

## Assignment 1

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### Preamble

### Guidelines for Submitting Assignments

Please follow these simple guidelines when submitting your assignments in this class. They are designed to maximize readability, gradeability, and credit received.

1. Assignments are due by the end of class on the due date.
2. It is your choice whether to write up your assignments in analog or digital formats.
3. Regardless of this choice, you must submit a paper copy of your assignment for grading, which should have your name and the assignment number clearly marked.
4. All supplementary electronic materials (e.g. large spreadsheets with intermediate results) should be submitted via Stellar but need not be printed.
5. Please start every problem (but not sub-problem) on a fresh page
6. Please  all of your final answers.
7. Please state all of your assumptions and show your work for maximum partial credit.
8. Be sure to follow all other guidelines set out in the class policy on academic honesty and integrity.

## Part One

### Case Study: A Rail/Truck Corridor

The objective of this case study is to introduce the concepts and methodologies associated with multi-modal transportation systems analysis. We will consider a corridor between one origin-destination (O-D) pair with an existing truck freight service and will study the possibility and implications of adding a rail service to that corridor.

Figure 1 shows the corridor connecting the two points A and B, the truck service currently in place, and the proposed rail service.

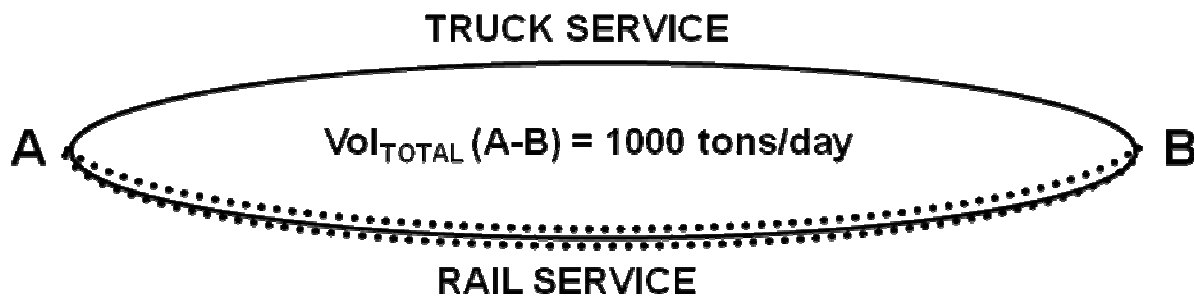


Figure 1

The following notation will be used:

$V_{TOT}$  : Total volume of freight transported between A and B (using both services).

$V_T$  : Volume of freight transported using the truck service.

$V_R$  : Volume of freight transported using the rail service.

$t_T$  : Service time between A and B by truck.

$t_R$  : Service time between A and B by rail.

$f_T$  : Price (per unit of volume) by truck.

$f_R$  : Price (per unit of volume) by rail.

For the purpose of this case study, we will consider only prices and service times to compare the two services, although there may be other variables that would influence the decision of which service to use (such as reliability, for example). Also, we will assume that  $V_{TOT}$  is fixed at 1000 tons/day. In other words, we will only consider the mode split between truck and rail under different scenarios.

#### I. Demand Analysis

Since the rail service has not yet been put in place, the obvious way to assess its feasibility is to collect data from similar O-D pairs elsewhere with similar commodities being shipped. The data, a portion of which is shown in Table 1, include the share of total tonnage transported by rail ( $V_R/V_{TOT}$ ), the difference in service times ( $t_R - t_T$ ), and the difference in prices ( $f_R - f_T$ ) between the truck and rail services.

**Table 1:** Demand model data

| $V_R/V_{TOT}$ (actual) | $t_R - t_T$ (hrs) | $f_R - f_T$ (\$/ton) |
|------------------------|-------------------|----------------------|
| 0.40                   | 25                | -0.5                 |
| 0.39                   | 35                | -0.3                 |
| 0.31                   | 50                | -0.2                 |
| 0.24                   | 75                | -0.7                 |
| 0.49                   | 15                | -0.9                 |
| 0.55                   | 40                | -1.6                 |
| 0.34                   | 55                | -0.3                 |
| 0.56                   | 0                 | -0.5                 |
| 0.64                   | -10               | -0.3                 |
| 0.68                   | -40               | -0.1                 |

