

# Introduction to Transportation Systems

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**PART II:**

**FREIGHT**

**TRANSPORTATION**

# **Chapter 17:**

## **The Kwon Model --**

### **Power, Freight Car Fleet Size, and Service Priorities: A Simulation Application**

- ◆ Oh Kyoung Kwon developed some ideas that relate to the concept of “yield management”, applied to freight movements in the rail industry.

*Kwon, O. K., Managing Heterogeneous Traffic on Rail Freight Networks Incorporating the Logistics Needs of Market Segments, Ph.D. Thesis, Department of Civil and Environmental Engineering, MIT, August 1994.*

# Power, Freight Car Fleet Size and Service Priorities

## A Simple Network

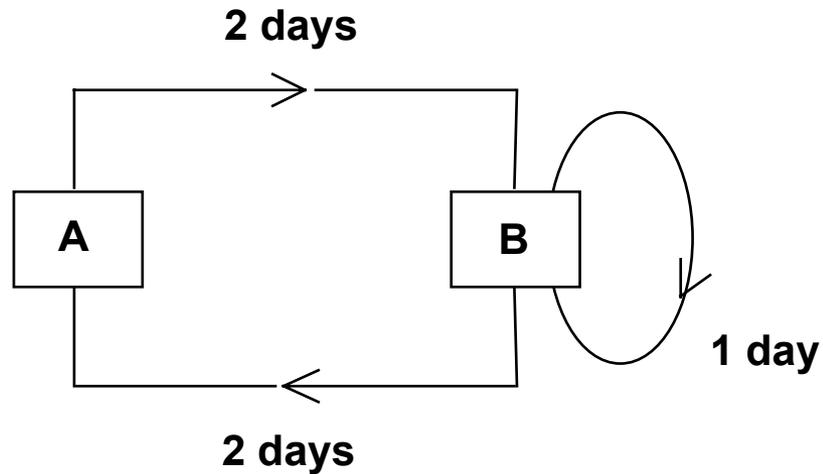


Figure 17.1

- ◆ A shipper is generating loads into the system at node A; this shipper is permitted to assign priorities to his traffic.
- ◆ So, the shipper can designate his traffic as high-, medium- or low-priority, with high, medium and low prices for transportation service.
- ◆ Assume that the volumes of traffic at each priority level are probabilistic.

# Power Selection

- ◆ Suppose that the railroad has to make a decision about the locomotive power it will assign to this service, which, in turn, defines the allowable train length.
- ◆ So the railroad makes a decision, once per time interval -- for example, a month -- on the power that will be assigned to this service.
- ◆ A probability density function describes the total traffic generated per day in all priority classes: high, medium and low.
- ◆ This would be obtained by convolving the probability density functions of the high-, the medium- and the low-priority traffic generated by that shipper, assuming independence of these volumes.

