1.201J / 11.545J / ESD.210J Transportation Systems

FALL 2006

ASSIGNMENT 6: Expanding the Panama Canal (Part A)

Date assigned: November 17, 2006

Date due: Friday, December 1, 2006

Value: 10 points for Part A; 4 points for Part B

Assignment 6 will have two parts.

Part A addresses issues related to the capacity, performance, and demand for the Panama Canal. You have been assigned to a team of three to work on this assignment. The teams may split up the work in whatever way they wish, and they must report how each member contributed to the assignment. This is not a "pull an all-nighter the day before it is due" kind of assignment. You need to get your team organized quickly and work uniformly over the next two weeks to be successful.

Part B is an individual assignment (to be handed out on November 28th). It will ask you to consider policy issues from the perspective of various actors based on the numerical results you developed in Part A.

Background

A DIAGRAM OF THE PANAMA CANAL
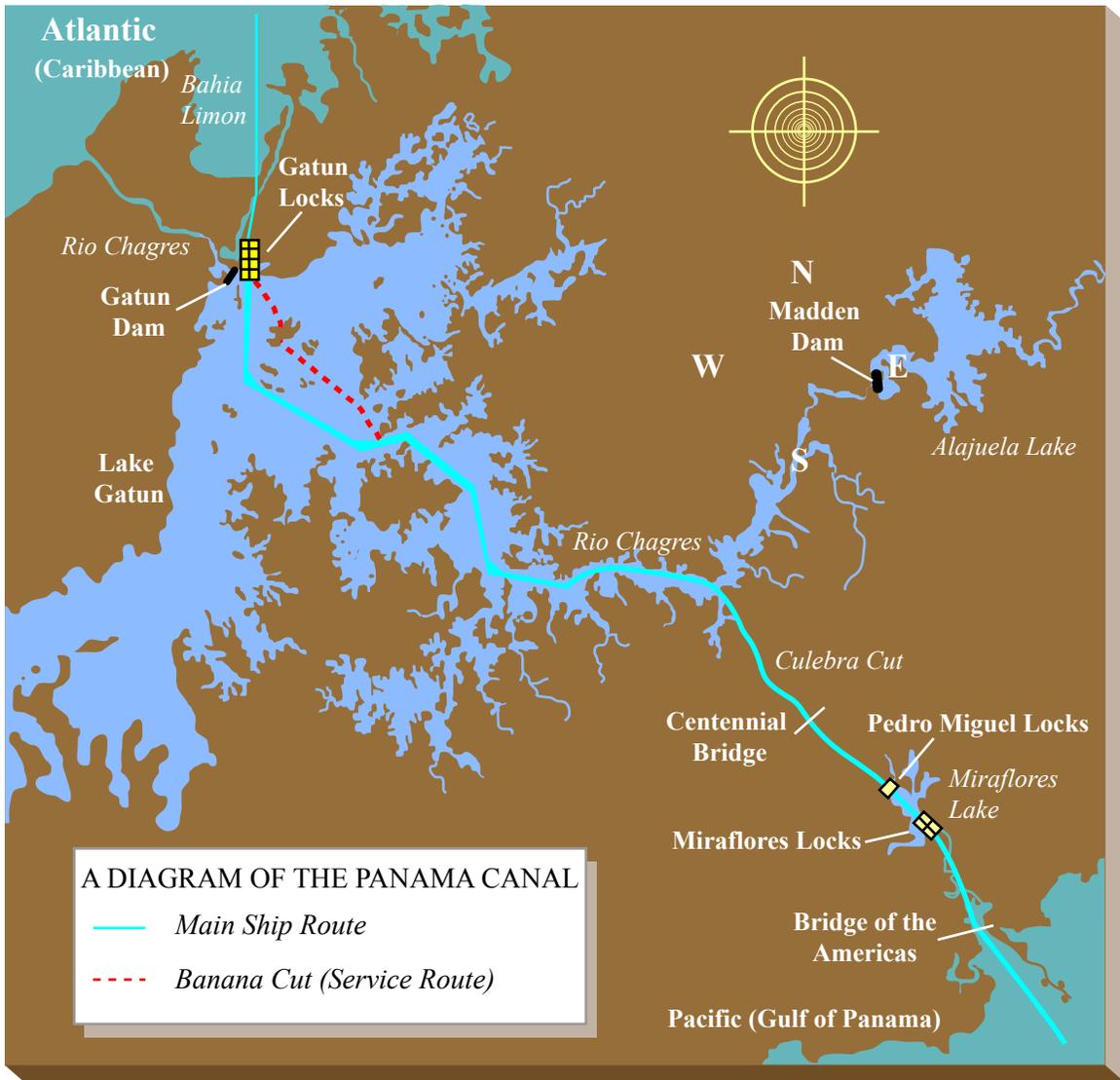— Main Ship Route
---- Banana Cut (Service Route)

