Evaluating Container Ship Routes: A Case For Choosing Between The Panama Canal And The U.S. Land Bridge

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Abstract-*For container traffic from the Far East to Europe, shipping routes and transportation choices are about to be taken to a new competitive level. Ship sizes have increased through time, yet the Panama Canal has remained unchanged, struggling to keep pace with larger size traffic. Over that same time span, more logistical pressure has been placed on the U.S. as a land bridge for container traffic from Asia to Europe. However, the canal is set to open new locks to accommodate today's biggest container ships, creating more choices for container traffic to many eastern Atlantic ports.*

In our work, we investigate choices for container ship transportation from the eastern Pacific to the western Atlantic based solely on time. Choices include traveling through the Panama Canal or using the U.S. as a land bridge (via truck and rail car). A breakeven methodology, given vessel size, is employed to discriminate between paths. Implications for decision-making are then presented and discussed. Interested parties of our work might include those investigating multi-modal integration opportunities, those seeking transportation efficiencies in water, truck and rail, and students as a case assignment in Transportation and Logistics courses.

Keywords- *Transportation; Container Ship; Route*

1. INTRODUCTION

A new era in container shipping is coming. The Panama Canal Authority is about to complete a third lane to the water-way that will double its capacity and allow access to the largest cargo-carrying vessels. However, the impact that the canal will have on global trade patterns remains to be seen. Roughly 65% of the goods sailing through the canal go to or from U.S. ports, and those ports and American rail-yards that compete with the canal will fight to retain as much business as possible (Lynch, 2009). Cargo from Asia, for example, can reach U.S. markets either through the canal or by docking at a west coast port and riding rail lines to inland or east coast destinations.

The issues of container transportation traffic and timely route choice are ones that increase in complexity, as opportunities for trade expand and supply chain activities evolve internationally. Today's container traffic moves mostly from the Far East to the U.S., Europe and other western ports. Two routes of choice have evolved over time. One is through the Panama Canal, and the other uses the United States as a land bridge where container ships dock on the west coast, unload, then travel by truck and/or rail car to the east coast and are loaded onto other container ships headed across the Atlantic.

With the expected expansion and evolution in the industry, we explore route choice for containers within three of the five basic modes of transportation – water, rail and truck. Intermodal shippers must balance numerous factors (fuel costs, freight type, time, distance, etc.) in determining optimal routes for cargo.

However, time is the variable of most importance, as time is the common denominator to both distance and cost in this industry. "Estimated Time of Arrival (ETA)" is the cry of many ship captains and others in the industry, making time of arrival, dock time, and time of departure very important parameters in the shipping industry.

Time does equate to money, and costs do play an important role in the logistics industry. We must not overlook that point. The number of times a container is touched equates to additional costs. Every time a crane, train, truck, laborer, etc. touches a container, a fee is added, and total logistics and transportation costs rise. Those in the industry understand this concept, but simply pass those costs on to the customer. Once those costs are passed, time is the variable that comes back into focus.

Our work begins with a review of the major modes of transportation. From there we discuss how the U.S. is used as a land bridge, and how poor port productivity and congestion create dead time for vessels that end up waiting in a queue for service. We then give careful consideration to the impact of the Jones Act in restricting U.S. maritime commerce. Next, we discuss how canal expansion in Panama stands ready to alleviate port productivity and congestion problems by moving cargo to other areas for dispersion. We then move to the development of our modeling methodology for determining best choice routing – through the Panama Canal or the U.S. land bridge. Finally, we create a simple example for routing multiple size container vessels from off the U.S.'s west coast (Long Beach, CA) to just off the U.S.'s east coast (Savannah, GA). Results and implications of our work are presented and discussed.

2. MODES OF TRANSPORTATION

Transportation infrastructure consists of rights-of-way, vehicles, and carriers that operate within the five basic modes of transportation. Those five basic modes are rail, highway, water, pipeline, and air. In the U.S. data from the American Transportation Association indicates that the highway share of the domestic freight market far exceeds that of all other modes combined (Bowersox, et al., 2010). However, while all modes are essential to providing a sound national transportation infrastructure, it is clear that U. S. commerce depends heavily on motor carriers. For our work, we concentrate on rail, highway and water modes since container route choice is affected most by those. A brief discussion of each follows.

