

1.201 Introduction to Transportation Systems

Final Exam

Dec 20, 2006

Solutions

Question 1A (12.5 points)

- a) 3 out of 30 key points, with justification (2.5 points)
- 1) #1, Behavior
 - 2) #2, Transportation as part of a broader system
 - 3) #8, Capacity
 - 4) #9, Supply
 - 5) #14, Cost/level-of service trade-offs
 - 6) #17, Capacity, cost and level-of-service
 - 7) #18, Peaking
 - 8) #19, Transportation demand
 - 9) #22, Equilibrium
 - 10) #23, Pricing
 - 11) #27, Transportation, economic development, and land-use
- b) 5 participants and stakeholders (3points):
- 1) Public transportation, bicycle and walking advocates: Transportation Alternatives. Support congestion charging as it will reduce vehicular traffic, and will probably improve alternatives
 - 2) Residents of outer boroughs. Worried about their access to Manhattan jobs
 - 3) Environmental advocates: Environmental Defense. Support congestion charging as it will reduce vehicular traffic
 - 4) Business groups: Partnership for New York. Support congestion charging as it will deal with congestion
 - 5) Local business owners. Support congestion charging as it will deal with congestion, but oppose it if it causes a reduction in access to customers.
 - 6) Rich drivers. Support congestion charging as it will deal with congestion and give them an easier commute
 - 7) Parking lot owners. Do not support congestion charging as it will reduce vehicular use
 - 8) Conservative thinkers. Support congestion charging as it is aligned to their ideology
 - 9) Politicians: Bloomberg, Doctoroff. Tentative about congestion charging as it could be a great political success or a great political disaster
 - 10) Public transportation authorities. Support congestion charging as it would probably give them more funds for public transportation, and increase demand for their services
- c) Memo to Mayor Bloomberg on how to spend toll revenues (7 points):
- 1) To collect tolls i.e. invest in the technology and implementation of the congestion charging scheme. If the system is cumbersome, and/or has errors, then the whole scheme fails. From London's example over half of toll revenues go in operating costs of collecting tolls
 - 2) Improve public transportation, all over the city and especially to/from outer boroughs
 - 3) Improve bike and pedestrian transportation
 - 4) Encourage transit oriented development, transit accessible affordable housing

- 5) Improve/increase taxi services
- 6) Educate people
- 7) Some modest improvement in vehicular transportation to reduce opposition

Question 1B (12.5 points)

a) 3 out of 30 key points with justification (2.5 points)

- 1) #1, Behavior
- 2) #2, Transportation as part of a broader system
- 3) #8, Capacity
- 4) #9, Supply
- 5) #11, Infrastructure shape
- 6) #16, Lumpy investment
- 7) #17, Capacity, cost and level-of-service
- 8) #21, Different time scales
- 9) #27, Transportation, economic development, and land-use
- 10) #28, Performance measures

b) 5 stakeholders (3points):

- 1) Large corporations. Worried about economic impact of congestion on their freight traffic needs. Might want to relocate
- 2) Local businesses. Worried about impact of congestion on their delivery needs, and so on their costs
- 3) Public transportation, environmental, and smart-growth advocates and planners. Want to preserve public transportation and smart growth policies
- 4) Politicians. Worried about possible relocation of corporations, impact on local businesses, economic loss due to congestion, and negative environmental impacts
- 5) Labor. Worried about possible relocation of businesses and loss of jobs
- 6) Residents. Worried about increasing congestion, as well as their transportation alternatives
- 7) Commuters. Worried about increasing congestion, as well as their transportation alternatives
- 8) Shippers. Worried about increasing cost of freight transportation
- 9) Department of transportation. Worried about state of the transportation system including public, private and freight transportation

c) 3 strategies for relieving congestion in the context of sustainability (7 points):

- 1) Only add highway capacity: economic mostly good, environmental mostly bad, equity mostly bad
- 2) Only improve public transportation: economic both good and bad, environmental good, equity mostly good
- 3) Improve both highways and public transportation: economic mostly good, environmental mostly good, equity mostly good
- 4) Congestion charging, with possibly variable rates for freight v. passenger vehicular traffic: economic good, environmental good, equity both good and bad
- 5) Variable parking rates for freight v. passenger vehicles: economic mostly good, environmental good, equity both good and bad

- 6) Investing in non-truck freight options: economic mostly good, environmental mostly good, equity mostly neutral

Question 2 (25 points)

a) Data requirements for mode choice analysis (5 points):