Figure by MIT OCW.

By 1990, the Panama Canal was operating close to capacity, and it was clear that major investments would be needed to keep pace with demand. The Canal, which had been designed for the largest ships envisioned at the beginning of the 20th century, was no longer able to handle the largest ships afloat at the end of the century. While the Canal certainly offered a cheaper and quicker route for many commodities and trade routes, it was less attractive to others because of the added costs imposed by the Canal tolls, the potential for delays if the Canal were to become congested, and the restrictions on vessel size.

Control of the Panama Canal was to be transferred from the U.S. to Panama on December 31, 1999. In preparing for the transfer, the Panama Canal Commission undertook a

variety of engineering and transportation systems studies to determine how best to respond to the growing demand. While under U.S. control, the Canal had always been operated on a self-sufficient basis, i.e. the Panama Canal Commission (PCC) used revenue from tolls to pay for operations and maintenance (approximately $250 million) and capital investment (also on the order of $200 million). It did not borrow any money (nor did it ever have to repay the U.S. government for the original cost of construction paid for by the U.S.). The annual revenue from tolls was also sufficient to make a $200 million contribution to the Government of Panama (GOP) ($100 million per year in 1990). U.S. policy sought to maintain a high level of service for users of the Canal without seeking to maximize either profits for the PCC or contribution to the GOP.

These policies would not necessarily be maintained once the PCC was controlled by Panama (and renamed the Panama Canal Authority (APC)). In particular, they would be able to borrow funds in order to increase the rate of investment, and they would be able to increase the amount of money that went to the GOP. They would also be able to raise tolls or adopt schemes to auction capacity should congestion become a problem.

In this part of the assignment, your team is acting as an advisor to the PCC and the GOP. It is 1993, and no major decisions have yet been made as to whether, when or how to expand the capacity of the Canal. You have been asked to consider issues related to the supply and demand for Canal services and to conduct analyses concerning the benefits and costs associated with various options for expanding the canal.

Table 1 describes the existing performance of the Panama Canal as of the early 1990s. At that time, the Canal was approaching capacity, as evidenced by increasing delays. While the minimum time required for a complete transit of the canal was 9 hours, the average time was 12 hours. Projections indicated that average transit times would reach 15-20 hours within a few years; during peak periods, transit times would exceed 32 hours. Delays could be even worse during periods when lock maintenance was being performed. Capacity of the canal was limited by three major factors:

- The size of ships that could use the canal
- The time required for one lock cycle (i.e. the time to raise or lower a ship or ships[1] in a lock)
- The geometry of the Cut[2], which was too narrow to allow bi-directional operations of Panamax vessels[3].

Table 1 also shows some statistics related to the option of using the US rail system as a "landbridge" for containers moving from the Pacific Rim to points in the eastern United States. The "landbridge" option was very attractive for high-valued freight, and it captured 84% of the containerized trade between Japan, Taiwan and South Korea and the eastern US in the early 1990s.

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[1] Each lock was large enough to hold two or more smaller vessels.

[2] The Cut is the 8-mile portion of the Canal that was excavated through the hills in Central Panama. The rest of the "Canal" crosses lakes or tidal inlets that are much wider than the Cut.

