for future scenarios, it needs to have well-recorded details of TSPs in action. While performance history is included in the current decision-making process, these details need to be translated into model inputs for a comprehensive assessment of alternatives. Given the nature of AHP/ANP's 1-9 scale, a score of 1-9 could be used to evaluate a TSP's reliability, timeliness, quality, and flexibility. These 1-9 scores could be applied after utilizing a supplier scorecard, a common practice throughout supplier selection practice and academic literature (Gencer and Gurpinar, 2007). Then, these scores could be stored in FEMA's Logistics Supply Chain Management Systems (LSCMS) and recalled when a new movement requirement and subsequent decision needs to be made. By recording TSP performance profiles using the AHP/ANP scale, and storing it in their LSCMS, FEMA can tailor selection decisions based upon those TSP's most well-positioned to perform against a specific criterion.

Use Modeling Software for Conducting TSP Selection

This research uses AHP and ANP methodologies in SuperDecisions to orient variables and select alternatives. The pairwise comparison analysis provides a methodology for the decision process. By using a software or modeling tool that can work through the decision at hand – either through a pairwise comparison process or another technique – FEMA can ensure an objective decision-making process is executed on behalf of the STOS. Additionally, throughout the academic literature, there are a variety of programs used in the scenarios in the case SuperDecisions is not a suitable option for FEMA.

Future Research

Kim *et al*'s 2018 research represented the first academic work focused solely on developing criteria for logistics service provider (LSP) selection in disaster relief. Their case organization was a humanitarian response organization (HRO) in India. This research builds upon their recommendation to examine this decision from the perspective of a different organization – FEMA. Given the new nature of this line of research, additional analysis of HROs and their LSP/TSP decision matrix is recommended. Further analysis in this area will allow for comparative studies between HROs and regions as they go about selecting potential partners when responding to natural disasters.

Additionally, there is ample room for FEMA-specific research in this supplier selection decision. Given the notional approach to this analysis, selection criteria currently employed in the STOS should be evaluated against TSPs to determine if they are adequate measures of performance. In large part, these variables mirror much of what the academic community has indicated is important in selecting providers, and has ultimately been determinative of performance. However, selecting partners for disaster relief is a unique supplier selection decision and more research into evaluating metrics will better positions HROs for their response obligations.

Lastly, methodological variations should be examined for this MCDM problem. While this analysis used AHP and ANP for its research, there are several other approaches to this type of problem. Hybrid MCDM, fuzzy MCDM, fuzzy AHP, and TOPSIS are just a few of the methodologies that are used to approach similar questions (Mardani *et al*, 2015)

Limitations

The TSP selection process was completely notional. While the framework was developed from academic literature, federal contracting documentation, and historical information, there was no hard data used in the analysis. The socio-technical framework drove variable identification and grouping while STOS-based estimates informed the model's weighting mechanics. Since FEMA does not currently employ a mathematical formula when considering variables, this was the necessary approach, but limits the immediate application of the analysis. However, it does not limit the application of the decision methodology, the primary answer to this research question. Future research including a FEMA-designed weighting procedure could alleviate this limitation and provide an actual evaluation tool instead of the theoretical methodology demonstrated in this notional analysis.

Additionally, notional profiles of potential TSPs were used in the analysis. While these notional TSPs are reasonable depictions of alternatives, they do not include real-world providers. While this limits the immediate application to an actual decision, it does allow for adaptability to future FEMA decisions if aligned with the above recommendation to record and store TSP performance profiles.

Conclusion

Hurricane Maria marked the single most devastating disaster in the history of the United States and its effects on Puerto Rico are still seen today (Eschner, 2019). Humanitarian aid backlogs in federal staging areas were a direct result of an absent middle mile and destroyed infrastructure. As the disaster and its aftereffects unfolded, FEMA was largely unprepared to execute on the activities and measures required by response doctrine when entire supply chains and institutions are devastated. These realities are acknowledged in its 2017 After Action Report and guide much of the priorities established in the 2018-2022 Strategic Plan. The challenges of 2017 "demonstrated that additional people, processes, doctrine, and contracted services are needed to effectively move resources from point of origin to disaster survivors during large-scale incidents" (Strategic Plan, 25). Born from this acknowledgement is this central research question: how can FEMA select the best transportation service provider (TSP) in preparation for disaster response?

