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Application of Transportation Economics to the Evaluation of Urban Transit Service

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APPLICATION OF TRANSPORTATION ECONOMICS TO THE EVALUATION OF URBAN TRANSIT SERVICE

by
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and
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December 1986

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Application of Transportation Economics to the Evaluation of Urban Transit Service

Presentation Outline

Instructors:

Robert Cervero
Douglass Lee
Anthony Rufolo

Center for Transit Research and Management Development

Portland State University

Portland, Oregon



December 1986

FINAL REPORT

PREPARED FOR
U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Technical Assistance
University Research and Training Program
Washington, D.C. 20590

PREFACE

This presentation outline was prepared for use in a Workshop on Application of Transportation Economics to the Evaluation of Urban Transit Service held in Portland, OR, August 4-5, 1986. The outline is intended to facilitate replication of the Workshop in other locations, either with the same or different instructors. The outline is not designed to serve as a self-paced instruction manual, however. Experienced economists with considerable knowledge and experience in transportation are necessary.

Anthony Rufolo, Professor of Urban Studies and Planning, Portland State University, served as the lead instructor. Robert Cervero, Associate Professor, University of California-Berkeley and Douglass Lee, Jr., Research Investigator, Transportation Systems Center, Cambridge, MA, also served as instructors in this initial offering of the workshop in Portland. They pooled their experience and materials and produced a highly efficient short course and supporting materials. This Presentation Outline is the product of their effort and is being disseminated to insure this significant effort is not lost and will benefit others.

The purpose of workshops supported with this presentation outline is to provide transit professionals with the basic economic concepts needed to evaluate the impact of a change in price or service characteristics; to gain sufficient understanding of the concepts to communicate the results to others, particularly with governing board members.

Workshops using this material are designed for professionals working in public transportation. Professionals in public transportation come from many fields, such as law, marketing, finance, personnel, public administration, planning, and engineering. Even those who have had training in economics may have difficulty in applying it to public transportation, and will find this material useful.

Experience gained from the initial offering of the Workshop resulted in modification of the presentation materials, which are reflected in this document. The instructors found that the prepared materials facilitated presentation and they were able to present the material in less time than originally estimated. This, in part, reflects the audience having a better background in economics than was anticipated. The self selection process associated with choosing to come to the Workshop resulted in a higher level of attendee. It is difficult to turn out those most in need of the transportation economics training. The following schedule reflects the original estimate of times to deliver the material to the intended audience.

The supporting materials were prepared by the instructors for the Workshop held under the auspices of the Center for Transit Research and Management Development. Portland State University,

and funded by the University Research and Training Program, Urban Mass Transportation Administration, U.S. Department of Transportation.

I am grateful to the instructors for their instructional efforts and for the additional effort required to prepare this Presentation Outline to facilitate replication of the course elsewhere and by others. I am also grateful to William Benz and Denise Penner for their assistance in preparing for the Workshop and with the supporting material.

Kenneth J. Dueker
Co-Director, Center for Transit Research and Management
Development, and
Director, Center for Urban Studies
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Schedule

Monday

9:00	Introduction	Cervero, Dueker, Lee, Rufolo
10:00	Coffee	
10:15	Submarkets	Cervero
11:15	Mode Choice	Rufolo
12:00	LUNCH	
1:30	Elasticity	Rufolo
3:00	Break	
3:15	Costs	Lee
5:00	Reception	

Tuesday

9:00	Costs (continued)	Lee
10:00	Break	
10:15	Synthesis	Cervero
11:30	Form Workshop Teams	Cervero
12:00	LUNCH	
1:00	Team Preparation	
2:00	Presentations	
4:00	Wrap-up	Dueker

I - 1 Goals

- Efficiency: Most valuable output for society's scarce resources. Evaluated according to willingness-to-pay for output.

- Equity:

- Benefit Principle: Provide services on basis of contribution to cost.

- Ability-to-pay: Those with higher income pay larger share of cost relative to service received.

Primary objective in workshop analysis is efficiency.

- Cost minimization in production is only one aspect of economic efficiency. Another major issue is creating the right mix of outputs.

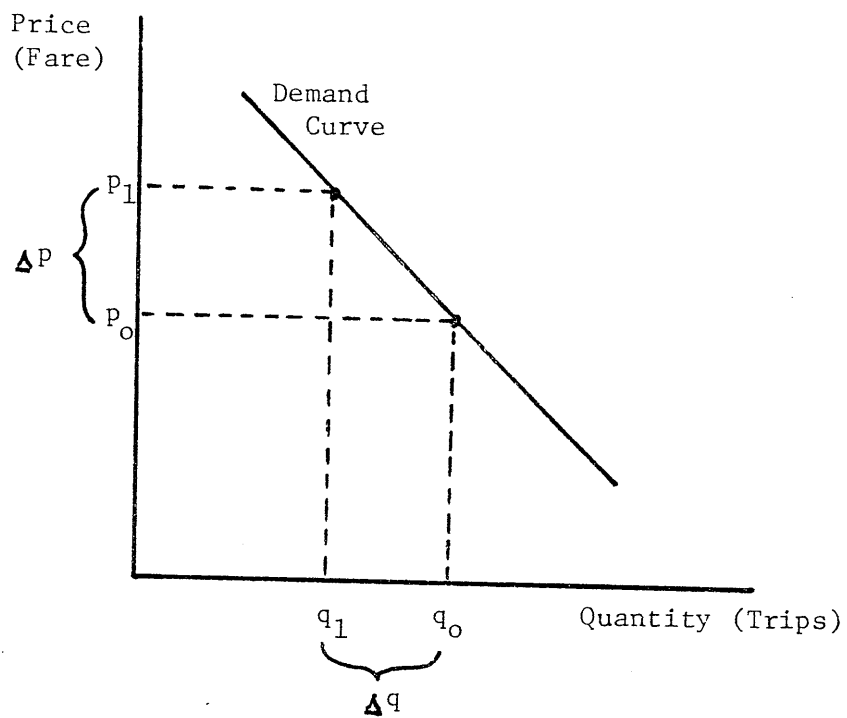
- There are also differences between short term and long term evaluations of efficiency. Many production decisions are fixed in the short term but can be varied in the future, and consumers often take time to adjust to changes.

- Many people think of efficiency as trying to create the biggest pie using society's limited resources.

- Formal evaluations of efficiency can be done using cost-benefit analysis. However, many actions can improve efficiency without use of a formal analysis. Many choices regarding the service characteristics and production decisions in transit can both improve efficiency and lower operating deficits.

- Efficiency concerns must be tempered by some concern for equity, but the two are often not in conflict. Further, there are a variety of equity principles to consider.

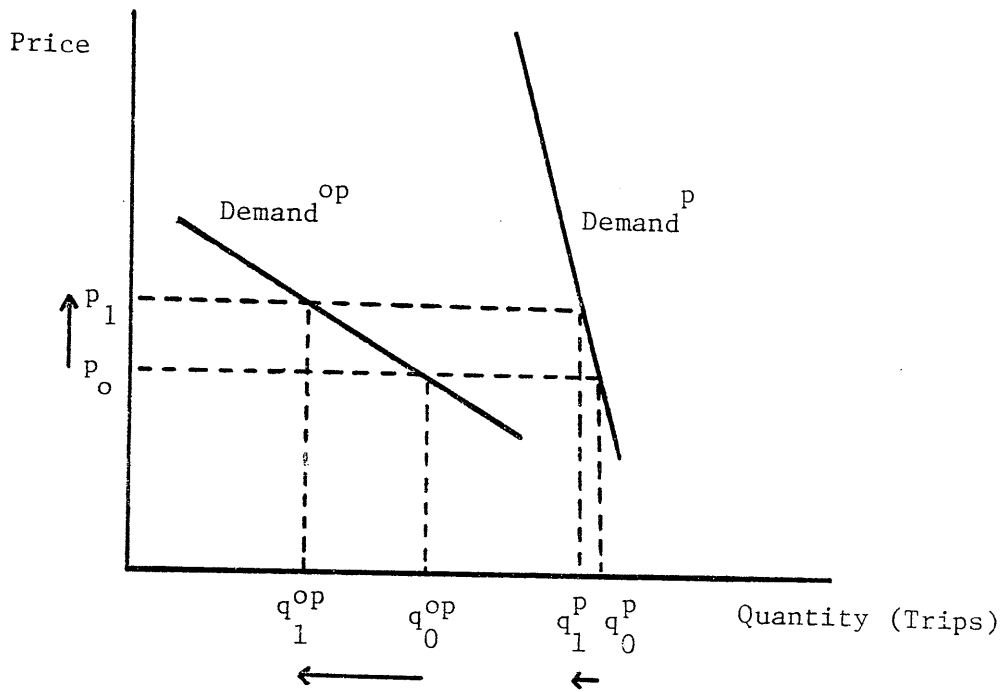
1 - 2 Demand Curve



$$\text{PRICE ELASTICITY : } E = \frac{\Delta q / q_0}{\Delta P / p_0} = \frac{\Delta q}{\Delta P} \cdot \frac{p_0}{q_0}$$

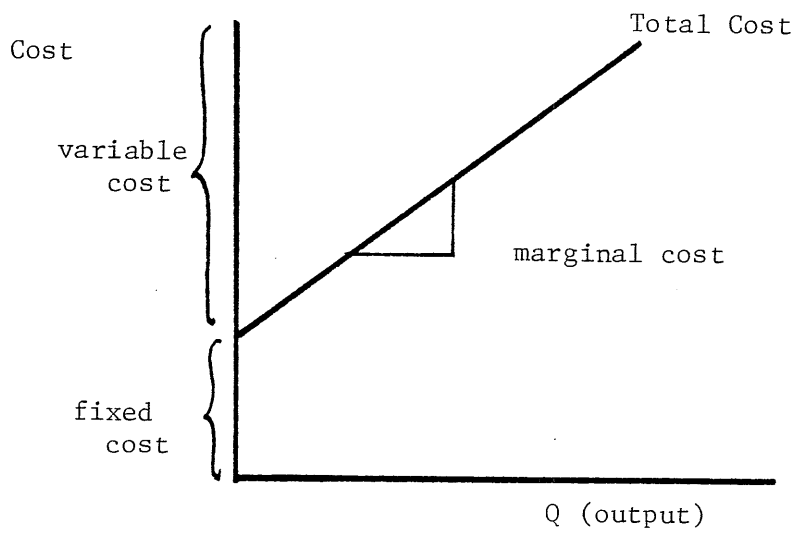
- Demand Analysis: Study of peoples' willingness to pay for the consumption of goods and services.
- Demand Curve: At any point in time, a downward-sloping line (or curve) reflects the fact that number of trips decline ($q_0 - q_1$) as price increases from p_0 to p_1 .
- Slope of Line: Steepness of line reflects how sensitive riders are to a change in price. The steeper the line, the less sensitive riders are to a price change. The flatter the line, the more sensitive they are to a price change.
- Price Elasticity: A single index of the relative sensitivity of riders to a change in price. Mathematically, it is the change in trips as a result of a change in price, expressed in percentage rather than absolute terms.
- Sign and Size of Price Elasticity: The sign is normally negative (price and quantity move in opposite directions). A value greater than 1 is an elastic demand (highly sensitive to fare change). A value equal to 1 is a unitary elasticity, and a value less than 1 is an inelastic demand (relatively insensitive to fare change). Nationwide, the average fare elasticity is around -0.30.

I - 3
Sensitivities of Peak and Off-Peak
Ridership



- Elasticities vary by submarkets.
- For instance, the demand curve for peak hour trips is steeper (i.e., more elastic) than for off-peak trips. A given price increase (Δp) produces a greater decline in off-peak ridership (Δq^{OP}) than in peak ridership (Δq^P).

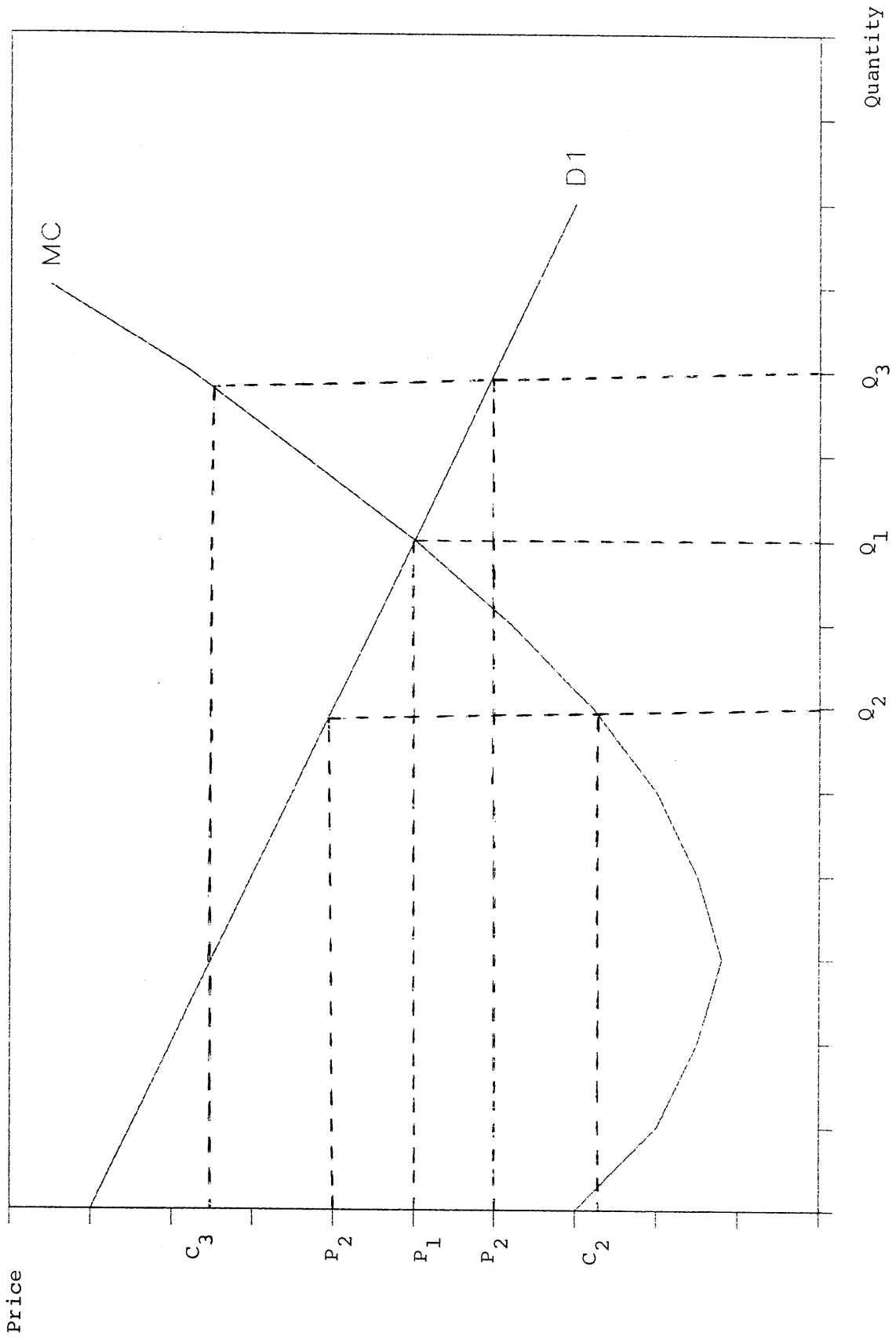
I - 4
Basic Cost Concepts



I-4

- Economic concept of cost is opportunity cost: the value of the output given up by society as a result of diverting resources to the specified purpose.
- Also stated as the value of the resources in their next best use.
- Actual expenditures or price paid are not necessarily equal to cost.
 - e.g., highway wear (no expenditure until replacement)
 - highway space (no price paid; cost is delay)
 - peak operator (requires more than direct cost)
 - depreciation of vehicle (loss of service life)
 - externalities (air and noise pollution)
- Planning concern is with incremental or avoidable costs, or 'marginal' costs.
- Cost estimation can be accomplished by identifying which cost components will be affected by an alternative, and applying a simple 'model.'

I - 5 Efficient Pricing



- The efficient quantity occurs when willingness-to-pay by consumers (as measured by the demand curve) is equal to the opportunity cost of providing the services (as measured by the marginal cost curve). Hence, an efficient pricing scheme is to set price equal to marginal cost.

- If price is too high (P_2) people will not take trips that are worth more than the cost of providing them. If price is too low (P_3), then the value of additional trips is less than the cost of providing them (C_2). Hence, an efficient pricing scheme is to set price equal to marginal cost.

- Marginal cost pricing maximizes net benefits.

II - 1 Identifying Submarkets

Submarket Type

Submarket Specification

User

- * Demographic -- Age, Sex
- * Economic -- Income, Occupation
- * Trip Characteristics -- Purpose, Length

Service

- * Operating Environment (e. g., urban vs. suburban)
- * Service Type (e. g., express vs. local)
- * Time - of - Day (e. g., peak vs. off-peak)
- * Mode Type (e. g., rail vs. bus)

II-1

- Market Segmentation: Identification of subgroups which are fairly homogenous in their responses to service and price changes.
- Some submarkets can also be distinguished in terms of their similar cost characteristics.
- In theory, each submarket has its own distinct demand curve and cost curve.
- Two types of transit submarkets can be identified:
 - *) User
 - *) Service

II - 2 Inelastic Trips and Users

Non - Discretionary Trips

- * Work
- * Peak Period

Captive Users (Transportation - Disadvantaged)

- * Autoless
- * Young
- * Low Income
- * Disabled

- For user submarkets, demand generally varies depending on whether riders are "captive" or "choice" users and whether their trip is "discretionary" or "non-discretionary".
- Generally, captive riders and non-discretionary trips are the least sensitive (e.g., inelastic) to either fare or service changes.
- Those making peak hour, work trips (typically over longer distances) are less sensitive to price or service changes.
- Transportation-disadvantaged are also less sensitive.

II - 3 User Groups

<u>Submarket</u>	<u>Submarket Group</u>	<u>Price & Service Sensitivity</u>	<u>Comments</u>
AGE	Young Middle Age Senior	Highest Moderate Lowest	More discretion Higher incomes; more choices Most captive
INCOME	Low High	Lower Higher	More captive High auto ownership; high premium on time
AUTO ACCESS	No Car Has Car	Lowest Higher	No substitute options Higher incomes; more choice
TRIP PURPOSE	Work Shop School Medical Recreation	Lowest Higher Lower Lower Highest	Least sensitive in large cities Most sensitive in suburban areas Young tends to be captive Especially low for low-income users Most discretionary trip
TRIP LENGTH	Short Long	Higher Lower	Walk option; fare price high compared to time Typically peak hour, work trips

- Age: Price elasticities fall with age. Based on two cases, the following were estimated: *
 - <16 years: -.32
 - 17-64 years: -.22
 - >64 years: -.14.

- Income: Price elasticities rise with income. From four cases, the following were estimated: *
 - <\$5,000: -.19
 - >\$15,000: -.28.

- Income elasticities do seem to vary be city size, however. In New York City, one study found low income passengers to be most sensitive to fare increases. Where corridors are highly congested and parking is restricted, such as Manhattan, higher income users are fairly insensitive to price changes.*

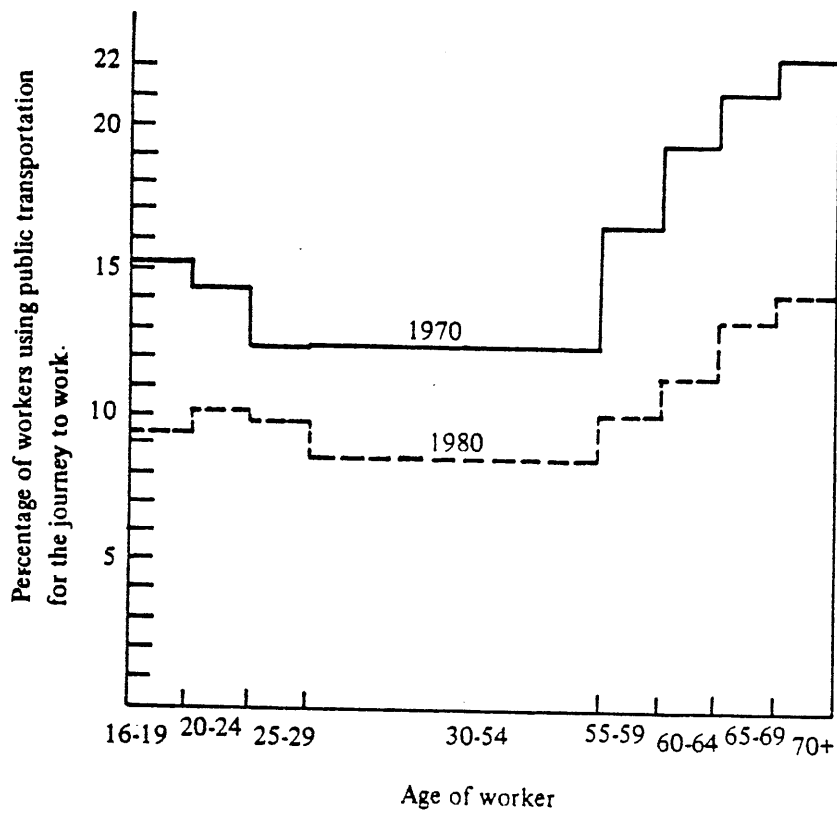
- Auto Availability: This is the strongest indicator of captivity. From two cases, the following were estimated: *
 - no car: -.10
 - car available: -.40.