- 1) Binary choice: bus and metro
- 2) Best path for bus and metro for each origin-destination pair.
- 3) Revealed preference survey data between bus and metro
 - i) Home interview surveys
 - ii) On-board surveys
 - iii) Stated preference surveys could be helpful for supplemental data
- 4) Need socio-economic characteristics of the individual e.g. income, gender, education etc.
- 5) Need their selected path definition i.e. links making up path, and attributes of selected mode e.g. travel time (access, wait and in-vehicle travel times), travel cost, frequency, comfort, reliability, level of service, etc. and transfer/interchange attributes
- 6) Need their actual choice

b) Reasons for model estimation results (5 points):

- 1) Two types of explanations:
 - i) Modeling assumptions
 - ii) Actual behavior
- 2) Assumes that all individuals are aware about all alternatives (paths and attributes), but knowledge about bus paths and attributes is likely to be much lower than for metro paths for some individuals. This alone could explain the results.
- 3) Also, finding the best path for buses is likely much harder than for metro, so some individuals may be comparing inferior bus paths to the truly best metro path.
- 4) Often stopping and starting (in traffic, at stop lights and to pick up passengers) in buses as compared to metro
- 5) Real and perceived unreliability in terms of in-vehicle travel time in buses as compared to metro
- 6) Real and perceived crowding, exposure to the weather, discomfort, lack of safety etc. in buses as compared to metro
- 7) Real or perceived negative connotation of bus versus rail (especially in the US)

c) Implications for investment (5 points):

- 1) The key issue is that the old assumption (note: not the result of estimation) will have allocated more passengers to buses and fewer to metro than in fact occurs in reality. Thus buses will have more capacity than required and metro will have less capacity than required, and so actual crowding on metro will be higher than on buses. This will tend to increase value of additional investment in metro as compared to buses. This means that the capacity constraint on metro (if capacity cannot be increased, or if it is very expensive to do so) may in fact be binding (in the real world) when the model suggests it is not.
- 2) A second but less key issue is that the old model underestimates the importance of in-vehicle travel time for buses. For example the old model estimates that an investment that reduces travel time for buses by 10 minutes is considered the same as one that that reduces travel time for metro by 10 minutes. However, in reality the 10 minutes reduction

in travel time for buses has a much bigger effect on travel behavior, and so on mode choice than a similar reduction for metro. Consequently, the current model underestimates the importance of investment in bus modes to reduce in-vehicle travel times. An updated model using the new estimated coefficients for bus versus metro in-vehicle travel times will tend to increase value of in-vehicle time reducing investment in buses as compared to metro.

- d) Changes to the structure of the model for a path choice analysis (5 points):
 - 1) The key issue is that this is no longer a binary mode choice model but a multi-nominal path choice model with correlation across some paths
 - 2) Alternate paths have a number of links and modes, which might overlap
 - 3) Introduces the complexity of bus-metro transfers for the first time
- e) How to deal with issues of path overlap i.e. violation of iid assumption (5 points):
 - 1) Alternative paths are not always independent (i.e. there is correlation) as some paths might share same links
 - 2) Use a nested logit model structure (*need some discussion of alternative ways of structuring the nests i.e. tree structure*)
 - 3) Common portions of paths (links and modes) separate from the overlapped portions

Question 3 (25 points)

a) Train cycle for options A and B (1 point):

- 1) Option A: $(1.5+.5+1.5+.5)*2=8$ hours
- 2) Option B: $(2.5+.5)*2=6$ hours

b) Number of trains for 12 trains/day i.e. one every 2 hours, for Option B (1 point):

- 1) Option B: $6 \text{ hours}/2 \text{ hours per train}=3$ trains

c) Frequency for Option A, with same number of trains as Option B (1 point):

- 1) Option A: $\text{Headway}=8 \text{ hours}/3 \text{ trains}=2.67 \text{ hours per train}$, $\text{Frequency}=24/2.67=9$ trains/day

d) Demand between all city pairs (2 points):

K		Opt A	Opt B
	B-NH	50	
	NH-NYC	100	
	B-NYC	200	200

Fare		Opt A	Opt B
	B-NH	100	
	NH-NYC	100	
	B-NYC	200	200

T		Opt A	Opt B
	B-NH	1.5	
	NH-NYC	1.5	
	B-NYC	3.5	2.5

Options	Freq	Opt A	Opt B
		9	12

Demand		Opt A	Opt B
	B-NH	3000	
	NH-NYC	6000	
	B-NYC	2571	4800
	Total	11571	4800

Revenue		Opt A	Opt B
	B-NH	300000	
	NH-NYC	600000	
	B-NYC	514286	960000
	Total	1414286	960000

e) Should the train company stop at New Haven (9 points):

- 1) Total demand (potential ridership) is 11571 for Option A v. 4800 for Option B (double if considering both directions)
- 2) Total revenue is \$1,414,286 for Option A v. \$960,000 for Option B (double if considering both directions) (*make explicit assumption that train company captures all demand i.e. ridership = demand*)