The research takes the opportunity to present the answer through a methodology recommended for implementation as a "process […] to effectively move resources from point of origin to disaster survivors" (Strategic Plan, 25). The methodology builds on existing academic literature categorizing TSP selection as an MCDM supplier selection challenge answered through AHP/ANP analysis. Ultimately, if used, FEMA can continue to build its "culture of preparedness", and shape middle mile selection practices for the disasters to come.

Appendix A

Variables discussed in FEMA's STOS

1. Cost
2. Past performance
3. Capacity
4. Factors specific to requirements of the move
5. Percentage of on-time deliveries
6. Percentage of shipments that include overcharges or undercharges
7. Percentage of claims received in a given period
8. Percentage of returns receive on-time
9. Percentage of shipments rejected
10. Percentage of billing improprieties
11. Average response time on tracing shipments
12. TSP's safety record (accidents, losses, damages, or misdirected shipments) as a percentage of all shipments
13. TSP's driving record (accidents, traffic tickets and driving complaints) as a percentage of shipments
14. Percentage of customer satisfaction reports on carrier performance
15. TSP withdraws from commitment
16. TSP refusal to accept transportation tender
17. TSP fails to meet Required Delivery Date (RDD)
18. TSP fails to provide In-Transit Visibility (ITV)
19. TSP fails to meet pickup time
20. TSP loses or damages shipment
21. Ability to provide accessorial and special services
22. Adherence in observing Federal, State, local and FEMA shipping facility regulations
23. Unwarranted refusal of shipments or selective acceptance of shipments, which are prohibited by this STOS

Appendix B

Variables grouped with literature and academic framework

Cost	***Reliability***	***Timeliness***	***Flexibility***	***Quality***	***ITV***	***Operational Safety***
Cost	Past performance	Percentage of on-time deliveries	Capacity	Percentage of claims received in a given period	Average response time on tracing shipments	TSP's driving record (accidents, traffic tickets and driving complaints) as a percentage of shipments
	Percentage of shipments that include overcharges or undercharges	Percentage of returns receive on-time	Factors specific to requirements of the move	TSP's safety record (accidents, losses, damages, or misdirected shipments) as a percentage of all shipments	TSP fails to provide In-Transit Visibility (ITV)	Adherence in observing Federal, State, local and FEMA shipping facility regulations
	Percentage of shipments rejected	TSP fails to meet Required Delivery Date (RDD)	Ability to provide accessorial and special services	TSP loses or damages shipment		
	Percentage of billing improprieties	TSP fails to meet pickup time				
	Percentage of customer satisfaction reports on carrier performance					
	TSP withdraws from commitment					
	TSP refusal to accept transportation tender					
	Unwarranted refusal of shipments or selective acceptance of shipments, which are prohibited by this STOS					

Bibliography

Abidi, H., Leeuw, S. D., & Klumpp, M. (2015). The value of fourth-party logistics services in the humanitarian supply chain. *Journal of Humanitarian Logistics and Supply Chain Management, 5*(1), 35-60. doi:10.1108/jhlscm-02-2014-0010

Advanced Training System. (2020, June 23). Middle-Mile Logistics Play Evolving Role in U.S. Consumer Supply Chain. Retrieved September 13, 2020, from https://www.sdcexec.com/transportation/press-release/21137985/advanced-training-systems-llc-middlemile-logistics-play-evolving-role-in-us-consumer-supply-chain

Atapattu, R. (2017, October 11). Logistics Front and Center in the Puerto Rico Disaster; Who is to be Blamed? Retrieved September 13, 2020, from https://www.shipoci.com/logistics-front-center-puerto-rico-disaster-blamed/

Baharmand, H., Comes, T., & Lauras, M. (2017). Managing in-country transportation risks in humanitarian supply chains by logistics service providers: Insights from the 2015 Nepal earthquake. *International Journal of Disaster Risk Reduction, 24*, 549-559. doi:10.1016/j.ijdrr.2017.07.007

Baldemir, E., Kaya, F., & Şahin, T. K. (2013). A Management Strategy within Sustainable City Context: Cittaslow. *Procedia - Social and Behavioral Sciences, 99*, 75-84. doi:10.1016/j.sbspro.2013.10.473

Bealt, J., Barrera, J. C., & Mansouri, S. A. (2016). Collaborative relationships between logistics service providers and humanitarian organizations during disaster relief operations. *Journal of Humanitarian Logistics and Supply Chain Management, 6*(2), 118-144. doi:10.1108/jhlscm-02-2015-0008