- Trip Purpose: Work trips are least effected by price changes. Based on six cases, the following were estimated: *
 - work: -.10
 - shop: -.23.

- Trip Length: Short trips are more elastic because there are more travel options (e.g., walking) and fares usually constitute a significant share of total costs (fares plus travel time) to users. A study in London found the following price elasticities: *
 - <1 mile: -.55
 - 1-3 miles: -.29.

* Source: Ecosometrics, Inc., "Patronage Impacts of Changes in Transit Fares and Services". Report prepared for Urban Mass Transportation Administration, U.S. Dept. of Transportation, 1980.

II - 4
Transit Work Trips by Age

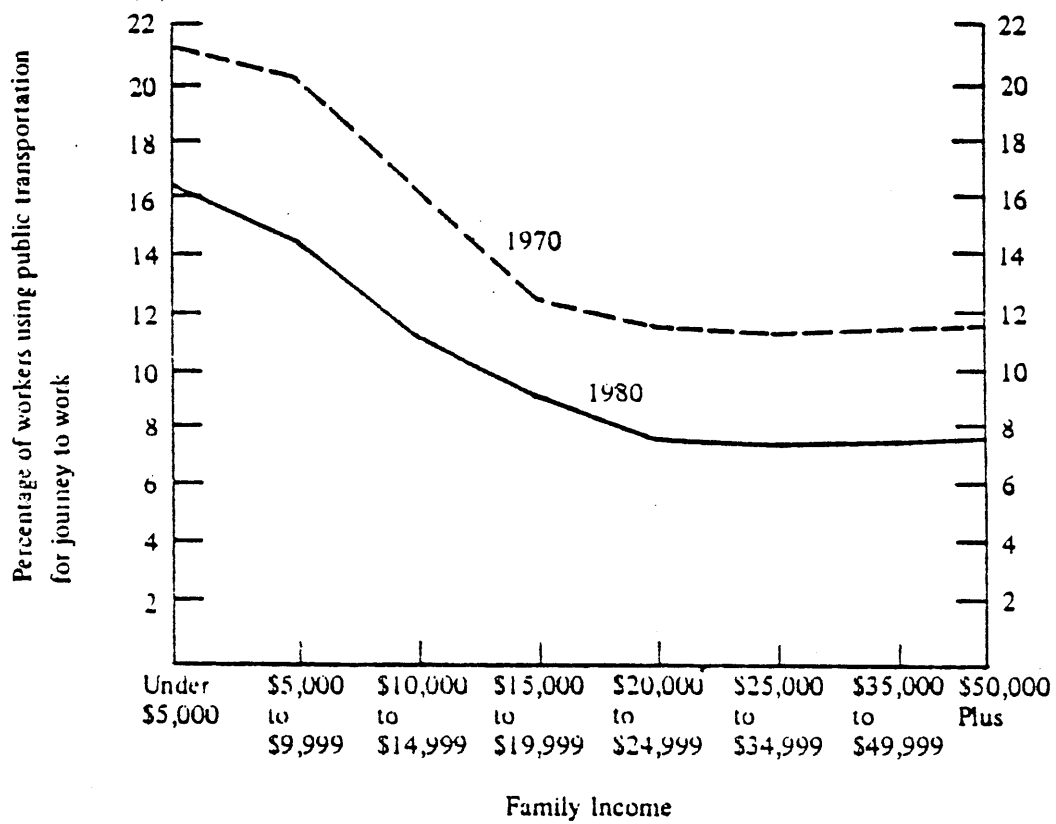


Source: Joint Center for Political Studies, "Demographic Change and Recent Worktrip Travel Trends." Report prepared for the Urban Mass Transportation Administration, U.S. Department of Transportation, 1985.

II-4

- Those in the mid-stages of lifecycle, 30-54 years of age, patronize transit the least. This, of course, reflects the fact that middle-age persons tend to have higher incomes and thus more choice options.
- Seniors are the most reliant on transit for work trips.

II -5 Transit Work Trips by Income

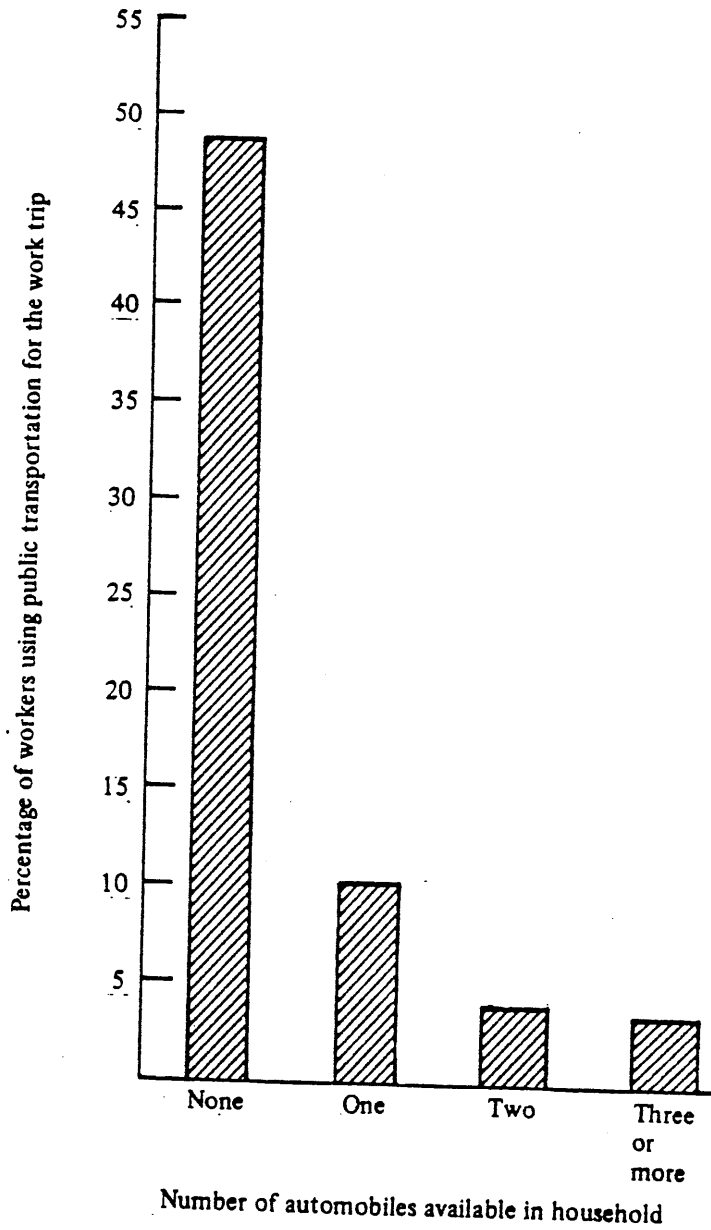


Source: Joint Center for Political Studies, 1985.

II-5

- A strong negative relationship between transit usage and income.
- Families with annual incomes of \$20,000 or more patronize transit the least for work trips.
- The steepest decline in transit usage in 1980 was in the \$5,000 to \$15,000 income range (1980\$s).

II - 6
Transit Work Trips by Auto
Availability



Source: Joint Center for Political Studies, 1985.

II-6

- Transit usage for work trips is most strongly related to whether or not someone has a car available.
- While nearly half of families with no auto used transit to get to work in 1980, only 3 percent of those with two or more vehicles patronized transit for work trips.

II - 7 Transit Operating Environment

<u>Type</u>	<u>Submarkets</u>	<u>Price & Service Sensitivity</u>	<u>Service Characteristics</u>	<u>Cost/Rider</u>
	Density:			
	Low	High	High speeds, long headways, circuitry	High
	High	Low	Slower, more frequent, more crowded	Low
LAND USE	Composition:			
	Single-Use	High	Long headways, circuitous routing	High
	Mixed-Use	Low	Slower, more frequent	Low
	Intrasuburban	Higher	High speeds, long headways, circuitry	High
	Intraurban	Lowest	Slower, more frequent, most ubiquitous	Low
LOCATIONAL SETTING/ CORRIDORS	Intra-CBD	Highest	Slowest, most frequent, most congested	Low
	Suburb-to-City	Varies	Express, radial, limited-stop, fast	High
	City-to-Suburb	Varies	Less frequent, circuitous, cross-town	High

- In low density areas, riders are relatively sensitive to fare and service changes. Services are typically less frequent, faster, and more circuitous. The cost of serving each passenger tends to be high, while, because of higher average speeds, less stop-and-go boarding, fewer accidents, etc., the cost per mile of service is relatively low.
- Mixed-use environments (e.g., mixture of residential, commercial, industrial uses) tend to be of a higher density, to afford the opportunity for trip-chaining, and to have jobs and housing more closely in balance. Because of density and income effects, users tend to be less sensitive to fare and service changes. Transit is generally more frequent, slower, and more crowded in mixed-use settings. Costs per rider are relatively low while (because of slower speeds, more frequent boarding, etc.) costs per mile are relatively high.
- Intracity trips tend to be less sensitive to price and service changes than intrasuburban ones, reflecting differences in density and land use composition.
- Intra-CBD elasticities have been shown to be relatively high. Seattle and Portland's free downtown fare programs in the mid-1970s produced elasticities of $-.46$ and $-.70$, respectively.*
- In San Diego, across-the-board expansion of vehicle-miles of service produced elasticities of $+0.72$ on urban routes and $+1.01$ on suburban routes.*

Source: Ecosometrics, 1980

II - 8 Locational Changes in Work Trips

Type of Journey-to-Work Trip	Percent of Work Trips		
	1960	1970	1980
Within the central city	47.2	37.6	31.7
Central city to suburbs	5.2	7.5	6.6
Suburbs to central city	17.1	18.6	19.8
Within the suburbs	<u>30.5</u>	<u>36.3</u>	<u>41.9</u>
Total	100.0	100.0	100.0

Source: Philip N. Fulton, "Changing Journey-to-work Patterns: The Increasing Prevalence of Commuting Within the Suburbs in Metropolitan America", Paper presented at the Annual Meeting of the Transportation Research Board, Washington, D.C., January, 1986.

- Because of the steady migration of both residences and employment from central cities to suburbs over the past two decades, there have been dramatic shifts in the geographic pattern of commuting in most metropolitan areas of the country.
- From 1960-80, work trips made within central cities fell from 47 percent to 32 percent while trips made wholly within suburbs rose from 30 percent to 42 percent.
- Radial suburb-to-central city trips, those traditionally associated with "the transportation problem", constituted only 20 percent of trips in 1980.
- Trip patterns are becoming more diffuse and lateral, a trend that bodes unfavorably for traditionally downtown-oriented transit.

II - 9
Percent of 1980 Work Trips by
Mode

Type of Journey-to-Work Trip	Percent				Total
	Drive Alone	Carpool	Public Trans- portation	Other Means or Worked At Home	
Within the central city	56.1	16.3	16.1	11.5	100.0
Central city to suburbs	69.3	22.1	5.6	3.0	100.0
Suburbs to central city	68.1	22.2	8.0	1.8	100.0
Within the suburbs	<u>69.7</u>	<u>17.8</u>	<u>1.6</u>	<u>10.9</u>	<u>100.0</u>
Total	64.9	18.4	8.0	8.7	100.0

Source: Philip N. Fulton, 1986.

- For suburb-to-suburb trips, the largest and fastest-growing market, transit carried only 1.6 percent of all work trips in 1980.
- Major service reforms are in order if transit is to effectively compete with the auto in burgeoning suburban markets. Possibilities might include transit centers/timed-transfer networks and selective busways.

**II - 10
Service Submarkets**

Type	Submarkets	Price/ Service Sensitivity	Service Characteristics
Service:	Radial Express Local, regular	Higher Lower	High speed, limited stop, long headways Slower, more frequent, more crowded
Mode Type	Conventional Bus Heavy rail	Higher Lower	More flexible, lower density markets Less flexible, higher density markets
Time-of-day	Peak Off-peak	Lower/Higher Higher/Lower	More frequent, more crowded Less frequent, less crowded

- Local, regular services tend to operate in dense, mixed-use settings, and thus experience lower price and service elasticities, lower costs per passenger, and higher costs per vehicle-mile.*
- Off-peak services are far more price-elastic than peak services. From five cases, the following time-of-day elasticities were estimated: *
 - off-peak: -.40
 - peak: -.17.
- Travel time elasticities of peak services are roughly twice the size of those in the off-peak. Based on six cases, the following travel time elasticities were estimated: *
 - off-peak: -.59
 - peak: -1.03.
- Cost per rider of peak services is relatively high because peak wage rates are higher (due to work rules such as guaranteed and spreadtime pay) and because increments of capital costs are usually high (e.g., acquisition of peak-only and back-up buses). *
- Since heavy rail systems generally operate in more congested, large cities, price elasticities tend to be lower than those of all-bus systems. From 16 cases, the following price elasticities were estimated: *
 - bus: -.35
 - rapid transit: -.17.
- Cost per rider of rail services is high because the high service quality requires a large capital investment. The extra cost of serving a passenger on rail is generally low because capacity is usually readily available. *

* Source: Ecosometrics, 1980.

II - 11 Modal Options

	Private	For-Hire	Public or Common Carrier
<u>Modes:</u>	Automobile Motorcycle Bicycle Walking	Taxi Jitney Dial-a-ride Charter bus	Conventional Bus Light Rail Heavy Rail
<u>Best Operating Environment:</u> Density Trip Patterns Trip Purpose	Low - medium Dispersed All	Low Dispersed Business, medical, Shop	Medium - high Concentrated Radial Work, shop, business
<u>Price/Trip:</u>	Automobile travel price is high and low travel time	Generally high travel price and moderate travel time	Generally low travel price and high travel time

Source: Vucan R. Vichic, "Urban Passenger Transport Modes." In George E. Gray and Lester A. Hoel, Public Transportation: Planning, Operations, and Management. Englewood Cliffs, New Jersey: Prentice-Hall, p. 69.

- Modal options are best distinguished by service and price characteristics.
- Private transport is the fastest, most flexible, most convenient mode. Accordingly it is the most expensive in direct dollar terms. It is the least expensive in travel time terms for most trip purposes.
- For-hire services are most competitive in low-density settings with dispersed trip ends. Dial-a-ride lowers the high cost per trip of taxi services through group-ridesharing, at the expense of some service deterioration. For-hire services are also referred to as paratransit, which can be distinguished by either immediate-response (e.g., taxi) or pre-arranged, advanced-booking (e.g., subscription) services.
- Transit services are most warranted in medium-to-high density radial corridors. Price of travel is comparatively low, though travel times tend to be high.

II - 12
**Average Travel Time for Work
 Trips**

Mode of Transportation	Average Travel Time
Automobile	20.8 Minutes
Other private vehicle	22.7 Minutes
Autos plus other private vehicles	21.1 Minutes
Bus or streetcar	37.8 Minutes
Subway or elevated trains	47.4 Minutes
Railroad	63.8 Minutes
Taxi	18.6 Minutes
All public transportation	42.2 Minutes
Walked only	10.2 Minutes
All Modes	22.5 Minutes

Source: Joint Center for Political Studies, 1985.

II-12

- The service feature that most influences mode choice is travel time, which is to say travelers are generally more sensitive to service changes (affecting time) than price changes.
- For work trips in 1980, the mean travel time via auto was roughly one-half that of transit. Since average trip distances were roughly the same in 1980 (9 miles for transit vs. 9.4 miles for auto), autos enjoyed nearly a twofold speed advantage over transit.

III - 1
Key Factors in Mode Choice

- Money Price
 - * Fixed
 - * Variable
- Time
 - * In Vehicle
 - * Waiting
 - * Walking
 - * Transfer
- Travel Characteristics
 - * Reliability
 - * Comfort
 - * Security
 - * Flexibility
 - * Privacy

- Relevant money price in the choice of transit mode is different for short run and long run decisions. Many expenditures occur whether or not a particular trip is made on a particular mode, but they may be variable in terms of general mode choice. Once the general decisions are made they influence the cost of a particular trip. An automobile trip is very expensive if the car must be rented for the one trip, but if a car is owned the cost of one more trip is often small.

- Fixed expenditures may include the basic ownership costs of a car or the cost of a transit pass.

- Variable expenditures may include: parking fees, fuel, higher insurance and depreciation for auto; and zone fares or peak surcharges for transit.

- Time is the most important non-monetary expenditure in mode choice. People are willing to pay more in order to shorten trip time. The amount they are willing to pay will vary by person and over how the time is spent, such as waiting or traveling.

III - 2 User Cost Calculation

Cost Component	<u>Transportation Type</u>		
	<u>Bus</u>	<u>Car</u>	<u>Walking</u>
Fixed	0	2.00	0
Variable	1.50	2.00	0
Time	45 min.	15 min.	2 Hrs.

Total Cost
With Time
Valued At:

\$1.00 per hr.	\$2.25	\$4.25	\$2.00
\$4.00 per hr.	\$4.50	\$5.00	\$8.00
\$8.00 per hr.	\$7.50	\$6.00	\$16.00

Variable Cost
With Time
Valued At:

\$1.00 per hr.	\$2.25	\$2.25	\$2.00
\$4.00 per hr.	\$4.50	\$3.00	\$8.00
\$8.00 per hr.	\$7.50	\$4.00	\$16.00

- The differences in choice of mode as a function of value of time and fixed versus variable cost can be quite significant. The example shows how this choice is made in terms of the perceived total cost to the passenger. The last set of figures relate to a person who already owns a car.

- Car ownership is influenced by perceived need for it for recreation and shopping trips as well as for commuting.

- Mode choice is also strongly influenced by collection and distribution options. People who must drive to a transit stop are more likely to use auto for the entire trip than those who can make entire trip without an auto.

III - 3 Elasticity

Definition: Elasticity is the percentage change in quantity divided by the percentage change in price

$$= (\Delta Q/Q) / (\Delta P/P)$$

$$= (\Delta Q/\Delta P) / (P/Q)$$

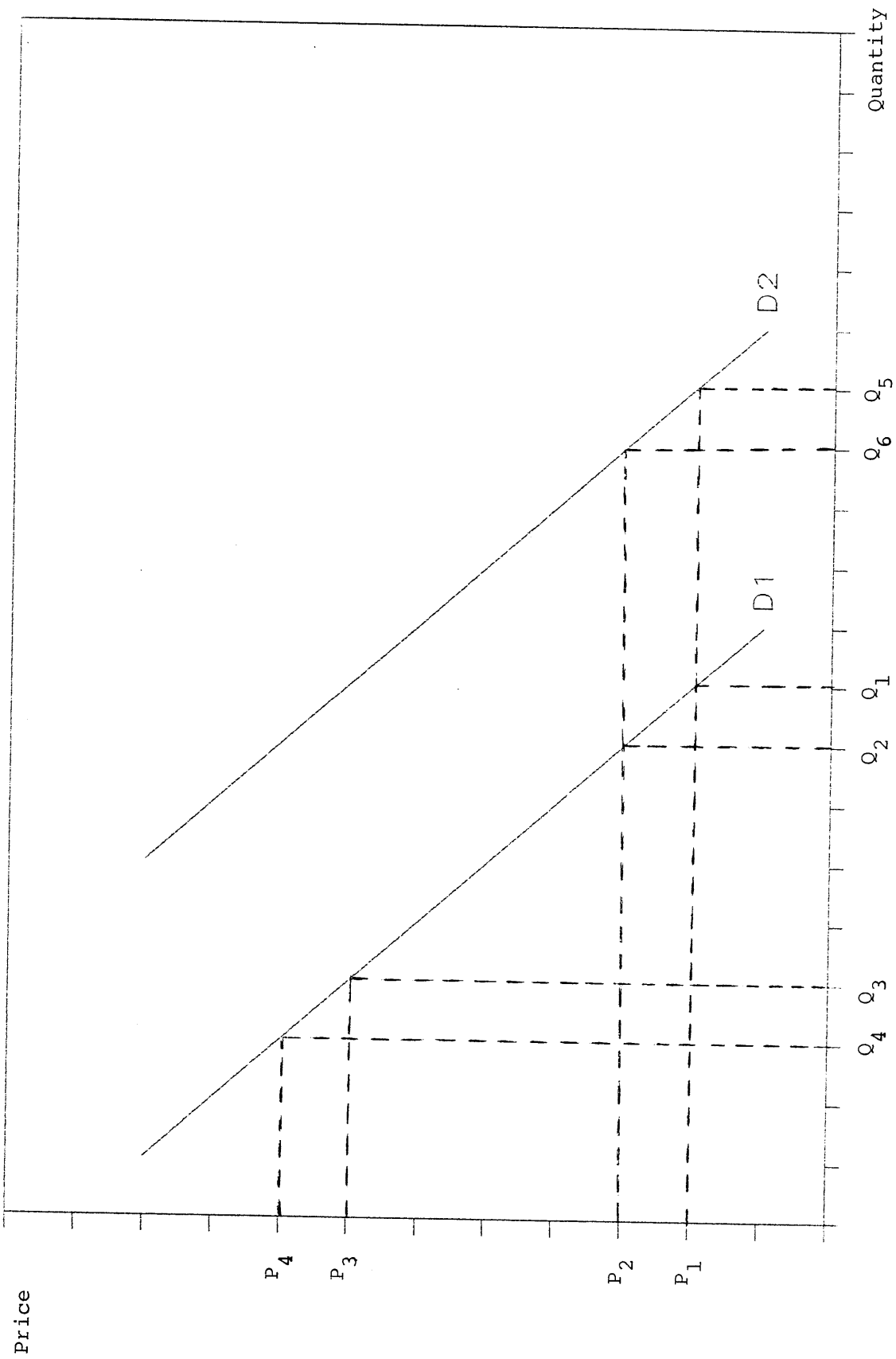
Elasticity	< 1	Inelastic
	= 1	Unit Elastic
	> 1	Elastic

- Elasticity is a measure of how responsive consumers are to a change in a parameter such as price. If they are very responsive then elasticity will be high, and if they are not very responsive then elasticity will be low. Low values of elasticity are those near zero. Values between zero and one are termed inelastic, and values from one on up are elastic.

