Transportation Costs

• Introduction & Motivation
• Duality of Production Functions & Cost Functions
• Types of Cost Functions
• Engineering Cost Functions
High Costs & Poor Productivity

Peak Traffic Demands Cause Delays at Bottlenecks

Clark Junction, CTA

Photo: C.D. Martland, January 2003
High Costs & Poor Productivity: Capacity for Peak Loads

Tate Modern Subway Station, London

Photo: C.D. Martland, October 2002)
High Costs & Poor Productivity: Limits on Vehicle Size/Weights

Photos: C.D. Martland
Improving Costs & Productivity: Tailoring Services to Demand

San Juan, Puerto Rico  (Photo: C.D. Martland)
Improving Costs & Productivity: Information & Control

Photo: C.D. Martland
Improving Costs & Productivity: Increasing Vehicle Size/Weight

Photos: C.D. Martland
Duality of Costs & Productivity

• Cost Function
  – Minimize cost of resources required to produce desired services

• Production Function
  – Maximize value of output obtained from given resources
Basic Economic Concepts- Differing Perspectives of Economists and Engineers

- Production functions
  - Economists either assume this is known or try to estimate a very aggregate model based upon actual performance
  - Engineers are constantly trying to "improve productivity", i.e. find better ways to use resources to produce more or better goods and services

- Cost functions
  - Both use total, average, variable, and marginal costs; engineers go into much greater detail than economists
  - Short-run and long-run cost functions
    - Economists typically focus on effects of volume and prices
    - Engineers typically focus on costs and capacity

- Duality of production and cost functions
Using Average and Marginal Costs

- Profitability/Subsidy Requirements
  - Comparison of average costs and average revenue
    - Average revenue per trip is a natural way to look at revenue, so this becomes a useful way to look at costs
- Profitability of a particular trip
  - Comparison of marginal cost and marginal revenue
- Economic efficiency (or business common sense)
  - Price = MC (Price > MC)
- Regulation of industries with declining costs
  - May need to segment markets and have differential pricing in order to cover total costs
Fixed vs. Variable Costs

- **Fixed Costs**
  - Unaffected by changes in activity level over a feasible range of operations for a given capacity or capability over a reasonable time period.
  - For greater changes in activity levels, or for shutdowns, the fixed cost can of course vary.
  - Examples: insurance, rent, CEO salary.

- **Variable Costs**
  - Vary with the level of activity.
  - Examples: construction labor, fuel costs, supplies.

- **Incremental Costs**
  - Added costs for increment of activity.
Fixed, Variable, and Incremental Costs

Total Cost \( (V) = \) Fixed Cost + \( f(\text{volume}) \)

Avg. Cost \( (V) = \) Fixed Cost/\( V \) + \( f(\text{volume})/V \)

Incremental Cost\( (V_0,V_1) = f(V_1) - f(v_0) \)

Marginal Cost \( (V) = \) \( \frac{d(\text{Total Cost})}{dV} = f'(V) \)

\( (Assuming \ we \ in \ fact \ have \ a \ differentiable \ function \ for \ variable \ costs!)\)
Long-Run & Short-Run Costs

- **Long-run costs**
  - All inputs can vary to get the optimal cost
  - Because of time delays in reaching equilibrium and the high costs of changing transportation infrastructure, this may be a rather idealized concept in many systems!

- **Short-run costs**
  - Some (possibly many) inputs are fixed
  - The short-run cost function assumes that the optimal combination of the optional inputs are used together with the fixed inputs
A Simple, Linear Cost Function:
$TC = a + bV = 50 + V, \ 10 < V < 100$
A Simple, Linear Cost Function:

Avg Cost = \( \frac{a}{V} + b = \frac{50}{V} + 1 \)

Marginal Cost (V) = \( \frac{d(TC)}{dv} = b = 1 \)
Classic Tradeoff: Can we afford higher fixed costs in order to get lower variable costs?

Breakeven point B is where TC1 = TC2

TC2 = 95 + V/2

TC = 50 + V
More Comments - CEE Projects

- Typical major projects reduce both marginal and average costs **per unit of capacity**
- Will there be sufficient demand to allow prices that cover average costs?
- In general, smaller projects will be better at low volumes until poor service and congestion hurt performance
Some Other Cost Terminology

- **Opportunity Cost**
  - A key economic concept! What else could be done with these resources?