# Probability Density Function for Daily Traffic

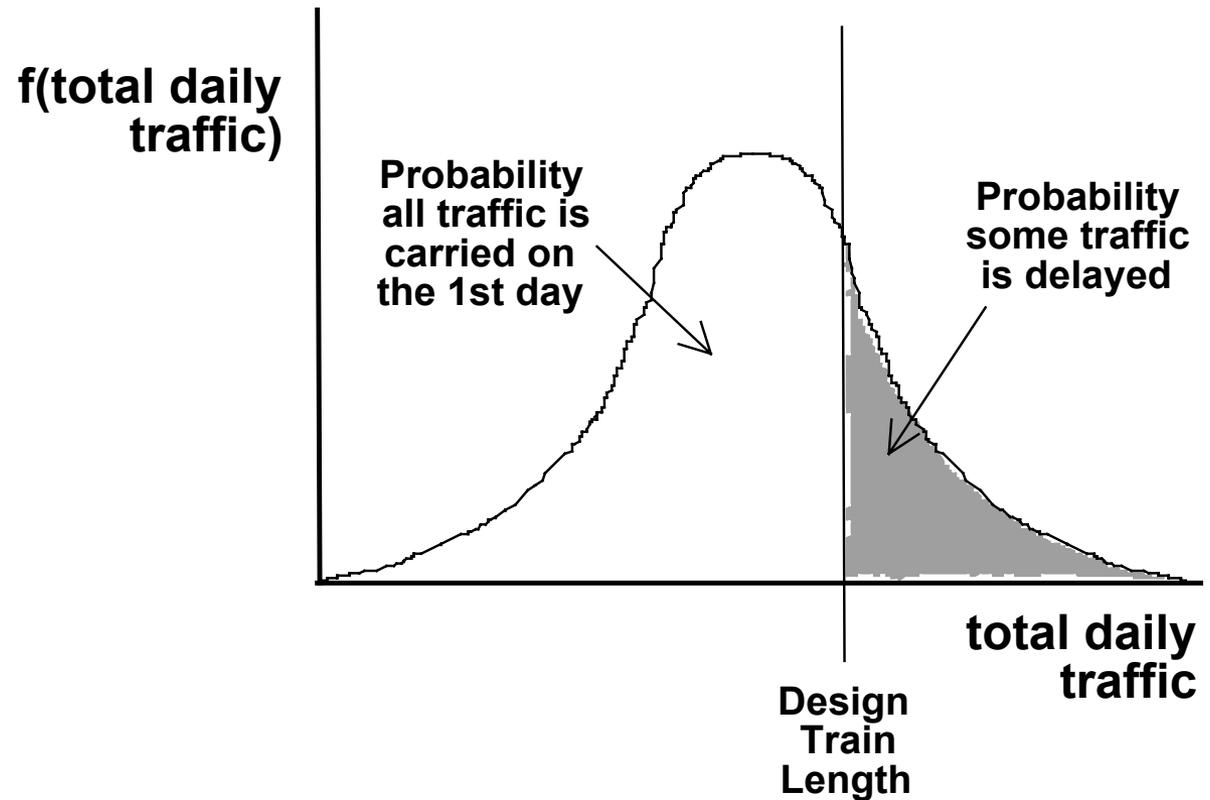


Figure 17.2

# Car Fleet Sizing

- ◆ In addition to power, the question of car fleet sizing affects capacity. There is an inventory of empty cars.
- ◆ While in this particular case transit times are deterministic, we do have stochasticity in demand.
- ◆ So the railroad needs a different number of cars each day.

# Train Makeup Rules

## Makeup Rule 1

The first train makeup rule is quite simple. You load all the high-priority traffic; then you load all the medium-priority traffic; then you load all the low-priority traffic; finally you dispatch the train.

Day 1 Traffic:

High = 60

Medium = 50

Low = 60

Train

High = 60

Medium = 40

Traffic left behind:

High = 0

Medium = 10

Low = 60

Day 2 Traffic:

High = 40

Medium = 50

Low = 50

# Train Makeup Rules (continued)

## Makeup Rule 2

Consider a second train makeup rule. First, clear all earlier traffic regardless of priority. Using the same traffic generation, the first day's train would be the same. On the second day, you would *first* take the 10 medium-priority and 60 low-priority cars left over from Day 1, and fill out the train with 30 high-priority cars from Day 2, leaving behind 10 highs, 50 mediums, 50 lows.

# Train Makeup Rules (continued)

## Makeup Rule 3

A third option strikes a balance, since we do not want to leave high-priority cars behind. In this option we:

- ◆ Never delay high-priority cars, if we have capacity;
- ◆ Delay medium-priority cars for only 1 day, if we have capacity; and
- ◆ Delay low-priority cars up to 2 days.

