1.221J /11.527J / ESD.201J Transportation Systems
Fall 2001

Assignment #3 – Passenger / Freight

Date assigned: Thursday, September 27, 2001
Date due: Oct 18, 2001

(30 points)

Instructions

Answer all parts of the questions below. You may use any books or notes at your disposal, but material given in class (lecture notes and readings) should be sufficient for all aspects of this problem. In addition, the data and equations given within the problem set will be sufficient to complete all quantitative aspects of the problem – if you find yourself needing anything else (beyond analytic skills and reasonable assumptions), then you are likely doing too much. You are not required to use all the information provided. Selecting which information in the narrative is germane is part of the assignment. You *will* need to make some assumptions in your analysis – carefully document and justify them.

This is an individual assignment. You are permitted to discuss basic concepts and approaches with your fellow classmates, but not with students from previous years. The analysis and report must be done on your own.

It is recommended that you first read through the problem carefully to get an idea of the situation as a whole. Before beginning any actual work, review the appropriate materials and plan the necessary steps of your problem-solving strategy.

Introduction to the Problem

Congestion and related transportation concerns are of increasing importance to cities and regions across the world. As commercial and recreational travel grows, these activity centers must prevent rising traffic congestion from eroding the quality of the visitor's experience and the competitiveness of the area's businesses. If these problems are not addressed, then shoppers, businessmen, and manufacturers will find better locations. Yet choosing the best investment in order to achieve a long-term solution is often far from simple.

In this assignment, you will assume the role of a transportation planner working on the staff of the Oresund Link Joint Committee (OLJC) in 1996. The OLJC was formed by the governments of Sweden and Denmark in order to evaluate strategies and make final suggestions regarding potential improvements to the transportation linkages across the Oresund Strait from Copenhagen, Denmark, to Malmo, Sweden. As the head planner, you have been asked to assemble a report for the Chair of the Committee, Ms. Ilsa Lund, on the future of the passenger and freight transportation systems between Malmo and Copenhagen.

You will be focusing your analysis on a system that has the potential to significantly alter the transportation landscape in the fast-growing Oresund Region. With Copenhagen as its hub and a radius of about 60 miles, nearly 3.5 million people live in the Oresund Region. The European Union has designated Oresund as a model region for greater employment, and the area is also one of Europe's most significant research centers, with fifteen colleges and universities and many cross-border programs. Advanced industrial firms have flourished here, including leaders in biotechnology, food production, pharmaceuticals manufacture, medical technology, IT, and environmental technology.

Yet the seemingly bright future of the Oresund Region could be dampened if transportation issues are not addressed. Passenger and freight traffic in the Malmo-Copenhagen corridor is currently served only by ferries. These ferries currently handle three types of traffic: walk-up passengers, family automobiles, and container (freight) trucks. The ferries travel slowly across the Strait, and during peak times of the day, they become very crowded. Yet few alternatives are currently available (no bridge exists at the narrower northern crossing near Helsingborg, Sweden), and it is feared that continued reliance on these ferries will hamper the growth of trade and tourism in the region.

With these concerns in mind, the OLJC commissioned several detailed consulting studies and determined that there are two options that will best add transportation capacity to the corridor:

1. Build a **roadway-only** bridge across the Oresund Strait. This bridge would have two lanes of traffic in each direction and would charge tolls for both automobiles and freight trucks. In addition, a "shuttle" motorbus service would be offered by the bridge authority for those passengers without cars.
2. Build a **combination road/rail** bridge across the Strait. This bridge would offer trackage appropriate for both passenger and freight trains, but it would come at the expense of motor traffic – only one lane of traffic would be available in each direction. Tolls would again be charged, but no bus service would be offered.

However, a recent development has thrown more uncertainty into the mix. After years of lackluster management and performance, Oresund Ferry Services (the private company that owns and operates the ferries) recently selected a new CEO, Mr. Bergman. He has been a noticeable presence at public meetings regarding a potential bridge, and he has spoken of improving the ferry services in the Strait. While Mr. Bergman's intentions are unknown, the technology for ferries has been improving over the years. With new propulsion systems and hull designs allowing for greater speed on the water, and new ship layouts and dock facilities allowing for faster loading and unloading, the potential for a competitive response by the ferries must now be considered.

