PHASE I of NCFRP 50

Improving Freight Transportation Resilience in Response to Supply Chain Disruptions

DRAFT for Comment

Task 1: Review and Assess Freight Resiliency
Research Practices and Approaches

Prepared for

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1. Literature Review

Various documents, including journal articles, reports, conference papers, articles in periodicals, news articles, presentations and electronic sources were reviewed as part of the assessment of freight resiliency research practices and approaches found in the U.S. and other countries. The primary focus was to collect literature that presented freight disruption case studies, provided mitigation measures that minimized the impact of the disruptive event and/or provided lessons learned to assist in expedited recovery efforts in the future. General literature that addressed types of disruptions, resiliency factors, and broad mitigation strategies focused on the freight supply chain were also reviewed. More than 100 documents were considered out of which about 75 document became part of this review. About 63 documents that specifically focused on case studies and mitigation strategies for a disruptive event, formed part of a searchable literature database. The time period of literature reviewed spanned from year 2000 to 2016. This chapter presents a summary of the literature review as part of Task 1.

1.1. Disruption Types and Characteristics

A disruptive event is one that causes direct short-term or long-term impacts such as fatalities, infrastructure destruction and economic loss (Purdue University, 2013). In terms of freight transportation, disruption can be defined as the unplanned and unanticipated events that affect the normal flow of goods and operations in supply and transport networks (Svensson, 2000). Disruption, in the context of seaports, can be defined as any significant loss of a port's regular cargo handling capacity (GTRC, 2014). Port disruptions not only affect those freight businesses directly involved in maritime operations, but can also affect the broader regional economies and industrial sectors they support (GTRC, 2014).

In order to enhance freight transportation system resilience, it is important to understand various types of disruption and their characteristics. The following sections discuss these characteristics using a number of well-documented past disruption events as examples.

1.1.1. Advance Notification

An important characteristic of disruption related to system resiliency is advance notification, or the amount of time before which we can know that a disruptive event will occur. This is also known as "lead time", which is defined as "the time between knowing that a disruptive event will take place and the event's first impact." (Sheffi, 2015). This timeframe can vary depending on the type of disruption and it can help characterize types of disruptive events. Some disruptions may involve a long-term trend, such as climate change, which provides ample notification. Other disruptions could be planned, such as a lock closure, which provides relatively accurate advance notification and opportunity to make alternate arrangements. Disruptions can also occur without any advance notification, such as an earthquake or fire. Based on the advance notification time, a disruptive event can be characterized as follows. These categories can be further classified into man-made and natural events:

- **Abrupt events** – disruptions that occur with zero to extremely little advance notification. These could be natural events such as earthquakes, tsunamis, or man-made events such as terrorist attacks, bridge failures, fires, technology failures or financial failures. These events show very little to no prior warning signs. Advance notification of such events could be measured in minutes or hours.

  The September 11 tragedy, an abrupt event, temporarily prevented movement of goods across all borders into the U.S. (Oke & Gopalakrishnan, 2009). Manufacturers began to experience disruptions to the flow of materials. Ford Motors had idle assembly lines intermittently. Toyota was about to halt production at its Sequoia SUV plant in Indiana due to lack of steering sensors as all inbound traffic via ports and airports was shut (Sheffi, 2002).

Similar consequences were observed after the March 2011 earthquake in Sendai, Japan which measured M9.0 on the Richter scale (OSSPAC, 2013), and in turn generated a tsunami. The damage caused by the earthquake and the resultant tsunami shut down the parts manufacturing plants in Japan (Baymout, 2014). A Hitachi Automotive plant, shut down by this disaster, produced a $2 sensor for a $90 airflow sensor used in many vehicles. Due to this, the General Motors engine plant in New York ran out of parts and its vehicle assembly plants in Europe and the U.S. also had to be shut down (Rice, 2011).

- **Rapid events** – disruptions that occurs with little to moderate advance notification. These could be natural events such as a hurricane, snow or ice storm, flood, or man-made events such as a labor strike. These events show some warning signs before occurring and notification could occur days in advance of the actual event onset.

  Superstorm Sandy was a major hurricane which struck the City of Santiago de Cuba on October 26, 2012. Within three days, on October 29, 2012, Sandy also made land fall near Atlantic City, New Jersey, causing a major and very disruptive storm surge in New York and New Jersey (GTRC, 2014).

  In 2002, negotiations between the International Longshoremen and Warehouse Union (ILWU) and the Pacific Maritime Association (PMA) stalled, resulting in a work slowdown on all U.S. west coast ports and a strike by ILWU workers (GTRC, 2012) (Farris III, 2008).

  In 2007, a combination of heavy snow in the Cascade Mountains followed by heavy rains in the southwest portions of Washington State resulted in major flooding. The rainfall intensities were 140 percent higher than the 100-year amount (GTRC, 2012). This led to closure of section of I-5 due to landslides, flood debris and downed powerlines blocking the road (WSDOT, 2008).

- **Planned/Predictable events** – disruptions that occurs with an ample amount of advance notification. These could be natural events such as climate change, or man-made events such as a lock or bridge closure. The majority of these events are planned and hence, they provide sufficient warning signs before occurring. Advance notification of such events could be measured in weeks to months to years.

  An example of such a planned event is the Columbia-Snake river lock closure. Based on a series of inspection reports, in order to replace aging lock gates and repair other components, the U.S. Army Corp of Engineers (USACE) closed the Columbia-Snake Rivers to barge traffic. Five of the locks from The Dalles in Oregon to Lewistown in Idaho were closed for repairs. This led to closure of the entire waterway for a 14-week period. Advance notification of about 18 months was provided to all the stakeholders to prepare for this planned disruption (GTRC, 2014).

  Another example of a predictable event is climate change. It has been reported that, in 2014, the transportation sector accounted for some 33 percent of U.S. CO_2 emissions from fossil fuel combustion (USEPA, 2016). Sea level rise is also a potential outcome of climate change, while stronger hurricanes, an increase in the number of hot days and heat waves, and an increase in intense precipitation events are other changes that directly affect the logistics and infrastructure components of the transportation sector (TRB, 2008), (Becker & Caldwell, 2015).

1.1.2. Disruption Impact –Geographic Scope

Another important characteristic of a disruptive event is its impact in terms of its geographic scope, which may be:

- **Local –** disruptions that affect the local area and can be mitigated by providing detours or other alternate routes for freight transportation. For example, in 2013, the northern span of I-5 over the Skagit River Bridge in northwestern Washington State, collapsed as an oversized load struck the cross truss and sway braces. This led to closure of the bridge and two detours were established. The primary detour route added 0.5 miles of additional travel and the secondary detour added 3 miles of additional travel. The bridge was reopened within 115 days of its collapse after a permanent span was in place (Horton, 2015).

- **Regional –** disruption that impacts the freight transportation and supply networks of an entire region and requires mitigation strategies to overcome its impacts. One example of a regional level disruption is the CSX Howard Street Tunnel Fire in Baltimore. In July 2001, a CSX freight train, carrying a mix of freight and hazardous material, derailed in the Howard Street Tunnel in downtown Baltimore (NTSB, 2004). The fire led to closure of the tunnel to rail traffic for a week. Due to this, all CSX trains were rerouted through Norfolk Southern Corp's tracks. Significant delays, cancellations and diversions of CSX's freight trains were observed. CSX's entire east coast system, as well as the system in the Midwest and as far as Ohio were affected (SAIC, 2002).