Railroads once ranked first among all modes in terms of the number of miles in service. That ranking began to decline after World War II as there were significant shifts around the country in the development of roads and highways to support the growth of motor carriers. However, the capability to efficiently transport large amounts of freight over long distances is the main reason railroads continue to handle significant city-to-city cargo. Rail operations have high fixed costs because of expensive equipment, rights-of-way, tracks, switching yards, and terminals. In contrast, rail enjoys fairly low variable operating costs (Bowersox, et al., 2010).

In comparison to rail, motor carriers have relatively small fixed investment in terminal facilities and operate on publicly financed and maintained roads. Although the cost of license fees, user fees, and tolls is considerable, these expenses are directly related to the number of motor carriers and miles operated. The variable cost per mile for motor carriers is high because a separate power unit and driver are required for each trailer/container. Labor requirements are also high because of driver safety restrictions and dock labor. Overall, motor carrier operations are characterized by low fixed and high variable costs (Bowersox, et al., 2010). However, they are considered an industry workhorse for their speed, efficient handling, and ability to deliver door-to-door.

Water is the oldest mode of transportation in the U.S. The main advantage of water transportation is the capacity to transport very large shipments. Water carriers generally employ two types of vessels for shipping: Deepwater vessels for coastal, ocean, and Great Lakes transport; and towed barges that operate on rivers and canals with greater flexibility. Water transportation ranks between rail and highway in terms of fixed cost. Though water carriers must develop and operate their own terminals, their right-of-way is developed and maintained by the government and results in moderate fixed costs when compared to rail (Bowersox, et al., 2010). The main disadvantages of water transportation are the limited range of operation and slow speed. Unless the origin and destination of freight movement are adjacent to a waterway, supplemental transportation by rail or highway is required – as in the case of a land bridge.

3. THE U.S. LAND BRIDGE AND WEST COAST PORT TRAFFIC

European bound cargo from Asia has several options for reaching its destination. One would be to go west over many treacherous mountain ranges and several seas. Customs stops are required by many countries along the route, making the trip quite long and segmented. Another route would be to go east across the Pacific Ocean, cross the U.S. by rail or highway, then cross the Atlantic Ocean to reach Europe. This path takes the freight through only one country, requiring only one customs checkpoint. It is obvious that the second option may be longer in miles, but stands to be shorter in time, prompting those in the global transportation industry to refer to it as a "land bridge" across the U.S. Figure 1 illustrates this with a path from Los Angeles to New York. When time is the important factor, the U.S. "land bridge" is the option many use. However, there is one bottleneck along the way – the U.S.'s west coast ports.

The Ports of Los Angeles and Long Beach are the first and second busiest container ports in the U.S, respectively. The Port of Los Angeles is located just north of the Port of Long Beach on the California coastline. Together, the two ports are known as the San Pedro Bay Ports. These two ports handle more than 40% of the nation's total containerized cargo import traffic and 24% of the nation's total exports (Port of Long Beach, 2007). Combined, the San Pedro ports moved 1.16 million containers in January 2012, up from 1.14 million a year earlier (White, 2012).

Figure 1
The U.S. Land Bridge – Los Angeles to New York (Wikipedia, 2010)

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In turn, the large amount of cargo traffic has led to a rise in congestion at the two bustling ports. Such deep draft ports experience delays as space for increasing volumes of import and export cargo is limited by environmental and community concern factors. Congestion also occurs when vessels arrive at the same time rather than dispersed throughout the week (U.S. Department of Transportation, 2009). The time lost as a result of this bottleneck can be 3 to 6 days depending on the season (Conway Consulting, 2008). Even when ports can berth and unload ships quickly, the increasing size of container ships is moving congestion from ports to access roads, rail and highways (U.S. Department of Transportation, 2009). Such delays and congestion at the Long Beach and Los Angeles ports have shippers and receivers looking for more reliable, efficient options for transportation.

