Abstract

The H5N1 influenza threat is resulting in global preparations for the next influenza pandemic. Pandemic influenza planners are prioritizing scarce vaccine, antivirals, and public health support for different segments of society. The freight, bulk goods, and energy transportation network comprise the maritime, rail, air, and trucking industries. It relies on small numbers of specialized workers who cannot be rapidly replaced if lost due to death, illness, or voluntary absenteeism. Because transportation networks link economies, provide critical infrastructures with working material, and supply citizens with necessary commodities, disrupted transportation systems can lead to cascading failures in social and economic systems. However, some pandemic influenza plans have assigned transportation workers a low priority for public health support, vaccine, and antivirals. The science of Transportation Geography demonstrates that transportation networks and workers are concentrated at, or funnel through, a small number of chokepoints and corridors. Chokepoints should be used to rapidly and efficiently vaccinate and prophylax the transportation worker cohort and to implement transmission prevention measures and thereby protect the ability to move goods. Nations, states, the transportation industry and unions, businesses, and other stakeholders must plan, resource, and exercise, and then conduct a transportation health assurance and security campaign for an influenza pandemic.

Key words: pandemic, public, health, transportation, influenza

Introduction: The risk of pandemics

The H5N1 influenza threat is resulting in global preparations for the next influenza pandemic. The 1918 Spanish flu pandemic was particularly severe and 30 percent of the world’s population became ill, 50 million died, and healthy young adults were at high risk. The virus was spread around the globe by infected crews and passengers of ships and trains and severe epidemics occurred in shipyards and railway personnel. According to Barry, “Thirty-eight hundred Pennsylvania Railroad workers were out. The Baltimore and Ohio Railroad set up its own emergency hospitals along its tracks. The entire transportation system for the mid-Atlantic region staggered and trembled, putting in jeopardy most of the nation’s industrial output.” Recent epidemic impact and transportation disruption studies indicate that modern urban populations cannot be sustained without reliably continuous deliveries of food, fuel, electricity, and other resources. The next influenza pandemic could be equally severe and widespread illness or absenteeism in today’s freight transportation sector can cause cascading disruptions of social and economic systems.

Why is the global transportation system at risk? Pandemic pathogens, including influenza, have historically spread along transportation routes with their rate of diffusion limited by the speed and range of the transportation modes of the era. Today’s global transportation system rapidly concentrates then disperses passengers and freight into ports, rail terminals, trucking, and air freight hubs via high-speed
international transportation corridors. Infectious pathogens can be acquired and spread by transportation workers and epidemics within this cohort can prevent or degrade the ability to move goods. Severe degradation can also occur if transportation workers refuse to leave their homes and families during a pandemic and travel into or through areas experiencing an epidemic—even if they are not personally at high risk of severe illness from a medical or epidemiological viewpoint.

Because of the economically efficient “just-in-time” inventory system,\textsuperscript{12} in which businesses and service providers hold limited quantities of product, widespread impacts quickly occur when even a single component of one transportation sector is disrupted. For example, in 2002, a federal injunction halted a 10-day lockout of 11,000 longshore union members in US West Coast ports that caused global disruption of other transportation sectors and caused immediate economic damages to retail, wholesale, and production industries.\textsuperscript{13} Since unsustainable harms occurred when this small cohort within the global transportation industry was temporarily lost, the resiliency of critical infrastructures and national, social, and economic systems is in serious doubt during a pandemic event that can last for months.\textsuperscript{14,15}

An understanding of US pandemic policies and modern freight transportation networks and geography will assist decision makers and planners to develop the strategic and tactical policies, plans, and legislation to protect this vital activity.