- Elasticity usually varies as one moves along a demand curve. However, we usually depict an elastic demand curve as being relatively flat and an inelastic one as being relatively steep.

- The negative relationship between price and quantity mean that elasticities calculated from the formula will have a negative sign. By convention the sign is treated as positive for price elasticity, but the sign is important for other elasticities.

III - 4 Elasticity and Slope



- Elasticity varies along a straight-line demand curve, and it varies with the level of demand.

- The changes in price from P_1 to P_2 and from P_3 to P_4 are equal. The changes in quantity from Q_1 to Q_2 , from Q_3 to Q_4 , and from Q_5 to Q_6 are also equal to each other. Yet the three elasticities will differ.

- $(\Delta Q / \Delta P) * (P_1 / Q_1) < (\Delta Q / \Delta P) * (P_3 / Q_3)$

- $(\Delta Q / \Delta P) * (P_1 / Q_1) > (\Delta Q / \Delta P) * (P_1 / Q_5)$

III - 5 Revenue and Elasticity

- Revenue = $P \cdot Q$
- As P goes up, Q goes down; and vice versa
- Inelastic:
 - $\% \text{ change } Q < \% \text{ change } P$
 - The change in P dominates, so revenue rises and falls with P
- Elastic:
 - $\% \text{ change } Q > \% \text{ change } P$
 - The change in Q dominates and changes in revenue are in the opposite direction from changes in P .
- Unit Elastic:
 - $\% \text{ change in } Q = \% \text{ change in } P$
 - Revenue is constant as price changes.

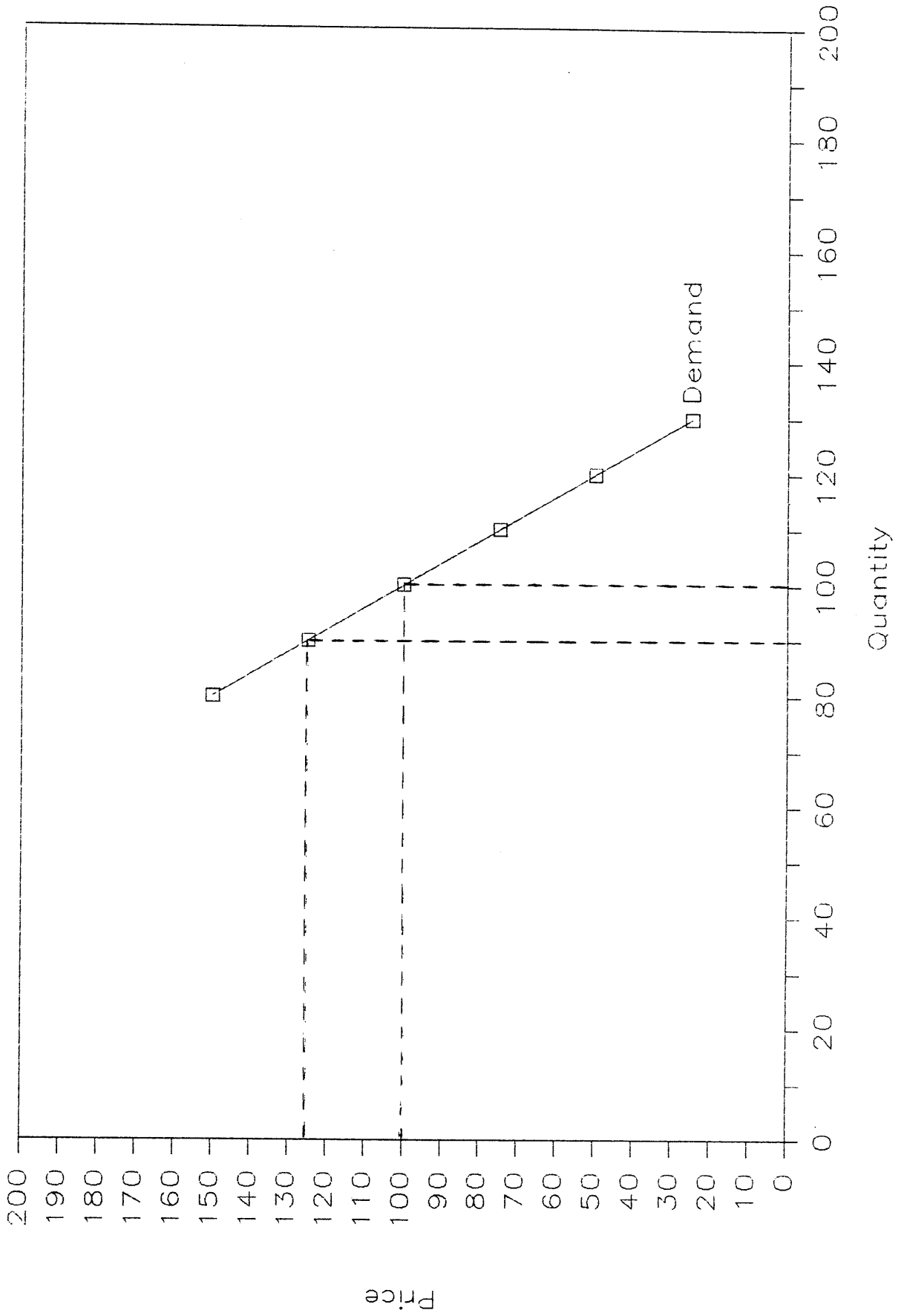
- The relationship between price and revenue is very important in terms of understanding the options to raise revenue from the farebox. Because of the loss in ridership as fare increases, revenue will not rise in proportion to price. However, because most of the price elasticities are low for transit, there is significant opportunity to raise revenue from this source.

- In cases where the elasticity is high there is an opportunity to raise revenue by lowering fare. Such cases are rare in transit.

- The changes in quantity will often require that capacity be raised or lowered. This usually changes service characteristics such as average waiting time, and this may in turn require additional analysis. Thus, if demand is elastic then lowering fare will cause more people to ride and increase revenue; however, if this happens with no change in capacity, there is likely to be crowding and other problems.

- With unit elastic demand, price and quantity changes offset each other to leave revenue unchanged.

III - 6
Inelastic Demand



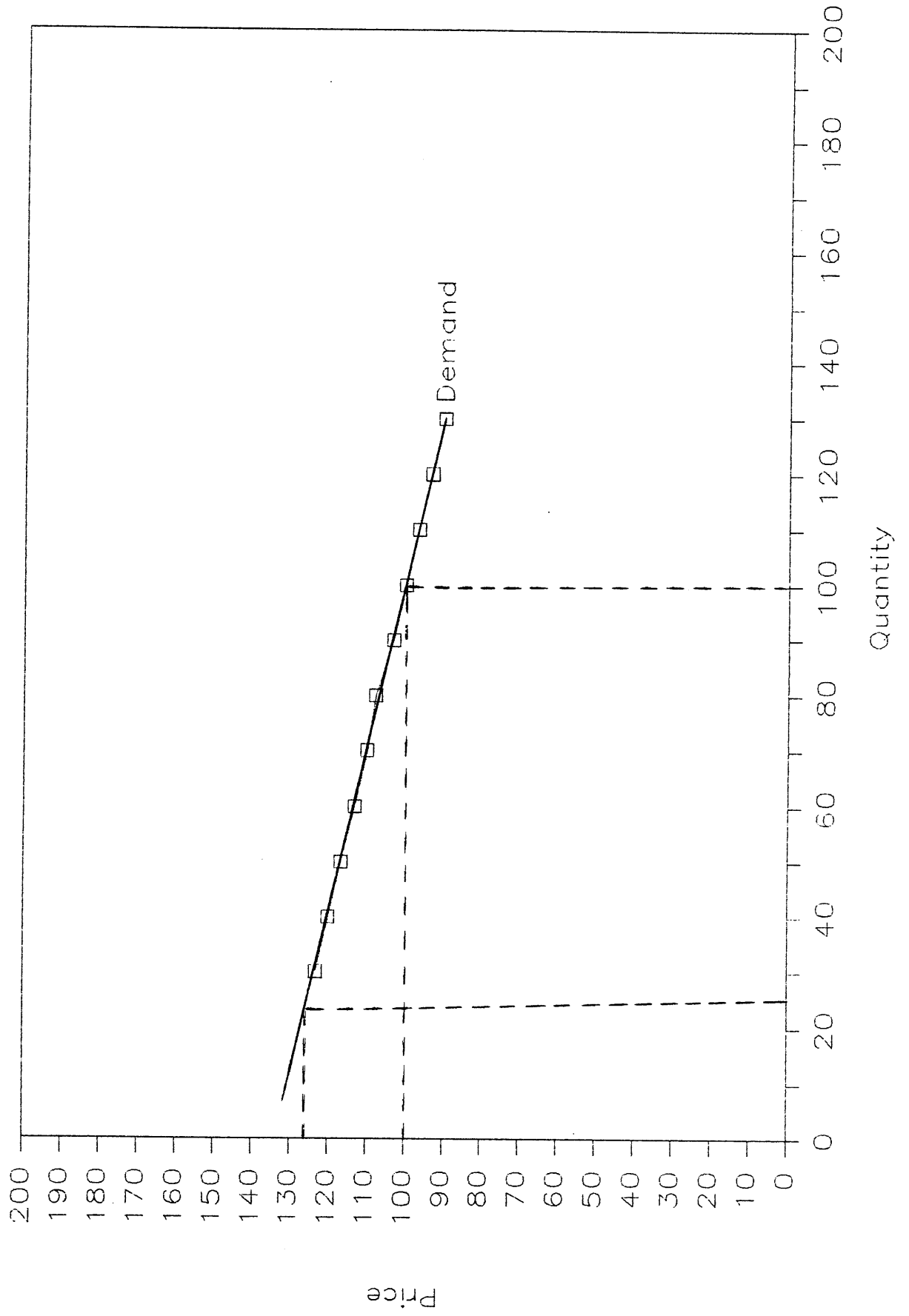
- The figure illustrates the affect on revenue of an increase in price when demand is inelastic. The initial loss in quantity is likely to increase over time since demand is more elastic in the long run than it is in the short run; however, if long run demand is also inelastic then revenue will still rise.

- The initial price is \$1.00 and the quantity demanded at that price is 100. This gives revenue of \$100.00.

- The rise in price to \$1.25 causes a decline in quantity to 90. Thus revenue increases to \$112.50 rather than \$125.

- There is a ten percent change in quantity in response to a twenty-five percent change in price, so the elasticity is calculated as 0.4 which is inelastic.

III - 7 Elastic Demand

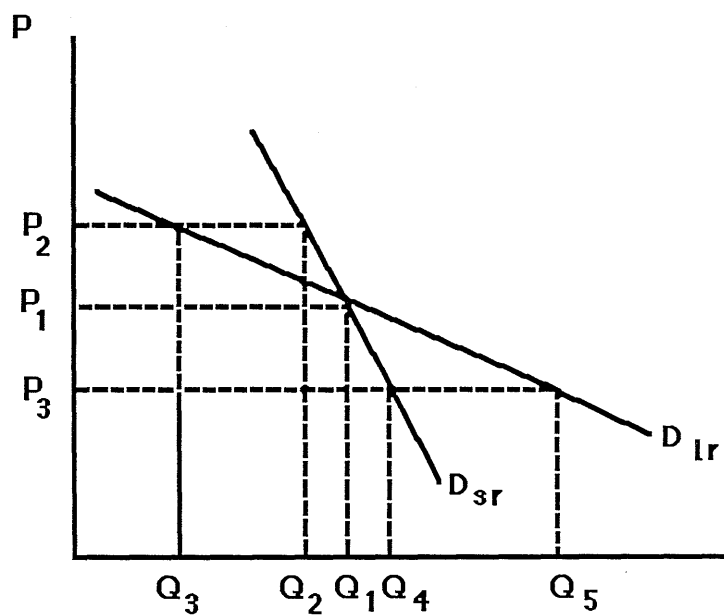


- In the case of elastic demand, the same rise in price is more than offset by the fall in quantity. In this example, the rise in price to \$1.25 causes quantity to fall to 25. Hence revenue declines to \$31.25. If this is a short run curve than revenue will decline even more in the long run since the curve will be more elastic.

- The quantity change is calculated as seventy-five percent while the price change is still twenty-five percent. Hence, the elasticity measure is 3.0 which is very elastic.

- One factor which makes demand curves elastic is the existence of good substitutes. The low elasticity of demand for transit is an indication that people who use transit do not consider the alternatives to be good substitutes.

III - 8
All Elasticities are Greater in Long
Run



- Demand curves are more elastic in the long run because of the time people have to make adjustments in their behavior. Thus, if transit fares rise, it may not make sense to run out and buy an automobile; but it may raise the probability that a person will choose to buy an automobile in the near future. Once the auto is purchased, transit use will stop.

- Other factors also take some time to adjust. Once a new route is opened it may become more advantageous for certain types of activity to locate near the route. The new development may take significant time to complete, but it may alter the number of potential riders along the route.

- When the price rises to P_2 the initial change in quantity is only to Q_2 . Thus, the measured elasticity is likely to be small. Over time people adjust their behavior to reflect the change in price, and quantity falls to Q_3 . The calculated elasticity may still be inelastic, but it will be more elastic than the elasticity calculated on the basis of the initial change.

- A price drop to P_3 causes an initial quantity increase to Q_4 and an eventual increase to Q_5 . Even if it is still inelastic, the long run elasticity will be higher than the short run elasticity.

III - 9
Responses to Price Increases

All Prices Rise

- *Walk
- *Carpool
- *Single Car
- *Stay Home

Only Peak Price Rises

- *Travel At Off Peak
- *All of Above

Long Run

- *Move Residence
- *Change Jobs
- *Buy Car

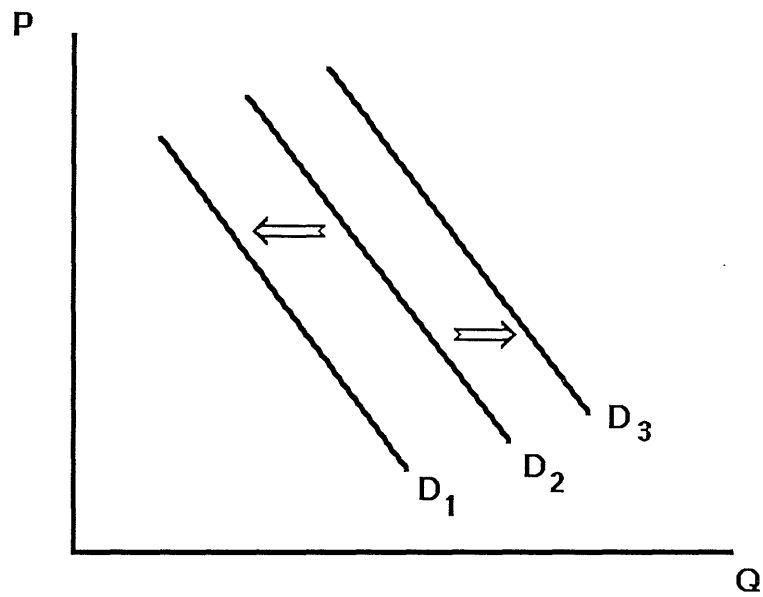
- Analysis of the loss in ridership associated with a fare increase can give some idea of why the demand for transit tends to be inelastic. The most direct response is to simply stop making trips. However, many riders do not consider this a viable option since they ride to work or other important destinations.

- The alternative methods of making the trip are often very different from transit. The decision to use a car is much more expensive in money terms although it has other advantages. Other modes are also not close substitutes in the sense of being almost like transit.

- One advantage of a peak period increase rather than a general fare increase is that it may shift some of the riders to off-peak times, although this effect is usually small.

- The price of transit is not likely to have much influence on some of the major long run adjustments people can make, but it may tip decisions for some percentage of the population.

III - 10
Demand Shifts



- A demand curve shows the relationship between price and quantity holding everything else constant. Changes in almost anything else may cause the demand curve to shift. A shift in the demand curve means that either more or less will be purchased at any given price to the consumer.

- Shifts in the demand curve due to other factors may be much more significant than the changes in quantity of rides due to a change in price of transit.

- Since such changes occur with price held constant, the changes in quantity are not mitigated by changes of price in the opposite direction. Changes in revenue are simply changes in quantity times price.

III - 11
Shift Factors

- * Taste
- * Income
- * Price of Alternatives
- * Availability of Alternatives
- * Location Patterns
- * Value of Time
- * Service Characteristics

- Some things that might cause a positive shift in the demand for transit are:
 - Higher gasoline prices or parking costs.
 - Increased speed of transit service.

- Negative shifts in the demand for transit might be caused by:
 - Lower gasoline prices or parking costs.
 - More dispersed locations of employment and residences.
 - More problems with crime or crowding on transit.

- Three general categories of shift factors are those relating to income, those relating to the price and availability of alternatives, and those relating to the characteristics of the transit service which is available.

III - 12

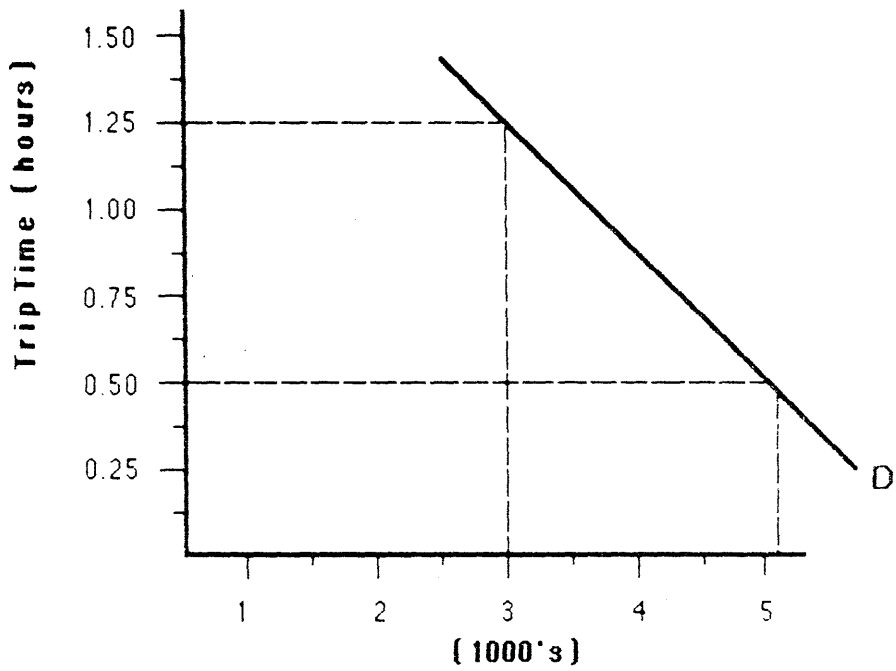
Estimates of Service Elasticities

	Peak	Off-Peak	All Hours
Headway Elasticities			
Bus	-0.37	-0.46	-0.47
Commuter Rail	-0.38	-0.65	-0.47
Vehicle-Miles Elasticities			
Bus	+0.33	+0.63	+0.68
Rapid Rail	+0.10	+0.25	+0.55
Total Travel-Time Elasticities			
Bus	-1.03		-0.92
Bus and Rapid Rail		-0.59	
In-Vehicle-Time Elasticities			
Bus (Quasi-Experimental)	-0.29	-0.83	
Bus (Non-Experimental)	-0.68	-0.12	
Rapid Rail	-0.70		
Bus and Rapid Rail	-0.30		-0.27
Commuter Rail			-0.59
Total Out-of-Vehicle Time Elasticities			
Bus and Rapid Rail			-0.59
Walk-Time Elasticities			
Bus	-0.26	-0.14	
Wait-Time Elasticities			
Bus and Rapid Rail	-0.20	-0.21	-0.54
Transfer-Time Elasticities			
Bus and Rapid Rail	-0.40		
Number-of-Transfer Elasticities			
Bus		-0.59	

Source: Lago, Armando M., Mayworm, Patrick, and McEnroe, J. Matthew, "Transit Service Elasticities," Journal of Transport Economics And Policy 15,2 (May 1981), pp. 99-119.