4. THE JONES ACT

The Merchant Marine Act of 1920, commonly referred to as the Jones Act, is a U.S Federal statute that regulates maritime commerce in U.S. waters and between U.S. ports (Brackins, 2009). Two parts of the Jones Act are of specific importance. The first part heavily supports American built, owned, and staffed ships. This was accomplished by restricting shipping and passenger trade within the U.S. to American-owned or American-flagged ships, and specifying that at least 75% of a ship's crew must comprise American citizens. In the second part of the Jones Act, the use of foreign parts and labor in ship construction and repair was also greatly restricted. This section of the Jones Act was created to produce a strong, well staffed merchant marine that could be responsible for efficiently serving the U.S. (Smith, 2010).

It is important to realize that at the time the Jones Act was enacted, a strong, resilient merchant fleet was crucial for a country's success and commerce. Today, the effects of the Jones Act have been felt widely in the shipping industry as foreign cargo vessels are not allowed to travel port-to-port in the U.S. – they must drop off and pick up only. In comparison to other nations that lack such cabotage restrictions, there has been a noticeable decline in the U.S. shipping fleet, losing out to the competition of other nations using alternate routes (Brackins, 2009).

5. THE PANAMA CANAL

As vessels, containers and other cargo grew in size over time, the country of Panama and the Panama Canal Authority were paying attention. They realized that Panama could help alleviate U.S. west coast port congestion and provide another route for cargo ships. However, canal modifications were needed as global water carriers were developing economies of scale strategies for moving their freight. Such strategies involved the use of bigger and bigger ships – ships that were not envisioned when the canal was first built. Figure 2 illustrates the growth through time of container ships in length, draft and TEUs (Twenty ft. Equivalent Units).