# Service vs. Priority

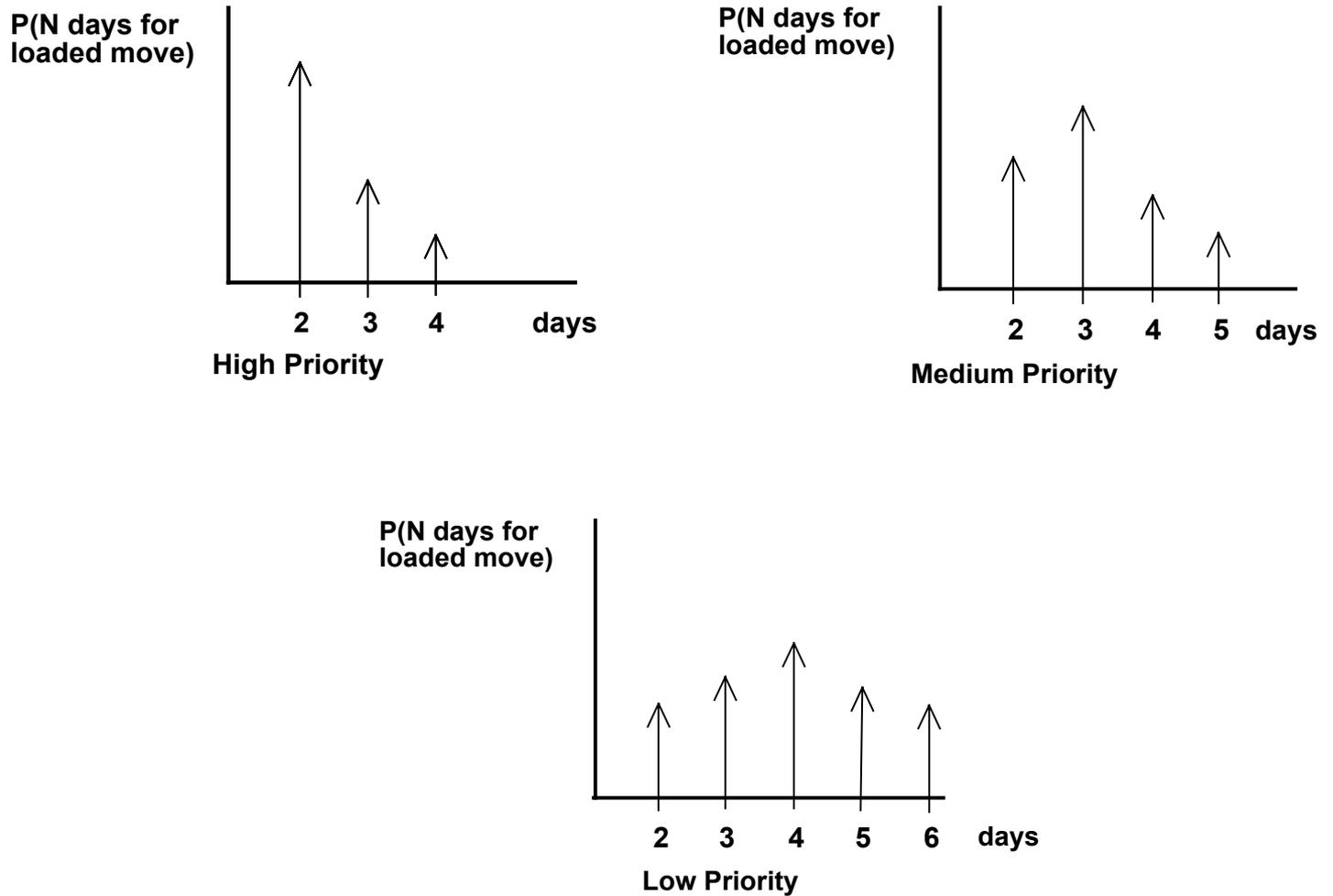


Figure 17.3

# Do You Want to Improve Service?

CLASS DISCUSSION

# Allocating Capacity

- ◆ The railroad is, in effect, allocating capacity by limiting which traffic goes on that train. It decides on the basis of how much one pays for the service.
- ◆ The railroad is pushing low-priority traffic off the peak, and in effect paying the low-priority customer the difference between what high-priority and low-priority service costs to be moved off the peak.

# A Non-Equilibrium Analysis

- ◆ Understand, though, that the analysis we just performed is a *non-equilibrium* analysis. We assumed that the shipper just sits there without reacting. And, in fact, that is not the way the world works, if one applies microeconomics principles.

CLASS DISCUSSION

Many non-equilibrium analyses are quite legitimate analyses. In fact, very often as a practical matter, analyses of the sort that we did here turn out to work well especially in the short run, where the lack of equilibrium in the model causes no prediction problem.

Remember

**All models are wrong;  
However, some are useful.**

Kwon's model is “wrong” but it is useful also.

# Investment Strategies -- “Closed” System Assumption

- ◆ In a “closed system” in this particular sense, we treat the shipper and the railroad as one company. It is a closed system in the sense that the price of transportation -- what would normally be the rate charged by the transportation company to the shipper -- is internal to the system. It is a transfer cost and does not matter from the point of view of overall analysis.

# Investment Strategies -- “Closed” System Assumption

(continued)

If we choose the locomotive size and choose the number of cars in the fleet, we can compute operating costs.

- ◆ We can -- using the service levels generated by the transportation system operation with those locomotive and car resources -- compute the logistics costs for the shipper.
- ◆ We use inventory theory and we can estimate the total logistics costs (TLC) associated with a particular transportation level-of-service.