The Chair, Ms. Lund, needs an analysis of the options so that the OLJC can make its recommendations to the Swedish and Danish governments. More specifically, she is interested in determining the effectiveness of several strategies to utilize the proposed options, and she wants to understand the seriousness of the potential competitive threat posed by the ferries. There are many stakeholders in this decision, and they bring different ideas to the table about what is the most effective strategy:

- The head Danish road engineer, Mr. Bohr, is in favor of constructing the roadway-only bridge. He sees truck traffic across Europe growing because of their speed and flexibility, and he thinks a high capacity roadway bridge will best serve this market. He supports low bridge tolls to encourage traffic.

- Ms. Garbo, the Director-General of Banverket (the Swedish national rail administration), supports the combined road/rail bridge. She believes that fast and reliable train service can capture a significant percentage of the passenger market, if priced correctly relative to the bridge auto toll. With many of those travelers then off the road, she thinks the remaining passenger and truck traffic will be modest enough to not cause too much congestion on the bridge.

- Mr. Kierkegaard, the mayor of Copenhagen, wants to draw shoppers from Malmo and beyond to the city's retailers, but his constituents have also made clear their desire for a "livable" city, which includes actions to discourage automobile usage. Mr. Kierkegaard supports the bridge concept, but he wants to consider the effect of raising parking rates in Copenhagen to reduce the number of automobiles that cross the link.

- Finally, Mr. Hammarskjold, Sweden's Deputy Environmental Planning Minister, is afraid the bridge will threaten the marine ecosystems of the Strait and damage the shorelines in both Sweden and Denmark with the required approaches. He opposes building either bridge, but he is pragmatic and recognizes that the need for transportation improvements cannot be completely ignored. He would support the changes Mr. Bergman would require to upgrade the ferry services.

Tasks

1. The base-case consists of current operating characteristics and conditions. Using the base-case information provided in Appendix 1, the parameter and equations provided in the Appendices, and other assumptions, calculate the following for present Year 1996 conditions:

   - Passenger level of service (total cost, access time, total time) for walk-up and auto
   - Passenger mode split (i.e., walk-up or auto) and ferry revenue
   - Freight level-of-service (total cost, access time, total time)

   In your write-up, demonstrate your understanding of the concepts and models you used to determine these base-case conditions. Again, please explicitly state any assumptions you used in your analysis.

2. After calculating the base-case, you should evaluate, in a similar fashion, the proposed strategies that represent the viewpoints of Bohr, Garbo, and Kierkegaard for the Year 2001. You should evaluate these strategies in light of the potential competitive response by Bergman (which is supported by Hammarskjold). That is, you should evaluate the strategies against both "status quo" ferry service and "improved" ferry service. Does the likelihood of a particular response by the ferries change your recommendation to Ms. Lund? This will require changing the values of the relevant system attributes or parameters, and explaining/justifying why the changes you made are appropriate. In making these changes, observe the sensitivity of the most important parameters and report on your observations. Describe the results of your analysis of alternative strategies. Use the forecasted 2001 traffic data in Appendix 2.

3. Similarly, you should evaluate the proposed strategies for their effectiveness in handling the expected volumes in 2010 and in affecting the long-term travel behavior between Malmo and Copenhagen. Use the forecasted 2010 traffic data in Appendix 3 as well as the tools you used in the previous scenarios to conduct your analysis.

4. Include a thorough description and justification of each assumption you make (both explicitly and implicitly) in your analysis. Describe the limitations or weaknesses of the analysis given the assumptions you made and the methods you used. Discuss which strategy provides the best solution to the problem.