Beecham, M. (2020, February 19). Robo-van B2B logistics for the retail industry. Retrieved September 13, 2020, from https://www.just-auto.com/interview/robo-van-b2b-logistics-for-the-retail-industry_id193764.aspx

Bloomberg News (2020, June 19). Walmart's self-driving, middle-mile partner is changing ecommerce economics. Retrieved September 13, 2020, from https://www.digitalcommerce360.com/2020/06/19/walmarts-self-driving-middle-mile-partner-is-changing-ecommerce-economics/

Chatterjee, A., & Layton, A. (2020). Mimicking nature for resilient resource and infrastructure network design. *Reliability Engineering & System Safety, 204*, 107142. doi:10.1016/j.ress.2020.107142

Chinoy, S. (2018, May 24). The Places in the U.S. Where Disaster Strikes Again and Again. *The New York Times.*

Chou, C. (2011). Evaluating the quality of airport service using the fuzzy multi-criteria decision-making method: A case study of Taiwanese airports. *Expert Systems, 29*(3), 246-260. doi:10.1111/j.1468-0394.2010.00574.x

Chou, C., & Ding, J. (2013). Application of an Integrated Model with MCDM and IPA to Evaluate the Service Quality of Transshipment Port. *Mathematical Problems in Engineering, 2013*, 1-7. doi:10.1155/2013/656757

Closs, D. J., Jacobs, M. A., Swink, M., & Webb, G. S. (2007). Toward a theory of competencies for the management of product complexity: Six case studies. *Journal of Operations Management, 26*(5), 590-610. doi:10.1016/j.jom.2007.10.003

Cozzolino, A., Wankowicz, E., & Massaroni, E. (2017). Logistics service providers' engagement in disaster relief initiatives. *International Journal of Quality and Service Sciences, 9*(3/4), 269-291. doi:10.1108/ijqss-04-2017-0040

Elkhayat, Y. O., Ibrahim, M. G., Tokimatsu, K., & Ali, A. A. (2020). Multi-criteria selection of high-performance glazing systems: A case study of an office building in New Cairo, Egypt. *Journal of Building Engineering, 32*, 101466. doi:10.1016/j.jobe.2020.101466

Eschner, K. (2019, July 10). The most dangerous places to live in America that are prone to natural disasters. *CNBC.*

F. (2018). *Robert T. Stafford Disaster Relief and Emergency Assistance Act, 100th United States Congress (1988).* (pp. 1-65, Rep.). Washington, D.C.

FEMA. (2018). *2017 Hurricane Season FEMA After-Action Report* (pp. 1-65, Rep.). Washington, D.C.: FEMA.

FEMA. (2018). *2018-2022 Strategic Plan* (United States of America, Department of Homeland Security, Federal Emergency Management Agency). Washington, D.C.

FEMA. (2018). *Federal Emergency Management Agency Standard Tender of Service* (Second ed.) (United States of America, Department of Homeland Security, Federal Emergency Management Agency). Washington, D.C.

FEMA. (2019). *National Response Framework* (4th Edition ed., pp. 1-57) (United States of America, Department of Homeland Security, Federal Emergency Management Agency). Washington, D.C.

Gencer, C., & Gürpinar, D. (2007). Analytic network process in supplier selection: A case study in an electronic firm. *Applied Mathematical Modelling, 31*(11), 2475-2486. doi:10.1016/j.apm.2006.10.002

Gillespie, P., Romo, R., & Santana, M. (2017, September 28). Puerto Rico aid is trapped in thousands of shipping containers. *CNN.*

Gorener, A. (2012). Comparing AHP and ANP: An Application of Strategic Decisions Making in a Manufacturing Company. *International Journal of Business and Social Science, 3*(11), 194-208.

Green, N. (2019). *Humanitarian Logistics: Shipping Designs for the Post Disaster Cargo Surge* (Doctoral dissertation, Air Force Institute of Technology, 2019). Wright-Patterson Air Force Base, Ohio: Air Force Institute of Technology.