- Service elasticities are higher than price elasticities, although they are still inelastic.
- Most of the estimated elasticities relate to time, but other service characteristics are likely to be important also.

III - 13
Demand as a Function of Service
Characteristics



- The shifts in demand as service characteristics change can be summarized as a relationship between those service characteristics and quantity. This can be thought of as a demand curve which holds price and other factors constant. It shows how ridership would change at the existing fare structure if service were changed in a certain way.

- Generally the service characteristics to which people are most responsive are those relating to the time of the trip. However, the other characteristics of the trip such as comfort, convenience, and privacy can also shift the demand curve.

- The figure illustrates a service characteristic versus quantity relationship. It says that given the price and other characteristics of the transit service, changes in the total time needed for the trip will influence the number of riders. In the example, if the trip takes one hour and fifteen minutes, then 3000 people will go. However, if the trip time is only half an hour, then more than 5000 trips will be made.

III - 14
Other Modes

- * Congestion Increases Time Cost
- * Gasoline Prices Increase
- * Rain Makes Walking Unpleasant
- * Bicycles Provided With
Separate Paths.

Availability May Also
Be Very Important

- * Gasoline Shortages
- * Parking Availability

- The second major factor in changing the demand for transit is the cost of other modes. As they become more convenient or less expensive to use, passengers are likely to shift to them. Factors which make alternatives less attractive or more expensive in turn increase the demand for transit services.

- The money cost of the other mode may not be the best measure of its influence on the demand for transit. For example, increases in transit demand during the oil crises of the 1970's were associated with increases in the price of gasoline. However, the major impact was probably the difficulty in getting gasoline at that price. Because of the long lines, many people who would have been willing to pay the price for gasoline chose to conserve it and take the bus. Thus, the true price was higher than the measured price.

III - 15
Cross-Price Elasticity of Demand

Definition: % change in Q
divided by the %
change in the
price of another
good.

Positive value implies
goods are substitutes.

Negative value implies
goods are complements.

- The concept of cross-price elasticity of demand is useful in summarizing the relationship between transit and the other modes. The magnitude of the cross-price elasticity tells us how responsive demand for transit is to changes in the prices of these other modes.

- The cross-price elasticity of demand for auto trips with respect to transit prices is estimated to be very small. This means that auto ridership is relatively insensitive to transit pricing policy.

- Estimates of the cross-price elasticity of demand for transit with respect to changes in the cost of automobile commuting are somewhat higher. This indicates that there is potential to affect the demand for public transit by increasing the perceived cost of automobile commuting.

III - 16
Income Elasticity of Demand

Definition: % change in Q divided
by the % change in
income

A positive value defines a
"normal" good.

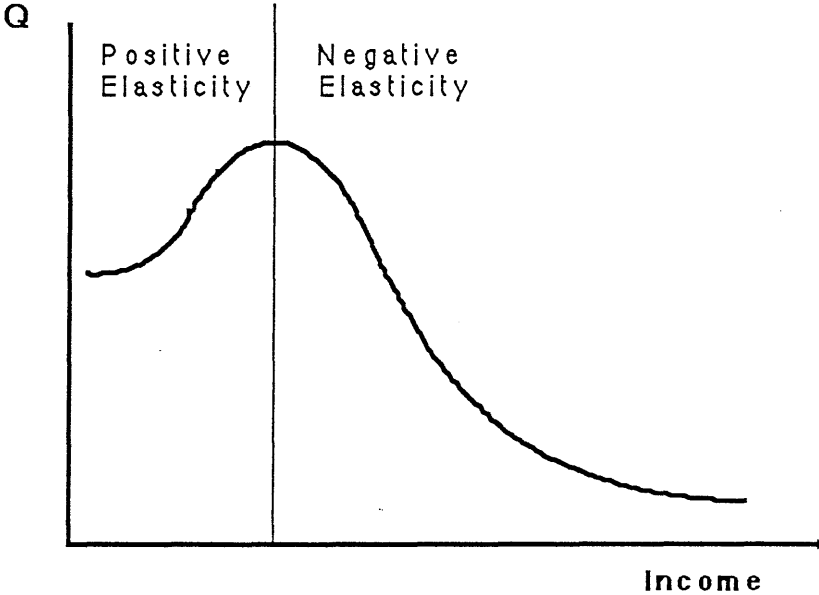
A negative value defines
an "inferior" good.

Transit has a negative income
elasticity of demand.

- The final factor which has a major impact on the demand for transit is income. We define the income elasticity of demand as the percentage change in quantity divided by the percentage change in income. While the magnitude of this elasticity can tell us how responsive demand for transit is to changes in income, the most interesting part of this number is the sign. If the sign is positive then consumption of the item increases as income increases, and the good is a "normal" good. However, for some goods the amount consumed tends to decrease as income increases. These are termed "inferior" goods. Generally an inferior good is one which has a higher quality replacement which is used as income increases.

- The income elasticity measure for transit show it to be an inferior good. People tend to switch to automobiles as their income increases.

III - 17
Income Elasticity of Transit
Demand



- At very low income levels, demand for trips does not seem very sensitive to changes in income, hence there appears to be little relationship between income and transit demand. As income increases but remains low, people make more trips and many of the additional trips are on mass transit. Beyond some point, however, the increase in trips is likely to result in some other mode being used and transit use on average declines.

III-16
Income and Transit

- * Changes in automobile ownership
Fixed cost drops from mode
choice calculation
- * Higher income implies that person
places a higher value on time.
- * More likely to choose non-central
location.

- As income increases people are more likely to buy automobiles. The income elasticity of demand for this good is positive. Once the automobile is owned it becomes more attractive for use in commuting.

- One reason people buy automobiles as their income increases is that they place greater value on their time. Hence, they are willing to incur greater monetary expenditures to reduce their time spent traveling.

- People are also more likely to choose non-central locations for their residences as their incomes increase. Transit is at a relative disadvantage in serving such markets.

- Many of the factors which lead to a decline in the demand for transit as income increases might be offset by changes in the type of service provided. For example, the higher value placed on time means that efforts to reduce the time cost of transit may be more effective in attracting this group than efforts aimed at keeping fares low. Also, changes in travel patterns may make more flexible transit options more attractive.

IV - 1 Cost Distinctions and Terms

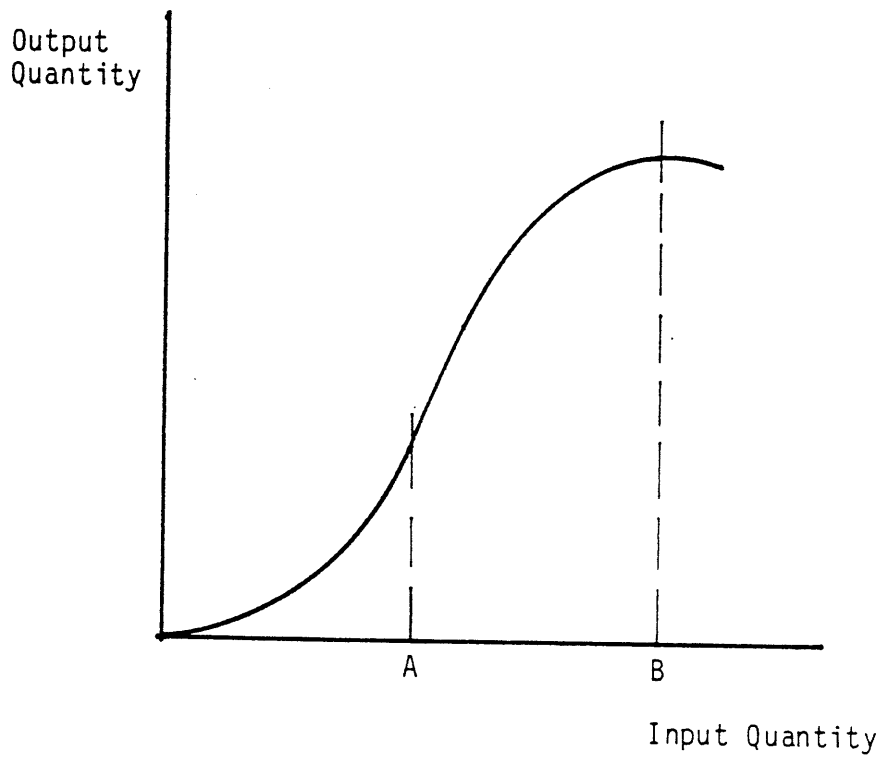
Terms

Capital	vs. Operating	Lifetime greater than one year
Variable	vs. Fixed	Varies with output (output = service, passengers)
Marginal	vs. Average	Effect of a one-unit change in output
Incremental	vs. Total	Effect of an alternative, relative to a base case
Avoidable	vs. Sunk	Only avoidable costs are of interest
Short Run	vs. Long Run	Short run is temporary or transitional
Production	vs. Deployment	Two phases in transit service supply

IV-1

- These terms express basic concepts in understanding costs.
- The terms are not interchangeable, e.g., capital is not the same as fixed, marginal is not the same as incremental.
- All relevant costs are avoidable, in the opportunity cost sense; if they are not avoidable, they are not relevant.
- Because most proposed changes (other than explicitly experimental tests or demonstrations) are not temporary, long run costs are usually applicable.
- Cost side of transit service has a service production component and a service deployment or utilization component.

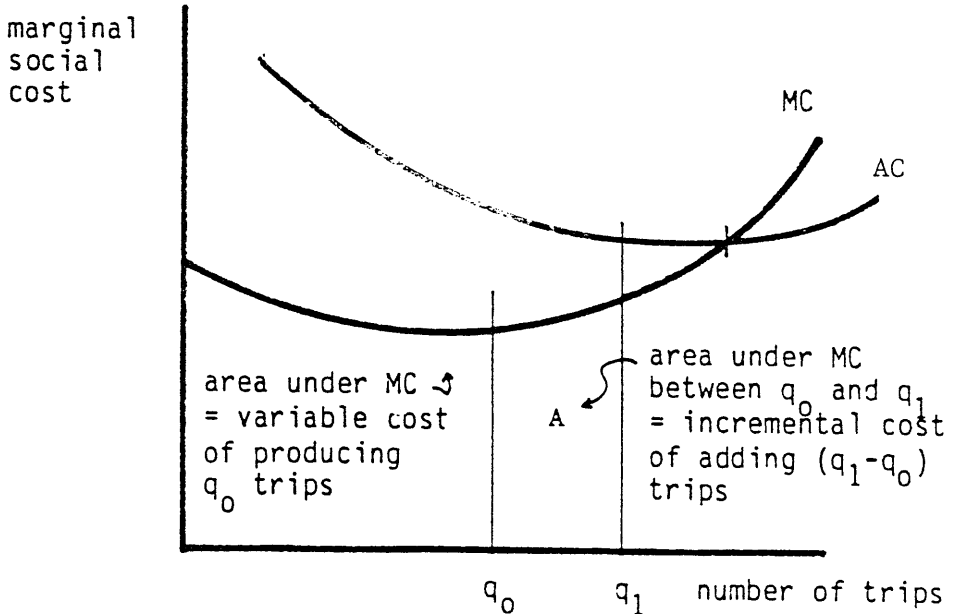
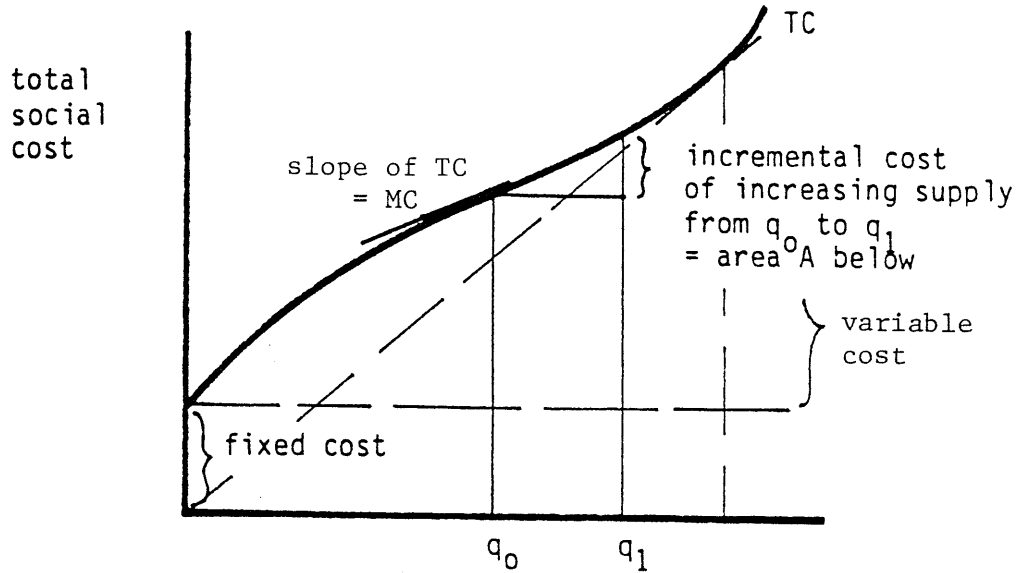
IV - 2
A Production Function, with One
Input



IV-2

- Production function transforms "physical" inputs into physical (or service) output.
- Inputs are capital, labor, and materials.
- For any given input, its marginal productivity tends to be high at low levels of input, its productivity declines as more of it is used, and eventually the input cannot add anything more to output.
- Production function is determined by technology and the productivity with which it is used (waste, or lack of it).

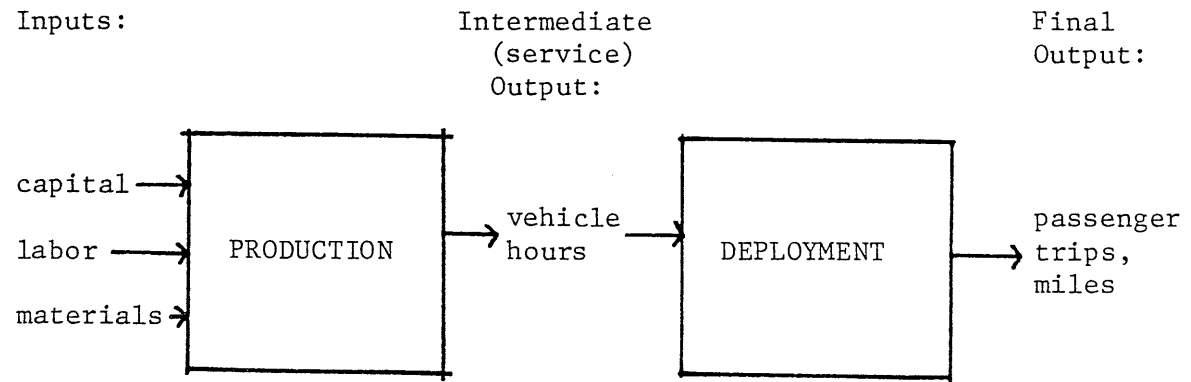
IV - 3 Total, Marginal, and Average Cost Functions



IV-3

- Cost function combines production function with prices of inputs.
- Optimum mix of inputs includes tradeoffs between prices of inputs and productivities.
 - Capital versus maintenance tradeoffs.
 - Vehicle size versus operating labor tradeoff.
 - Automation versus labor tradeoff.
- Average cost = total cost divided by output quantity.
- Marginal cost = slope of total cost function; MC is not affected by fixed costs.
- Variable costs change depending on the amount of service produced; fixed costs do not.

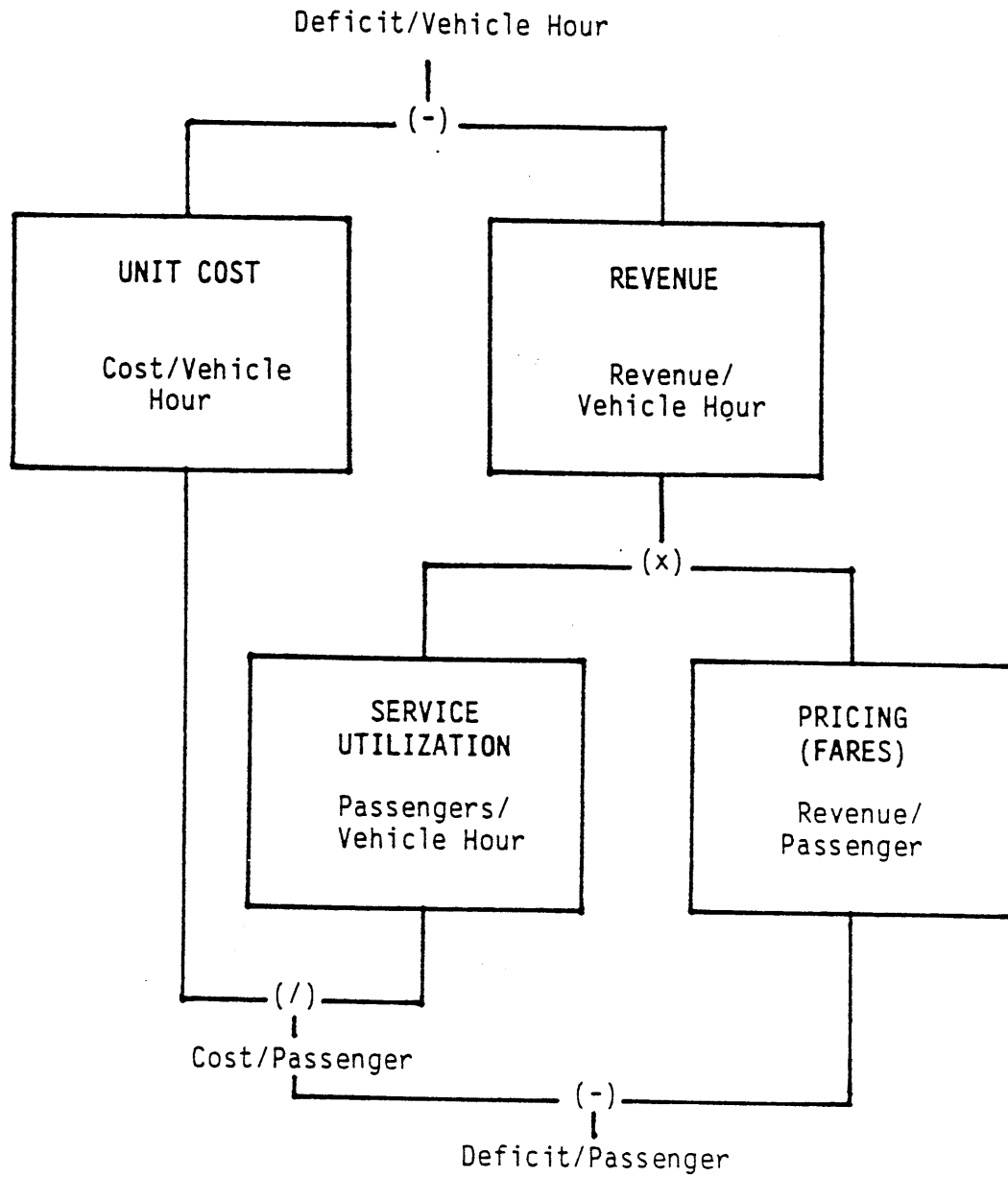
IV - 4
Two Phases in Supply of Transit
Services



IV-4

- Process of transforming inputs into passengers carried can be usefully broken into two phases: production and deployment.
- Service output in vehicle hours assumes a time distribution, i.e., blocks of vehicle hours by time period.
- Speed is considered a deployment factor.