5. Where appropriate, discuss any larger issues that you feel are not captured well by the analysis. For example:
   - If your analysis shows a particular mode having a low utilization rate, do we expect that mode to maintain the same operating plan or stay in business over the long term?
   - How do we include things like "environmental protection" and "livability" in our analyses when they are intrinsically hard to measure?
   - This bridge will not link two cities or even two states, but two sovereign nations. How might the political and social ramifications of this linkage be brought into the analysis?

- The proposed bridge will be built with public funds. Would your recommendations change if the funding were joint public/private or even fully private?

6. Ms. Lund has not asked you to give quantitative projections for 2001 and 2010 with no bridge and no improved ferries, as she feels that traffic projections and public opinion have made it clear that some improvements will certainly occur. However, a minor local politician in Copenhagen, Mr. Andersen, has recently tried to raise his profile by taking a very strong position against *any* actions to raise capacity in the corridor. In the U.S., this might be considered a NIMBY (Not In My Backyard) phenomenon, where small but determined local groups oppose larger projects by claiming disproportionate impact. He is likely to appear at upcoming public meetings and oppose both the OLJC and Mr. Bergman. As part of your report, add a brief **qualitative** section that suggests to Ms. Lund how to respond to his statements.

7. Ms. Sorenstam is the owner of a small plant in Malmo Manufacturing Center, and she prides herself on prompt deliveries and low logistics costs. She is currently shipping her containers by truck across the Oresund Strait to her many customers in Denmark and northern Germany. However, she is worried that the increasing congestion and some of the proposed solutions may severely impact shipping time and her ability to provide low logistic costs to her customers. Thus, Ms. Sorenstam is considering her options for the future, including shifting to rail transportation and even moving the plant across the Strait to Copenhagen. (The volume of her shipments is small relative to the overall flows and therefore you can assume they will not affect the travel times and traffic volumes of other modes.)

Ms. Sorenstam's senior analyst, Mr. Wallenberg, has obtained a copy of your report to Ms. Lund. Put yourself in Mr. Wallenberg's place and write Ms. Sorenstam a short memo containing an analysis of the situation, related issues, and thoughts on what actions Ms. Sorenstam should take. This memo should take into account the recommendations you made in the report composed for the OLJC. You may need to make additional assumptions for this task.

Deliverables

The deliverables include your report for Ms. Lund and Mr. Wallenberg's memo to Ms. Sorenstam. Both Ms. Lund and Ms. Sorenstam are technically trained, but unfamiliar with the specifics of transportation analysis. Each deliverable should be organized appropriately for its audience and purpose. It should not simply follow the list of tasks above, but should be presented as a professional report. Your report format and tone will be taken into consideration in your grade.

You may find some of the following elements helpful in organizing and presenting your work:

- An Executive Summary, in which you present your key findings and recommendations
- A description of the methodology used to analyze the problem
- Graphs & tables, in addition to descriptive text, illustrating the results of your quantitative analysis
- Appendices which contain extensive equations, data, or calculations you wish to include

How to Proceed

By far, the most important element of this assignment is demonstrating your knowledge of the fundamental transportation concepts illustrated by the problem at hand, and represented in the parameters and equations given in the Appendices. You should be sure your discussion shows your understanding of how the equations interact, their strengths, weaknesses, and the assumptions upon which they rely. Your actual results should be presented thoroughly and concisely.

It is up to you to determine (and explain to the report recipient) how to put the given analytic tools and methodologies together. Current background data, growth projections, and operations parameters are found in the Appendices. Please note that you may not need to use all the information that has been provided. Information from a previous study by the OLJC should be used to calculate travel times and ferry congestion, and this information is also in the Appendices. You should use the LOGIT model to determine how travelers choose between traveling between different modes, and how freight shippers choose between truck and rail modes. The LOGIT model and the estimated parameters that should be used are also provided in the Appendices. The Appendix entitled "A Basic Introduction to the LOGIT Model" is a primer for the fundamental concepts of this approach.

It is highly recommended that you use a spreadsheet program such as Microsoft Excel in your analysis. A key timesaver is to carefully think about the methodology you are going to use and structure the spreadsheet accordingly. If structured correctly, the analysis should not be too time intensive, once you have modeled the base case and your first option.