Hadid, W., Mansouri, S. A., & Gallear, D. (2016). Is lean service promising? A socio-technical perspective. *International Journal of Operations & Production Management, 36*(6), 618-642. doi:10.1108/ijopm-01-2015-0008

Ho, W. (2008). Integrated analytic hierarchy process and its applications – A literature review. *European Journal of Operational Research, 186*(1), 211-228. doi:10.1016/j.ejor.2007.01.004

Ilhan, A. (2011). The Humanitarian Relief Chain. *South East European Journal of Economics and Business, 6*(2), 45-54. doi:10.2478/v10033-011-0015-x

Kim, S., Ramkumar, M., & Subramanian, N. (2018). Logistics service provider selection for disaster preparation: A socio-technical systems perspective. *Annals of Operations Research, 283*(1-2), 1259-1282. doi:10.1007/s10479-018-03129-3

Kovács, G., & Spens, K. M. (2007). Humanitarian logistics in disaster relief operations. *International Journal of Physical Distribution & Logistics Management, 37*(2), 99-114. doi:10.1108/09600030710734820

Kull, T. J., Ellis, S. C., & Narasimhan, R. (2013). Reducing Behavioral Constraints to Supplier Integration: A Socio-Technical Systems Perspective. *Journal of Supply Chain Management, 49*(1), 64-86. doi:10.1111/jscm.12002

Kyavars, V., & Subramanian, S. (2017). Multi Criteria Decision Making to Select the Suitable Method for the Preparation of Nanocrystals Using an Analytic Hierarchy Process. *Indian Journal of Pharmaceutical Education and Research, 51*(2), 249-259. doi:10.5530/ijper.51.2.30

Leiras, A., Jr, I. D., Peres, E. Q., Bertazzo, T. R., & Yoshizaki, H. T. (2014). Literature review of humanitarian logistics research: Trends and challenges. *Journal of Humanitarian Logistics and Supply Chain Management, 4*(1), 95-130. doi:10.1108/jhlscm-04-2012-0008

Long, S. (2013). *Socioanalytic methods discovering the hidden in organisations and social systems*. London: Karnac Books.

Mardani, A., Zavadskas, E. K., Khalifah, Z., Jusoh, A., & Nor, K. M. (2015). Multiple Criteria Decision-Making Techniques In Transportation Systems: A Systematic Review Of The State Of The Art Literature. *Transport, 31*(3), 359-385. doi:10.3846/16484142.2015.1121517

Nematkhah, F., Raissi, S., & Ghezavati, V. (2017). An integrated fuzzy DEMATEL-fuzzy ANP approach to nominate diagnostic method and measuring total predictive performance score. *Safety and Reliability, 37*(1), 48-72. doi:10.1080/09617353.2017.1411676

Nematkhah, F., Raissi, S., & Ghezavati, V. (2017). An integrated fuzzy DEMATEL-fuzzy ANP approach to nominate diagnostic method and measuring total predictive performance score. *Safety and Reliability, 37*(1), 48-72. doi:10.1080/09617353.2017.1411676

Pettit, S., & Beresford, A. (2009). Critical success factors in the context of humanitarian aid supply chains. *International Journal of Physical Distribution & Logistics Management, 39*(6), 450-468. doi:10.1108/09600030910985811

Rezaei, J., Fahim, P. B., & Tavasszy, L. (2014). Supplier selection in the airline retail industry using a funnel methodology: Conjunctive screening method and fuzzy AHP. *Expert Systems with Applications, 41*(18), 8165-8179. doi:10.1016/j.eswa.2014.07.005

Robert T. Stafford Disaster Relief and Emergency Assistance Act, 100th United States Congress (1988).

Robles, F. (2018, July 12). FEMA Was Sorely Unprepared for Puerto Rico Hurricane, Report Says. *New York Times*.

Rodríguez-Espíndola, O., Albores, P., & Brewster, C. (2018). Disaster preparedness in humanitarian logistics: A collaborative approach for resource management in floods. *European Journal of Operational Research, 264*(3), 978-993. doi:10.1016/j.ejor.2017.01.021

Saaty, T. L. (1990). *The analytic hierarchy process: Planning, priority setting, resource allocation*. Pittsburgh, Pennsylvania: RWS Publ.

Saaty, T. L. (1996). *Decision making with dependence and feedback: The analytic network process*. Pittsburgh, PA, Pennsylvania: RWS Publ.