Impact mitigation, critical infrastructures, and pandemic planning

The US Government published the “National Strategy for Pandemic Influenza” (NSPI) to mitigate impacts by using “all instruments of national power to address the pandemic threat.”\textsuperscript{16,17} A functioning transportation system is deemed essential:

\textit{Movement of essential personnel, goods and services, and maintenance of critical infrastructure are necessary during an event that spans months in any given community.}

This national security objective is not unique to pandemic influenza. According to the Congressional Research Service, the United States’ definition of a “critical infrastructure” has undergone revisions in the last 25 years but transportation systems have always been identified as essential.\textsuperscript{18}

Currently, 17 critical infrastructures and key resources (CI/KR) are identified in Homeland Security Presidential Directive-7 and the National Infrastructure Protection Plan (NIPP).\textsuperscript{19,20} The NIPP recognizes that four “cross-sector” critical infrastructures are especially important:

\textit{Many CI/KR sectors rely on the service grids of the Energy, Information Technology, Telecommunications, and Transportation sectors. Failures in these sectors can prevent others from functioning properly.}

The Department of Homeland Security (DHS) is responsible for overall national CI/KR protection planning in collaboration with other agencies.

In accordance with the NSPI, the “National Strategy for Pandemic Influenza: Implementation Plan” assigns CI/KR planning responsibilities to specific US federal agencies.\textsuperscript{16,17} Of the nation’s CI/KR sectors, only transportation has a separate chapter (Chapter 5: Transportation and Borders). Transportation planning responsibilities are assigned to DHS in collaboration with the Department of Transportation, with the Departments of Defense and Health and Human Services (HHS) in support.

As required by the implementation plan, DHS published “Pandemic Influenza Preparedness, Response, and Recovery Guide for Critical Infrastructure and Key Resources.”\textsuperscript{21} The guide states that “Disruptions in international trade could result in cascading impacts across US private sector businesses even before pandemic disease outbreaks reach the United States.” Three “continuity of operations-essential” scenarios are presented based on pandemic severity but no integrated strategy to preserve global and national transportation systems and worker health is presented. This plan acknowledges that government and industry must prepare employees but fails to mention
a role for labor unions. As some US transportation sectors are heavily unionized (as are other CI/KR sectors), this omission is a serious oversight because union leaders and rank-and-file members may not cooperate or work if they have had no role in plan development.

The HHS Pandemic Influenza Plan promulgated immunization priorities that appear to be based on seasonal influenza priorities and states:

Only limited information was available from which to assess potential impacts on critical infrastructure sectors such as transportation and utility services.

As a result, the estimated 3.8 million US transportation workers are assigned the low vaccination (and antiviral) priority of Tier 2.b (higher tiers comprise 110 million individuals) and foreign-national workers who deliver essential freight to the United States none at all. Most workers in other critical infrastructures have no designated priority. HHS and DHS have recently proposed revisions to the national vaccination policy in which transportation workers are again assigned a relatively low priority.

Transportation geography, freight transportation systems, and response strategy

Transportation geography

Transport geography is concerned about movements of freight, people, and information. It seeks to link spatial constraints and attributes with the origin, the destination, the extent, the nature, and the purpose of movements. Three “geographical” formations define the global transportation system:

- Gateways dominate the import and export activity of nations or continents and are situated on seaboards at the confluence of rivers, harbors, highways, rail, and air terminals.

- A hub collects, sorts, and distributes goods to a regional area and connects with one or more gateways.

- A corridor is a high-throughput highway, rail line, sea lane, or air route that connects gateways, hubs, production centers, and consumptive markets.

These formations create transportation chokepoints that the industry uses to move, consolidate, and disperse workers and goods (see Figures). They also contain the infrastructure necessary for administration, repair and maintenance, and health and welfare activities.

Freight transportation systems

The “container” revolutionized the transportation industry in terms of infrastructure, workforce, load management, and the ability to rapidly “transship” loads from one transportation mode to the next (with the exception of the air freight industry). Since the container is an International Organization Standard with base dimensions calculated in Twenty-foot Equivalents Units (TEUs), specialized intermodal equipment (such as container ships and trains) and global communication systems (such as the global ship Automatic Identification System) have been developed to precisely load, transfer, and track containers and the transportation workforce. The container system requires 25 times less labor than is required to move free-on-board material. These integrated elements allow the Emma Maersk, the world’s largest container ship, with a capacity 12,500 TEUs, but a crew of only 13 mariners, to make 18 rapid loading-unloading stops along its 60 days pendulum route between Western Europe and East Asia. Approximately 80 percent of US trade value is now containerized.