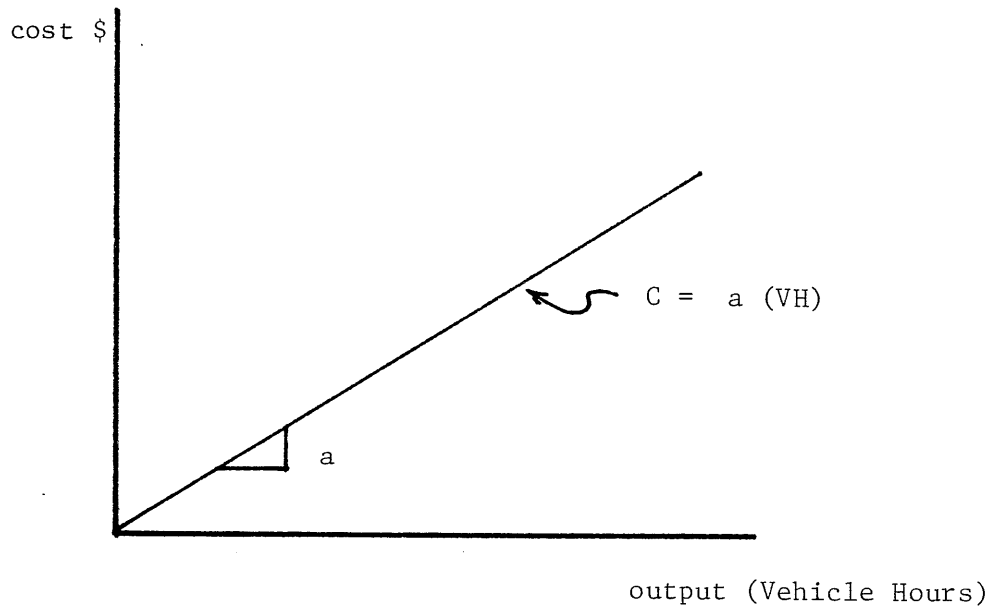
IV - 5 Summary Cost and Performance Measures



IV-5

- Measure of production phase is unit cost, per vehicle hour.
- Measure of deployment phase is revenue per vehicle hour.
- Revenue side can be broken into two components, passengers/hr and revenue/passenger.
- All relationships are identities, i.e., true by definition.
- Only three of the seven are needed to mathematically determine the others.
- Deployment has generally small impacts on cost per vehicle hour.
- In the literature on transit performance indicators, unit cost is sometimes referred to as "efficiency" and utilization as "effectiveness".

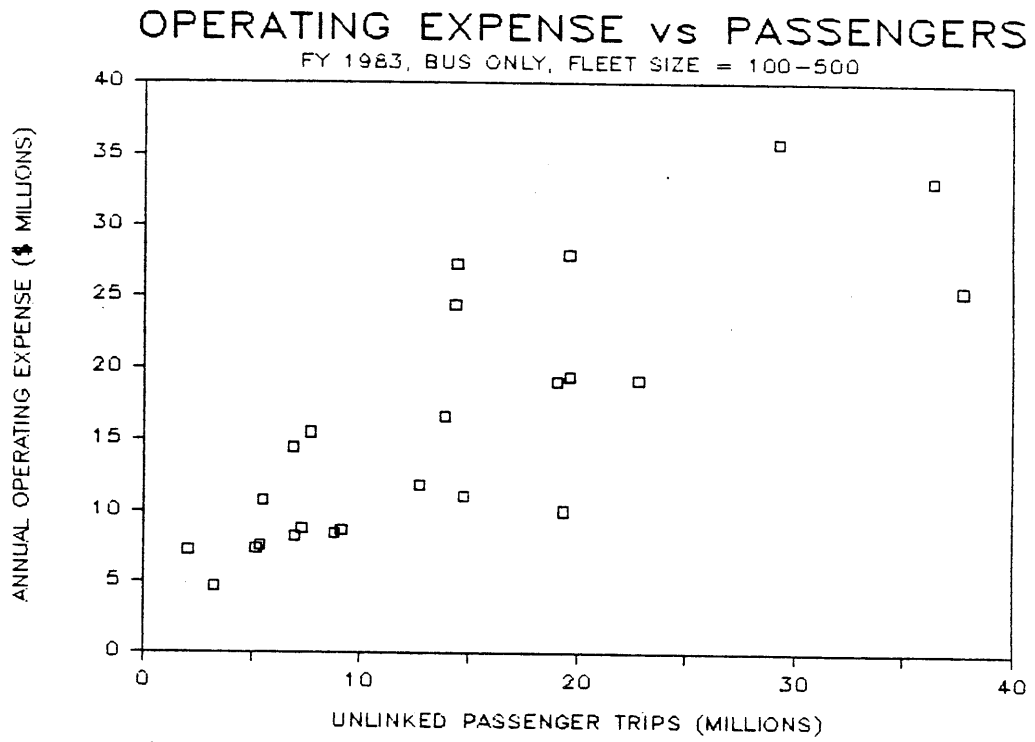
IV - 6
Simple Empirical Cost Function



IV-6

- This simple functional relationship is often used implicitly, often when it is not appropriate, e.g., by assuming costs stay constant per vehicle mile.
- In general, a cost function has two parts: a functional form (e.g., $Y = aX$) and parameters (e.g., a)
- In this example, the functional form is linear "homogeneous" (goes through the origin), and its $MC=AC$ =parameter, namely ' a '.
- It is desirable to be explicit about cost functions or models being used, so assumptions can be checked.
- For cost estimation, relationships should be as simple as possible and still do the job; black box models and multi-factor cost allocation models are seldom necessary and often misleading and incorrect.

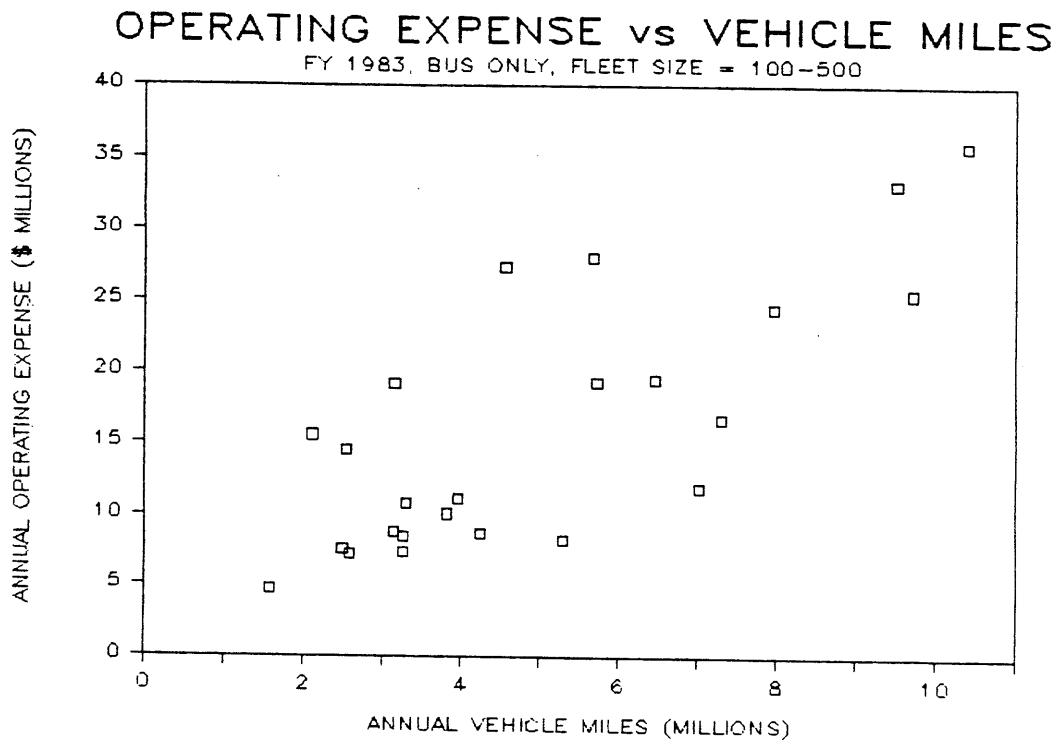
IV -7 Relationship Between Cost and Passengers



IV-7

- Graph shows the relationship between cost and passenger trip output.
- Although more passengers is generally associated with more cost, the relationship is very weak.
- The sample consists of 24 bus-only properties reporting Section 15 data for 1983, and having vehicle fleets of 100-500 vehicles.

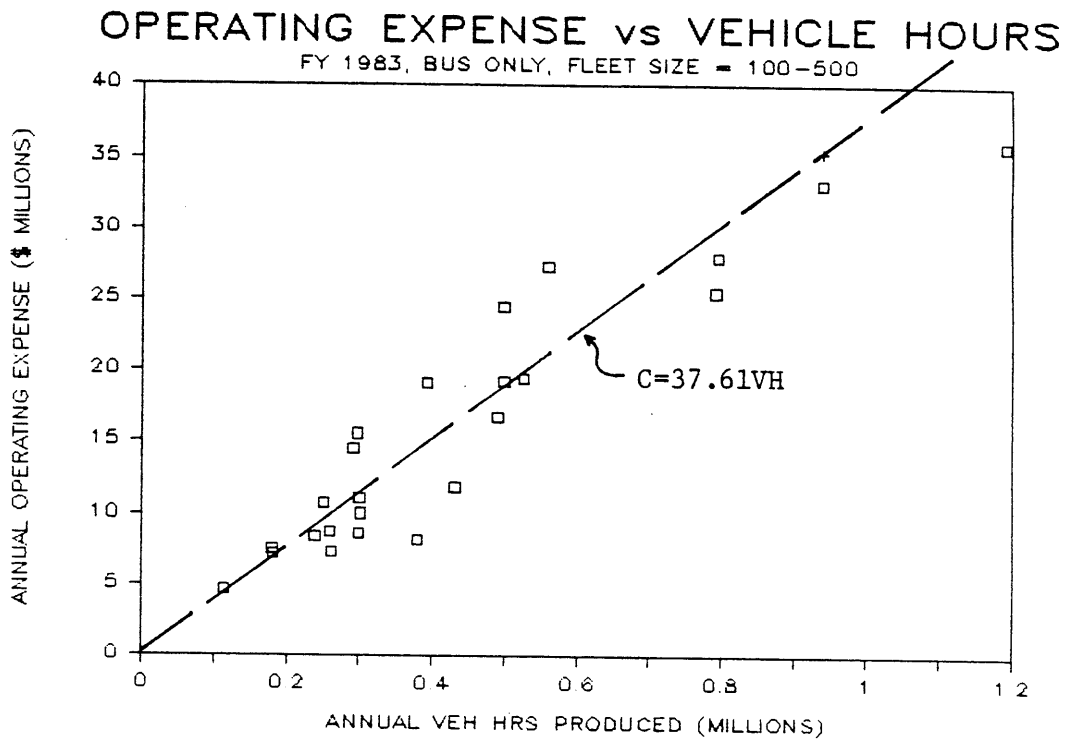
IV - 8 Relationship Between Cost and Vehicle Miles



IV-8

- Graph shows the relationship between cost and vehicle mile output.
- Although, again, more output means more cost, the relationship is weak.

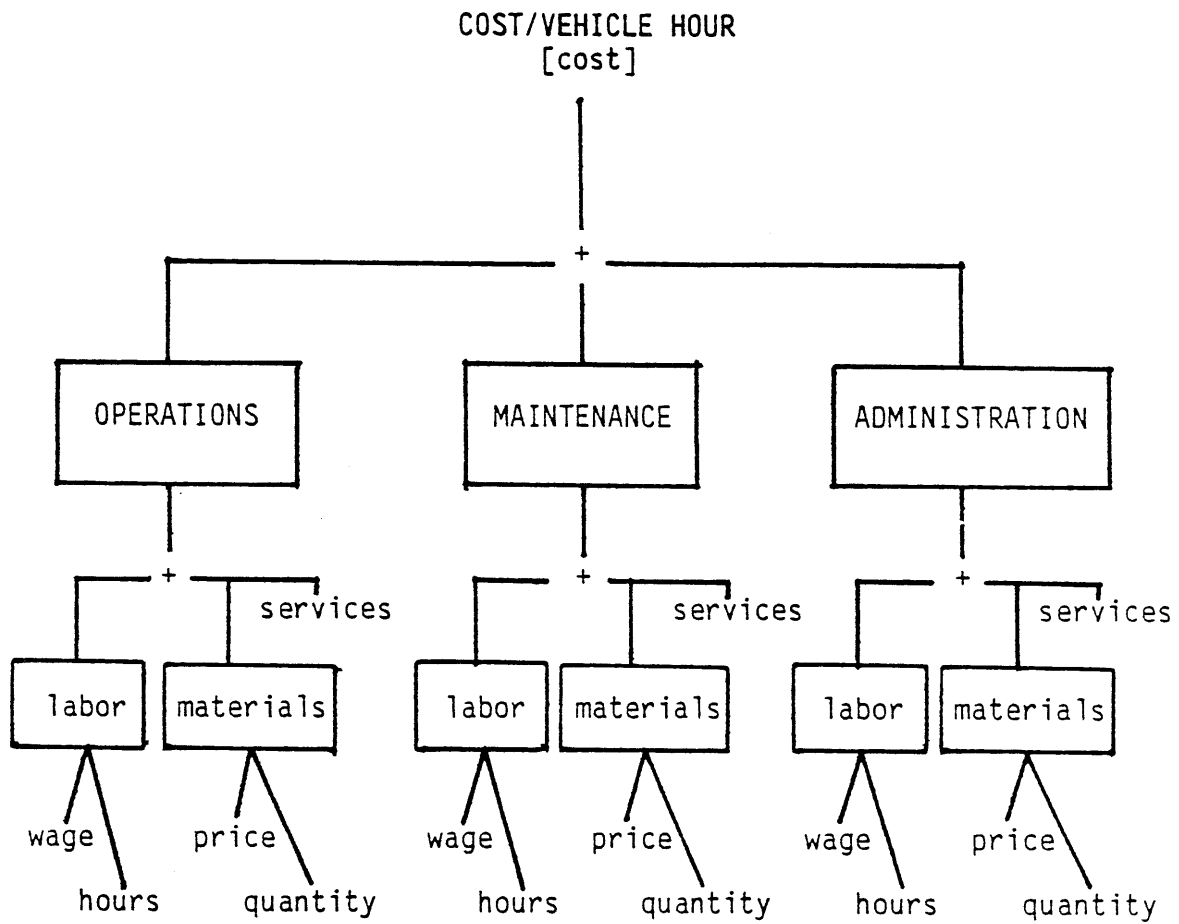
IV - 9 Relationship Between Cost and Vehicle Hours



IV-9

- This graph shows the relationship between vehicle hours of service and total cost.
- The relationship is much stronger than the previous ones, and a cost function has been fitted to the data. The slope of the line is the average cost per vehicle hour (\$37.61) for the 24 properties.
- A good starting point for service costing is to translate the service (or change in service) into vehicle hours, and multiply this by the average cost per vehicle hour for the property.
- This "average cost" model applies only to service segments that match the peak/off-peak distribution of the property as a whole. For service segments that do not meet this condition, costs per vehicle hour for peak and off-peak (at least) must be estimated separately.

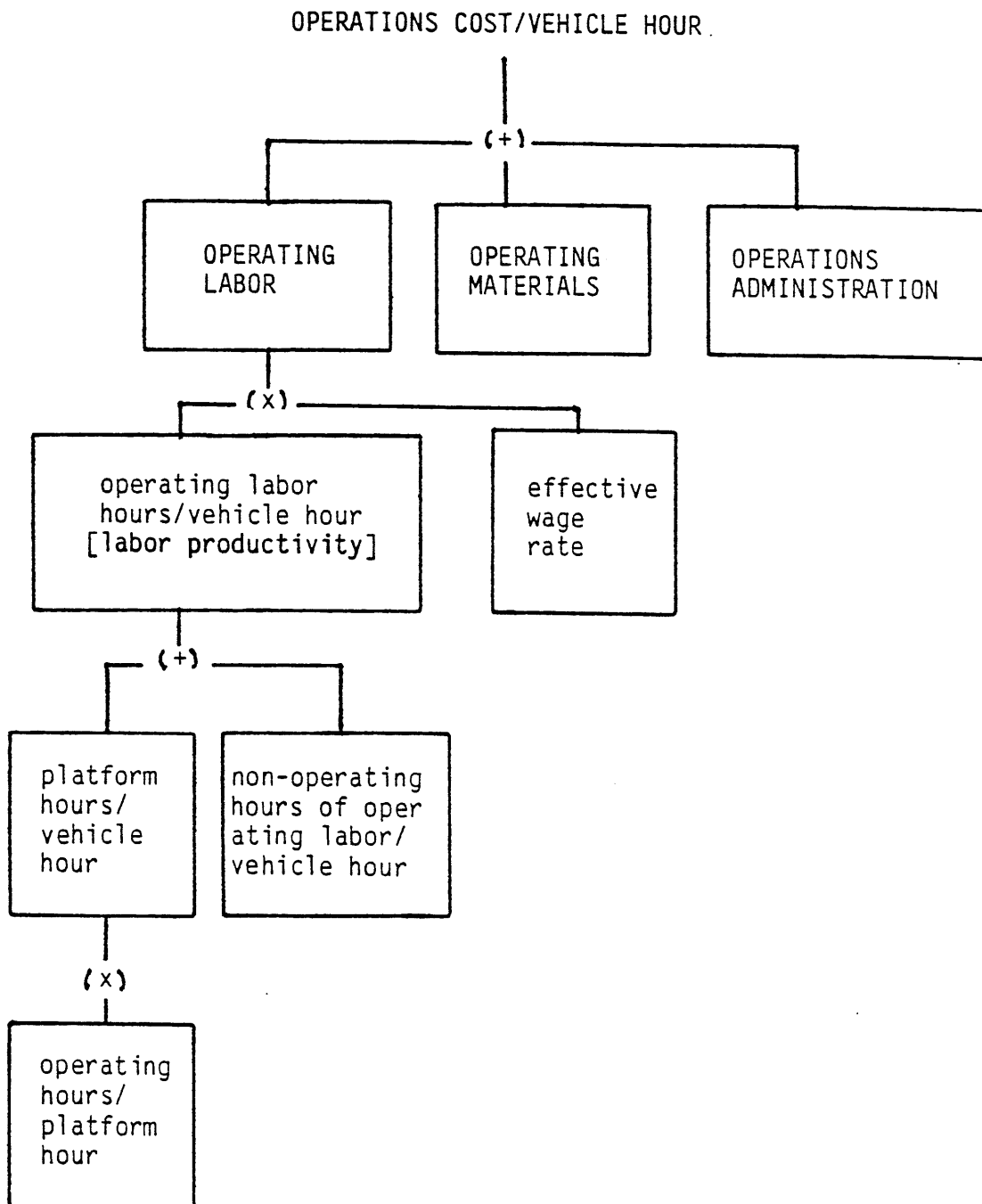
IV - 10 Components of Service Production Cost



IV-10

- For improved accuracy in estimating cost impacts, production costs can be disaggregated into components.
- Disaggregation should be exhasutive and non-overlapping, which allows unit cost components to "nest" together, maintaining control over all costs (at whatever level of detail) at all times.
- Components can be disaggregated by additive (summation) or multiplicative relationships.
- Objective is to determine more precisely which components will be affected by a particular change, e.g., maintenance cost per vehicle hour may be increased by freeway express service.

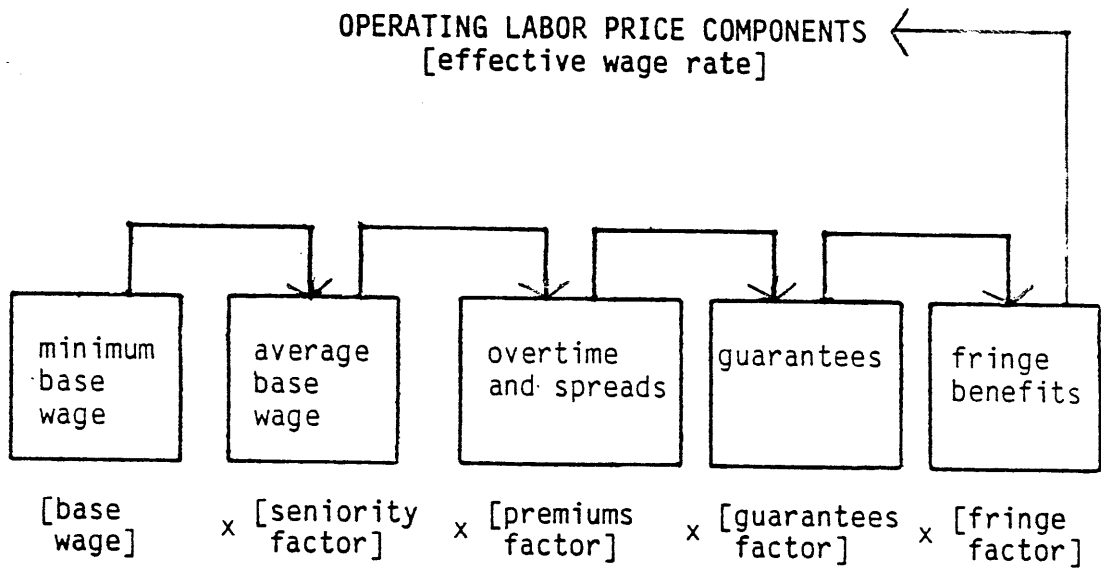
IV - 11 Components of Operations Cost



IV-11

- Details of Operations (Transportation) costs.
- Total operating labor hours per vehicle hour is operating labor productivity.
- Total compensation per operating labor hour is "wage" rate (includes fringe benefits).
- As with other components of cost, these are defined to be identities, whether multiplicative or additive.
- Fuel consumption per hour might be affected by speed (e.g., express) or terrain.
- Both labor productivity and labor compensation are affected by many factors. Service changes might affect productivity through peak/base distribution and compensation through overtime.