Saaty, T. L., & Vargas, L. G. (2001). The Seven Pillars of the Analytic Hierarchy Process. *International Series in Operations Research & Management Science Models, Methods, Concepts & Applications of the Analytic Hierarchy Process,* 27-46. doi:10.1007/978-1-4615-1665-1_2

Schulz, S. F., & Heigh, I. (2009). Logistics performance management in action within a humanitarian organization. *Management Research News, 32*(11), 1038-1049. doi:10.1108/01409170910998273

Sigala, I. F., & Wakolbinger, T. (2019). Outsourcing of humanitarian logistics to commercial logistics service providers. *Journal of Humanitarian Logistics and Supply Chain Management, 9*(1), 47-69. doi:10.1108/jhlscm-12-2017-0073

Smith, A. (2020, January 08). 2010-2019: A landmark decade of U.S. billion-dollar weather and climate disasters: NOAA Climate.gov. Retrieved September 13, 2020, from https://www.climate.gov/news-features/blogs/beyond-data/2010-2019-landmark-decade-us-billion-dollar-weather-and-climate

Staff, J. (2017, October 5). Snarled distribution networks hamper Puerto Rico relief. Retrieved September 13, 2020, from https://www.joc.com/international-logistics/snarled-distribution-networks-hamper-puerto-rico-relief_20171005.html

Swanson, R. D., & Smith, R. J. (2013). A Path to a Public-Private Partnership: Commercial Logistics Concepts Applied to Disaster Response. *Journal of Business Logistics, 34*(4), 335-346. doi:10.1111/jbl.12031

Thomas, A., & Kopczak, L. (2005). *From Logistics to Supply Chain Management: The Path Forward in the Humanitarian Sector* (Rep.). San Francisco, CA: Fritz Institute.

Tomasini, R. M., & Wassenhove, L. N. (2009). From preparedness to partnerships: Case study research on humanitarian logistics. *International Transactions in Operational Research, 16*(5), 549-559. doi:10.1111/j.1475-3995.2009.00697.x

Tomasini, R. M., & Wassenhove, L. N. (2009). From preparedness to partnerships: Case study research on humanitarian logistics. *International Transactions in Operational Research, 16*(5), 549-559. doi:10.1111/j.1475-3995.2009.00697.x

Trist, E. L., & Bamforth, K. W. (1951). Some Social and Psychological Consequences of the Longwall Method of Coal-Getting. *Human Relations, 4*(1), 3-38. doi:10.1177/001872675100400101

Van Wassenhove, L. (2006). *Humanitarian Aid Logistics: Supply Chain Management in High Gear*. Lecture presented at Blackett Memorial Lecture.

Vega, D., & Roussat, C. (2015). Humanitarian logistics: The role of logistics service providers. *International Journal of Physical Distribution & Logistics Management, 45*(4), 352-375. doi:10.1108/ijpdlm-12-2014-0309

Wu, W., Sukoco, B. M., Li, C., & Chen, S. H. (2009). An integrated multi-objective decision-making process for supplier selection with bundling problem. *Expert Systems with Applications, 36*(2), 2327-2337. doi:10.1016/j.eswa.2007.12.022

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
01-10-2020	Master's Graduate Research Paper	June 2020 - October 2020

4. TITLE AND SUBTITLE
ON THE SELECTION OF FEMA’S TRANSPORTATION SERVICE PROVIDERS: HOW TO EMPLOY THE ANALYTICAL HIERARCHY AND NETWORK PROCESSESS TO MAKE GUIDED DECISIONS

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Barrows, Denver, Capt, USAF

5d. PROJECT NUMBER
AFIT-ENS-MS-20-036

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/EN)
2950 Hobson Way
Wright-Patterson AFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT-ENS-MS-20-036

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Intentionally Left Blank

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Hurricane Maria caused massive supply chain disruptions in Puerto Rico. This was most evident in the middle mile, where humanitarian aid was supposed to move from federal staging areas to regional staging areas. As a result, more than 3 million Americans failed to receive the life-saving support they needed in a timely manner. The research uses this historical account and FEMA contracting documentation to develop a notional analysis evaluated with two methodologies to examine potential transportation service providers in the middle mile. The supplier selection question is framed as a multi-criteria decision-making problem where criteria are grouped through a socio-technical system lens and evaluated using Analytical Hierarchy and Network Processes in SuperDecisions. The research recommends this methodology and tool be employed as a standard process in FEMA’s selection of transportation service providers in an effort to operationalize its culture of preparedness.

15. SUBJECT TERMS
Transportation Service, Network Processes

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
U	U	U	UU	56	Lt Col Timothy Breitbach, AFIT/ENS
					19b. TELEPHONE NUMBER *(Include area code)* (937) 255-3636 timothy.breitbach@afit.edu

Reset