  Another example of a regional level disruption is the above referenced Columbia-Snake River Lock Closure. This river system supports goods movement from Washington, Oregon and Idaho, consisting mainly of agricultural products, paper, forest products, and mineral bulk products. The lock closure affected all of these States for a period of 14 weeks, requiring mode shifts and other (e.g. higher price) responses to freight movement (GTRC, 2014).

- **National –** disruptions, significant enough, that impacts to the freight transportation and supply networks of the nation require extensive mitigation strategies, with multiple agencies involved. Such disruptions may lead to declaring a state of emergency.

  Superstorm Sandy, in 2012, was one such disruption that had a national impact. In the aftermath of Superstorm Sandy, the Port of New York and New Jersey was closed for a week. This led to supply chain disruptions, especially when merchandise was arriving for the holiday season. Vessels were diverted to the Port of Halifax, Canada and Port of Virginia, Norfolk and then containers were trucked to their final destinations, inflating overall transportation costs (Stevens Institute, 2013).

  The West Coast Labor Dispute of 2002 which led to port shutdowns was a national level disruption. The PMA's lock out of labor affected all the ports on the west coast of the U.S. and lasted for 10 days. More than 200 ships were at anchorage outside the ports of Los Angeles and Long Beach, and it was estimated that it took six to seven weeks to clear the backlog (GTRC, 2012). When the disruption occurred, the six largest west coast ports handled about 253 million tons of cargo, more than half of all containers passing through the U.S. ports (Farris III, 2008).

- **International –** disruptions that are large enough to affect the international freight transportation and supply networks and require extensive mitigation strategies involving multiple countries. The 2011 earthquake and tsunami in Sendai, Japan was large enough to disrupt the supply networks not only in Japan but also around the world. Japanese manufacturing plants were shut down due to the M9.0 magnitude earthquake (OSSPAC, 2013) and the subsequent tsunami that it generated. This led to shortage of parts for companies such as General Motors, Ford, Apple, etc. across the globe (Baymout, 2014) (Rice, 2011).

  The September 11 terrorist attacks in 2001 also generated an international level disruption. This event not only affected the airline passengers due to a North American airspace closure for three days, but also the freight moving through the ports of New York and New Jersey, which were also closed for three days. While the ports and their freight were not affected in the long term, for a number of days, vessels had no place to go, as all international port of entries were closed (GTRC, 2012). Airline passengers and the aviation industry were also severely impacted. All international flights were either cancelled or diverted to other airports outside the U.S. In the aftermath of the attacks the aviation industry lost significant air traffic and revenue. The event also seems to have led to the failure of some financially weak carriers. Swissair and Sabena went bankrupt within months of the attack (IATA, 2011).

1.1.3. Disruption Impact - Level of Loss

The level of loss, in terms of loss of lives and economic costs, is difficult to quantify, especially for less severe and short-lived disruptions. Moreover, even when literature is available there can be some inconsistency between reporting on the same disruptive event. For example, USA Today reported that Hurricane Sandy caused $65 billion in damage in the U.S. and was responsible for 159 deaths (USA Today, 2013), while a report produced by AON estimated damages worth $72 billion (AON, 2013).

The impact of a disruptive event, depending on its geographical scope, level of predictability, duration, and loss of lives and economic activity, can be classified as:

- **Severe impact –** disruptive events that can affect national or international freight transportation and rank very high in terms of economic loss incurred, and/or due to which many lives are lost. Such events include the 2011 Japan Earthquake, the 2002 West Coast port shutdown, and the September 11 terrorist attacks.
- **High impact –** disruptive events that can affect national or regional freight transportation and rank high on economic loss incurred, and/or due to which lives were lost. Events such as Superstorm Sandy or Hurricane Katrina can be considered as high impact events.
- **Low impact –** disruptive events that can affect regional or local freight transportation and rank low to moderate on economic loss incurred, and/or due to which people were injured. Events such as the Columbia-Snake river closure or the I-5 Skagit River Bridge failure fall in this category.

1.1.4. Disruption Impact – Military Surges

Military overseas deployments begin with the movement of troops, material and equipment from military installations within the continental U.S. (CONUS), with designated U.S. seaports as their most common domestic destination. With more than 95 percent of U.S. warfighters' equipment and supplies passing through U.S. seaports, a great deal of stress is placed on both the cargo handling and transporting capabilities of these ports, as well as on the highways, railways and waterways feeding into them (MARAD, 2005). With a heavy reliance during such “sealift surges” on the nation’s commercially operated ports and modal carriers, a great deal of cooperation and coordination is also required between the numerous military and civilian government agencies and private sector companies involved. Adding to the unique nature of such cargo surges, such deployments usually involve the transport of large pieces of military equipment, such as helicopters, and tanks, that are not otherwise commonly dealt with, using in some instances military vessels designed specifically for the purpose.

Within the DOD, the U.S. Transportation Command (USTRANSCOM) has overall responsibility for managing and coordinating the provision of land, sea and air transportation in times of peace and war. This includes the movement of people, equipment and supplies during large scale military deployments (JCSa,b,c. 2013). Under the USTRANSCOM umbrella, the Military Surface Deployment and Distribution Command (SDDC) handles cargo movements overland and within ports, and the Military Sealift Command (MSC) handles cargo movements by sea.[1]

The Federal Highway Administration (FHWA) works closely with the USTRANSCOM/SDDC’s Transportation Engineering Agency (TEA) to support these overland components of military mobilizations, as do the nation’s private

[1] The Airlift Mobility Command (AMC) also delivers cargos by air as part of USTRANSCOM’s defense transportation mission. http://www.ustranscom.mil/dtr/

railroads. On the military side, a specific SDDC Transportation Battalion (TBN) is responsible for assisting the military units being deployed, by ensuring that the equipment to be convoyed to a seaport is best configured for loading onto the ships that will transport it. There are five such TBNs located within CONUS, each sending personnel to assist at both the military installations and the seaports of embarkation within its jurisdiction, as well as coordinating with multiple seaports involved in large military deployments. This activity leads the U.S. DOT's Maritime Administration (MARAD), at the request of SDDC, to create port planning orders (PPOs) that ensure both sufficient space for arriving military equipment dockside, and a sufficient number of vessel berths for the outbound ships receiving this equipment. These orders specify which port facilities, staging areas, and berthing space the DOD will require in the event of a deployment, and they establish timelines for access. MARAD also coordinates with the commercial ports to maintain operational readiness reports that outline each port's ability to meet the PPO requirements.