Appendix 1
Base Demographic and Travel Data

Malmo and Copenhagen are separated by the Oresund Strait, with only ferry service currently available for both passenger and freight traffic. You will model a simplified version of their situation in order to come up with the recommendations for the OLJC.
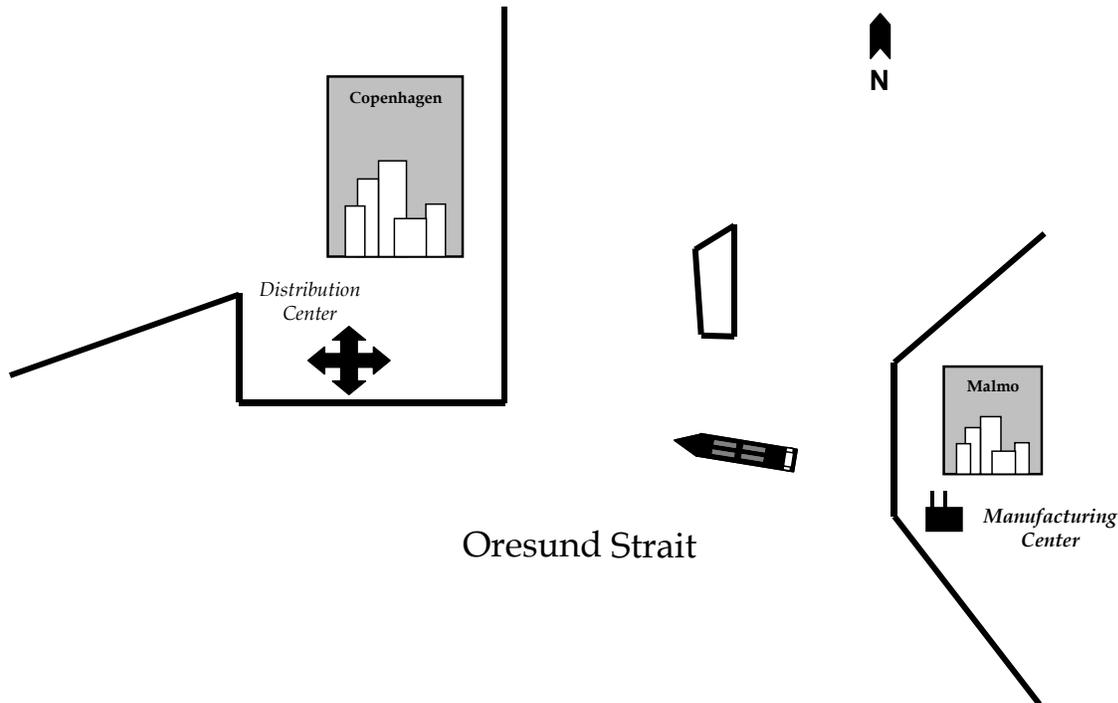
Figure 1: The Current Situation

We will model traffic congestion and freight movement during the morning peak hour (8am-9am) from Malmo to Copenhagen. Clearly, this is an abstraction from real life, but it makes our model tractable. For the travelers, we simply envision tourists, shoppers, and businesspeople making trips across the corridor. For freight, we imagine the Malmo Manufacturing Center, near the docks. The plants in this center need to get their containers across the Strait to a major distribution center near the docks in Copenhagen. From there, the containers will be shipped to their final destinations.

Demographic and travel data for the region, as well as operational data for determining the base case with the current ferries, are given below.