- **Sunk Cost**
  - Expenditures that cannot be recovered and that are common to all options and therefore can be ignored ("focus on the differences")

- **Direct, Indirect, and Standard Costs**
  - Direct - easily related to a measurable activity or output
    - Excavation cost/cu. yd.
  - Indirect (or overhead or burden) - other costs related to the overall operation
    - Utilities, marketing, property tax
  - Standard costs - used in budgeting, estimating & control
Even More Cost Terminology

- Recurring vs. Non-recurring costs
  - Recurring - repetitive; could be fixed or variable
  - Non-recurring - typically the one-time expense of getting started

- Cost vs. Expense
  - "Expense" is a specific cash or other expenditure that can be followed in the accounting system
    - Depreciation is a non-cash expense - according to tax rules
    - Repayment of principal on a loan is definitely cash, but not a current expense item
  - "Cost" can refer to non-financial matters, such as lost time, aggravation, or pollution
Special Characteristics of Transportation Costs

- Infrastructure and equipment last a long time:
  - Life cycle costing
  - Deterioration rates, condition assessment, and need for maintenance and rehabilitation

- Transportation takes place over a network: space is critical!
  - Cost of network vs. cost of operation
  - Congestion

- Output is complex
Lifecycle Cost - Greatest Potential For Lifecycle Savings is in Design!

- Design
- Construct
- Expand
- Operate
- Decommission
- Salvage

Time:

Annual Expense:

Still possible to make some modifications in design or materials

Easy to modify design and materials

Limited ability to modify infrastructure or operation

Few options - cost already incurred
Net Present Value (NPV)

The NPV is an estimate of the current value of future net benefits:

Given:

Future Value (t) = B(t) – C(t)
Discount Rate = i

Then

\[ \text{NPV}(t) = \frac{(B(t) - C(t))}{(1 + i)^t} \text{ after } t \text{ years} \]

\[ \text{NPV(cash flows)} = \sum \left( \frac{(B(t) - C(t))}{(1 + i)^t} \right) \]
Annuity

An annuity is a sequence of equal payments over a period of time. To find an annuity that is equivalent to an arbitrary sequence of cash flows

- Step 1: convert cash flows to NPV
- Step 2: convert NPV to an annuity $A$:

$$A = NPV \times (A/P, i, N)$$

$$= NPV \times i \times \frac{(1+i)^N}{((1+i)^N - 1)}$$

$$= PMT(NPV, i, N) \quad (in \ Excel)$$
Cash Flows, NPV, and Equivalent Uniform Annual Net Benefits
Network Considerations

• How best to structure the network?
  – Economies of scale
  – Economies of density
  – Economies of scope

• Congestion
  – Cost to users
  – Cost to operators
  – Relationship to capacity
Economies of Scale

Average costs may decline and markets expand if the network is larger. Corps of engineers is responsible for all inland waterway projects, including extending portions available handle larger shipments.

Source: US Army Corps of Engineers
Economies of Density

It may be cheaper to handle traffic on one facility rather than two:

\[ C(V_1 + V_2) < C(V_1) + C(V_2) \]

Larger grain elevators, fewer branch lines, longer truck trips from the farm

Coal trains at UP fueling facility in North Platte; triple track line handles 150 trains/day
Journey-to-Work Travel Times, 1980-2004

Figure by MIT OCW.
Economies of Scope

It may be cheaper to provide facilities for multiple services than to provide separate facilities for both. Highways serve auto, bus and many kinds of trucks; transport projects can service multiple modes, plus fiber optics, and other functions.

Triple transport tiers in a gorge – interstate plus bike path on opposite side of river from Amtrak (Colorado)
Output is Complex – What Measures Are Needed?

- Cost per trip?
- Cost per passenger or per ton?
- Cost per vehicle-mile?
- Cost per passenger-mile or ton-mile?