- 3) The train company's evaluation criteria: could be revenue maximizing or ridership maximizing or both (*be explicit about this; remember this is a 9 point question*)
 - 4) Yes, would stop at New Haven i.e. Option A, as it has more revenue and more ridership
 - 5) Option: maybe have some trains stopping at New Haven and some going directly
- f) Explore some changes to Option B, and suggest which are a good idea (7 points):
- 1) K and T are fixed. Cannot change
 - 2) Reduce fares. This will increase demand, but will have no effect on revenues due to the model structure - demand is inversely proportional ($\text{demand} = f(1/\text{fare})$) to fares, and so revenue ($\text{demand} * \text{fare}$) stays the same. So don't reduce fares if revenue maximizing, reduce fares if ridership maximizing. Realize that capacity must be sufficient.
 - 3) Increase frequency, add another train. This will increase demand and revenue - demand is directly proportional ($\text{demand} = f(\text{frequency})$) to frequency, and so revenue ($\text{demand} * \text{fare}$) increases. So increase frequency if revenue maximizing or ridership maximizing. Realize that costs will increase (*remember this is a 7 point question*)
- g) Some shortcomings in the model (4 points):
- 1) Considers the relationship between demand and frequency, and between demand and fares as linear, when it should follow the law of diminishing returns
 - 2) Does not consider seasonal and hourly variations in demand
 - 3) Does not consider capacity limits
 - 4) Does not consider other level-of-service variables besides fare and frequency
 - 5) Does not consider alternatives, competitors, substitutes' level-of-service
 - 6) Is a deterministic model. Should be probabilistic

Question 4 (25 points)

- a) Complaints or objections (5 points), and b) Response to complaints or objections (5 points)
- 1) Politicians in Panama: They will undoubtedly want a share of the increased revenue from the tolls. This is a matter of negotiation. Key questions are how quickly to build the third set of locks, how much (if any) to borrow, and how much to give to GOP now and in the future. Like the international construction companies, they might want a bigger project sooner, especially since they aren't directly paying for it. On the other hand, they might want to defer investment by charging even higher tolls and having more going to GOP right away. They may also see this major project as an indication that the Panama Canal is more profitable than they realized – so that they might push for related projects, e.g. a new bridge or better development of the waterfront by the Canal.
 - i) Want more revenue from tolls. Response:
 - (1) Increase contribution to GOP
 - ii) Want more benefits for Panamanian citizens. Response:
 - (1) Show number of jobs will increase
 - (2) Promise jobs to citizens
 - (3) Reduce foreign workforce
 - iii) Want bigger project sooner. Response:
 - (1) Show that toll revenues will not support it
 - iv) Want to defer investment, charge higher tolls now, and get greater share of revenue. Response:
 - (1) Show that this is unsustainable
 - (2) Congestion will increase
 - (3) Will lose demand in the long run
 - v) Environmental concerns. Response:
 - (1) Start environmental impact study
 - (2) Propose mitigation measures
 - 2) Bulk shippers: From Assignment 6A, it is clear that the bulk shippers will be most hurt by higher tolls, while they have the most to gain from larger ships. They could argue for tolls based upon ability to pay and they might push for a per-ship toll, since they have the most tons/ship. They presumably would push for a faster timetable, as they are unable to make use of the canal right now (because of competitive reasons, as addressed in Assignment 6A)
 - i) Want lower tolls esp. lower per ton toll. Response:
 - (1) Refuse
 - (2) Give some discount to larger ships
 - ii) Want per ship toll. Response:
 - (1) Partially accept
 - iii) Want faster project i.e. increased capacity sooner. Response:
 - (1) Show that toll revenues will not support it