There are currently 22 strategic seaports within the CONUS, 17 of which are commercial ports and 5 are military (Blower, 2009; GAO, 2013). These ports[2] provide both staging areas and berthing facilities for military operations, typically requiring the use of non-military contracted labor for large scale deployments, including the supply of common-user sealift through the Voluntary Intermodal Sealift Agreement (VISA), the DOD's primary sealift mobilization program.[3]

Sealift assets available to the DOD consist of ships belonging to the MSC; ships in the Ready Reserve Force (RRF), which are owned and maintained by MARAD; and commercial ships that have been committed to the Voluntary Intermodal Sealift Agreement (VISA). This commercial fleet support is essential to rapid military deployments, moving, for example, 63% of all military cargo during Operations Enduring Freedom and Iraqi Freedom (Lyons, 2016). During a major mobilization various types of ships are used, notably roll-on/roll-off ships (RO/ROs) such as LMSRs (large, medium-speed roll-on/roll-off ships) – designed to handle the loading and unloading of vehicular cargo, as well as other dry-cargo ships including container, heavy-lift, auxiliary crane, break-bulk, and specialty support vessels, tankers and hospital ships (CBO, 2005). This commercial fleet also includes both container and break bulk 'liner service' on scheduled trade routes in support of sustained military (re)deployments.[4]

In 2005 MARAD produced a report assessing conditions at U.S. commercial ports during the multi-modal movement of military cargo in the build-up to Operation Iraqi Freedom (OIF). The assessment includes the performance of three major components of the intermodal system: waterside, port/terminal intermodal interface, and landside movements, with an emphasis on the ability of the nation's commercial freight transportation infrastructure to handle an unexpected surge in cargo during a military deployment. The problems that a military surge in cargo deployments can pose for commercial ports is well summed up as follows:

"…, U.S.-based forts may load and dispatch six trains per day to ports, while the receiving port may only have the capability of handling and unloading one to two trains per day. Military deployments, which must preserve unit integrity, may require that a port receive materials and supplies from more than a dozen different U.S. military installations in a short timeframe. Trains and trucks may be dispatched from bases and arrive at the terminal gates with little advance warning." Also, noting that…

[2] The ports of Anchorage, AK; Beaumont, TX; Charleston, SC; Corpus Christi, TX; Guam; Gulfport, MS; Hampton Roads, VA; Jacksonville, FL; Long Beach, CA; Morehead City, NC; Oakland, CA; Philadelphia, PA; Port Arthur, TX; San Diego, CA; Savannah, GA; Tacoma, WA; and Wilmington, NC.

[3] All major US flag carriers are enrolled and more than 90 percent of the US flag dry cargo fleet is covered under its contingency commitments through which the DOD requests a percentage of a commercial company's fleet capacity.

[4] Requirements for additional liquid cargo carriers may also be activated by MARAD, using Voluntary Tanker Agreements (VTAs) with contracted commercial shipping companies.

"DOD logistics planners have adopted successful commercial methods of handling freight and will redirect cargo at the last moment to accomplish a just-in-time (JIT) delivery. Usually these changes occur with little or no warning to the receiving port." (MARAD, 2005, page 10).

The MARAD report also notes the significant projected growth in international trade through U.S. ports, and hence in increased volumes of freight movement, represents a considerable challenge for the nation's marine transportation system. Nowhere is the challenge seen as more acute than at the nation's strategic seaports, with large projected cargo handling capacity shortfalls in coming years, notably in the movement of containerized freight. Port site visits by MARAD staff indicated that a surge in seaport traffic resulting from a military deployment could lead to significant commercial as well as military shipment delays for a number of reasons, re-ordered here into physical asset issues associated with (a) landside access and (b) within-port cargo handling operations, and (c) issues associated with inter-agency coordination and communications:

a) Landside Port Access:

- Truck Access- trucks entering a port may undergo time-consuming at-gate credentialing /security checks.
- Rail Access - including restricted rail use due to low overpass bridges, limited or non-existent on-dock rail handling facilities, and the possibility of congestion at rail-highway traffic crossings.
- Highway Capacity -inadequate highway access capacity leading to multi-truck queues into the port. Adequate signage was also an issue at some ports.

b) Within-Port Cargo Handling:

- Training - an insufficient number of skilled laborers, especially skilled drivers and handlers of large pieces of military equipment.
- Staging Areas - inadequate space in cargo staging areas within the port

c) Coordination and Communications:

- Coordination - a lack of understanding of the composition of the military cargo to be deployed through the ports/an incomplete in-transit cargo tracking capability.
- Communications – including up-to-date information sharing between trucking firms, railroads, port operators, USTRANSCOM and its deploying units, and the non-DOD federal agencies involved in port regulation and monitoring vis-à-vis the composition, scheduling, port access requirements, cargo staging area locations and special handling needs associated with military unit moves.

A similar list of supply chain based deficiencies is provided by Stribling (2009), with each of these issues a recurring theme in the literature referenced at the end of this chapter.

1.1.5. Disruption Classification

Based on the literature reviewed for characteristics of disruptive events, a disruption classification chart was created. This is similar to a risk management chart involving color coding for risk severity. Figure 1.1 shows this Disruption Classification chart with Advance Notification on the vertical axis and Disruption Impact on the horizontal axis. Disruption events that fall under rapid notification with low impact and events that fall under planned/predictable notification with low to high impact are classified as Class 1 Disruptions, shown in yellow boxes. Similarly, events that falls under abrupt, rapid and planned/predictable notification with low, high and severe impact respectively are classified as Class 2 Disruptions, shown in orange boxes. Events that fall under abrupt notification with high to severe impact and events that fall under rapid notification with severe impact are classified as Class 3 Disruptions, shown in red boxes.