[3] A "Panamax" vessel is the largest that can move through the Canal. "Post-Panamax" vessels are too large to go through the Canal; they are attractive because they offer substantial economies in operation.

Table 1: Base Case

Number of lanes for each set of locks	2
Number of locks per lane	6
Average time per lock	50 minutes
Minimum transit time	9 hours
Average transit time	12 hours
Transits per year	14,000
Tonnage per year	170 million
Toll	$3/ton
Total rail intermodal shipments per year in US	7 million
Time saved by using landbridge	5-10 days
Added cost of using landbridge	$200-500/container

Question 1: Supply Analysis (3 points)

Various options were available for increasing the capacity of the Canal:

a. Upgrade the navigational system to include GPS and digital communications so that it would be possible to implement algorithms that would optimize the sequencing of ships through the locks and through the Cut.

b. Replace and expand the fleet of PCC locomotives that are used to improve the efficiency of lock operations. The fleet was originally sized to maximize the utilization of the locomotives; expanding the fleet would allow operations to minimize the time required for each lock cycle.

c. Widen the Cut to allow larger ships to pass and to operate 24 hours/day (two large ships need ample room to pass, especially at night; if there is not enough room to pass, then the largest ships will be delayed so that they can be scheduled to move single file through the cut. This work can be staged first to allow Panamax ships, then to allow Post-Panamax ships. It is also possible to provide one or more locations within the Cut where the ships can pass, which would allow some capacity benefits before the entire Cut is widened.)

d. Add a 3rd set of locks that would be large enough to handle the largest Post-Panamax ships

e. Add a 4th set of locks

Some of the major characteristics of these options are shown in Table 2. Some of these options were expected to require only a year or two to implement, but major increases in capacity would require many years to implement. The table also shows the approximate operating costs for the base case Canal and the added costs for operating additional locks or a new Canal.[4] For these options, the time to implement is shown as a range between a minimum feasible time and an extended interval reflecting a decision to proceed more slowly with the projects (i.e. the range of times reflects options for the Canal Authority, not a lack of precision in the estimates). Two numbers are also shown for capacity: the first represents the capacity assuming an average delay of 6 hours (and an average transit time of 15 hours); the second represents an average delay of 10 hours. The numbers shown in the Table reflect the results of simulation analyses conducted for the PCC. The Canal is operated 24/7/365, and traffic volumes do not display any major daily, weekly, or seasonal peaks. The volume/delay curve therefore peaks sharply as traffic volumes approach capacity (the "hockey stick" phenomena). Additional locks would be large enough to handle larger ships. The so-called Post-Panamax ships include the largest that are able to use the Suez Canal ("Suezmax") and the largest bulk carriers that are used in service around Africa ("Capemax").

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[4] The operating costs shown in the table represent the costs of operating the facilities at full capacity (i.e. operations experiencing an average delay of 10-hours). Assume that half of these operating costs are fixed, while the other half would vary with the number of transits.

Table 2: Options for Expanding Capacity of the Canal (as of 1993)

Option	Investment Cost ($ millions)	Time to Implement (Years)	Impact on Productivity and Capacity	Capacity
Base Case	No investment; $250 million/year for operations	0	N.A.	38-39 ships/day or about14,000 per year)
Navigation System	$40 million	1	Increase capacity of the cut by 1 ship/day	39-40
PCC Locomotives	$100 million	2	Reduce cycle time for locks from 50 to 40 minutes	41-42 (capacity would still be limited by operations in the Cut)
Widen the Cut for Panamax Ships	$2,000 million	5-10	Enable 24-hour bi-directional operation of Panamax Ships	44-45
Further widen the Cut for Post-Panamax Ships	$1,000 million	3-6	Enable 24-hour bi-directional operation of Post-Panamax Ships	44-45
Third Set of Locks	$4,300 million plus $100 million/year for operations once opened	10-20	Allow Post-Panamax ships (up to 12,000 TEU container ships and 200,000 DWT bulk vessels)and more transits	60-62
Fourth Set of Locks	$3,500 million plus $100 million/year for operations	5-10	Allow more Post-Panamax ships and more transits/day	75-78
Sea Level Canal (Instead of 3rd and 4th sets of locks)	$15,000 million plus $50 million/year for operations	15-30	Allow more Post-Panamax ships	80-83