- 3) International construction companies that have the ability to finance and construct multi-billion-dollar infrastructure projects: a case could be made that the Canal Authority is going too slowly, so that they should be urged to increase the pace of construction in order to open up a third set of locks by 2015 or earlier. This would require financing – and it would get money to the big construction companies more quickly. In fact, if Panama goes slowly enough, they might be able to do much more of the work (especially routine dredging) on their own without requiring assistance from multi-national contractors.
 - i) Want to increase pace of construction. Response:
 - (1) Show that toll revenues will not support it and will require outside financing
 - (2) Show that this is best for Panama
 - 4) Environmental groups in Panama: they are likely to object to taking more land for the Canal and to the greater use of water for the lock operations. If the water is to be recycled, they may fear that it will get very contaminated over time, or that Lake Gatun will become salty. They may seek another bridge for better linkage between the two halves of Panama. The technical issues could be addressed through scientific studies, and there is time to develop new approaches to filtering or otherwise cleaning the water. Putting in another bridge might be a reasonable idea – and also a way to keep GOP happy.
 - i) Object to water contamination, land deforestation, loss of habitat and wildlife. Response:
 - (1) Start environmental impact study
 - (2) Propose mitigation measures
- c) Effect of Nicaragua's canal on the Panama Canal (5 points):
- 1) Tolls have doubled to \$6 per ton, which has limited growth of demand. The 200 million tons carried in 2006 is lower than would be expected given the demand projections in 6A (up from 157 in 1993 to 363 million tons by 2020), suggesting that the APC is driving traffic away with its aggressive toll (just as planned). 200 million tons at \$6 per ton is \$1.2 billion per year. Nicaragua's \$20 billion project will have interest costs of \$1.2 billion per year (equivalent to the total revenue from the Panama Canal) when it opens – assuming no overruns. Can they possibly expect to cover their costs? Implications:
 - i) If new canal is built, it will add a lot more capacity - so will APC need to add capacity? May not need to expand the Panama Canal
 - ii) Competition could lead to a rate war - but APC should win, since they don't have debt.
 - iii) Traffic might divert to the new route because it provides a quicker route between Asia and the Atlantic (a sea level route would allow for a quicker transit, and the route via Nicaragua would be a little shorter). Might take away high value large ship traffic. But overall demand might be enough for both canals.
 - iv) Development of container terminals and other trade-related activity could be diverted to Nicaragua.
 - v) The environmental disruption of the third locks project could be shifted to another country. Will reduce the environmental degradation due to Panama Canal expansion

- d) Possible responses to the Nicaragua Canal proposal, and e) advantages/disadvantages of each and justification of one (5 points):
- 1) Do nothing against the Nicaragua Canal, on the assumption that the new canal will never be built, and proceed with plan for Panama Canal Expansion. Nicaragua's \$20 billion project will have interest costs of \$1.2 billion per year (equivalent to the total revenue from the Panama Canal) when it opens – assuming no overruns.
 - i) Advantage:
 - (1) Costs nothing
 - (2) Failed project will increase value of Panama Canal
 - ii) Disadvantage:
 - (1) The Nicaragua Canal project might get built under different financing structure
 - 2) Expose the weakness of the case for the new canal via thorough studies involving independent agencies, shippers, etc. Question the technical and the economic feasibility. Question what profits, if any, will go to Nicaragua and what will go to the construction companies and the banks.
 - i) Advantage:
 - (1) The Nicaragua Canal project will be exposed as infeasible
 - ii) Disadvantage:
 - (1) The Nicaragua Canal project might come out better, if changed to meet criticisms
 - 3) Accelerate the Panama Canal schedule for a third set of locks - since Panama's capacity only costs about \$5 billion and presumably could be completed before Nicaragua's much larger project. However, if there is another canal, Panama doesn't have to worry about its capacity - and they can always undercut the new canal since they don't have any debt.
 - i) Advantage:
 - (1) Will give Panama Canal a head start, and a monopoly till the Nicaragua Canal is built
 - ii) Disadvantage:
 - (1) Toll revenues cannot support it, will have to borrow money
 - 4) Do nothing or defer the investment in the third set of locks, on the assumption that no capacity will be needed.
 - i) Advantage:
 - (1) Costs nothing
 - (2) Keeps Panama Canal monopoly in the meantime
 - (3) No environmental costs for Panama
 - ii) Disadvantage:
 - (1) May be wrong about demand v. capacity and so might lose out to Nicaragua Canal in the long run
 - (2) May lose out to Nicaragua Canal in the high value, large ship market
 - 5) Sell the Panama Canal to those who are backing the new canal - at a price less than that of the new canal; or pursue aggressive toll-based financing for the Panama Canal (a leveraged buyout, if you will)

- i) Advantage:
 - (1) Makes money
- ii) Disadvantage:
 - (1) Lose ongoing revenue source
 - (2) Selling national asset will stir political opposition
- 6) Join the consortium for constructing the sea-level canal or partner with the Nicaragua Canal
 - i) Advantage:
 - (1) Maintain monopoly in the long run
 - (2) Control international shipping as before
 - ii) Disadvantage:
 - (1) Costs money
 - (2) Could be seen as anti-competitive by the international community
 - (3) Take on risks of Nicaragua Canal project
 - (4) They might not want to do so
- 7) Call upon the World Bank to conduct an impartial assessment of the need for capacity and of the best options for achieving that capacity.
 - i) Advantage:
 - (1) Nicaragua Canal project might be stopped
 - ii) Disadvantage:
 - (1) Panama Canal expansion might be stopped too
- 8) Decrease Panama Canal tolls
 - i) Advantage:
 - (1) Will make Panama Canal more competitive v. the Nicaragua Canal
 - ii) Disadvantage:
 - (1) Will reduce toll revenues
 - (2) Will jeopardize Panama Canal expansion plan
 - (3) Will increase congestion till Nicaragua Canal opens