IV - 12 Components of Operating Labor Costs



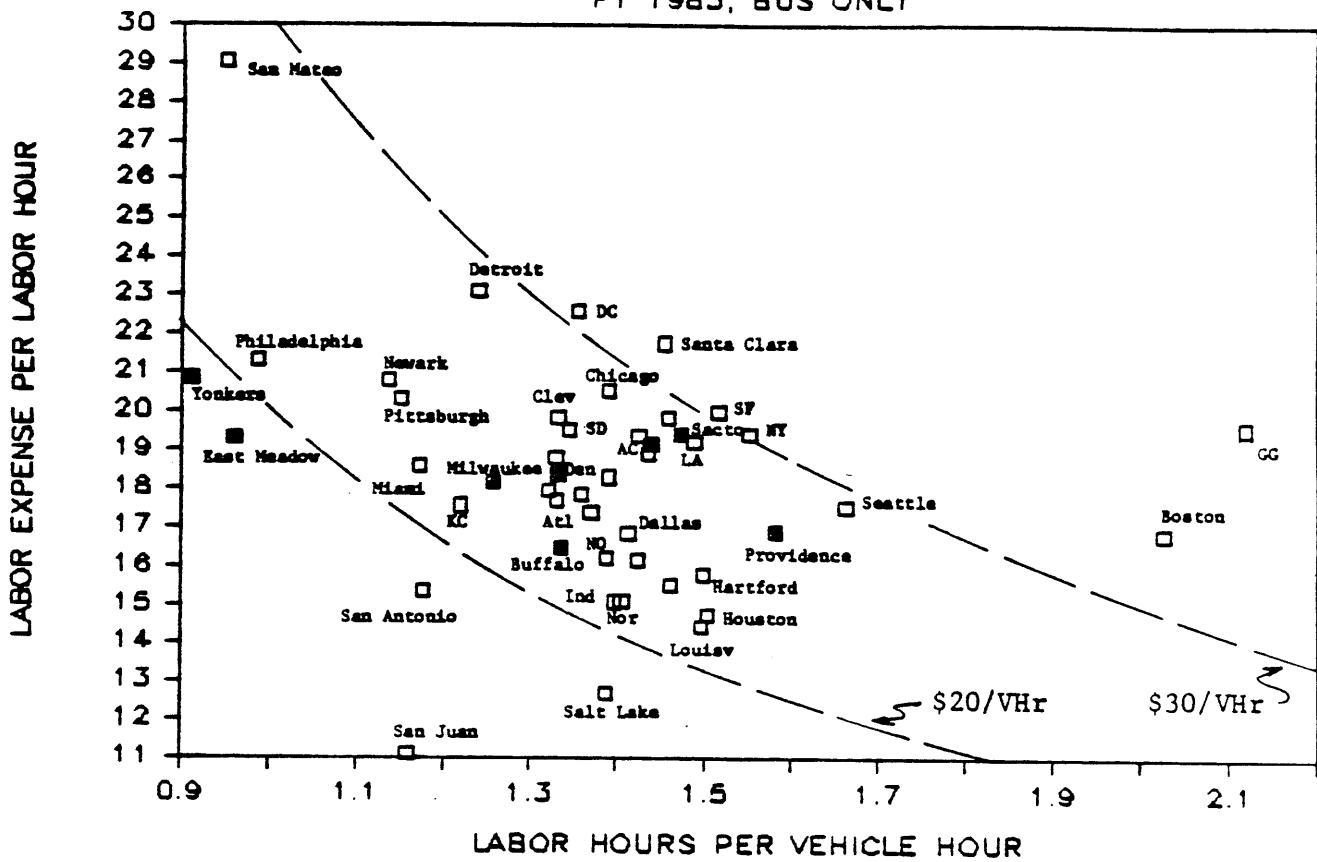
IV-12

- Operating labor compensation rate can be broken into several components, each of which may be affected differentially by policy or service changes.
- Ratio of average pay rate to base (or top) rate is "Seniority" factor, reflecting experience of operators.
- Spread premiums and overtime are partly a consequence of amount of peaking; also reliability, work rules, etc.
- Guarantees are payments for time not actually worked, and therefore amount to additional compensation rather than lower productivity.
- Example: use of part time operators reduces non-operating labor hours (productivity), reduces fringe payments (compensation), and reduces spread penalties (compensation), but increases accidents (inexperience), training costs (non-platform time), absenteeism (guarantees and overtime), and turnover (some administrative costs).

IV -13
 Relationship Between Operating
 Labor Productivity and Wage
 Rates

OPERATIONS LABOR PRODUCTIVITY

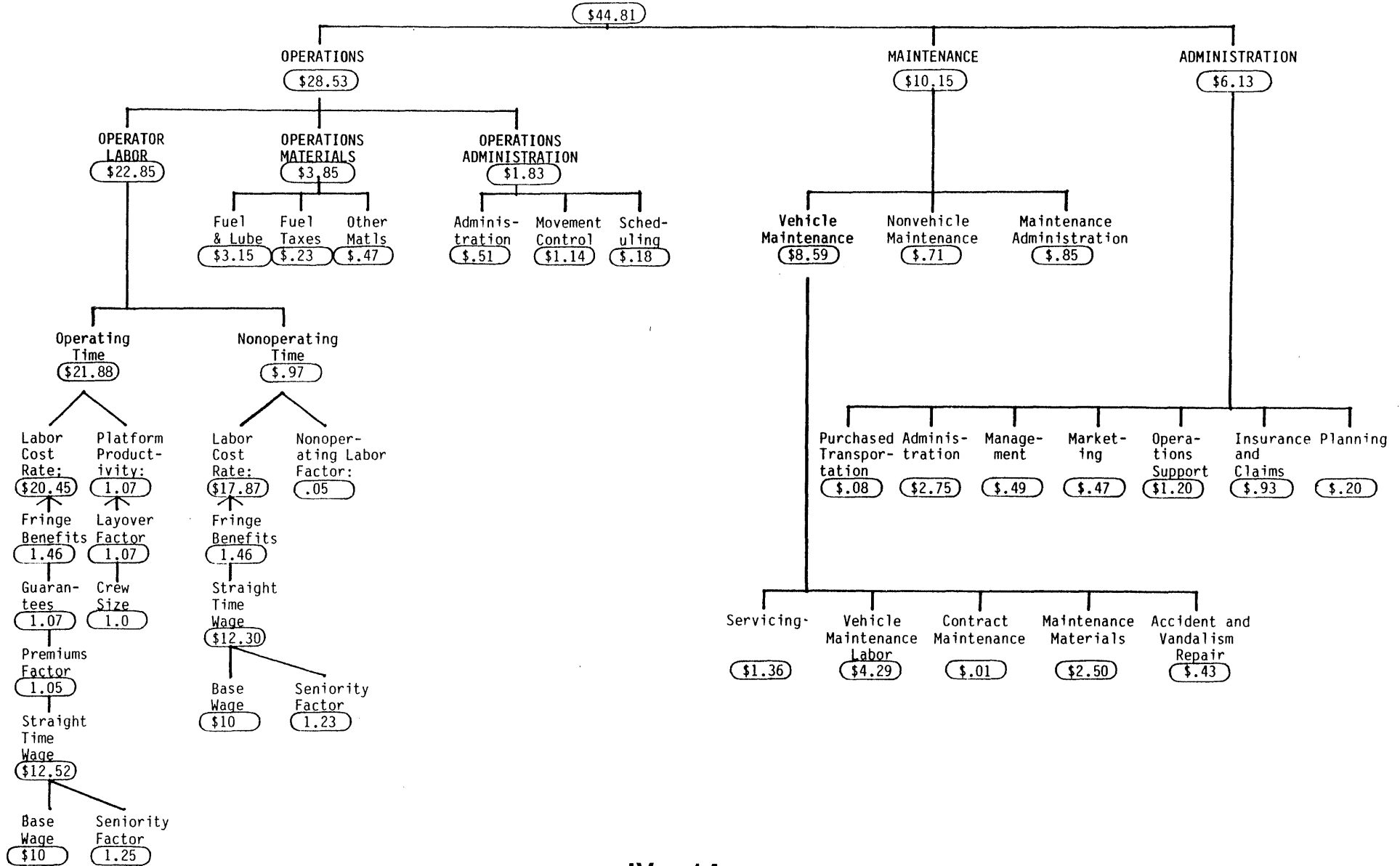
FY 1983, BUS ONLY



IV-13

- Graph shows little evidence of tradeoff between compensation rates and productivity.
- Comparison with other properties helps to suggest what factors are responsible for cost levels. For example, Boston's high cost per vehicle hour is due almost entirely to low labor productivity rather than high compensation rates.
- Because a vehicle hour requires at least one labor hour to produce, ratios below 1.0 on the productivity axis must be incorrect. If vehicle hours of service are overreported (more likely than underreporting of platform hours), the bias may be consistent across properties. If true, this would preserve their relative position, even though the scale is off.

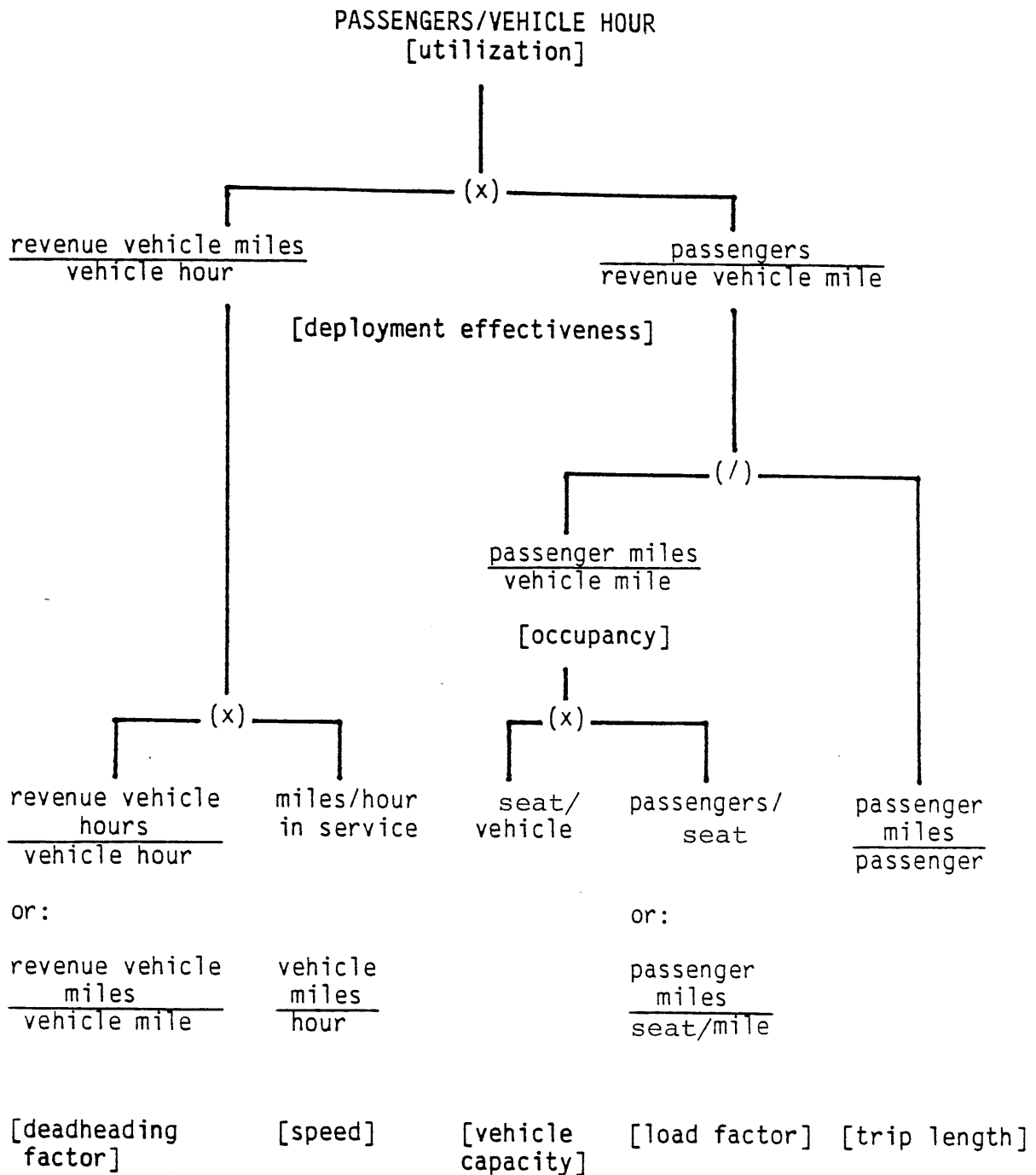
OPERATING COST
PER VEHICLE HOUR



IV - 14
Detailed Disaggregation of
Operating Costs

- Detail for comparison on operating costs is available from Section 15 reports. Example data are for San Diego.
- Categories can be tailored to individual property and purposes, but "nesting" (smaller pieces combine to yield next higher category) should be retained.
- To gain better understanding of magnitudes of cost components, three approaches can be blended:
 - (1) Compare own property with others.
 - (2) Track own property over time.
 - (3) Break out components in greater detail.
- This chart combines previous ones and adds components for Maintenance and Administration.
- Average cost and productivity components may be distorted by items such as purchased transportation (Administration) and planning for major new systems.
- Components not directly related to vehicle hours (e.g., fuel?) can be estimated by whatever method works best, and the results converted to vehicle hour rates for planning purposes, so long as forecast conditions are similar.

IV - 15 Components of Service Utilization



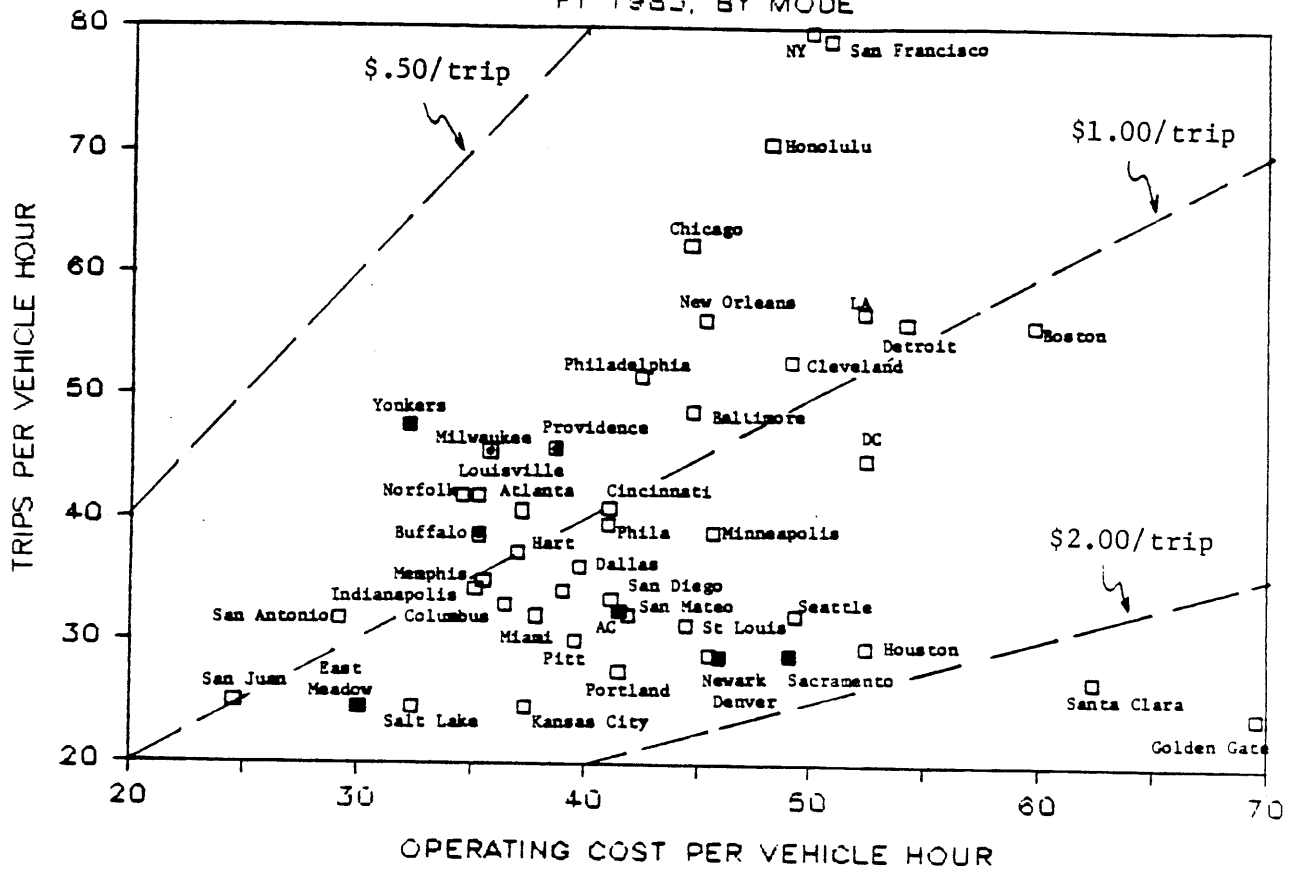
IV-15

- Details of the Utilization side of transit service production.
- Deadheading is affected by route design and garage or yard locations.
- Speed is traded off for passengers per mile.
- Occupancy affects comfort and hence user willingness-to-pay.
- Trip length should be related to fares, for both demand and cost reasons, but circuitry is a competitive disadvantage.
- Utilization determines cost per passenger, given production cost per vehicle hour.

IV - 16
 Relationship Between Cost and
 Utilization

UNIT COST VS. UTILIZATION

FY 1983, BY MODE



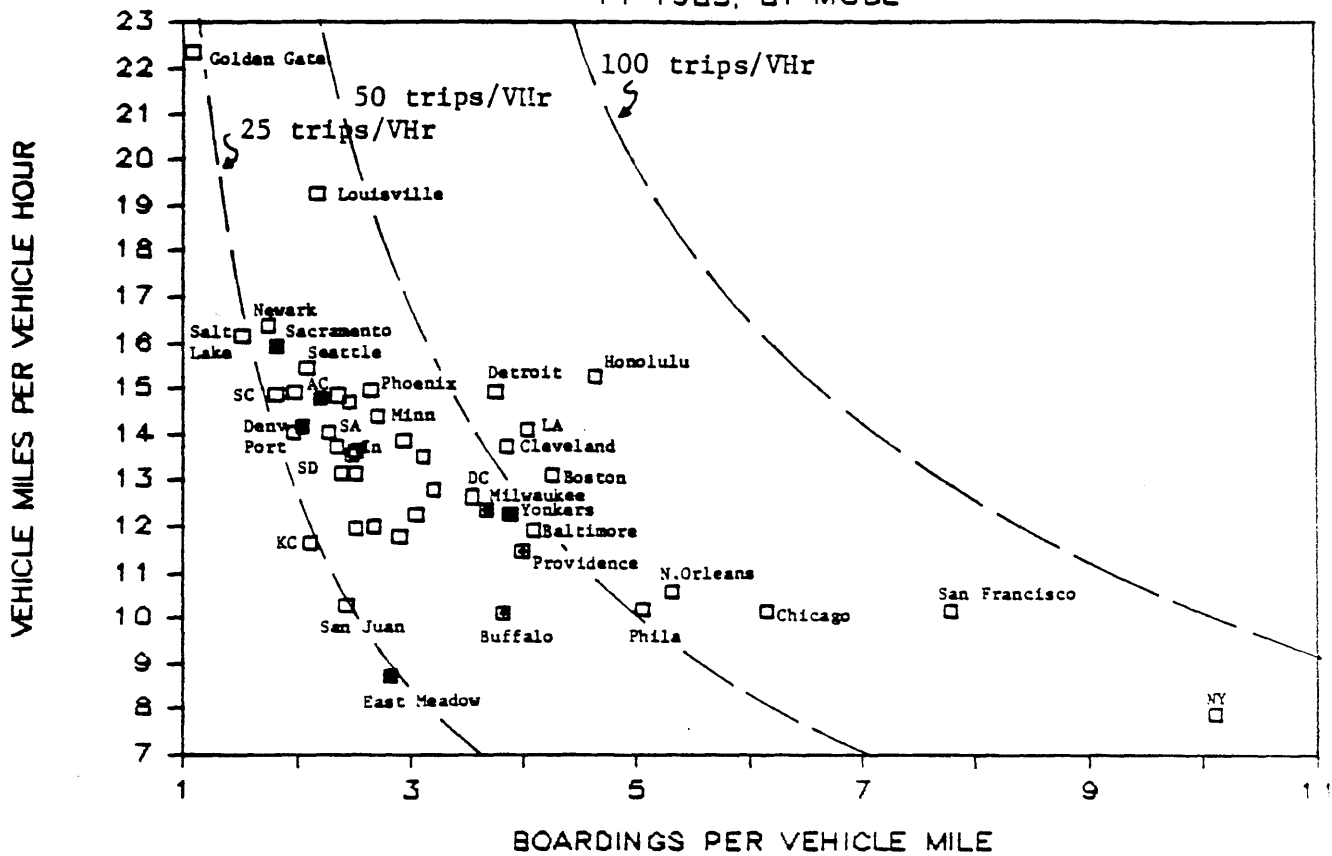
IV-16

- Graph shows two components of cost per trip, namely, cost per vehicle hour, and utilization.
- Comparisons show sources of average cost, e.g., Portland has a typical hourly operating cost but a low boarding rate per vehicle hour.
- Yonkers, Milwaukee, and Chicago show relatively favorable combinations of unit cost and utilization. High cost trips may also be long trips, e.g., Golden Gate.
- Successive breakdown of cost factors suggests where to focus attention for estimating costs or designing efficient service.