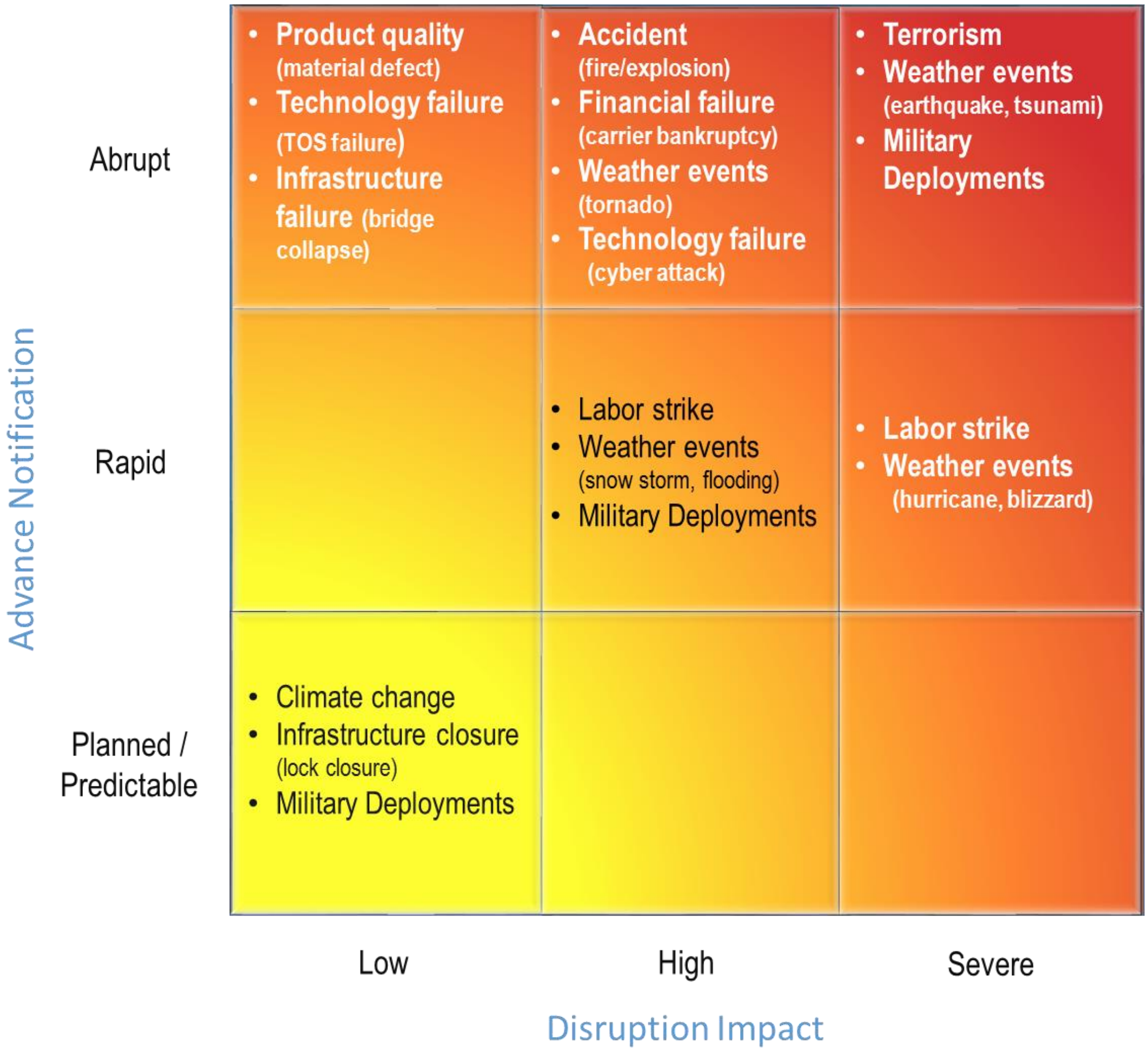

Figure 1.1: Disruption Classification

1.2. System Resiliency Factors

No individual or place is immune to disruption or disruption-related losses. Accidents, acts of terrorism, financial disasters, natural disasters, etc. can lead to large scale consequences for a region and its communities (NAS, 2012). It is impossible to attain 100 percent security against disruption and hence it creates a requirement for developing resiliency plans (Gajjar, 2016).

Resilience, as defined in Presidential Policy Directive 8 (White House and DHS, 2011), refers to the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies. New definitions of resilience and the systems or entities to which resilience refers have been seen in the literature on many different subjects (NAS, 2012), including resilience concepts applied to ecological systems, infrastructure, individuals, supply chains, financial systems, and communities.

At the level of the individual, financial resilience can be defined as the ability to withstand life events, such as unemployment, divorce, disability, and health problems. At the organizational level, it refers to the ability to withstand recessions, stock market meltdowns, and acts of terrorism (O'Neill, 2011).

Supply chain resilience is the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them, by maintaining continuity of operations at the desired level of connectedness and control over structure and function (Falasca, Zobel, & Cook, 2008). An interesting extension to the definition of Supply Chain Resilience is that it is not just managing risk but also offering an opportunity to be better positioned than the competition to recognize and respond to an event, and even to gain advantage from a disruption (Sheffi, 2005).

Another important concept is social resilience, which can be defined as the ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental change (Adger, 2000).

Based on the literature reviewed, the factors that can contribute to system resiliency have been divided into following resilience categories:

- Physical Infrastructure –components such as construction, cargo equipment, wharfs, road and rail infrastructure, etc.
- Logistical –components such as network rerouting, capacity flexibility, creating transportation management plans, risk pooling, etc.
- Transactional / Financial –components such as capital investment program, potential funding identification, investment decisions for infrastructure improvement, public private partnerships (PPP), etc.
- Communication / Informational – components such as inter-organization or stakeholder communications, emergency communications documentation, communication roles and responsibilities, information gathering, employee education, etc.
- Regulatory / Oversight –components such as lobbying on issues, post-event oversight, public policy updates and changes, promoting national programs and policies, etc.
- Institutional –components such as corporate policies, social and political aspects, and social capital, which reflects the interpersonal relationships and institutional structures that establish boundaries for interpersonal interactions.

1.3. Mitigation Strategies

Key mitigation strategies were identified and consolidated from the various literature. In doing so, the literature reviewed for this report was not limited to disruption events that have occurred in the past, but also included a consideration of events that might occur in the future, and how the supply chain community says it is preparing for those events. The various mitigation strategies, i.e. strategies for creating resilience to disruptive events, are discussed in this section for commercial and military operations in relation to the resiliency categories listed in Section 1.2.

1.3.1. Commercial Operations

Moving freight within, into, and out of the U.S. involves cooperation and coordination between numerous public as well as private sector agencies, from point of origin shippers and carriers (and their brokers), to intermediate warehouses and final customers, the latter including the nation's seaports and airports where the goods are imported or exported abroad. State and local government agencies also seek knowledge of such movements for the purposes of facilitating trade, ensuring public safety, and supporting environmental stewardship. Developing and sustaining a product supply chain is therefore a multi-actor process, and is only as strong as its weakest link, be it a physical, logistical, transactional, informational, regulatory or institutional one.

Physical Infrastructure

Hurricane Sandy identified the need to consider future high water surge events associated with ports and coastal communities. This includes a need to identify physical systems such as electrical grids, storm water outfalls, and road and rail infrastructures for facility hardening, chokepoint removal, capacity building and increased redundancy (Stevens Institute, 2013). It is important to improve physical infrastructure via "hard" resilience strategies which are designed to improve the structural integrity of infrastructure (such as the procurement of emergency generators and use of micro grid technology for electrical power (GTRC, 2014), as well as developing plans for elevating or redesigning facilities to avoid flooding due to storm surges (Sturgis, Smythe, & Tucci, 2014)).

A study conducted by the University College London on the resilience of the food supply to port flooding on the east coast of the United Kingdom also describes mitigation strategies for physical infrastructure, including improved flood defenses such as tidal barriers (Achuthan, Zainudin, Roan, & Fujiyama, 2015).

Some mitigation strategies deal with structural and inspection components of the existing physical infrastructure. Studies performed by Oregon and Washington State discuss mitigation strategies for physical infrastructure that deals with disruption events such as earthquake and catastrophic bridge failures, including the creation of a statewide inventory of critical buildings in both the public and private sectors, as well as the maintenance of an up to date inventory of local transit agency, port, and rail assets (OSSPAC, 2013) (WSDOT, 2008).

Mitigation strategies for physical infrastructure are also important to deal with longer lead-time threats such as climate change. Development of new design standards is likely to be necessary as progress is made in understanding future climate conditions and the options available for addressing them. With climate change, we are witnessing stronger hurricanes, an increase in the number of hot days and heat waves, and increases in intense precipitation events, all of which directly affect the infrastructure components of the transportation sector (TRB, 2008). Rehabilitation of transportation infrastructure at highly vulnerable locations to higher design standards is required, with greater attention also given to a degree of redundancy in infrastructure supply that balances the costs to construct and maintain against the costs associated with limited disruption response options (e.g. single route freight channels).

Of course, freight transportation is not the only system that relies on physical infrastructure. Emergency military deployments also rely on designated infrastructure within the nation's strategic seaports network. A report prepared by the Government Accountability Office (GAO, 2013) recently looked into how Department of Defense (DOD) has addressed all congressionally directed elements in their "Report on Strategic Seaports". The report states that it is important to assess the structural integrity and deficiencies of these port facilities and determine the infrastructure improvements needed to meet national security and readiness requirements. The report assessed the condition of the landside port infrastructure for all 22 strategic seaports, including roads, bridges, cargo staging and loading areas, rail infrastructure, and berths within the port boundaries.