All will be useful for something!
Methods of Estimating Costs

- **Accounting**
  - Allocate expense categories to services provided using:
    - Detailed cost data from accounting systems
    - Activity data from operating MIS

- **Engineering**
  - Knowledge of technology (possibly new technology) and operating capabilities
  - Prices of inputs

- **Econometric**
  - Knowledge of total costs for a varied set of firms or conditions
  - Aggregate data representing inputs and system characteristics
Accounting Costs

- Every company and organization will have some sort of accounting system to keep track of expenses by (very detailed) categories.
- These costs can readily (and possibly correctly or at least reasonably) be allocated to various activities, such as:
  - number of shipments
  - number of terminal movements
  - vehicle-miles
- This allows a quick way to estimate the average costs associated with each activity, which can be used to build a cost model (which can be quite useful even though they tend to be disparaged by both engineers and economists!)
- Refinements can reflect which elements of expense are fixed and which are variable.
### Example of the Accounting Approach


<table>
<thead>
<tr>
<th>Functional Category</th>
<th>Relevant Service Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pickup &amp; Delivery Expense</td>
<td>60% to shipments (running time) 40% to CWT (stop time)</td>
</tr>
<tr>
<td>Platform Expense</td>
<td>Weight moved across the terminal dock</td>
</tr>
<tr>
<td>Line Haul Expense</td>
<td>Traffic moved and distance, i.e. ton-miles</td>
</tr>
<tr>
<td>Other Expense (Clerical)</td>
<td>Shipments</td>
</tr>
</tbody>
</table>
## Trucking Example, Continued

<table>
<thead>
<tr>
<th>Function</th>
<th>Shipment Attribute</th>
<th>Expense Factor</th>
<th>Shipment Expense</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pick up</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Running</td>
<td>1 shipment</td>
<td>$3.37/shipment</td>
<td>$3.37</td>
</tr>
<tr>
<td>Stop</td>
<td>5 CWT</td>
<td>0.3140/CWT</td>
<td>$1.57</td>
</tr>
<tr>
<td>Platform –O</td>
<td>5 CWT</td>
<td>0.7413/CWT</td>
<td>$3.71</td>
</tr>
<tr>
<td>Line Haul</td>
<td>87.5 ton-mi</td>
<td>0.0874/ton-mi</td>
<td>$7.65</td>
</tr>
<tr>
<td>Platform - D</td>
<td>5 CWT</td>
<td>0.7413</td>
<td>$3.71</td>
</tr>
<tr>
<td><strong>Delivery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Running</td>
<td>1 shipment</td>
<td>3.37/shipment</td>
<td>$3.37</td>
</tr>
<tr>
<td>Stop</td>
<td>5 CWT</td>
<td>0.3140/CWT</td>
<td>$1.57</td>
</tr>
<tr>
<td>Other</td>
<td>1 shipment</td>
<td>13.90/shipment</td>
<td>$13.90</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$38.85</strong></td>
</tr>
</tbody>
</table>
Trucking Example: Significant Differences Depending Upon Method Used

A'Ville | B'Ville

- Shipment
- Weight
- Ton-Miles
- Function-System
- Function-Specific
Engineers need to examine the costs of different technologies and operating strategies, so historical costs may not be relevant.

When pushing the limits of technology (e.g. heavy axle loads or congested highways), it is necessary to include some science in the cost models.

Engineering models can go to any required level of detail, so long as there is some scientific or historical evidence available.

Most researchers work with some sort of engineering models as they examine the performance of complex systems.
Engineering Cost: Cost Elements to Consider

Cost = Carrier Cost + User Cost + Externalities

- Pickup & Delivery
- Terminals
- Routes
- Operations
- Equipment

- Planning
- Ordering
- Waiting
- Travel Time
- L&D

- Land Use
- Air quality
- Noise
- Water quality
- Aesthetics
- Risks
Econometric Cost Models

- Deal with the complexity problem by assuming a simplified, more aggregate cost model
  - Calibrate using available data
  - Structure so that it can be calibrated using standard regression analysis
  - Structure so that its parameters are in themselves interesting, e.g. the marginal product of labor
  - Focus on specific parameters of interest in current policy debates
# Summary: Comparison of Costing Methods

<table>
<thead>
<tr>
<th></th>
<th>Main Uses</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accounting</strong></td>
<td>Internal costing systems, Planning</td>
<td>Actual data Consistent with MIS</td>
<td>Limited to historical experience and technologies; Limited by structure of MIS</td>
</tr>
<tr>
<td></td>
<td>Investment planning Technology assessment, Service design, Strategic planning</td>
<td>Can deal with new technologies, operating practice, or networks</td>
<td>May not match history</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Analysis may be &quot;idealized&quot;</td>
</tr>
<tr>
<td><strong>Engineering</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Public policy research, Pricing strategy, Strategic planning</td>
<td>Can estimate economic parameters; Minor data requirements</td>
<td>Limited to historical conditions; not meaningful to managers</td>
</tr>
<tr>
<td><strong>Statistical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Is There a "Transportation" Cost Model

- In principle, a generic cost model could be developed for application to any mode
- In practice, specialized models are often used for each mode
  - Different costs dominate for different modes
  - Key players (e.g. port authorities) are concerned with only part of the system
  - Simplifying assumptions used in one mode won't work in another context
    - A bus stop is a very simple terminal
  - Complexities in one mode won't be needed in another
    - A rail right-of-way has complex deterioration relationships that aren't relevant in water transport
  - Specifying generic functions may not be (or seem) worth the effort
Selected Cost & Productivity Issues: 
The Details are Critical!