IV - 17
 Relationship Between Boardings
 and Speed

BOARDINGS VS. SPEED

FY 1983, BY MODE



IV-17

- Shows tradeoff between speed and boarding rate.
- Many ways to achieve high (or low) Utilization rates, e.g., Providence vs Louisville. Denver and Portland do no better on boardings than Sacramento and Santa Clara.

IV - 18
Components of Capital Cost

DEPRECIATION

Consumption of the service life of
a capital asset, e. g. , wear and tear

$$\text{Cost} = \frac{\text{value}}{\text{remaining life}}$$

OPPORTUNITY COST

Income foregone by retaining a
capital asset rather than selling it

(old bus is cheaper than new one)

IV-18

- Depreciation and Opportunity Cost are separate and additive costs of capital.
- Depreciation is a variable cost, while opportunity or "interest" cost is fixed with respect to service output.
- Capital depreciation is a variable cost, and should be included in hourly service costs. Opportunity costs of capital are attributable to peak service, and should be counted mostly or entirely in peak costs.
- Existing vehicles, highways, and other capital assets are not sunk costs (by and large), and represent costs that can be recovered or avoided. Buses can be bought and sold, highway land can be expanded or contracted, and buildings have alternative uses. Although these opportunity costs rarely show up in budgets, they should be included in cost analysis.
- Although a property may choose to make decisions solely on the basis of costs to itself, ignoring capital costs borne by Federal or other levels of government, the costs should nonetheless be recognized and made explicit.

IV - 19
Calculation of Peak versus
Off-Peak Unit Costs

	Total or Average	Peak	Off-Peak
Vehicle hours	100	40	60
Operating labor hrs	150	84	66
Productivity (Lab.Hr/Veh.Hr)	1.5	2.1 ^b	1.1 ^a
Operating Labor \$	2250	1307	943
Operating Labor \$ per labor hour	15	15.56 ^d	14.28 ^c
Maintenance Cost (\$)	1000	480	520
Maint. \$/veh. hr.	10	12.00 ^e	8.67 ^f
All other costs per vehicle hr.	10	10 ^g	10 ^g
TOTAL OPERATING COST per vehicle hour	42.50	54.68	34.38
Capital Depreciation per vehicle hour	4	4 ^h	4 ^h
Capital Opportunity cost per veh. hr.	1.75	4.37 ⁱ	0 ⁱ
TOTAL COST/VEH HR	48.25	63.05	38.38

Assumptions for Peak versus Off-Peak calculations:

- a Off-peak labor productivity is assumed to be the best achievable for the given property, taken to be 66 labor hours for 60 vehicle hours, or 1.1 labor hrs/veh. hr.
- b Remaining labor hours (84) are assigned to the peak, yielding a peak productivity of 2.1 labor hrs/veh. hr.
- c Overtime and spread premiums are assigned to peak service. Using San Diego's premium factor (1.05), the off-peak labor compensation rate would be \$14.28 if premiums are removed from the average.
- d Assigning the remaining labor costs (\$1307) to the peak yields an effective wage rate of \$15.56 per labor hour for peak service.
- e On the assumption that service peaking results in a mirror-image maintenance peaking, peak maintenance costs per vehicle hour are taken to be 20% greater than the average, or \$12 per vehicle hour.
- f Assigning the remaining maintenance costs (\$520) to the off-peak results in a rate of \$8.67 per vehicle hour.
- g All other operating costs are assumed to be the same for peak and off-peak.
- h Capital depreciation is based on a \$160,000 vehicle lasting 40,000 hours, or \$4 per vehicle hour.
- i Capital opportunity cost is calculated by assuming an average value per vehicle in service of \$100,000 and a discount rate of 7%, or \$7,000 per year. This cost is assigned entirely to peak service, yielding \$4.37 per vehicle hour.

(Input data items consist of the first row in the table and the first column down to capital cost; the remaining numbers are derived.)

IV - 20 Bus Costing Example

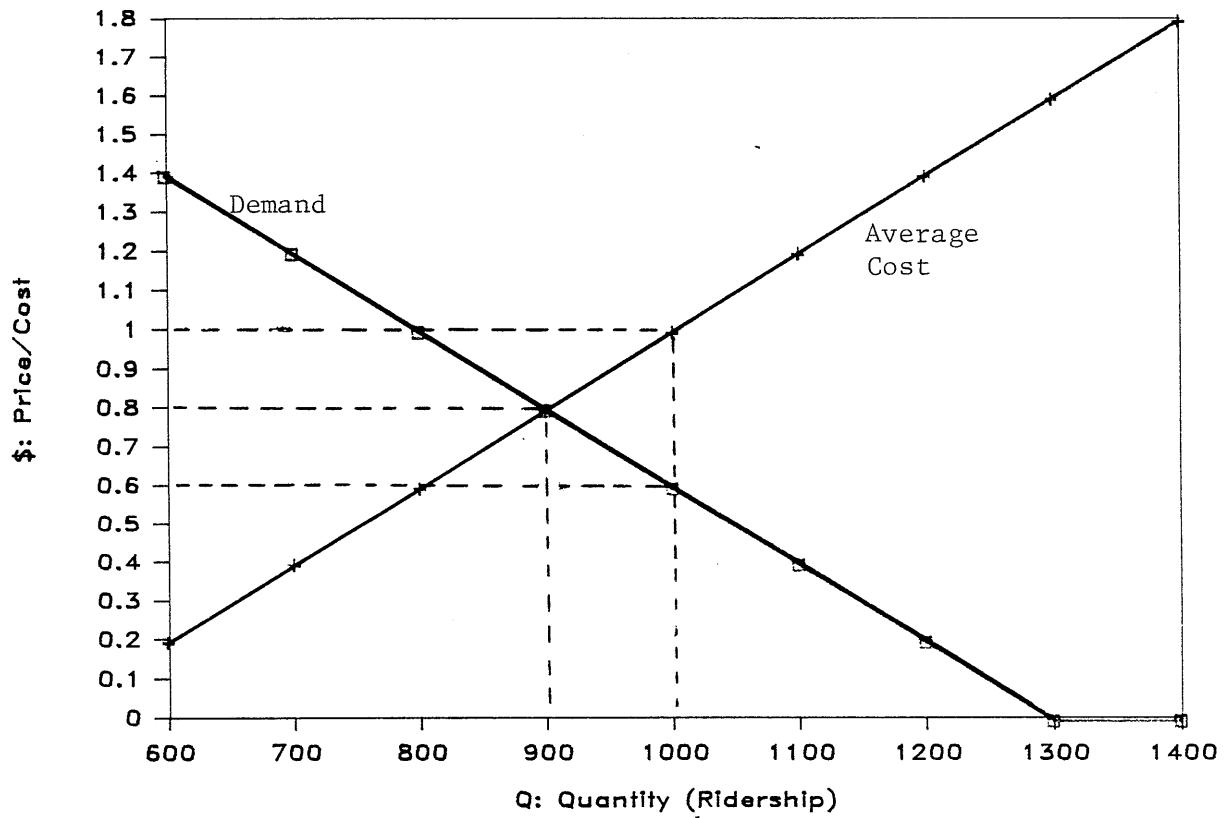
	Base	Extension		
DAILY RIDERS:			Pass/VeHr	
Peak	1800	1500	90.0	60.0
Offpeak	200	500	20.0	25.0
Total	2000	2000	66.7	44.4
VEHICLE HOURS OF SERVICE:			Pass/VehMi @	
Peak	20	25	Speed (mph) = 15	
Offpeak	10	20	6.00	4.00
Total	30	45	1.33	1.67
			4.44	2.96
UNIT COSTS OF SERVICE (\$/VeHr):			Occupancy @	
Peak	63.05	63.05	Trip Length = 4	
Offpeak	38.38	38.38	24.0	16.0
			5.3	6.7
CAPITAL AND OPERATING COST:			17.8	11.9
Peak	1,261	1,576		
Offpeak	384	768		
Total	1,645	2,344		
COST PER PASSENGER:				
Peak	0.70	1.05		
Offpeak	1.92	1.54		
Average	0.82	1.17		
REVENUE PER PASSENGER:				
Peak	\$0.60	\$1.00		
Offpeak	\$0.60	\$0.50		
Total Peak	1080	1500		
Total Offpeak	120	250		
Average	0.60	0.88		
PERFORMANCE EVALUATION:			Deficit/VeHr	
Peak Deficit/Pass	0.10	0.05	9.05	3.05
Offpeak Deficit/Pass	1.32	1.04	26.38	25.88
Total Deficit	445	594		
Avg Deficit/Pass	0.22	0.30		

IV-20. Bus Service Costing Example

- Impacts of service and fare changes are represented in the data contained in the shaded fields. Remaining numbers are derived.
- "Base" is existing service on a particular route, and "Extension" is a proposed expansion of service (alternatively, these might be reversed, for a service contraction).
- In the example, peak and offpeak service are both expanded, and fares differentiated between the two. Peak ridership declines, and offpeak ridership increases by an offsetting amount, leaving total ridership unchanged. Quality of peak service increases (less crowding, all passengers seated), and the amount of offpeak service increases.
- Unit costs per vehicle hour (peak and offpeak) are assumed to be unaffected by the service changes (alternatively, unit costs could be tied to costing assumptions that lead to different unit costs after the service changes).
- Evaluation of these results is not simple. The observations below are listed in decreasing order of importance:
 - (a) Overall deficit per passenger goes up, meaning the rate of subsidy increases, by about 35%. The efficiency case for service changes is strongest when the subsidy per passenger decreases.
 - (b) The same number of passengers is served, although the new passengers may place a higher value on the service than the previous ones did. The case would be stronger if ridership were increased, given the subsidy per passenger is increased.
 - (c) Farebox recovery improves for each type of service, and the reason for the decline in the overall per-passenger subsidy is that relatively more of the passengers use the high-loss offpeak service. In this example, peak passengers come much closer to paying their way than offpeak passengers.
 - (d) Total deficit increases, but this is inevitable for almost any service expansion. If total deficit is politically constrained, then the service and pricing problem is to allocate service so as to maximize benefits. Deficit per passenger or per passenger mile is probably the best basis for comparing routes and service.
- Further improvements require information that cannot be learned from these data. Peak service seems better with the changes, and peak demand does not appear to be tied to the additional offpeak service. Depending upon whether offpeak ridership growth occurs because of peak pricing (a shift of the offpeak demand curve), lower offpeak price (high price elasticity), or increased service (high service elasticity), offpeak service and pricing should be reconsidered.

V - 1

Impacts of Fare Increase



- Assume:

$$\text{Fare elasticity} = FE = -.3$$

$$\text{Current ridership} = q_0 = 1,000$$

$$\text{Current fare} = p_0 = \$.60$$

All other things, including service characteristics, are held constant. Diseconomies of scale (average costs are increasing).

- Compute:

$$\text{Current revenue} = R_0 = (q_0)(p_0) = \$600$$

Current average

$$\text{cost} = AC_0 = \$1.00/\text{rider}$$

$$\text{Current total cost} = C_0 = (AC_0)(q_0) = \$1,000$$

$$\text{Current deficit} = D_0 = R_0 - C_0 = \$400$$

Current cost

$$\text{recovery ratio} = R_0/C_0 = .60.$$

- Efficient fare: What is the ridership and cost impact of increasing fares to \$.80?

$$\begin{aligned} \text{Ridership Impact: } \Delta q &= (FE)(\Delta p)(q_0)/p_0 = (-.3)(.2)(1000)/.6 \\ &= -100 \end{aligned}$$

$$\begin{aligned} \text{New ridership} = q_1 &= q_0 + \Delta q = 1000 - 100 \\ &= 900. \end{aligned}$$

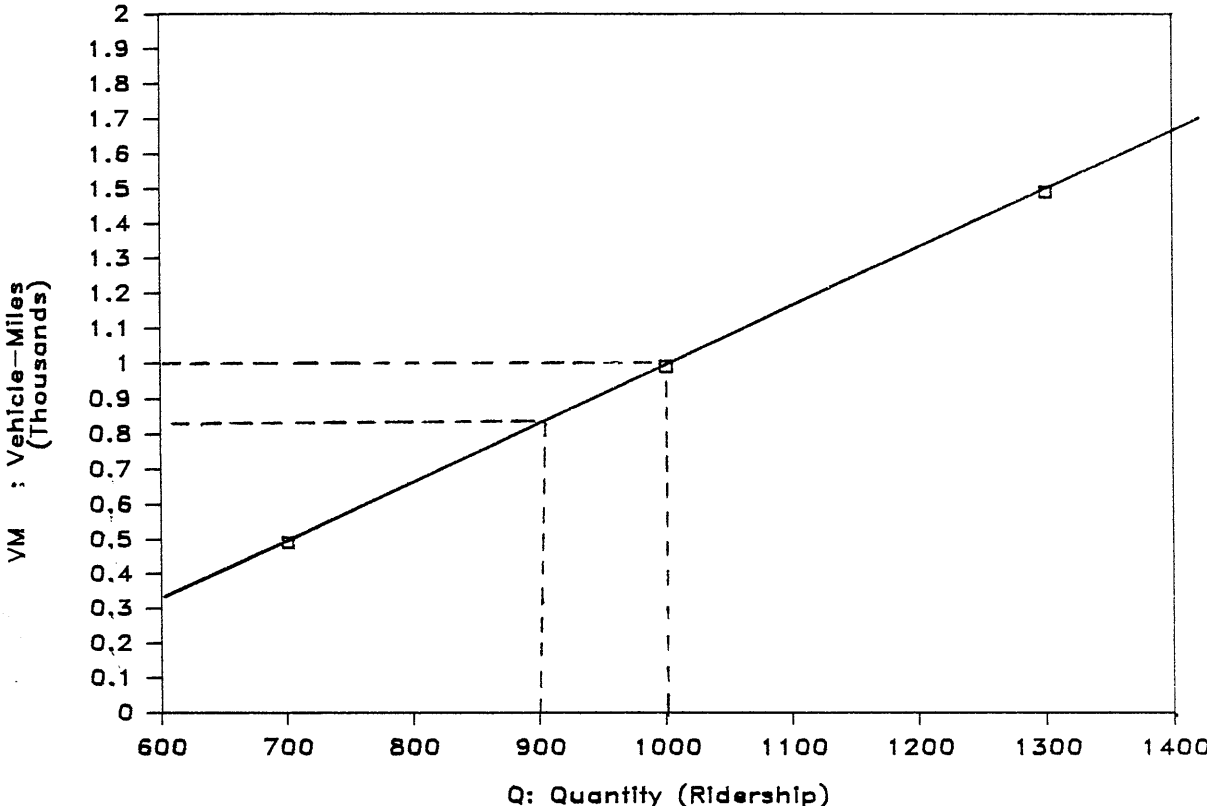
$$\begin{aligned} \text{Revenue Impact: } \text{Change in revenue} &= \Delta R = (q_1)(p_1) - (q_0)(p_0) \\ &= (900)(.80) - (1000)(.6) \\ &= \$120 \end{aligned}$$

$$\text{New revenue} = R_1 = R_0 + \Delta R = 600 + 120 = \$720.$$

$$\begin{aligned} \text{Cost Impact: } \text{New average cost} &= AC_1 = .80 \\ \text{New total cost} = C_1 &= (AC_1)(q_1) \\ &= (.8)(900) = \$720. \end{aligned}$$

$$\begin{aligned} \text{Deficit Impact: } \text{New deficit} &= R_1 - C_1 = \$720 - \$720 = 0 \\ \text{New cost recovery ratio} &= R_1/C_1 = 1. \end{aligned}$$

V - 2
Service Change Equivalent of Fare
Increase



- Assume: Service elasticity = $SE = +.60$
 Current vehicle miles = $VM_0 = 1,000$
 Current ridership = $q_0 = 1,000$
 All other things, including price, are held constant.
- Equivalent service change: What is the equivalent service change with respect to ridership of increasing fares to \$.80?

- Service impact: $\Delta VM = (\Delta q)(VM_0)/(SE)(q_0)$
 $= (-100)(1000)/(+.60)(1000)$
 $= -167$

New vehicle-miles = $VM_1 = VM_0 + \Delta VM = 1000 - 167 = 833$

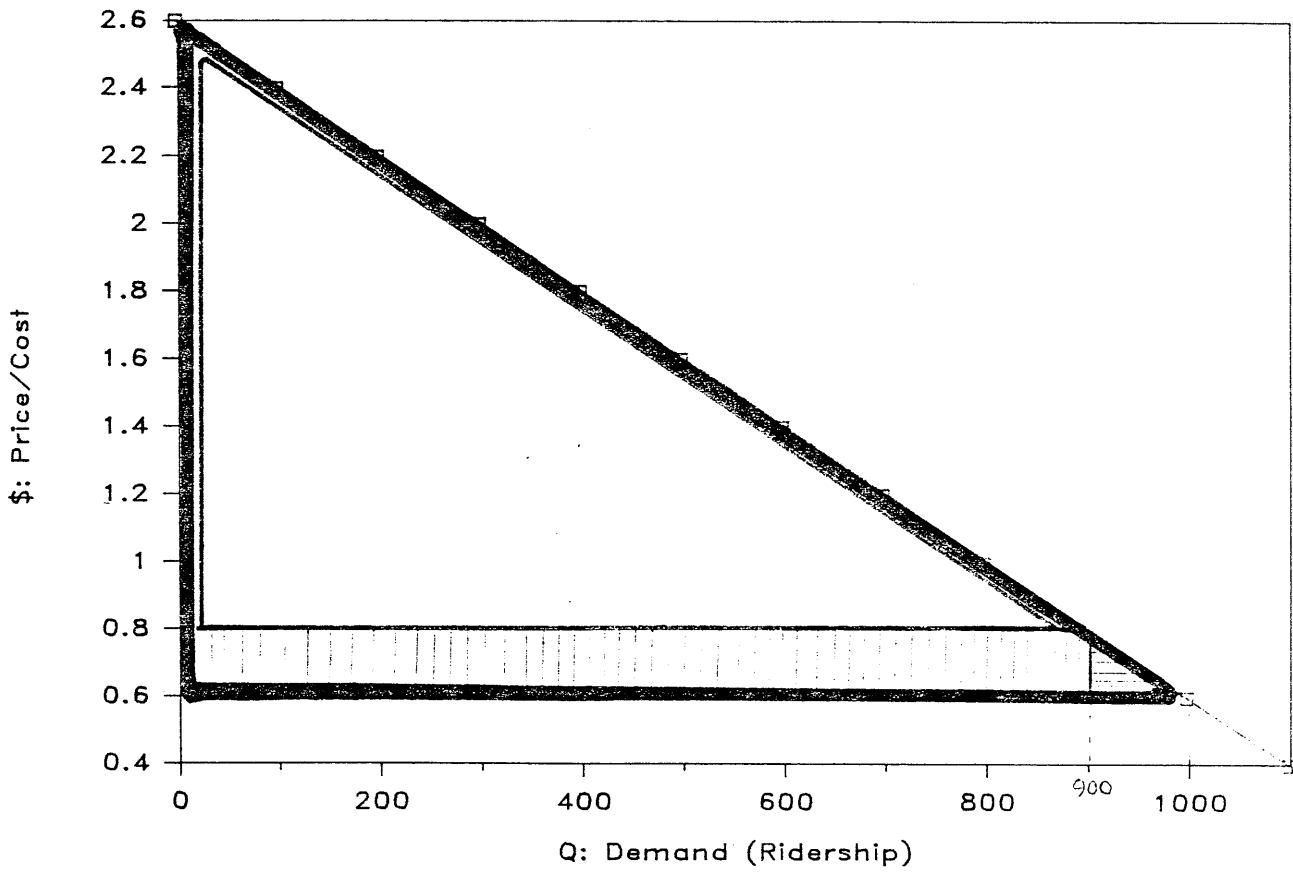
Thus, cutting daily services from 1,000 to 833 vehicle-miles is comparable to increasing fares from 60 cents to 80 cents in terms of ridership impact.