Logistical

Logistical mitigation strategies are required for all types of disruption, be it abrupt, rapid or planned. A well-organized logistics strategy increases resilience and helps in faster recovery.

One of the biggest wake-up calls in terms of formulating logistical mitigation strategies for supply chains was the 2011 Japan earthquake and tsunami. The literature on this event and its aftermath shows that it is important to identify the supply chain footprint, not only for Tier 1 critical suppliers, but for all suppliers and sub-suppliers throughout the entire supply chain. This helps in increasing supply chain visibility for inventory tracking and tracing as well as for physical audits and inspections. It also helps in forecasting expected demand (Rice, 2011) (Baymout, 2014). Working within such a supply chain perspective some common components of logistics plans include or consider the following:

Vehicle/vessel re-routing: The most common and key mitigation strategy is to plan for cargo re-routing, be it vessel re-routing during Hurricane Sandy or barge re-routing during Columbia-Snake River closure (GTRC, 2014), train re-routing during Howard Street Tunnel fire (SAIC, 2002), road traffic re-routing during Skagit River Bridge collapse (Horton, 2015) and the storm-related closure of I-5 and I-90 (WSDOT, 2008), the many air traffic re-routings due to the September 11 attacks (IATA, 2011) or during the 2010 Eyjafjallajokull volcano eruption that closed most of the European air space (EUROCONTROL, 2010).

Product sourcing and lean supply chains: A literature review revealed that during most of these and other disruptive events, the most affected supply chains were those relying on a single product source or those dependent on just-in-time (JIT) inventory to create a 'lean' delivery system. This points to the importance of developing multiple sourcing strategies rather than relying on one source (Oke & Gopalakrishnan, 2009), while geographical separation between sources can also be considered for added protection (Baymout, 2014). Moving away from JIT inventory management towards maintaining a "Strategic Emergency Pool" (for example, the Strategic Petroleum Reserve), also helps to minimize the effects of a disruptive event. (Sheffi, 2002), (Sheffi & Rice, 2005), (Rose & Wei, 2013). In today's supply chains this may include the use of "Sell-One-Store-One" concepts that seek to maintain parts availability within leaner supply chains. The idea here is to increase redundancy in parts supply while ensuring that an extra part is always on hand for last-minute customer demands, i.e., a trade-off between too much and too little inventory retention. A similar approach may also better support the need for replacement parts during disruption event-induced emergencies. Likewise, strategies of sourcing a critical part or component from multiple suppliers and storing the item in more than one location is prudent.

Traffic management is another logistical mitigation strategy that helps to increase resilience. For example, the SR520 Catastrophic Failure Plan developed by Washington State DOT talks about the development of a traffic management plan that identifies a toolbox of interdependent strategies to keep people moving throughout the central Puget Sound region in the event of SR520 bridge failure. This includes traffic management strategies for affected corridors, transit service, transportation demand management and system management, and freight considerations to keep commerce moving throughout the region. Other key transit strategies include emergency rerouting procedures, increasing public awareness and incentives, adding park-and-ride capacity, increasing transit service, consolidating transit routes and reprioritizing service hours (WSDOT, 2008).

Various other logistical mitigation strategies were also identified during the literature review. In a workshop on "Developing Freight Fluidity Performance Measures", organized by TRB, inventory management strategies that consider freight demand increases and a tightening transportation capacity are discussed, with the ability to hold inventory again brought up as a practical hedge against transportation constraints (TRB, 2014). In a paper by Rose and Wei, they state that using "Input Substitution", which is substituting production process goods that are similar to those whose production has been disrupted, should be considered: such as the use of natural gas instead of coal in electric utility and industrial boilers (Rose & Wei, 2013). More attention might also be given to lessons learned from many small-scale disturbances when preparing plans to handle larger disruptions (RAND Corp., 2009). The devil is often in the on-the-ground logistical details.

Transactional/Financial

Transactional/Financial mitigation strategies are important when investment decisions are to be made before, as well after a disruption, as an aid to faster recovery. A report published by the New Zealand Transport Agency titled "Measuring the resilience of transportation infrastructure" talks about undertaking economic and engineering research to better understand and quantify a suitable level of investment in resilience. This is generally where significant capital expenditure is required and is difficult to justify when funding is limited (AECOM, 2014).

As noted earlier, government funding is sometimes difficult to obtain for infrastructure projects that can lead to increase in system resilience. When funding is difficult to obtain, it is important to identify potential funding sources. A GAO report on Defense Logistics identifies six potential sources for infrastructure improvements – port revenues, general obligation bonds, revenue bonds, loans, grants, and other miscellaneous sources (GAO, 2013). A report by the Oregon Seismic Safety Policy Advisory Commission titled "The Oregon Resilience Plan" recommends creating a sustained capital investment program for seismic rehabilitation, upgrading transportation routes, and establishing a State Resilience Office (OSSPAC, 2013).

The report on Transportation Sector Resilience by the National Infrastructure Advisory Council (NIAC) recommended enhancing the partnership of the public and private sectors in securing and enhancing the resilience of critical infrastructure and their supporting functional systems. The report identifies PPPs as one of the most important priorities for achieving greater resiliency in infrastructure supply and maintenance. Increased involvement of the private sector through PPPs shifts more project risks onto private companies thereby incentivizing them to get more involved in longer-term port operations (Boyer, Cooper, & Kavinoky, 2011).

Communicational/Informational

Communication, coordination and information sharing is a key component of the workings of any sector. Based on the literature reviewed, various strategies for proper communication and information flow during disruptions were identified.

The most important characteristic of effective communication/information dissemination is coordination between the various stakeholders. It is important to establish committees such as Maritime Transportation System Recovery Units (MTSRUs) and to identify a single point of contact (public agency, advocacy group, or industry) through which all information will flow (Bynum, 2007); (GTRC, 2014). Inter-organizational and stakeholder communication can help in identifying the issues at all levels, from strategic planning to tactical and operational details prior to, during and immediately post-disruption. Faster response time and quicker information flow between stakeholders can lessen the impact of a disruption (Baymout, 2014). Coordination amongst various agencies and stakeholders also minimizes confusion in areas where peacetime jurisdictions overlap (RAND Corp., 2009).

The resilience literature talks about setting up various groups or task forces that can help enhance better communication and information flow between stakeholders. An Interagency Port Resiliency Task Force is necessary to connect maritime transport with road and rail links and identify chokepoints and critical supply chain paths for energy distribution and freight flow (Sturgis, Smythe, & Tucci, 2014).

Establishing stakeholder groups, creating an organizational charter and defining its goals, roles and responsibilities, establishing communications plans, and creating a contact informational database of key personnel are all important components of good communication (Stevens Institute, 2013). Washington State DOT describes developing a communications plan that supports emergency response and recovery and ensures a consistent messaging across agencies; provides suggested guidelines, strategies and tools for jurisdictions and agencies to effectively disseminate critical information to their constituencies; and provides guidelines, strategies and tools for use by communications staff (WSDOT, 2008).