• How will heavy axle loads affect costs related to track maintenance, vehicles, and operations?
• How will better communications help improve control?
• Will better inspection techniques allow lower lifecycle costs?
• Is it worth investing in communications-based train control in order to improve safety or operations?
• What changes should a railroad seek in labor agreements in order to improve labor productivity?
• How can we change our organizations & institutions to improve control over equipment utilization?
## Key Costs for Selected Transport Services

<table>
<thead>
<tr>
<th></th>
<th>Car Pools</th>
<th>Rail Bulk</th>
<th>Air Freight</th>
<th>Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>PU &amp; D Terminals</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>none</td>
</tr>
<tr>
<td>Route</td>
<td>none</td>
<td>none</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Crews</td>
<td>none</td>
<td>High</td>
<td>none</td>
<td>High</td>
</tr>
<tr>
<td>Vehicles</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Ordering</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>None</td>
</tr>
<tr>
<td>Waiting</td>
<td>High</td>
<td>Low</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Travel time</td>
<td></td>
<td></td>
<td></td>
<td>High</td>
</tr>
</tbody>
</table>
Vehicle Costs

• Estimating cost per trip or per shipment
  – Cycle time and load factors
  – Life cycle cost (purchase, maintenance, rehab scrap)
  – Equivalent uniform annual cost
  – Equivalent hourly cost, at achievable utilization levels
  – Allocation of costs to specific shipments or passengers based upon veh-hrs required

• Economic cost/hour: best alternative use
Example: Convert Life Cycle cost for A Truck to an Equivalent Truck Cost per Day (i = 10%)  

Cost/day = EUAC/(365*% utilization * % serviceability)  

= $11.98/day @ 95% utilization & 95% serviceability
A More Expensive Vehicle May Have Better Operating Cost

• Value of Fuel efficiency, assuming 100,000 mile/year and fuel @ $2.50/gallon
  – 5 mpg => 20,000 gallons or $50,000/yr
  – 6 mpg => 16,700 gallons/yr or $42,000/yr
• NPV of savings of $8,000 per year for 8 years is $43,000 => willing to pay a lot more for a truck with better mileage
A Larger Vehicle Can Earn More Revenue

- Standard Trailer Used in N. America
  - 1960s: 35’
  - 1970s: 40’
  - 1980s: 40’ & 45’
  - Early 1990s: 40 & 45’
  - Late 1990s to date: 45’, 48’, 53’

- 10% Larger Payload => 10% more revenue per trip (~ $10,000 per year @ 100,000/yr)
Horse-drawn Wagons competed successfully with Trucks into the 1930s

Source: Leonard Reich, “Dawn of the Truck”, Invention & Technology, Fall 2000, p. 19
When Is Equipment Obsolete?

- Compare expected EUAC for vehicle ownership & operations over the remaining life of the vehicles (assuming you plan to be in business that long)
Vehicle Cost & Design Issues

- Larger vehicles generally have lower cost per unit of capacity
  - 747s, articulated buses, containerships
- Lightweight materials increase payload or reduce operating costs
  - Aluminum, plastics, composites
- Improved reliability extends vehicle life
  - Automobiles
- Coordination among carriers and customers can allow higher utilization
- Lower interest rates reduce costs/hr
Vehicle Examples

• Automobile
  – First car can be justified for use in shopping, visiting friends & relatives, vacations, and emergencies
  – Marginal cost for commuting may just include gas, tolls, and maintenance
  – Second car may be harder to justify, but may also be cheaper (simply retain older car and use as needed – lower value, lower usage, lower insurance & taxes)

• Transit
  – Larger vehicles have lower cost per seat-mile, but smaller vehicles support more frequent service
Route Costs