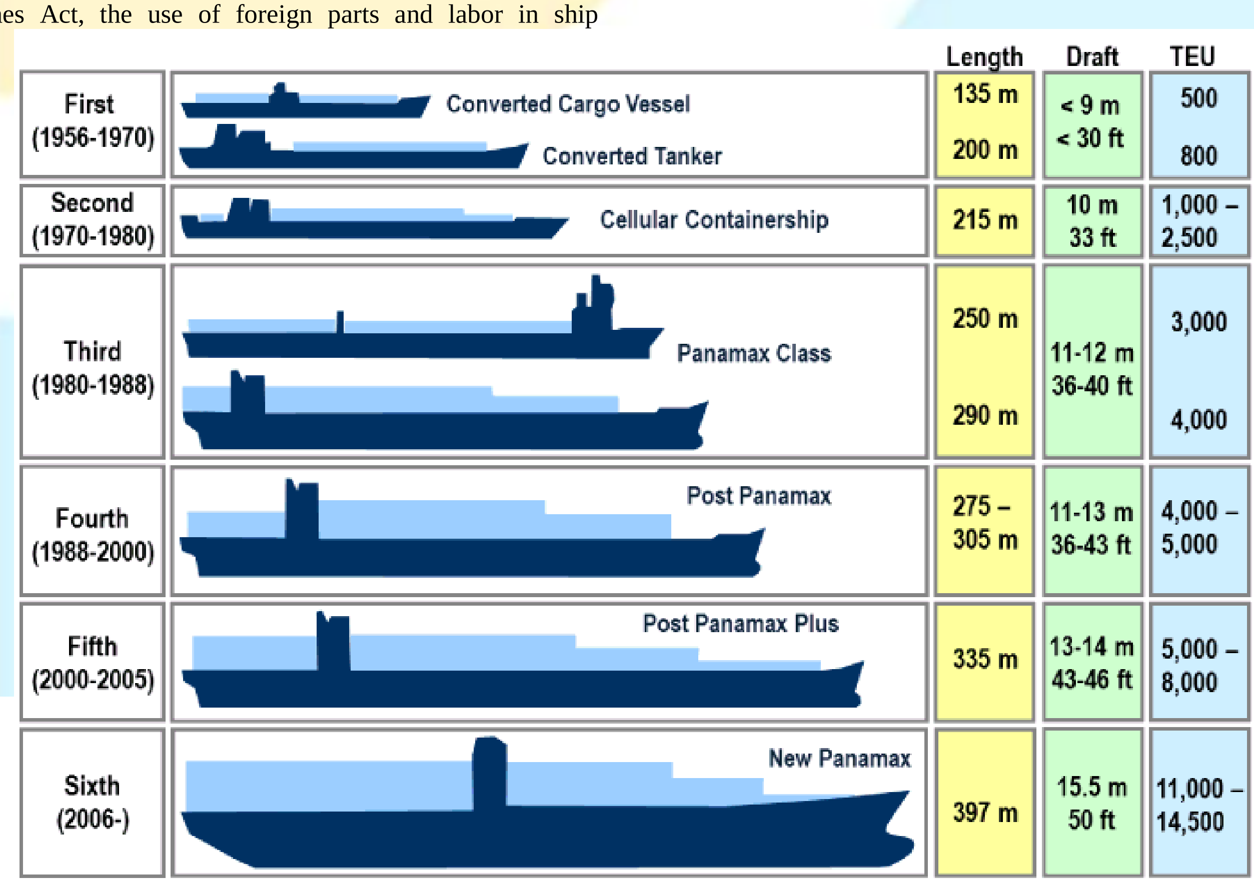

Figure 2 Generations of Container Ships (Rodrique et al., 2009)

The Panama Canal opened in 1914 and instantly revolutionized water transportation. For ships steaming between California and the east coast of the U.S., the canal turned a 15,000 mile journey around Cape Horn into a relatively swift 6,000 mile jaunt (Lynch, 2009). The current expansion includes dredging the existing channel to the depths needed for the largest cargo vessels. Table 1 contrasts the lock dimensions of the original canal lanes and the new lane.

Table 1

Panama Canal Lock Comparisons (Panama Canal Authority, 2006)

Dimen -sions	Current Locks	Panamax	New Locks	New Panamax
Length	320.04m (1,050ft)	294.13m (965 ft)	427m (1,400ft)	366m (1,200 ft)
Width	33.53m (110 ft)	32.31m (106 ft)	55m (180.5ft)	49m (160.7 ft)
Draft	12.56m (41.2 ft)	12.04m (39.5 ft)	18.3m (60 ft)	15.2m (49.9 ft)
TEUs		5,000		12,000

The centerpiece of the expansion is the pair of massive new locks at the Pacific and Atlantic canal entrances. Today, the largest ships that can use the canal are the *Panamax* class, capable of carrying about 5,000 standard shipping containers. They squeeze through the waterway's 110-foot-wode locks with just 2 feet to spare on either side (Lynch, 2009). Wider, deeper and longer than the existing portals, the new locks will handle a class of bigger ships known as *New Panamax* vessels, the world's largest cargo carriers, which can haul more than twice as many containers.

6. METHODOLOGY FOR ROUTE CHOICE

The methodology for route choice compares the sum of expected times and deviations from an import point to an export point on each side of the U.S. land bridge against the sum of expected times and variances using the Panama Canal. It is straightforward, but based on several assumptions:

1. Cost is not an issue. Any costs that arise will be passed on to the customer.
2. Import and export container ports work around the clock for loading, unloading, sorting, and preparing for additional container transportation.
3. There is adequate rail and highway infrastructure support, and an ample supply of trucks and rail cars to ferry containers across the U.S.
4. Containers vessels of similar size are waiting at east coast ports to complete the journey.

Our expected time functions and three step methodology follows.

<u>Calculation of Expected Travel Time across U.S. Land Bridge</u> (μ_{lb})

$$\mu_{lb} = (t_i + t_r + t_t + t_e) + \sigma_{lb} \quad \text{(Eq. 1)}$$

Where t_i = time at an importing port; t_r = time on a rail car; t_t = time on a truck, and t_e = time at an exporting port. A similar structure is used to determine the variance for the land bridge.

$$\sigma_{lb}^2 = (\sigma_i^2 + \sigma_r^2 + \sigma_t^2 + \sigma_e^2) \quad \text{(Eq. 2)}$$

<u>Calculation of Expected Sailing Time via the Panama Canal</u> (μ_s)

$$\mu_s = (t_{ie} + t_{pc}) + \sigma_s \quad \text{(Eq. 3)}$$

Where t_{ie} = sailing time from an import point to an export point, and t_{pc} = time through the Panama Canal. A similar structure is also used to determine the sailing variance.

$$\sigma_s^2 = (\sigma_{ie}^2 + \sigma_{pc}^2) \quad \text{(Eq. 4)}$$

<u>Step 1</u>: Evaluation of Time based on Container Ship Size

Using equations 1 & 2, determine the expected total travel time across the U.S. land bridge from import point to export point for each container ship size of interest. Placing this data in a table may help during analysis.