Siedl and Schweighofer, in their report on Inland Waterway Transport, talk about the use of Information and Communication Technology (ICT) for developing "smart waterways" for inland navigation, river information services, barge planning, and a management information system for inland container shipping: and how the success of ICT depends on collaboration between public and private stakeholders (Siedl & Schweighofer, 2014).

Another component of good communicational/information transfer is the education of stakeholders about the various disruptive event and mitigation strategies. Here Oke and Gopalkrishanan, in their article, state that it is important to educate not only employees but also customers regarding risk management. They also state that promotions and incentives for customers during times of capacity shortfalls or other crises can better allow port operators and carriers to manage demand on limited cargo handling resources (Oke & Gopalakrishnan, 2009).

Many papers talk about creating databases that holds critical information that can be used for either or both resiliency planning or during disruptive event operations. TRB's Disaster Resilience – A National Imperative, discusses developing a "National Resilience Scorecard" through collaboration between public and private stakeholders and led by the DHS (NAS, 2012), encouraging inter-agency sharing of best practices for addressing the potential impacts of various disruptive events, including the involvement of professional organizations such as AASHTO, FHWA, AAR, AAPA, and AOC. This involves sharing information about vulnerabilities to supply chain, about effective mitigation strategies, and about the effectiveness of past contingency plans and infrastructure protection plans (TRB, 2008) (DHS/OCIA, 2016).

Once various task forces, command centers, and advocacy groups have been established, it is important to improve effectiveness, transparency and accountability of their efforts. GAO (2016) talks about improving the above stated items for use within an Emergency Communications Preparedness Center (ECPC), by clearly documenting ECPC's strategic goals and the roles and responsibilities of ECPC's member agencies, and by developing a mechanism to track a Center's successes and failures (GAO, 2016).

Communication and information flow is also important for emergency military deployments. A Report by the FHWA – Office of Operation provides guidelines for local, state and federal civilian agencies and private companies for working with the nation's military services during national emergencies and military deployment. Effective communication and coordination of operations between the relevant Military Emergency Operations Center (EOC) and Civilian authority EOCs (which may include a State EOC, a Regional EOC and a Local EOC) is essential to the efficient movement of military convoys and their equipment and supplies both within the continental U.S. and through the nation's seaports (FHWA, 2005).

Regulatory/Oversight

Regulatory/Oversight mitigation strategies help guide the policy makers to work towards achieving the goal to increase or enhance the resiliency of the freight transportation system. The mitigation strategies for Regulatory/Oversight have some overlap with Communicational/Informational strategies as there needs to be some coordination with policy makers.

A disruptive event where many regulatory/oversight strategies are recommended is climate change and its effects. TRB's report on climate change recommends development of an interagency working group led by the USDOT, and a regulatory mandate to include climate change as a factor in the development of long term transportation plans (TRB, 2008). It also recommends that FEMA re-evaluate the risk reduction effectiveness of the National Flood Insurance Program and update flood zone maps that account for sea level rise.

In the aftermath of Hurricane Sandy, regulations such as the Jones Act came into the picture when considering cargo diversion to other ports, and the use of non-U.S. labor to move cargo when backlogs in freight movements occur during a severe port capacity limiting emergency. NCFRP Report 30 recommends coordinating with federal, state and local agencies to minimize the impacts to businesses and the environment. It recommends that protocols need to be developed by U.S. Coast Guard and Border Protection (CBP) to address the issue of diverted shipments in the future (GTRC, 2014) and discusses the possibly of a temporary waiver of the Jones Act to achieve a faster and cost-effective means for handling diverted cargo. (A temporary waiver with respect to fuel supplies was granted during the emergency). Such issues are sensitive politically, however, and may require aggressive lobbying of policy makers to help raise them at regulatory levels (Oke & Gopalakrishnan, 2009).

GAO's report on Critical Infrastructure Protection also provides regulatory recommendations on implementation strategies for developing a resilience framework. It recommends focusing on specific milestones, including goals and subordinate objectives, activities, and performance measures. Sources as well as types of resources and contingency investments should be provided alongside any mechanisms for coordinating recovery efforts (GAO, 2012).

Institutional

Institutional mitigation strategies include political and social aspects. Sadeka et.al, in their paper on Social Capital and Disaster Preparedness, state that despite the evidence about its efficacy, resiliency research and disaster management practices have yet to fully embrace social capital as a critical component (Sadeka, Mohamad, Reza, Manap, & Sarkar, 2015). The Gujarat and Kobe earthquakes in year 2001 and 1995 respectively, showed that communities with high trust, norms, participation, and networks were able to more quickly to recover from disaster (Nakagawa & Shaw, 2004). In the U.S., numerous federal agencies may be involved in a large-scale disruption, such as a seaport shut-down. Each of these agencies should ensure that they are promoting and coordinating national resilience in their programs and policies (NAS, 2012).

A report by Williams on Social Resiliency and Superstorm Sandy discusses how to build community resilience. The report states that it is important to foster local leadership and networks that connect vulnerable residents to local groups, government officials, neighborhood institutions and service providers, in order to develop social capital and preparedness programs in neighborhoods with vulnerable populations exposed to disruption risks (Williams, 2015). Becker and Caldwell, based on interviews with 57 stakeholders involved in port activities in Gulfport, Mississippi and Providence, Rhode Island, also encourage external to the port stakeholder involvement, and demonstrate that taking a local stakeholder-based approach to data gathering can throw up some thoughtful, including some longer-range port resiliency strategies (Becker & Caldwell, 2015).[5]

1.3.2. Military Operations

While the physical and logistical issues associated with cargo movements are somewhat similar, at least in concept, for both commercial and military cargo moves, military deployments come under a host of regulations and are subject to pre-specified federal, state and local agency roles and responsibilities that place considerable importance on inter-agency coordination and communication. As can be seen in the following discussion of past and proposed military operations, the DOD and DOT, as well as a number of other federal, state, and local government agencies have

[5] They identify 128 different mitigation strategies, which they arrange under the following higher level groupings: 1. Building codes and land use regulations, 2. Long-range planning, 3. Construction and design strategies – on and off port lands, 4. Private sector and insurance policies, 5. Emergency response, preparation and recovery, 6. Research, 7. Networks and new ways of thinking.

invested a great deal of effort to improve the physical capacity and inter-agency coordination of freight handling activities during large scale and rapidly developing military deployments.

Physical Infrastructure

Since MARAD's 2005 report to the U.S. Congress, a number of efforts have been made to address the above reported/anticipated shortcomings associated with future commercial seaport supported deployments, with some success. On the civilian government side this includes efforts by the Department of Homeland Security (DHS, 2006); (Bynum, 2007) to ensure the resilience of the maritime system's physical infrastructure, and U.S. DOT/MARAD's efforts to improve military as well as commercial cargo throughput and handling via its Agile Ports program[6] and National Ports Readiness Network.[7] On the military side this includes a number of congressionally requested studies to ensure the readiness of the nation's strategic seaports during military deployments, as well as port resilience when faced with a significant surge in military cargo through a seaport. (Simpkins et al, 2008; GAO 2007, GAO, 2011, GAO 2013). Yet aspects of each of these issues remain relevant today:

Truck Access. Access to the nation's seaports has become strictly monitored in light of recent terrorist activity, as well as evidence of a significant amount of cargo theft. Truckers entering a port require a Transportation Worker Identification Credential (or TWIC) card, which when combined with a bill of lading, allows unescorted access to DOD installations without additional background checks at the port gate. However, bills of lading may not always be available when going for a pickup, and long lines at port gates are not uncommon at many of the nation's seaports during heavy shipping periods or periods of raise threat level. The arrival of military convoys adds considerably to such delays for all commercial traffic. One improvement that may soon be forthcoming via the 2017 National Defense Authorization Act, passed by Congress in December 2016, is a provision to permit truck drivers to use their TWIC as sole proof of identity when entering the nation's military installations, taking advantage of the TWIC credential as a tamper ¬resistant "smart" card identification credential, with features such as an integrated circuit chip, digital certificates and biometric identifiers.