   a. *Create a chart or table showing the cost/transit as a function of volume as this series of capacity enhancements are implemented.* Assume that the navigation and locomotive projects have a life of 20 years, while the other projects have a life of 50 years. Use constant dollars. Convert the investment costs to an equivalent annual cost assuming an 8% discount rate. The cost per transit should include both operating and capital costs.

b. *Create a chart showing the estimated average delay per vessel as a function of transits as the various capacity enhancements are implemented. (Approximate numbers based upon the information given above will be fine – explain your reasoning.)*

c. *Summarize your results and discuss the implications for future expansion of the Panama Canal (max 1 page)*

Question 2: Demand Analysis (3 points)

Customers will route shipments through the Panama Canal only if this routes minimizes their Total Logistics Costs (TLC). If the landbridge route or the Suez Canal route or a route around Cape Horn is cheaper, they will use that route. If commodities can be obtained more cheaply from another source, then they will avoid supply chains that include the Panama Canal.

Table 3 provides base case cost and service factors for rail and ocean carriers. The costs do not include the toll for the Panama Canal, and the travel time assumes 12 hours per transit of the Canal.

Table 3: Base Case Assumptions Concerning Cost and Service

Mode	Fixed Cost/ton-mile	Variable Cost	Travel Time
Rail Intermodal	$200	$0.25/container-mile	2 days plus 40 mph plus 1 day if trip goes past Chicago
Rail Bulk	$2/ton	$0.01/net ton-mile	2 days plus 20mph
Inland Waterway	$2/ton	$0.005/net ton-mile	4 days plus 4 mph
Panamax Vessels			
Ocean Liner Service (Containers)	$50,000 per day (6,000 TEU)	$0.10/container-mile	500 miles per day
Ocean Carrier – Bulk	$40,000 per day 100,000 tons	$0.002/ton-mile	400 miles per day
Post-Panamax Vessels			
Ocean Liner Service (Containers)	$60,000 per day (9,000 TEU)	$0.09/container-mile	500 miles per day
Ocean Carrier - Bulk	$50,000 per day 200,000 tons	$0.0015/ton-mile	400 miles per day

Rapid growth is projected for international trade in general and for container shipping in particular. Containerized freight moving between Asia and the United States is therefore a critical market for the Panama Canal. Two key factors influence whether this trade goes by rail from West Coast ports or by the Panama Canal direct to East Coast ports:

- The cost, service and capacity of the U.S. ports and the intermodal rail system. Delays in the U.S. ports or rail system could add as much as 4-7 days to the land options, and railroads could increase their rates by 50-100% in an attempt to limit demand and maximize their profits
- The tolls, transit times and types of ships that can be handled by the Panama Canal

There is also an opportunity for freight to move via the Suez Canal if costs and delays increased on the U.S. rail system and the Panama Canal.   .

a. ***Create a spreadsheet model for estimating the differences in total logistics costs of the main routing and supply chain options available to the following classes of shippers:***
   - Container (land-bridge vs PCC vs. Suez Canal for moves between Asia and US & Canadian EC (value per ton averages $2000 and ranges from less than $500 to more than $10,000; container loads are assumed to average 13 tons in calculating tolls for the Panama Canal)
   - Grain (grain moving from Iowa or Saskatchewan to Asia via rail to west coast ports or via Mississippi River to NOLA and via PC to Asia) (value per ton averages $200). Assume that the grain would move in the same sized-ship whether it shipped via Panama or via west coast ports.
   - Coal destined to Brazil from Australia, South Africa, Appalachia (Kentucky & W. Virginia) or Brazil to Japan (Value per ton at originating port averages $10-$30, largely dependent upon the cost of rail transportation from the mine to the port). Assume the Pacific Routes use Post Panamax vessels, while the Panama Canal can only use the Post-Panamax if the third set of locks or a new canal is constructed.)