Current Population (1996) of Malmo: 250,000
Current Population (1996) of Copenhagen: 1.2 million
Average Per Capita Income of Travelers: $35,000

Peak Period Traffic (Malmo to Copenhagen) in 1996:
- Travelers: 1,000 people
- Freight: 50 containers

Operational data for current ferries:

- Total ferry capacity (vehicles):   400
- Ferry crossing time: 40 min.
- Unimpeded load/unload time for car: 5 min.
- Unimpeded load/unload time for truck: 10 min.
- Car fare: $10.00
- Individual passenger fare: $5.00
- Truck fare: $25.00

Miscellaneous:
- Passengers who walk on to the ferry must take buses to and from the docks. For simplicity, assume this part is deterministic – the total bus time for a passenger is 10 minutes on each end, and the fare is $1.00 on each end.
- Value of time for truck drivers: $20.00 / hour
- Truck drivers are not considered in the daily travelers in the data above.
- Value of time for travelers is $10.00 / hour
- Average walking speed: 3 mph
- Assume 1 auto = 1 vehicle, 1 bus = 2 vehicles, 1 truck = 3 vehicles
- Trucks can carry 1 container
- Note that you have **not** been told how many people to assume per automobile. This is an important assumption that you have to make, and you should provide some justification.

Appendix 2
Projected Demographics, Traffic, and Operational Data

As noted, there are many possibilities for dealing with the projected increases in traffic. The projected increases are given below, as are the projected operational data for the new ferries, the roadway-only bridge, and the road/rail bridge. While some things such as the length of the bridge and the lane capacity of the roadway are fixed, you should consider the values of other variables (such as the tolls, the fares, and the frequencies) to be merely the OLJC's best estimate of what the situation will look like in the future. When you examine the sensitivity of your models, you should consider changes in these variables. (If you want to consider the fares, etc., for the ferries to be fixed, since they are privately run and out of the OLJC's purview, that may be appropriate.)

	2001	**2010**
Projected Population of Malmo:	260,000	290,000
Projected Population of Copenhagen:	1.3 million	1.4 million
Average Per Capita Income of Travelers:	$37,000	$42,000

Anticipated Future Traffic:	**2001**	**2010**
• Travelers:	1,400	2,200
• Freight:	70	100

Operational data for potential new (advanced) ferries:
- Total ferry capacity (vehicles): 500
- Ferry crossing time: 25 min.
- Unimpeded load/unload time for car: 2.5 min.
- Unimpeded load/unload time for truck: 5 min.
- Car fare: $15.00
- Individual passenger fare: $5.00
- Truck fare: $35.00

Operational data for **roadway-only** bridge:
- Bridge length: 10 miles
- Traffic lanes in each direction: 2
- Lane capacity per hour (vehicles): 500
- Auto free-flow speed: 50 miles/hr
- Auto toll: $20.00
- Truck free-flow speed: 40 miles/hr
- Truck toll: $30.00
- Bus free-flow speed: 40 miles/hr
- Bus fare: $8.00
- Bus seating capacity: 40 people
- Buses per hour: 4

Operational data for **road/rail** bridge:
- Bridge length (miles): 10
- Traffic lanes in each direction: 1
- Lane capacity per hour (vehicles): 500
- Auto free-flow speed: 50 miles/hr

- Auto toll: $20.00
- Truck free-flow speed: 40 miles/hr
- Truck toll: $30.00
- Passenger train speed: 60 miles/hr
- Passenger train fare: $10.00
- Passenger trains per hour: 2
- Freight train speed: 45 miles/hr
- Charge per container on freight train: $30.00
- Freight trains per hour: 1
- Extra load/unload time per container on train: 10 min.

Appendix 3
Vehicle Travel Times and Ferry Congestion

You should model vehicle travel times on the roadway-only or road/rail bridges using the model estimated by the OLJC engineers:

$$T_a = T_0(1 + 0.5[X_a/K_a]^4)$$

Where:
T_a is the travel time (in minutes)
T_0 is the free-flow travel time (in minutes)
X_a is the number of vehicles on the link (a link = 1 lane)
K_a is the practical road capacity of the link (a line = 1 lane)

Similarly, you should estimate the loading/unloading congestion at the ferries (both old and new) by using the following model:

$$L_b = L_0(1 + 2[X_b/K_b]^2)$$

Where:
L_a is the load/unload time (total)
L_0 is the unimpeded load/unload time
X_b is the number of vehicles entering the ferry
K_b is the capacity of the ferry

Appendix 4
LOGIT Model of Choice

See Appendix 5 for a basic introduction for applying the LOGIT model.