The historical scale of production, transport, and retail was local (food) or regional (durable goods such as cars) but is now global. The transportation industry has consolidated into a small number of global and national mega-players to achieve massive economies of scale. Since the frequency, speed, and reliability of

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*The reference size is the 20 foot box; 20 feet long, 8’6” feet high and 8 feet wide, or 1 Twenty-foot Equivalent Unit (TEU). The most prevalent container size is, however, the 40 foot box, which is 2,400 cubic feet. A more recent size is the “high cube” 40 foot box, which is 2,690 cubic feet.*
shipments are high under normal circumstances, manufacturers have relocated their facilities to lower cost labor locations. Because transportation costs are lower than inventory management costs, retailers, and secondary manufacturers employ “just-in-time” inventory systems—their “stockpile” is flowing in the transportation stream. The typical efficiency, and potential nonresiliency, of critical infrastructures as a function of transportation can be demonstrated by considering food security in the context of modern food production and supermarket operations.

Two metrics (among others) are instructive: food miles—the cumulative distance for all ingredients and packaging that a particular food product travels from the time of production until it reaches the consumer—and stock turns—the number of times that an inventory product turns over within a given period. The food miles for typical food staples and products are hundreds to thousands of miles and the average stock turn in supermarkets for food products ranges from days to 1-2 weeks. Thus, the average citizen is at the very end of an intricately long food supply chain and whose demand for food is closely matched by timely deliveries from distribution centers to supermarkets. Food security is therefore defined by the ability of the transportation workers to move food from producers, to the bulk-storage facilities, to the processor, and last to the grocer.

The functional sectors of the transportation industry are indicated in Table 1. The workforce is

<table>
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<tr>
<th>Transport Sector</th>
<th>Function</th>
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<tbody>
<tr>
<td>Maritime shipping companies</td>
<td>Control long-distance segments of the global freight distribution linking major markets. Highly capital intensive industry. A modern containership has a crew of about 20 people.</td>
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<tr>
<td>Global port operators</td>
<td>Control important intermodal infrastructures within the world’s largest container ports. Have strong linkages with maritime shipping companies.</td>
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<tr>
<td>Port authorities</td>
<td>Key personnel dealing with the management and transshipment of global trade. Important intermediaries with good knowledge of regional distribution.</td>
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<tr>
<td>Maritime lock and canal operators</td>
<td>Insure the operation of strategic passages in global and national distribution. This includes the Panama canal, the Suez canal, the St Lawrence seaway, and the Upper Mississippi.</td>
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<tr>
<td>Class I rail operators</td>
<td>Strategic inland freight carriers transporting a wide array of raw materials, food, and energy.</td>
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<tr>
<td>Rail terminal operators</td>
<td>Responsible for many of the transshipments between rail and road, particularly for containerized freight.</td>
</tr>
<tr>
<td>Trucking industry</td>
<td>Control vast and diverse assets that include critical segments of freight distribution in all economic sectors.</td>
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<tr>
<td>Third party logistics providers</td>
<td>Important managerial and organizational skills. Key personnel would be able to set up “emergency” supply chains in collaboration with a variety of transport companies.</td>
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<tr>
<td>Air freight transport companies and major air freight terminals</td>
<td>Important assets for the rapid distribution of critical freight.</td>
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<tr>
<td>Specific distribution centers</td>
<td>A crucial element of modern supply chains. Perform tasks such as packaging, labeling, and the consolidation of shipments to customers. Tends to be a more labor intensive segment of freight distribution.</td>
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*Source: Ref. 23.
typically male and generally younger than other industries though 40 percent of the maritime officer corps is more than 50.\textsuperscript{29,30} Many are highly skilled technicians of specialized machinery who require extensive experience and cannot be rapidly replaced. The formal education, licensing, on-the-job-training, and experience necessary to safely and efficiently operate ships, planes, trains, port cranes, tractor trailers, and other machinery ranges from several years to months, respectively. An equally qualified managerial layer makes real time decisions to insure operational efficiency. An overview of the global maritime and North American freight transportation network can be used to visualize this integrated industry.