   The difference in the TLC will be a function of the tolls and delays at the canal, as well as the differences in distance and transportation rates between the canal route and the other routes.   Estimate in-transit inventory costs by assuming an annual rate of 10% per year.

b. ***Use your spreadsheet to determine how each traffic class might respond to increases in tolls, increases in delays, or increases in the size of ships that can use the canal.*** Note: Once you have your model, it will be easy to conduct sensitivity analysis or to look at other situations. You may therefore want to look at additional movements within one or more of these traffic classes. As you review your results, you may find other interesting issues to explore. The results from this section should be presented in one or more well-organized tables with appropriate titles plus a description of your method.

c. ***Summarize your results and discuss the implications for future demand for the Panama Canal (max 1 page)***

Question 3: Equilibrium Analysis (4 points)

The APC has the ability to manage demand by adjusting tolls and by offering multiple levels of service. Raising tolls will tend to divert some traffic to other routes and cause shifts in some supply chains (e.g. different sources of bulk products). Capacity could be allocated via various mechanisms, including higher tolls for "1st class service" or capacity auctions. In the absence of any action on the part of the APC, demand will rise to the point that congestion and unreliability cause customers to seek other routes or other sources of commodities. Your group has been asked to develop insight into the strategies that APC might pursue and the effects that these strategies might have upon demand and revenue.

a. ***Develop a model for estimating the traffic volume that would move through the canal as a function of the toll charged and the timing of the expansion*** (using the results of parts 1 & 2 as needed). Table 4 shows the actual tonnage for selected commodities for 1990 plus projected traffic through the canal. The projections to 2020 and 2060 were made based upon a simplifying assumption that there were no tolls and no delays at the canal (and no capacity problems on the rail systems). Obviously, if the capacity investments are not made, then the traffic volumes will be much lower. Also, if substantial tolls are charged, then traffic will be diverted from the canal.

Table 4: Annual Cargo Flows through the Panama Canal
(Actual for 1990; projected for 2020 and 2060 assuming third set of locks that allow 200,000 DWT ships with no tolls and no delays)

Commodity	Annual Tonnage (Millions)			Annaul Growth 1990-2020
	1990	**2020**	**2060**	
Selected Commodities				
• Containers	20.8	50.6	67.2	3.0%
• Coal & Coke	11.0	63.8	82.8	6.0%
• Bulk Grains	23.5	44.4	66.9	1.0%
Total	157.5	363.3	494.8	2.8%

Source: The WEFA Group, Executive Summary, Part 8, "Commodity and Traffic Projection Study", *Final Report of the Commission for the Study of Alternatives to the Panama Canal*, 1993

b. ***Based upon your analysis of supply and demand issues, identify 3 strategies that could be pursued.*** Each strategy should be defined in terms of a toll policy (of your design) and a capacity level (defined as in Table 2).

c. ***Estimate toll revenues, traffic volume, and traffic mix that will result from each strategy during the period from 2010 to 2060.*** To simplify the analysis, assume that 30% of the projected traffic (tonnage) for 2020 can be represented by the results for containers, 40% by the results for grain, and 30% by the results for

coal. The results from this section should be presented in several well-organized tables or charts with appropriate titles plus a description of your method.

d. *Summarize your results and discuss the implications for expansion of the Panama Canal (max 1 page)*

Note: the descriptions and numbers used in this assignment are intended to be realistic and representative rather than exact. This assignment will require you to exercise considerable judgment concerning what to investigate, what level of detail to use, and how best to present your results. The purpose of the various analyses is to provide insight into the key issues related to the nature and pace of expansion of the canal. Part B will explore these and other issues from the perspective of customers, carriers, and other governments, as well as from the perspective of the APC and the GOP. There is no unique "right" answer, but there is clearly a role for analysis in helping to understand and evaluate the various options for expanding the Canal.