# Investment Strategies -- “Closed” System Assumption (continued)

- ◆ Compute the operating costs and compute the logistics costs -- absent the transportation rate, which is a transfer cost in this formulation -- at a particular resource level and at a particular level of demand for high-, medium- and low-priority traffic.
- ◆ Then *optimize*. Change the capacity of the locomotive; change the size of the freight car fleet; and search for *the optimal sum of operating costs plus logistics costs*.
- ◆ Under the closed system assumption -- that transportation costs are simply an internal transfer -- you could come up with an optimal number of cars and an optimal number of locomotives for the given logistics situation.

# Simulation Modeling

How did Kwon actually compute his operating and logistics costs? This formulation is a hard probability problem to solve in closed form.

## Probability Density Function of 30-Day Costs

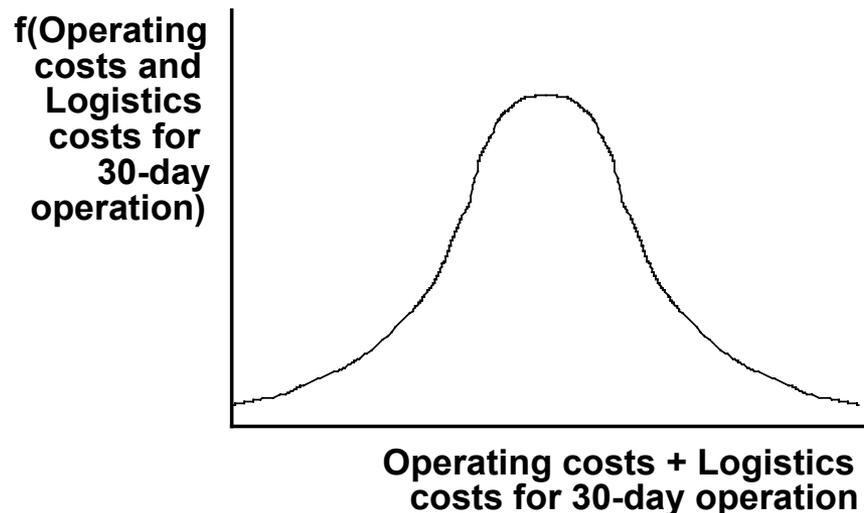


Figure 17.4

# Simulation Modeling (continued)

- ◆ *We do not know how to solve this problem in closed form.*
- ◆ *We need to use the technique of **probabilistic simulation** to generate results.*
- ◆ Probabilistic simulation is based on the concept that through a technique called random number generation, one can produce variables on a computer that we call pseudo-random.
- ◆ Produce numbers uniformly distributed on the interval  $[0,1]$ .
- ◆ Through this device, we obtain streams of pseudo-random numbers that allow us to simulate random behavior. We map those pseudo-random numbers into random events.