Initial Car/Walk-on Passenger Mode Choice

The binary LOGIT choice model is given by:

$$P_n(B) = \frac{e^{V_{Bn}}}{e^{V_{Bn}} + e^{V_{An}}} \quad \text{and} \quad P_n(A) = 1 - P_n(B) = \frac{e^{V_{An}}}{e^{V_{Bn}} + e^{V_{An}}}$$

Where $P_n(B)$ is the probability that traveler *n* will walk-on to the ferry from Malmo to Copenhagen, and $P_n(A)$ is the probability that traveler n will take an automobile on the ferry. V_{Bn} and V_{An} are the systematic components of the utility of traveler *n* for walking-on and automobile, respectively, and '*e*' is the exponential function.

Observe that, though the LOGIT model describes the mode choice decision by a single traveler, the results are easily extended to the aggregate case. We can simply let the proportion of travelers choosing the walk-on option over the automobile option equal the probability that the individual traveler will walk-on to the ferry.

The systematic utilities of the travelers have been previously estimated by the OLJC and are expressed by the equations below:

$$V_B = -0.0716*(i_B) - 0.101*(o_B) - 0.0055*(c_B)$$
$$V_A = 1.85 - 0.0716*(i_A) - 0.101*(o_A) - 0.0055*(c_A)$$

Where for each mode:

i is the total in-vehicle travel time (in minutes)
o is the out-of-vehicle travel time (in minutes)
c is the out-of-pocket monetary cost (in cents)

Future Passenger Mode Choice

With more than two choices, we can turn to a multinomial logit choice model. The systematic utility equations will look the same, and when we calculate $P_n(A)$, we simply sum the systematic utilities of *all* the options in the denominator. For example, if we had three choices (A, B, and C), our equation would be

$$P_n(A) = \frac{e^{V_{An}}}{e^{V_{An}} + e^{V_{Bn}} + e^{V_{Cn}}}$$

Below are the logit model parameters for the roadway-only bridge and the road/rail bridge. In the roadway-only bridge case, the bus option has an implied idiosyncratic preference of zero, while rail has an implied idiosyncratic preference of zero in the road/rail case.

TRAVELER MODE CHOICE WITH ROADWAY-ONLY BRIDGE		
Now, $P_0 = \exp(V_0)/(\exp(V_0)+\exp(V_1)+\exp(V2)+\exp(V3))$		
AF	2.35	Idiosyncratic preference for auto on ferry
WF	0.50	Idiosyncratic preference for walk-on to ferry
AB	1.05	Idiosyncratic preference for auto on bridge
(i)	(0.0716)	Total in-vehicle time (minutes)
(o)	(0.1010)	Total out-of-vehicle time (minutes)
(c)	(0.0055)	Out-of-pocket monetary costs (cents)

TRAVELER MODE CHOICE WITH ROAD/RAIL BRIDGE		
Now, $P_0 = \exp(V_0)/(\exp(V_0)+\exp(V_1)+\exp(V2)+\exp(V3))$		
AF	1.60	Idiosyncratic preference for auto on ferry
WF	-0.25	Idiosyncratic preference for walk-on to ferry
AB	0.30	Idiosyncratic preference for auto on bridge
(i)	(0.0716)	Total in-vehicle time (minutes)
(o)	(0.1010)	Total out-of-vehicle time (minutes)
(c)	(0.0055)	Out-of-pocket monetary costs (cents)

Container Distribution Mode Choice

The factories at the manufacturing center have also developed a systematic utility function with which they evaluate how they should distribute their shipments to the container port. Since they care only about cost and shipment time, there is no idiosyncratic preference, and the systematic utility for any mode looks like:

$V = -0.025*(i) - 0.00125*(c)$

Where for any mode:

i is the total travel time (in minutes)
c is the monetary cost of shipping (in cents)

As before, the probabilities can be calculated for either a binary or multinomial case. The results are the probabilities that the plants will ship via a certain mode. The probabilities can be aggregated to represent the fraction of the total shipments that are shipped by the respective mode.