- Opportunity cost of using the land is in fact an economic cost (i.e. value of the corridor for other services, value of the land for agriculture or development)
- Depreciation (which can be based in part upon time and in part upon usage) is a real cost
- Purchase cost or construction cost (except as reflected in depreciation) is a sunk cost for economic decision-making (i.e. we can and should ignore it)
- Maintenance cost (some activities vary with time, some with area, and some with usage)
- Note:
  - Accounting rules will be established by professional societies and/or governments; these rules may be more or less complicated than what is suggested here and they will be unlikely to reflect physical deterioration of the facility. In extreme cases, the accounting rules will bear little or no relation to reality!
Estimating Route Costs

- Identify route maintenance activities:
  - Inspection = f(time, condition, type of use)
  - Minor repairs = f(time, condition, amount of use)
  - Periodic maintenance = f(usage)
  - Renewal = f(time, usage)

- Estimate frequency, unit costs, and net present value of future costs for each activity for base traffic levels
  - Note: if we have a route where the activities have reached steady state, then the annual activities will be the same each year, and we can deal with average annual costs per unit of traffic instead of the more complex NPV analysis

- Estimate frequency, unit costs, and NPV for new traffic level

- Estimate the marginal cost as the increased cost for the increased traffic
Structuring the Analysis of a Rail Route

Track
- Rail
- Ties
- Fastening system
- Ballast

Turnouts
Crossings
Bridges
Signals & communications

Installation:
- Rail cost
- Transport cost
- Installation cost

Maintenance
- Inspection
- Grinding
- Defect repair

Safety Standards
Traffic Technology
Factors Influencing Costs

• Ability of components to withstand stresses
• Probability and impacts of component failure
• Traffic mix and volume
  – Requirements for comfort or L&D (lateral & vertical accelerations
  – Static & dynamic axle loads
  – Size and materials for wheels
• Technological options
  – Materials & design of components
  – Materials & design of vehicles
## Route Costs:

Adding 100 cars/day to a rail service

<table>
<thead>
<tr>
<th></th>
<th>BASE</th>
<th>NEW(add 100 cars/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Train/wk</td>
<td>10 Trains/day</td>
</tr>
<tr>
<td>Inspection Frequency</td>
<td>Monthly</td>
<td>Weekly</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Inspection Cost $/day</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>Minor repairs $/day</td>
<td>none</td>
<td>50</td>
</tr>
<tr>
<td>Periodic repairs $/day</td>
<td>none</td>
<td>50</td>
</tr>
<tr>
<td>Renewal $/day</td>
<td>none</td>
<td>25</td>
</tr>
<tr>
<td>Total Cost $/day</td>
<td>10</td>
<td>200</td>
</tr>
<tr>
<td>Avg. Cost/train</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>Bi-weekly</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Minor repairs $/day</td>
<td>30</td>
<td>110</td>
</tr>
<tr>
<td>Periodic repairs $/day</td>
<td>5</td>
<td>55</td>
</tr>
<tr>
<td>Renewal $/day</td>
<td>10</td>
<td>27.5</td>
</tr>
<tr>
<td>Total Cost $/day</td>
<td>55</td>
<td>217.5</td>
</tr>
<tr>
<td>Avg. Cost/train</td>
<td>48</td>
<td>19.8</td>
</tr>
<tr>
<td>Incremental cost (TC1-TC2)</td>
<td>45</td>
<td>17.5</td>
</tr>
</tbody>
</table>
Fleet Management

• Fleet sizing
  – Ability to provide service during peak
  – Low level of utilization during off-peak

• Fleet management
  – Acquisitions and retirements
  – Maintenance and rehabilitation
  – Allocation of vehicles to services
  – Empty vehicle distribution

• “Contribution to overhead and profit per veh-hr” vs. cost per veh-hr: framework for mgt

Photo: C.D. Martland
Crew Cost

- Allocate crew cost to volume handled on the vehicle (or possibly to the base load {i.e. only the market segment for which the service was initiated})

- Crew cost is inversely proportional to the expected load:
  - Crew$/unit = \frac{\text{Crew}\$}{\text{capacity}(\text{capacity utilization})}

- Crew$ varies with the size of the crew and wage rate
  - Importance of work rules
  - Union vs. non-union wage rates
  - Crew size relates to workload and safety, which ultimately determine the required crew size

- Marginal costs depend upon utilization:
  - 0 in short run if there is room
  - May be 0 in medium run if the minimum service is underutilized
  - Usually assumed to equal allocated cost at desired level of utilization in the long run
## Crew Cost Example:

### Marginal Costs of Adding 100 Cars/Day to a Rail Service

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base trains/day</strong></td>
<td>.15</td>
<td>1</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td><strong>Base cars/train</strong></td>
<td>35</td>
<td>20</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td><strong>Base cars/day</strong></td>
<td>5</td>
<td>20</td>
<td>1000</td>
<td>9000</td>
</tr>
<tr>
<td><strong>Short-run change:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>New cars/day</strong></td>
<td>105</td>
<td>120</td>
<td>1100</td>
<td>9100</td>
</tr>
<tr>
<td><strong>New trains/day</strong></td>
<td>.85</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>New cars/train</strong></td>
<td>105</td>
<td>120</td>
<td>100</td>
<td>91</td>
</tr>
<tr>
<td><strong>Δ Crews/100 cars</strong></td>
<td>.85</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Long-run change:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cars/train</strong></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td><strong>New trains/day</strong></td>
<td>1.05-.15</td>
<td>1.2-1</td>
<td>11-10</td>
<td>101.1-100</td>
</tr>
<tr>
<td><strong>Δ Crews/100 cars</strong></td>
<td>.9</td>
<td>.2</td>
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Examples of Productivity Issues Related to Crew Costs

- Truck driver shortage and extremely high turnover (40% and up) for TL companies
  - Deregulation created tremendously competitive market, depressing prices and thereby limiting wage increases
  - Substitution of non-union for union drivers as TL companies split off from trucking companies
  - No shortages in LTL, where union agreements have maintained wages
- Incursion of low priced drivers after formation of international trade pacts (e.g. NAFTA, EU)
  - Pressure to open up national markets & to protect national drivers
- Increasing vehicle size (aircraft, buses, trains)
  - Economies available *IFF* the added capacity can be utilized
  - Focus on vehicle and operating costs may hurt service and other elements of cost
Pickup & Delivery Cost

- Time, rather than speed or vehicle capacity is the key:
  - How many customers can be served by one crew within a single shift?
  - Cost/unit = (Crew$ + Veh $)/Units handled per shift
  - Units handled per shift = (Units/Customer)(Customers/shift)

- Marginal costs can be very high
  - Fully utilized PUD operation may require a new crew
  - Distant PUD operation may require excessive time

- Marginal costs can also be very low
  - Multiple units from one location
PU & D Examples

- Rail boxcar service to customers on light density lines
  - Per unit costs are so high that this traffic is more efficiently served by truck, which led to abandonment of roughly a third of the rail network

- Express parcel service is a leading user of technology
  - To make the PU&D work, they need to minimize the time and effort required (for customer and carrier)

- Strategic alliances are possible
  - Airborne express focuses on business customer for overnight services
  - USPS already has a vast delivery network to residences
  - Airborne and USPS have teamed up for priority small package services

- The highly visible airport access problem is a problem of PU&D of airline passengers
Terminal Costs

- Construction and land (as for route)
- Maintenance
- Crew and equipment (fixed plus variable)
- Management & clerical
- Detention time for road vehicles and their crews
- Detention time for passengers or freight

**Goal:** maximum utilization up to capacity constraint (delays during peak period must be acceptable)
Classic Problem of Terminal Management: Cost of Capacity vs. Cost of Delay
Classic Problem of Terminal Management: Cost of Capacity vs. Cost of Delay

- Size of Facility
- Personnel: supervisors, crews, etc.
- Ability to handle queues
- Ability to divert traffic to other terminals
- Time required in terminal
  - Crews
  - Vehicles
  - Passengers or Freight
- Quality and timeliness of information
Classic Problem of Terminal Management: Cost of Capacity vs. Cost of Delay

- Resources & their unit costs
- Incremental utilization rate
- Sustainable utilization rate for the facility (time for maintenance, recovery from incidents, and dealing with peak demands)
  - Managers and planners: 90%
  - Practical limit: 70%
- Incremental benefit for each resource
- Add resources if incremental benefit justifies incremental cost
Terminal Examples

- Ocean container shipping
  - Carriers want very large ships that are larger than what the ports can handle
    - What is best for the system?
- Airports located far from downtown may be only option, but these increase access costs
- LTL companies created vast networks with 600+ terminals across the US in order to highlight local presence - but costs proved too high and they have since consolidated
Transportation Costs & Productivity

• Important
• Complex
• Interesting

Photograph of roads and highways at the base of mountains. Image removed due to copyright restrictions.