A binary logit model was estimated on the data in Table 1 in order to measure the responsiveness of demand to changes in service times and prices. Using the estimation results, the following equation can be used to forecast the mode shares under various service time and price differentials:

$$\frac{V_R}{V_{TOT}} = \frac{1}{1 + e^{+0.02(t_R - t_T) + 0.5(f_R - f_T)}}$$

Answer the following questions:

1. Why are the *differences* in service times and prices used in the above estimation, rather than the absolute values of these attributes for each service?
2. For each of the ten data points in Table 1:
  - a. Calculate the *predicted* share for the rail service.
  - b. How good are the predictions compared to the actual shares?
  - c. What are the possible sources of error?
3. Sketch the demand for rail service in the corridor, with the *relative disutility*:  $(+0.02(t_R - t_T) + 0.5(f_R - f_T))$  on the x axis and the predicted share of the rail service on the y axis.

## II. Equilibrium Analysis

In order to forecast the volume of freight on each of the two services, we have to consider both demand and supply. In the section above, we provided the binary logit equation that characterizes the demand for rail service under a given service time and price differential. Here, we will provide some information on the supply side (i.e. the transportation network itself) and use that to produce a forecast for freight volumes on each service.

As a service becomes more congested, the service time (or travel time) on that service will increase. In our example, the performance of each of the two services is characterized by the following:

$$t_R = 100 + 0.066 V_R$$

$$t_T = 25 + 0.081 V_T$$

where  $V_R$  and  $V_T$  are measured in tons, and  $t_R$  and  $t_T$  are measured in hours.

Answer the following questions:

4. If rail prices were set at \$1.00/ton and truck prices at \$2.00/ton, what would be the predicted volumes of freight (to the nearest integer) on each service? (*Hint: You have four equations and four unknowns, and there exists one, unique solution. As long as you write all of your equations, you may find your answer graphically or with a solver.*)
5. Sensitivity Analysis: Suppose the demand model coefficient for prices is uncertain and can vary by  $\pm 50\%$ . How would the results in question 4 change?

### III. Profitability of the New Rail Service

Now that we have developed a framework to forecast volumes of freight on each service, we can assess the feasibility of providing the new rail service.

Assume that the new rail service will require an investment equivalent to \$200/day and that the variable costs for providing such a service are \$0.60/ton. (Prices, as indicated above, are \$1.00/ton for rail and \$2.00/ton for truck.)

Answer the following questions:

6. Should the rail service be provided? Show your work.
7. Would your conclusion change under the uncertainty assumption highlighted in question 5? Show your work.
8. Test the impact of different prices on the profitability of a new rail service. To do so, draw a plot with net profit on the vertical axis and rail prices (ranging from \$0/ton to \$3/ton) on the horizontal axis. Assume truck prices are fixed at \$2.00/ton, and ignore the uncertainty in the price coefficient.
9. If rail prices were set at the break-even point (i.e. the point at which net profits equal zero in the plot in question 8), what would be the impact of a new rail service on the profits of the truck service? Would truck operators support the new service? Assume the fixed costs of the truck service are \$100/day, and the variable costs of providing that service are \$1.50/ton.

### IV. Activity Shift Analysis

In this section, we will relax our initial assumption of a fixed total volume ( $V_{TOT}$ ). Assume that, due to economic growth, total volume between A and B increases from 1000 tons/day to 2000 tons/day. Rail and truck prices remain at \$1.00/ton and \$2.00/ton, respectively, and the fixed and variable costs of the rail service are as indicated earlier.

Answer the following question:

10. Should the new rail service be provided? Did your conclusion change from question 6? Show your work.

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**Part Two****Financing Transit through Road Pricing**

This part requires you to read and critique the paper: *"The Urban Transportation Problem: A Reexamination and Update"*, by John F. Kain (Chapter 11 in *Essays in Transportation Economics and Policy*).

Kain concludes the paper with a clear recommendation:

*"There remains a strong, if not compelling, case to begin charging road users the full social cost of their road use, for reversing the public ownership and operation of transit services, and for stopping wasteful expenditures on ineffective rail systems."*

Write a one-page (emphasis on one) report highlighting your arguments either in support of or against this recommendation.

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1.201J / 11.545J / ESD.210J Transportation Systems Analysis: Demand and Economics  
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