<u>Step 2</u>: Evaluate Sailing Time using Panama Canal

Using equations 3 & 4, determine the necessary sailing time through the Panama Canal traveling from the same import and export points selected earlier. This value should be valid for any size vessel.

<u>Step 3</u>: Analysis

Inspect the container ship-land bridge travel times for a "breakeven" point created by the travel time through the Panama Canal. Linearly interpret the "breakeven" vessel size. Assign smaller ships to the U.S. land bridge and larger ships to the Panama Canal route. Total travel time should be minimized for a given size vessel.

7. CASE EXAMPLE – LONG BEACH, CA to SAVANNAH, GA

To illustrate our methodology, we consider multiple size container ships sailing from the Far East to Europe. The choice of using the U.S. land bridge and unloading in Long Beach, CA, transporting the containers by truck or rail car across the U.S., then loading them onto vessels in Savannah, GA to complete the trip to Europe is compared to a continuous route utilizing the Panama Canal. Table 2 below presents the most optimistic expected time (in days) based on import and export berth productivity (Mongelluzzo, 2013), intermodal services by truck and rail car (www.google.com/maps and www.amtrak.com), and estimated variances for all. Google maps was used to estimate travel time across the U.S.'s Interstate Highway system, and Amtrak was used for rail estimates as it has the ability to travel across all rail lines. Variance estimates are mostly composed of logistical issues – not mileage issues.

Table 2
Expected Land Bridge Travel Times based on Ship Size: Long Beach, CA to Savannah, GA

Generation (TEUs)	Long Beach, CA (≈ 74 TEUs/hr.)	Truck or Railway (days)	Savannah, GA (≈ 60 TEUs/hr.)	σ_{lb} (days)	Expected Time (days)
1st : < 800	0.45	2.20 or 2.60	0.56	0.50	3.71–4.11
2nd : < 2,500	1.41	2.20 or 2.60	1.74	1.50	6.85–7.25
3rd : < 4,000	2.25	2.20 or 2.60	2.78	2.00	9.23–9.63
4th : < 5,000	2.82	2.20 or 2.60	3.47	2.50	10.99–11.39
5th : < 8,000	4.50	2.20 or 2.60	5.56	4.00	16.26–16.66
6th : < 14,500	8.16	2.20 or 2.60	10.07	6.00	26.43–26.83
Next: 16,000+	9.01	2.20 or 2.60	11.11	7.00	29.32–29.72

Table 3 below presents the estimated travel time from Long Beach, CA to Savannah, GA via the Panama Canal (www.sea-distances.com). The voyage calculator from sea-distance.com is used in conjunction with estimated variances along the route for the 4,514 nautical mile journey.

Table 3
Expected Sailing Times via Panama Canal: Long Beach, CA to Savannah, GA

Generation (TEUs)	Expected Travel Time Long Beach, CA to Savannah, GA (days)	σ_s (days)	Expected Time (days)
Any Size	18.80	2.00	20.80

After superimposing Table 3 into Table 2 and by inspection, Table 4 below indicates the point at which the time for container vessels sailing through the Panama Canal bisects the list of land bridge estimates. Through linear interpolation, the "breakeven" vessel size holds approximately 10,750 containers. The findings indicate that ships smaller than 10,750 containers should continue to use the land bridge, and larger ships should consider using the Panama Canal when time is the most important variable for shipping.

Table 4
Vessel Size Analysis: Long Beach, CA to Savannah, GA

Generation (TEUs)	Long Beach, CA (≈ 74 TEUs/hr.)	Truck or Railway (days)	Savannah, GA (≈ 60 TEUs/hr.)	σ_{lb} (days)	Expected Time (days)
1st : < 800	0.45	2.20 or 2.60	0.56	0.50	3.71–4.11
2nd : < 2,500	1.41	2.20 or 2.60	1.74	1.50	6.85–7.25
3rd : < 4,000	2.25	2.20 or 2.60	2.78	2.00	9.23–9.63
4th : < 5,000	2.82	2.20 or 2.60	3.47	2.50	10.99–11.39
5th : < 8,000	4.50	2.20 or 2.60	5.56	4.00	16.26–16.66
Using Canal	***N/A***	***N/A***	***N/A***	***N/A***	***20.80***
6th : < 14,500	8.16	2.20 or 2.60	10.07	6.00	26.43–26.83
Next: 16,000+	9.01	2.20 or 2.60	11.11	7.00	29.32–29.72