Rail Access. Private sector railroads, in addressing ports' needs to accommodate commercial and military cargo simultaneously, have employed double-stacked trains. These trains sometimes require larger pickup and drop off facilities, and higher tunnel and bridge clearances than currently exist in some areas, and have renewed discussions about public/private rail investment in equipment and facilities in and near our seaports.

Labor Force Issues: Strategic sealift forces available to the DOD consist of ships belonging to the Military Sealift Command; ships in the Ready Reserve Force (RRF), which are owned and maintained by the Department of Transportation's Maritime Administration (MARAD); and commercial ships that have been committed to the Voluntary Intermodal Sealift Agreement (VISA). This commercial fleet support is essential to rapid military deployments, moving 63 percent of all military cargo during Operations Enduring Freedom and Iraqi Freedom (Lyons, 2016). These "surge sealift" forces include various types of ships, notably roll-on/roll-off ships (RO/ROs) such as LMSRs (large, medium-speed roll-on/roll-off ships) – designed to handle the loading and unloading of vehicular cargo, as well as other dry-cargo ships including container, heavy-lift, auxiliary crane, break-bulk, and specialty support vessels, tankers and hospital ships (CBO, 2005). Here the need to deliver complete combat units to a theatre of war can pose significant additional logistics problems for within-port commercial operations: requiring not only extensive staging areas and loading equipment suitable for moving large and heavy vehicles, but also a labor force trained in

[6] https://www.marad.dot.gov/ports/office-of-port-infrastructure-development-and-congestion-mitigation/intermodal-transport-networks/agile-port/
[7] See footnote #s 4 and 5.

handling such non-containerized freight, typically under heavy security. Ports such as Philadelphia have invested in such training since becoming part of the nation's strategic ports network, with positive results.[8]

Staging Areas. The availability of within-port mixed commercial-military and/or dedicated military cargo staging areas was seen as a "critical infrastructure impediment" to rapid cargo throughput during the early build-up to OIF deployment. Adding new staging capacity is difficult because competition for waterfront real estate is intense, and competing uses make it very difficult to acquire suitable new land. In some cases, empty containers must be stored on needed terminal space for staging cargo. Various approaches are used by different ports, including stacking containers, using off-port storage centers, and moving port business offices outside the port area to make more room. Other options include extending port gate opening hours, and using information technology to signal that a port could accept additional cargo, rather than having the shippers simply send the cargo. And the congestion caused by a lack of on-dock and staging area space is likely to get worse as economies of scale cause the size of modern container ships to increase to, with carrying capacities now in excess of 9,000 TEUs. (MARAD, 2005).

Transactional/Financial

As noted above under commercial sector mitigation strategies, a GAO report on Defense Logistics identifies six potential sources of funds for infrastructure improvements – port revenues, general obligation bonds, revenue bonds, loans, grants, and other miscellaneous sources (GAO, 2013). The goal here is cargo throughput capacity building leading into and out of as well as through a seaport.

Logistical/Communicational/Informational

For security as well as efficiency purposes, and with so many different actors playing a part in a particular military deployment, a great deal of real time communication and coordination is required between stakeholders, including port and individual terminal operators, commercial carriers, and different branches of federal, state and local government (DHS, 2006; JCSa, 2013). In today's world of increasingly high-tech communications, this also means that cargo movement logistics are heavily dependent on in transit visibility (ITV), of both the cargo to be moved and the surface lift and sealift assets needed to move it. In short, ITV has become a major resource in the military's development of efficient, adaptable, and sustainable deployment supply chains (Stribling, 2009).

Starting with the overland portion of a military convoy movement, a State's Defense Movement Coordinator (DMC), housed within the National Guard, helps to plan, permit, and provide Convoy Movement Orders, and coordinate overland convoy movements to and from the seaport of embarkation. This includes obtaining the necessary permits for hauling oversized and overweight vehicles and equipment over public roads. The DMCs make use of the MOBCON (Mobilization Movement Control) system for scheduling convoy movements over the US highway system, allowing the DMC to control the density of military traffic at any given time on all State roads, freeways, and interstates. Use may also be made of the Intelligent Road/Railroad Information Server (IRRIS), a real-time, web-based tool that enables users to obtain timely information about road conditions, construction, incidents, and weather conditions that might interfere with the rapid deployment of people, equipment, and munitions (Keever & Soutuyo, 2005).

During a national security emergency, and depending on state law, the governor or his/her designated agency representatives may also decide to activate local, state, or regional Emergency Operations Centers (EOC) to provide continuous communication, coordination and resource support to the deployment process. This includes provision of resources in support of both the response and recovery phases of an emergency. In addition to direct contact between a DMC and a state's civil agency officials, during an emergency or other abnormal situation the seaport and other civil authorities may also need to have contact with a Port Support Activity (PSA) officer, who is a member of

[8] http://www.joc.com/port-philadelphia-handles-sizable-military-cargo-october-second-big-military-outload-45-days

the deploying unit's originating military installation. Within the port, this onsite PSA representative reports to the SDDC TBN and is responsible for, among other things, ensuring that equipment to be shipped out is properly marked, labeled, and prepared for loading, and for communicating any changes in port status back to the TBNs. On notification of a deployment, port officials and civilian support agencies will also meet with PSA officers to establish joint military/civilian/federal EOC priorities and communications channels, coordinate convoy operations, including use of port labor and cargo staging areas, and confirm port security requirements.

The USTRANSCOM maintains and updates detailed procedures for moving these cargos into and through seaports (USTRANSCOM, 2014-2016) and attempts to resolve transportation or logistics conflicts during deployments with in-transit visibility (ITV) reporting via its Integrated Data Environment/Global Transportation Network Convergence (IGC) system, including communication with deploying units, ports and terminal operators, commercial transportation service providers, and service/supply depots. A variety of automated identification technologies (AIT) are used to keep track of both in-transit as well as scheduled cargo details, "such as bar codes, magnetic strips, integrated circuit cards, optical laser discs (optical memory cards or compact discs), satellite tracking, and radio frequency identification (RFID) tags used for marking or "tagging" individual items, equipment, air pallets, or containers" (JCSa, 2013).