**u[0,1] Distribution**



Figure 17.4

# Simulation as Sampling

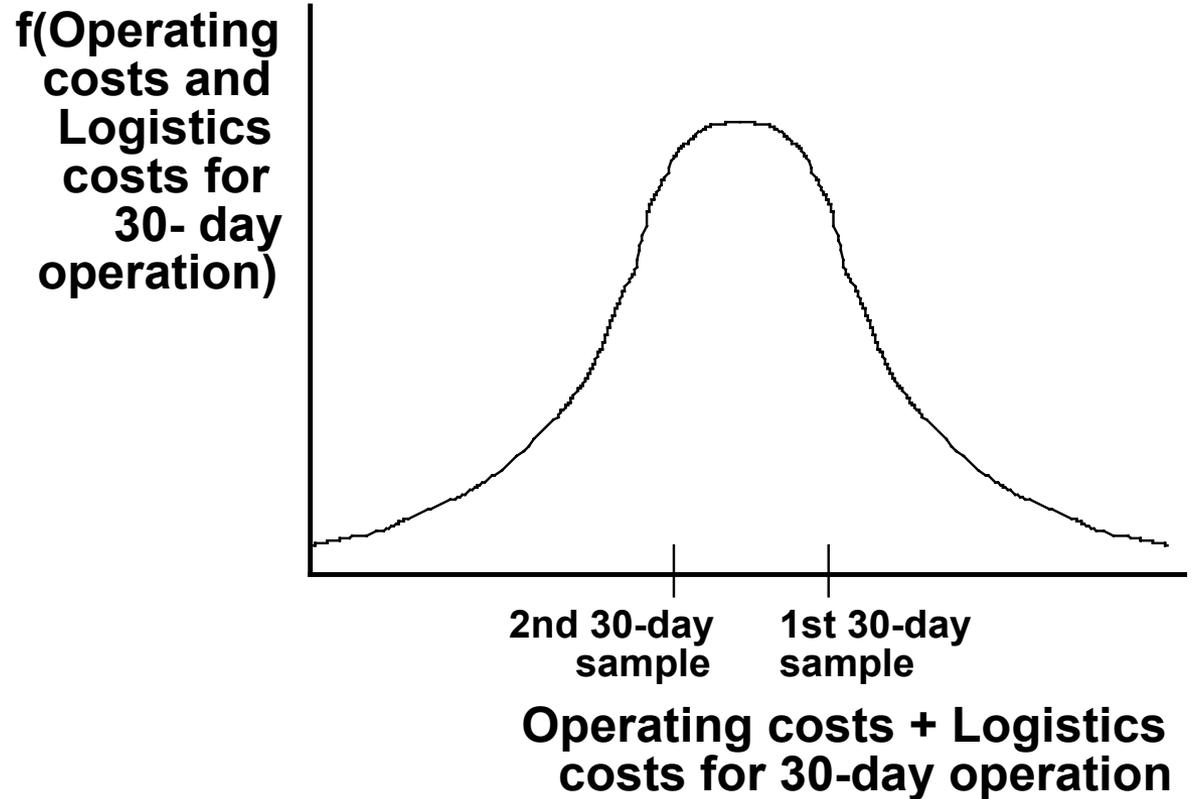


Figure 17.6

# Analytic vs. Simulation Approach

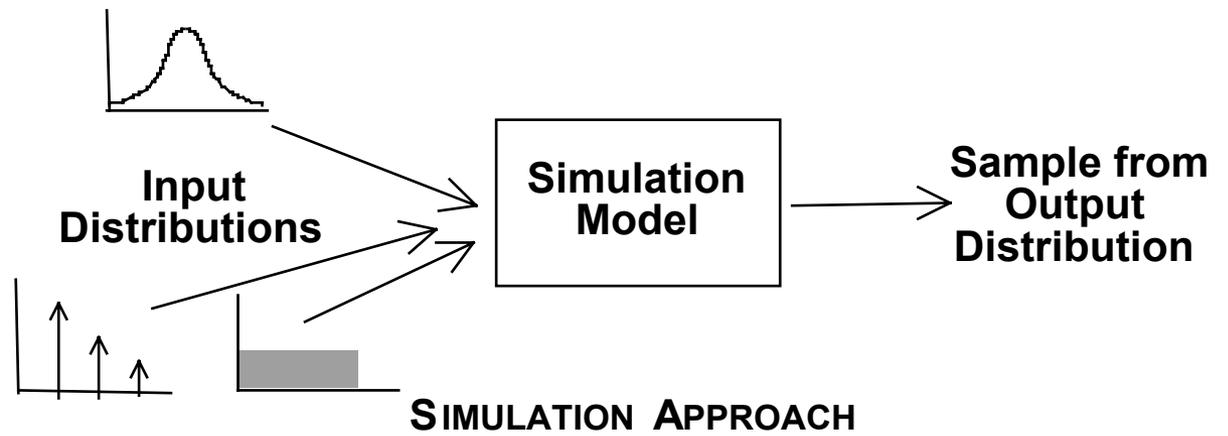
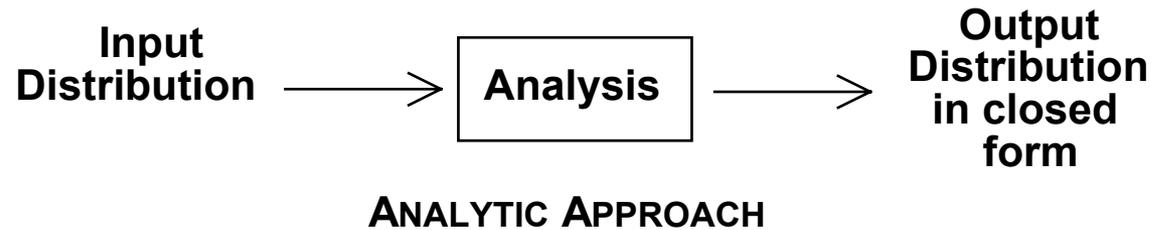


Figure 17.7