**Global maritime transportation**

The majority of maritime transportation is conducted by approximately 50,000 ships operated by 1,200,000 mariners (of which approximately 50 percent are from less developed countries),\textsuperscript{31} with a few major shipping conglomerates controlling most of the industry. Maritime chokepoints funnel vessels through nine strategic waterways and most of the major ports are operated by a group of six major international port conglomerates\textsuperscript{1} (Figures 1 and 2). Their port holdings accounted for more than 58 percent of container port capacity and 67 percent of global

\textsuperscript{1}APM Terminals (controlled by the Danish maritime shipper Maersk), Dubai Ports World (United Arab Emirates; DPW), Hutchison Port Holdings (Hong Kong; HPH) and the Port of Singapore Authority (PSA).
containerized throughput in 2005.\textsuperscript{32} The Strait of Malacca is particularly important because 30 percent of the world’s annual maritime trade transits through this strait with about 50,000 ship transits per year or 150 per day.\textsuperscript{33}

**North American freight distribution**

It is estimated that there are 3.7 million transportation workers in the United States, including public transportation workers.\textsuperscript{32} North American port, rail, trucking, and air freight distribution systems show a high level of geographical and industry concentration that is defined by gateways, hubs, and high-throughput corridors (Figures 3 and 4). For instance there are eight major rail companies in the United States and they operate from fixed rail terminals. While trucking involves many actors, a few major trucking companies and interstate highways account for a disproportionate share of freight truck traffic (Figure 3). The US and Canadian highway and rail systems are remarkably uniform with intelligently located weigh stations, truck stops, and rail terminals throughout.

**Pandemic response strategy**

The basic strategy to protect the transportation system is to provide the workers with vaccine, prophylactic medications, protective equipment, and physical security under the umbrella of transmission shielding operations as they move from and into transportation chokepoints and at suitable points along major

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**Figure 2. Holdings of the six major port operators, 2007.** Six conglomerates operate the majority of the major ports and they facilitate the trade of many nations. Modern ports are co-located with rail, truck and air hubs, and the entire “multimodal” hub is highly mechanized and operated by small numbers of workers. A public-private pandemic response effort between the shipping industry and governments should be conducted at these locations. (Source: Data compiled by Dr Jean-Paul Rodrigue.)
corridors (ie, ports, rail terminals, highway weigh stations, etc). Transportation workers must also have a well-enunciated priority for healthcare services if they become ill during their work travels. This will require that some national, state, and local pandemic resources and response activities are reprioritized from traditional influenza priority groups (elderly, etc) to insure that all citizens have a reliably adequate supply of essential supplies and services. Using modern communication systems, national, state, and local licensing and regulatory authorities, industry and unions can identify, locate, educate, and train the transportation workforce. The US Department of Homeland Security, in conjunction with the Departments of Transportation, Defense, Health and other stakeholders (industry, unions, and workers), must create a cooperative plan that identifies roles, resources, and responsibilities.

The international maritime domain presents unique challenges. The naval services of nations should prepare to establish task forces in international waters to quickly provide vaccine/antivirals and other health assistance to the multinational mariners of commercial vessels as they transit into or out of maritime chokepoints and sea lanes. International entities, such as the North Atlantic Treaty Organization, the International Maritime Organization, or the Global Maritime Partnership initiative, can provide the organizational framework to protect global maritime commerce.34,35
Conclusion

Cascading disruptions in vulnerable freight transportation systems and strategic supply chains can compound the difficulties of maintaining social cohesion and critical infrastructures during a pandemic. Transportation workers must therefore receive a high priority for support—including vaccine, prophylactic antivirals, public health interventions, and access to healthcare. Pandemic planners must cooperatively develop plans and obtain the agreements and resources necessary to conduct health assurance campaigns at transportation chokepoints and corridors. Because transportation workers must cross international and local borders, national and local entities, industry and unions, health agencies and other stakeholders must provide this support without regard to their nationality or state of origin.

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