Kramek (2009) provides the following example of using AIT to improve the in-transit visibility of military cargo movements within the Port of Beaumont, Texas:

"The USNS Red Cloud, a 950-foot large, medium-speed roll-on/roll-off military cargo ship that spans the length of nearly three football fields, has just crossed through the Sabine pass and is transiting northbound for the Port of Beaumont. In the Port, the Army's U.S. Surface Deployment and Distribution Command's (SDDC) 842nd Transportation Battalion is feverishly working with stevedores, Port representatives, its interagency partners to ready the more than 1,650 trucks, heavy tracked vehicles, and helicopters, as well as a port opening package that enables the landing of all the equipment for an infantry brigade that will be loaded aboard *Red Cloud*.…Also working to organize this outload, though much less visible, is the Army's global logistics management system (LMS), which allows the Army an in transit visibility (ITV) on all of its equipment from the depot to the field. LMS information is entered with handheld wireless scanners and via passive scanners for shipments containing RFID tags, which is all made possible by the 842nd's wireless network. The 842nd is very concerned with the safety and security of vessels carrying military cargo that must navigate the busy and, in places, confined 42-mile Sabine-Neches *waterway that includes both large commercial traffic, like petroleum and chemical tankers transporting hazardous cargos to shore-side facilities, and small commercial traffic such as fishing vessels.* The 842nd works closely with its federal partners, including the Coast Guard and the FBI, as well as state and local security partners to coordinate the safety of all military cargos."

According to the GAO's latest update of its "High Risk Areas" (GAO, 2015) the DOD is in the process of implementing some initiatives that could serve as a basis for an improved management of its supply chain activities. This includes the Defense Logistics Agency (DLA) developed Distribution Effectiveness Initiative to improve logistics efficiencies in DOD's materiel distribution network and reduce transportation costs by storing materiel at strategically located DLA supply sites. This includes establishing metrics and goals to monitor performance for certain segments of its distribution pipeline: such as "time definite delivery", which measure of the probability that a customer will receive an order within an established time period, and customer wait time, or the total elapsed time between issuance and actual delivery of an order (GAO, 2015, page 189).

Regulatory/Oversight/Institutional

Regulations, oversight and institutional roles during military deployments have been the subject of a great deal of legislation among both military and civilian branches of government. Keever and Soutuyo review in detail, and stress the importance of inter-agency cooperation, in the form of an FHWA supported guide for state and local government agencies involved in military deployments (Keever & Soutuyo, 2005). They identify six "key agencies", or agency types, that need to be involved in such deployments: the State DOT, State and local departments of public safety and law enforcement, the Port of Embarkation, the Military Units deploying, State, regional and local emergency management agencies, and the State's DMC.

Institutionally, USTRANSCOM uses what it terms the Single Port Manager (SPM) approach for all worldwide common-use seaport operations. Upon receipt of military movement requirements, the SDCC acts as the SPM for military deployments, assigning workload to military ocean terminals and (contracted) commercial port facilities, taking responsibility for the "strategic flow of deploying and redeploying forces, unit equipment, and sustainment supply in the SPOEs" (seaports of embarkation) (JCSa, 2013). However, as members of the National Port Readiness Network (NPRN), nine federal agencies – SDDC and MSC, U.S. DOT's Maritime Administration (MARAD), the U.S. Army Corps of Engineers (USACE), the U.S. Coast Guard (USCG), the U.S. Army Forces Command (FORSCOM), U.S. DOT's Transportation Security Administration (TSA), and the U.S. Army's Northern Command – have also evolved specific responsibilities in support of the secure movement of forces through U.S. ports during military contingencies.[9] At each of the 17 designated "strategic commercial ports", representatives of these nine agencies establish Port Readiness Committees, chaired by the USCG Captain of the Port, are charged with port operations during national defense emergencies.

1.4. Conclusions

It is essential to understand the characteristics of a disruptive event before working on any resiliency planning or mitigation strategies. This process can usefully begin by classifying a disruption event according to the classification presented in Figure 1.1, and based on the nature of the event's advance notification (abrupt event, rapid event or planned/predictable event) and disruption impact (severe impact, high impact or low impact based on geographical scope, level of loss and military involvement).

In this literature review, various mitigation strategies were identified according to the physical, logistical, transactional/financial, communicational/informational, regulatory/oversight and institutional resiliency categories. Communications is arguably the most important factor for fast and efficient recovery from a disruptive event. The recent disruption literature puts a lot of emphasis on communication and information sharing. It is important to have good communication and collaboration not only between the public and private stakeholders dealing directly with cargo and personnel movements, but also between civilian authorities and communities which can be either directly or indirectly be affected by the disruptive event. And procedures for developing lessons learned from the past disruptive events should be taken into account while planning for the next event.

As far as freight transportation is concerned, physical strategies include ensuring the continued operation of ports, railroads, roadway and inland water infrastructure. Contingency plans should look into the strengthening of existing infrastructure, as well as building of new infrastructure for additional capacity. Such plans should also establish and monitor the availability of emergency services such as electrical power, water, telecommunications and fuel supplies, each of which may become critical bottlenecks during recovery operations. Other actions that have been proposed include updating infrastructure design standards, for example with respect to climate change and sea-level rise, and creating a database of critical infrastructure components, including public transit, port, highway (trucking) and rail assets and their operation during contingencies by private sector as well as federal, state and local agencies.

[9] Upon declaration of war or Presidential direction, the USCG, as the primary agency for waterway safety and security (including establishment, certification, and supervision of ammunition loading operations and port capability) comes under the operational control of the Department of the Navy for port safety and port security responsibilities.cf footnote #7.

Some information was also available on the topic of social resilience, but it was difficult to find literature for disruption impacts on communities. Similarly, there is lack of literature for institutional components as well. For example, the bankruptcy of Hanjin Shipping Lines is a very recent event and hence it is difficult to find peer reviewed literature that talks about the mitigation strategies for such events.

The literature review also showed the lack of information on the cascading effects of not prioritizing certain essential systems such as electrical power, water, communications and fuel. There is a need to create a "Priority Decision Tree", which will help rank the systems that start malfunctioning during and immediately after a disruptive event, in order to facilitate faster and more cost-efficient recovery and to avoid cascading failures of other interdependent systems.

The special case of military cargo surges through the strategic seaports was also reviewed. The nation's commercial waterborne fleet is obviously an essential component of the U.S. military's deployment operations and operation plans. At the same time, commercial shipping might benefit from a better understanding of the military's cargo tracking and communications between its supply chain members concerning both cargo details and the location and condition of the physical assets needed to move such cargo. Inter-agency coordination is clearly a key to success in moving both men and materials through U.S. ports in a time sensitive (and cost effective) manner. Such communication would benefit from a better understanding of the limitations that each of the involved parties have to deal with during periods of joint commercial and military cargo movement. Recent literature on the general topic of under-capacitated ports during cargo surges is promoting the use of standardized port performance measures that can be used to capture and, to the extent useful, quantify these various concerns (GAO, 2012; TRB 2012; Caldwell, 2012; MRBTC, 2015). Some work is already available in this area that might be adapted to capture worst-case or "sealift surge" conditions during periods such as joint military-commercial cargo operations within a port (for example, Bichou and Gray, 2004; AAPA, 2012; Brooks and Schellinck, 2015; Schellinck and Brooks, 2016).

As part of the assessment, a literature database was created that tabulates various articles, reports and presentations. The purpose of this database is to provide the reader with a searchable tool that can be filtered based on type of disruption event, impact severity, and resiliency strategies employed. Besides identifying the types of cargo movement dealt with, the table identifies the modes impacted, the nature and geographical scope of the disruptive event, its location and disruption type, as well as its impact, resiliency category, any resiliency strategies adopted or suggested, and a summary of each reference reviewed.

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