8. IMPORTANT IMPLICATIONS

Our case scenario suggests that smaller ships would cross the Pacific one after the other (in assembly line mode) and unload their containers at west coast ports. Truck and rail transportation would then complete their journey across the country. On the east coast, another group of smaller ships would be ready and waiting to complete the journey to European ports and beyond. Larger ships would bypass the land bridge and complete their journey via the Panama Canal, and time would be minimized for all involved. However, there are some issues to consider, namely revenue shifts and infrastructure deterioration.

First, if the shipping industry decides to utilize larger vessels in the future and sail through the Panama Canal, the canal would have the opportunity to increase revenue – especially if fee restructuring takes place. Additionally, one would expect the use of the land bridge to diminish, relieving pressure on U.S. transportation infrastructure and queuing relief to several west coast ports, especially to the San Pedro Bay Ports. It is there that some ship captains reported having to wait days for the opportunity to unload cargo. Such relief would be welcomed and provide an opportunity for much needed infrastructure maintenance.

Conversely, should the shipping industry place heavier emphasis on smaller ships, an increase in commerce within the entire U.S. transportation industry is possible. Ports, rail lines, trucking firms, airlines and even pipelines could see revenue increases as the continuous docking of smaller vessels would provide constant work for the industry. However, an increase in workload comes at a cost. Many transportation participants are already greatly concerned over rising issues related to safety, congestion, and inadequate system capacity. Professionals in the industry agree that the U.S. is in need of a far-reaching National Transportation Plan to facilitate both the repair and reinvention of its infrastructure (Bowman, 2007).

Another component to consider concerns the future of the Jones Act. Although originally written for national security reasons long ago, an overhaul to the Jones Act is necessary before the U.S. shipping industry can compete on a level trading field with the rest of the world. In June of 2010, Senator John McCain presented an act that would allow for such repeal. According to McCain, the Jones Act:

> "Hinders free trade and favors labor unions over consumers. Specifically, the Jones Act requires that all goods shipped between waterborne ports of the United States be carried by vessels built in the United States and owned and operated by Americans. This restriction only serves to raise shipping costs, thereby making U.S. farmers less competitive and increasing costs for American consumers" (McCain Introduces Legislation, 2010).

In our opinion, such a change would help to increase commerce and create significant changes to shipping routes along U.S. coasts. Officials are aware of this and are currently at work negotiating a favorable solution for all.

9. CONCLUSIONS & FURTHER STUDY

After reviewing the Panama Canal's exciting expansion news, our work indicates that the U.S. transportation industry is poised for a revolution in container cargo movement in the near future. We studied the choice between traveling the U.S. land bridge or the Panama Canal using only one west coast and one east coast port. However, other maritime and Canadian opportunities may exist in the future creating a network of routes from which to choose.

One such opportunity may lie with the implementation of LIGTT (Louisiana International Gulf Transfer Terminal), a deep draft container terminal planned for the mouth of the Mississippi River, south of New Orleans, LA. It is likely to become a new "on/off ramp" to the U.S.'s land bridge. Connecting east and west coast ports, LIGTT, and other inland transfer points throughout the U.S. by truck and rail (e.g. Long Beach, San Francisco, Seattle, New Orleans, St. Louis, Chicago, Savannah, Baltimore, New York/New Jersey) would make an interesting network for case study by students in Transportation and Logistics classes.

Through the methodology presented here, we have been able to discriminate between route choices for container vessels based solely on ship size and time. In future research, we plan to explore more of the economic effects on commerce associated with shifts to and from the land bridge and the canal. The objective is to transfer a "perfect" shipment from point A to point B as cheaply, quickly and consistently as possible (Bowersox, et al., 2010). However, in the long run we expect that costs will continue to be passed on to the customer and delivery speed (time) will still be the variable of interest in the shipping industry.

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