- Note, however, that since fare is unchanged, a deficit remains:
 New Revenues = $(900)(\$.6) = \540
 Costs = $\$720$
 New Deficit = $\$720 - \$540 = \$180$
- Equivalent service change: What is the equivalent service change with respect to the deficit level of increasing fares to \$.80?
- Service impact: $\Delta VM = (\Delta q)(VM_0)/(SE)(q_0)$
 $= (-200)(1000)/(+.60)(1000)$
 $= -333$

New vehicle-miles = $VM_2 = VM_0 + \Delta VM = 1000 - 333 = 667$

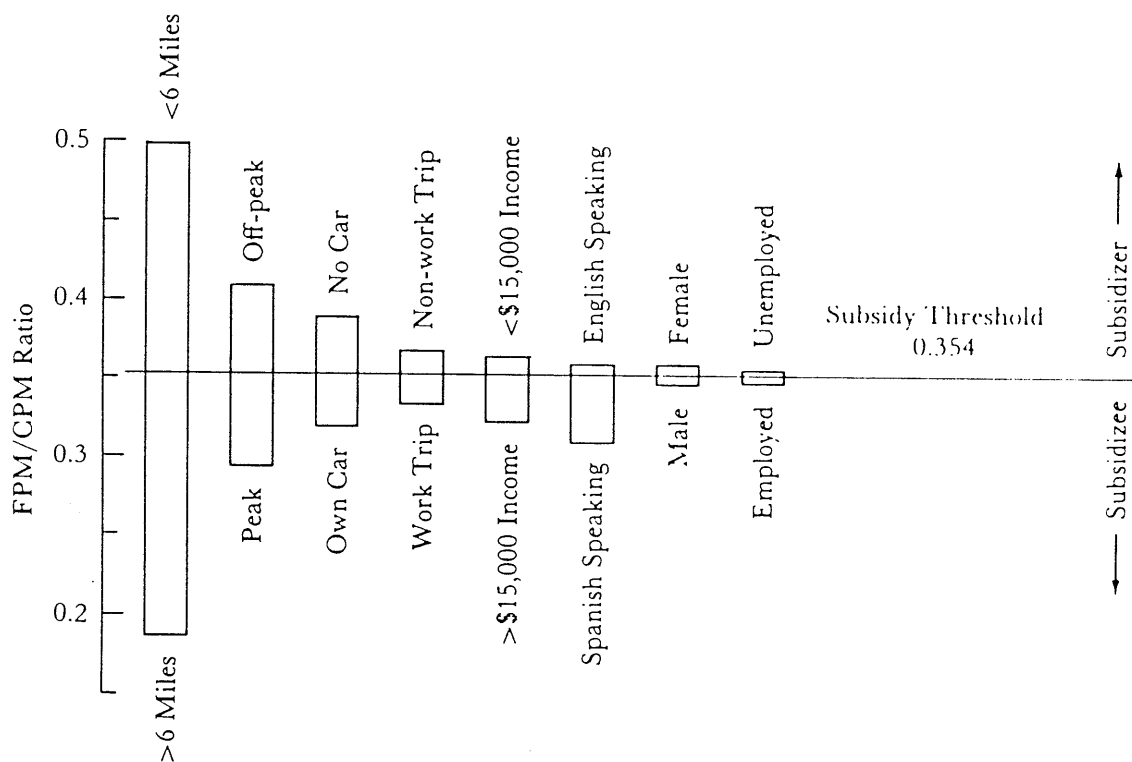
- Deficit Impact:
 New Revenues = $(800)(\$.60) = \480
 New average cost = $\$.60$
 New Costs = $(800)(\$.60) = \480
 New deficit = $\$480 - \$480 = \emptyset$.

V - 3 Distributive Impacts of Efficient Price



- Three different groups impacted: 1) continuing users; 2) those priced off; and 3) non-users.
- The overall loss in benefit to the first two groups can be measured by shrinkage of what economists call the "consumer surplus" -- the difference between what users are willing to pay relative to what they actually pay. Any price they pay that is below what they would agree to pay can be considered a benefit to those users.
- Change in consumer surplus:
 - Consumer surplus before fare increase (or service cut):
 $(\$2.60 - \$.60)(1000)(.5) = \$1,000$
 - Consumer surplus after fare increase (or service cut):
 $(\$2.60 - \$.80)(900)(.5) = \$810$
 - Loss in consumer surplus = $\$1,000 - \$810 = \$190$
- This \$190 loss in benefits can be further divided into losses incurred by the two user groups:
 - Loss to continuing users: $(\$.80 - \$.60)(900) = \$180$
 - Loss to those priced off: $(\$.80 - \$.60)(1000 - 900)(.5) = \$10$
- Impacts to non-users: Motorists might lose because more cars will be added to streets by those priced off transit. If there's available street capacity to accommodate them, losses will be negligible. Society-at-large may be affected by the additional pollutants and energy consumption attributable to some switching from bus to auto. Who benefits then? Generally, the major beneficiaries are the taxpayers who no longer have to subsidize the \$400 deficit previously incurred by the transit agency.

V - 4 Equity Analysis for San Diego Transit

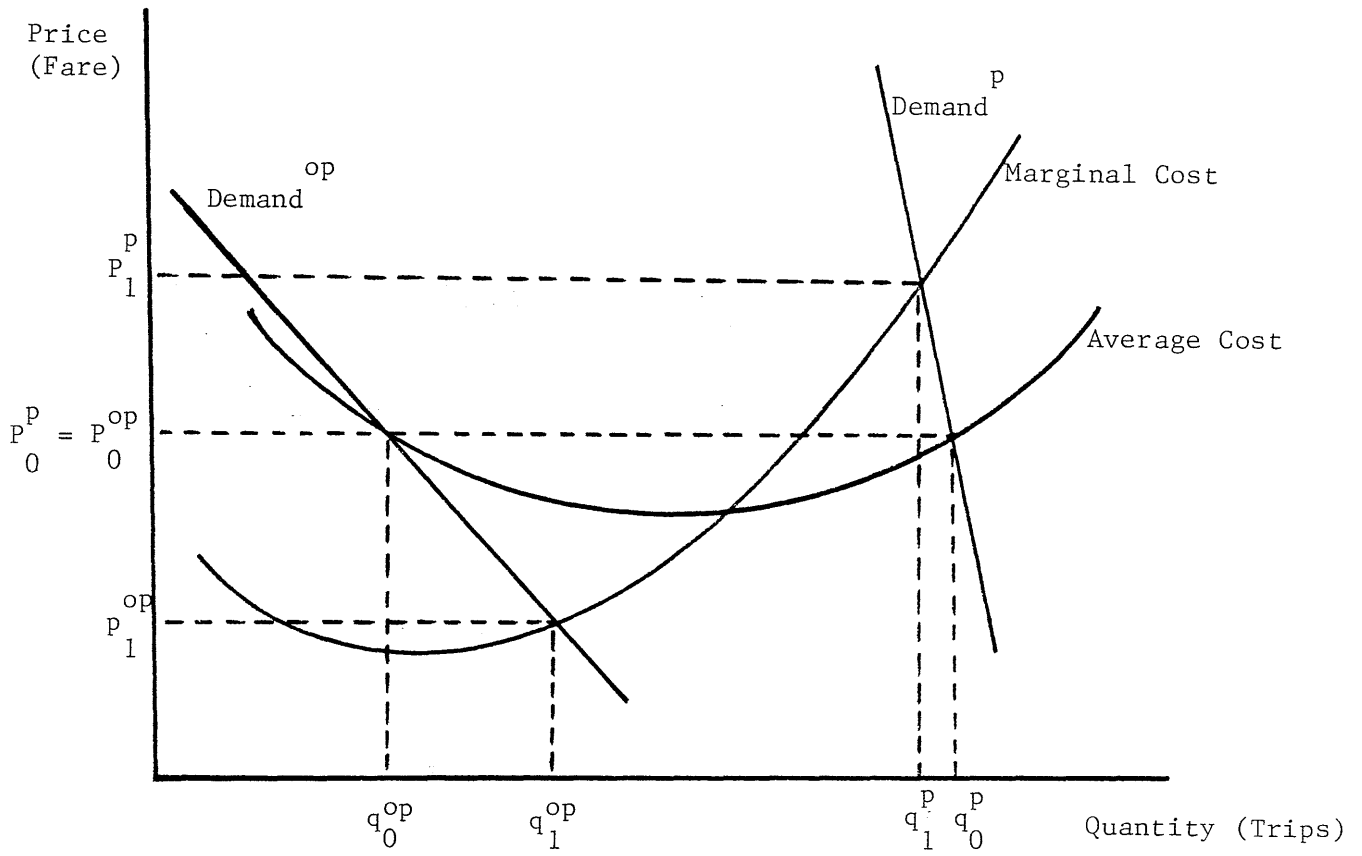


Source: Robert Cervero, "Transit Cross-Subsidies", Transportation Quarterly, July, 1982.

- Do fares conform to beneficiary and ability-to-pay principles of equity? Do those who impose the highest cost pay more? Do submarkets cover equal shares of cost?

- A study of San Diego Transit's flat fare system addressed these equity issues. It compared the fare per mile to the cost per mile for different submarkets. Those paying disproportionately more relative to their costs were short distance, off-peak users who were unemployed, female, autoless, and making non-work trips. Thus, captive users were generally covering higher shares of costs than choice users.

V - 5 Differential Fares



- The cost curves show initial increasing returns to scale. At certain threshold demand levels, system capacity is being approached, reflecting diminishing returns ($MC > AC$).
- Current fare system is flat where $p_0^P = p_0^{OP}$ (price of peak and off-peak services are equal).
- This is clearly inefficient since the marginal cost (MC) of peak services far exceed price -- peak users draw upon resources that could have provided greater economic satisfaction if used elsewhere.
- Pricing peak and off-peak services at their respective marginal cost provides the most efficient and equitable fare structure.
- Overall ridership increases: $q_1^{OP} - q_0^{OP} > q_0^P - q_1^P$
- Revenues increase. Gains in revenue (shaded rectangles) exceed loss in revenue (unshaded rectangles).
- More equitable from an ability-to-pay standpoint. Peak users generally have higher incomes than off-peak users.
- Overall, then, efficiency and equity criteria are both satisfied by differential (marginal cost) transit pricing.

V - 6
**Outline Procedure for Evaluation
of Service**

1. Translate service change or service segments into estimates of changes or levels in:
 - Vehicle hours of service
 - Cost per vehicle hour (peak and off-peak)
 - Ridership (occupancy, trip length)
 - Average revenue per passenger (by distance, peak or off-peak, fare type)

2. Calculate incremental costs and revenues for each segment or alternative.

3. Evaluate changes or service segments according to suitable criteria:
 - Incremental net revenues (revenues exceed costs or cost savings exceed revenue loss).
 - Incremental effect on the systemwide operating ratio (increase or decrease).
 - Incremental contribution to deficit meets some prespecified standard with respect to subsidy per vehicle hour or per passenger.

- Not all dimensions of detail are needed for all questions. If, for example, the peak versus off-peak distribution is not affected by the service change or component, the distinction is not necessary.
- All increments should be relative to a base and estimated systemwide, whether or not they occur on the segment under study.
- Criteria listed pertain to efficiency, but equity impacts may also be relevant to decisions about implementing fare or service changes.
- Determining efficient actions to take in transit is not easy, since almost any reduction in service will reduce the total deficit. Different criteria may be relatively more applicable to different decisions. The subsidy per passenger trip or passenger mile is probably one of the more useful indicators.

EXERCISE ON COSTS

From the data given below, calculate the indicated measures. "Existing" refers to current service, and "Proposed" refers to estimated conditions after a set of changes has been implemented.

	Existing	Proposed
Operating Labor hours per vehicle hour	1.2	1.3
Operating Labor com- pensation rate	\$20	\$20
Other Operating Costs per vehicle hour	\$10	\$10
Annual Vehicle Hours	100,000	120,000
Passengers per vehicle mile	2.0	2.4
Miles per hour	15	15
Average fare per pass.	\$.50	\$.50
Cost per Vehicle Hour		
Total Cost		
Revenue per Veh. Hr.		
Deficit per Veh Hr.		
Total Passengers		
Cost per Passenger		
Deficit per Passenger		

EXERCISE ON ELASTICITIES

Suppose that for bus rides, the income elasticity of demand is -0.2 ; and the price elasticity of demand is -0.4 . Assume that this year 100,000 rides are being consumed, the price is \$1.00 per ride, and the average income per person is \$6,000.

- a. If the income per person is expected to be \$6,300 next year but the price remains \$1.00, estimate the number of rides that will be consumed next year.
- b. Suppose that a fare hike is imposed this year which raises the price to \$1.20. Estimate the reduction in the number of rides.

GROUP PRESENTATION PROBLEM

For the policy options described in the following pages, choose one alternative to the existing service to analyze and present to the "Board". Presently, 40-passenger buses operate along the Westway corridor of Metropolis, a medium-size west coast city. Metropolis is the financial, retail, and distributional hub for a large agricultural and forest product region. It is experiencing a healthy growth rate of 2 percent per year. Several large high-technology firms, moreover, have moved to Metropolis within the past five years.

Presently, buses operating along the Westway corridor feed into residential neighborhoods and then provide line-haul connections to the regional downtown. Generally, middle-income, white-collar workers who are employed in downtown patronize services along the corridor. A flat fare of 60 cents is charged along the twenty-mile service corridor.

Metropolis Transit, the regional transit agency, presently recovers around 40 percent of its costs through the farebox. The Board wishes to increase this to over 50 percent within the next two years in response to declining state and federal operating assistance. The board's overriding objective is to introduce various services and pricing changes that are efficient and that promise to reduce deficit levels.

Groups of four persons (or less) are to choose one of the following four policy options being considered by Metropolis Transit's board:

- * Change in service levels: substitution of articulated for conventional buses, holding capacity constant.
- * Change in capacity: increase in capacity using articulated buses, holding headways constant.
- * Change in service design: conversion from a standard to a feeder/line-haul route design.
- * Change in fares: switch from a flat to a peak/off-peak fare structure.

Each group presentation must contain a specific recommendation (pro or con), and must take no more than fifteen minutes. The recommendation must be analytically sound, and buttressed by supporting documentation.

Group Presentation Problem

POLICY OPTION 1: Change in Services Using Articulated vs. Standard Buses

The Board wants to know whether the changeover from standard to articulated buses along the Westway corridor would be an efficient move. No changes in capacity are being sought; rather, the board is interested in knowing whether large buses operating on slightly longer headways are more cost-effective than conventional buses operating more frequently. Given the changes in travel time that would result from a conversion to articulated buses, would the articulated bus policy be an efficient, deficit-reducing one?

POLICY OPTION 2: Change in Service Quality by Expanding Capacity

Another policy option the board is interested in is the efficiency potential of increasing capacity while keeping headways constant. This would involve the conversion to 60-passenger articulated buses that operate as frequently as standard 40-passenger buses. The major benefit to users would be an increase in the probability of getting a seat from .80 (before the conversion to articulated buses) to 1.0 (after the conversion to articulated buses). Using available cost and elasticity information, would this be an efficient strategy for the Westway corridor?

POLICY OPTION 3: Service Design Options

Conventional 40-passenger buses operating along the Westway corridor presently circulate through residential neighborhoods to pick up passengers and then provide mainline connections to downtown (e.g., standard collection). Thus, no transfers are necessary under the current arrangement. The Board is considering converting to a feeder/line-haul arrangement (whereby passengers would now have to transfer at designated transit centers) at a cost savings of 10 percent. Under this arrangement, 20-passenger vans would serve as feeders and conventional buses would provide the line-haul connections. Using cost and travel time data provided, is the conversion from a standard collection to a feeder/line-haul service an efficient policy?

POLICY OPTION 4: Peak/Off-Peak Fare Differential

Given differences in costs of peak versus off-peak services, the board is interested in possibly converting from the present flat fare system to one involving a time-of-day differential. What might be an appropriate differential? Indicate how you allocated fixed and variable costs in arriving at this differential. What would be the likely ridership and fiscal impact of this fare differential? What might be the equity and fare collection implications of switching from a flat to a peak/off-peak fare structure?

Cost Data For Westway Corridor

<u>Cost Component:</u>	<u>Type of Service</u>	
	<u>Standard Collection (Non-transfer service)</u>	<u>Feeder and Line Haul (Transfer Required)</u>
Capital	\$1,000,000	\$900,000
Maintenance	500,000	450,000
Labor	2,000,000	1,800,000
Other	500,000	450,000
Total	\$4,000,000	3,600,000

<u>Vehicle Type:</u>	<u>Cost Per Hour</u>	
	<u>Labor</u>	<u>All other</u>
Articulated (60 Passenger)	\$20.00	\$30.00
Conventional (40 Passenger)	20.00	20.00
Vans (20 Passenger)	20.00	10.00

<u>Time-of-Day Characteristics</u>			
<u>Submarket:</u>	<u>Hours of Operation</u>	<u>Passengers</u>	<u>Labor Cost</u>
Peak	50,000	2,000,000	\$1,300,000
Base	50,000	1,000,000	700,000
Total	100,000	3,000,000	2,000,000

Passenger Data For Westway Corridor

Elasticities

	<u>Price</u>	<u>Travel Time</u>	<u>Seat Probability</u>
Peak	-0.2	-1.0	0.5
Off-peak	-0.4	-0.6	0.5

Average Trip Times

<u>Service Type:</u>	<u>Conventional Bus</u>	<u>Articulated Bus (Same Capacity)</u>	<u>Articulated Bus (Same Schedule)</u>
Standard	25 minutes	28 minutes	25 minutes
Feeder	10 minutes	10 minutes	10 minutes
Line-haul	20 minutes	22 minutes	20 minutes

Fare = \$0.60

PREFACE

This presentation outline was prepared for use in a Workshop on Application of Transportation Economics to the Evaluation of Urban Transit Service held in Portland, OR, August 4-5, 1986. The outline is intended to facilitate replication of the Workshop in other locations, either with the same or different instructors. The outline is not designed to serve as a self-paced instruction manual, however. Experienced economists with considerable knowledge and experience in transportation are necessary.

Anthony Rufolo, Professor of Urban Studies and Planning, Portland State University, served as the lead instructor. Robert Cervero, Associate Professor, University of California-Berkeley and Douglass Lee, Jr., Research Investigator, Transportation Systems Center, Cambridge, MA, also served as instructors in this initial offering of the workshop in Portland. They pooled their experience and materials and produced a highly efficient short course and supporting materials. This Presentation Outline is the product of their effort and is being disseminated to insure this significant effort is not lost and will benefit others.

The purpose of workshops supported with this presentation outline is to provide transit professionals with the basic economic concepts needed to evaluate the impact of a change in price or service characteristics; to gain sufficient understanding of the concepts to communicate the results to others, particularly with governing board members.

Workshops using this material are designed for professionals working in public transportation. Professionals in public transportation come from many fields, such as law, marketing, finance, personnel, public administration, planning, and engineering. Even those who have had training in economics may have difficulty in applying it to public transportation, and will find this material useful.

Experience gained from the initial offering of the Workshop resulted in modification of the presentation materials, which are reflected in this document. The instructors found that the prepared materials facilitated presentation and they were able to present the material in less time than originally estimated. This, in part, reflects the audience having a better background in economics than was anticipated. The self selection process associated with choosing to come to the Workshop resulted in a higher level of attendee. It is difficult to turn out those most in need of the transportation economics training. The following schedule reflects the original estimate of times to deliver the material to the intended audience.

The supporting materials were prepared by the instructors for the Workshop held under the auspices of the Center for Transit Research and Management Development. Portland State University,

and funded by the University Research and Training Program, Urban Mass Transportation Administration, U.S. Department of Transportation.

I am grateful to the instructors for their instructional efforts and for the additional effort required to prepare this Presentation Outline to facilitate replication of the course elsewhere and by others. I am also grateful to William Benz and Denise Penner for their assistance in preparing for the Workshop and with the supporting material.

Kenneth J. Dueker
Co-Director, Center for Transit Research and Management
Development, and
Director, Center for Urban Studies
School of Urban and Public Affairs
Portland State University

Schedule

Monday

9:00	Introduction	Cervero, Dueker, Lee, Rufolo
10:00	Coffee	
10:15	Submarkets	Cervero
11:15	Mode Choice	Rufolo
12:00	LUNCH	
1:30	Elasticity	Rufolo
3:00	Break	
3:15	Costs	Lee
5:00	Reception	

Tuesday

9:00	Costs (continued)	Lee
10:00	Break	
10:15	Synthesis	Cervero
11:30	Form Workshop Teams	Cervero
12:00	LUNCH	
1:00	Team Preparation	
2:00	Presentations	
4:00	Wrap-up	Dueker

- The shifts in demand as service characteristics change can be summarized as a relationship between those service characteristics and quantity. This can be thought of as a demand curve which holds price and other factors constant. It shows how ridership would change at the existing fare structure if service were changed in a certain way.

- Generally the service characteristics to which people are most responsive are those relating to the time of the trip. However, the other characteristics of the trip such as comfort, convenience, and privacy can also shift the demand curve.

- The figure illustrates a service characteristic versus quantity relationship. It says that given the price and other characteristics of the transit service, changes in the total time needed for the trip will influence the number of riders. In the example, if the trip takes one hour and fifteen minutes, then 3000 people will go. However, if the trip time is only half an hour, then more than 5000 trips will be made.

V - 6
**Outline Procedure for Evaluation
of Service**

1. Translate service change or service segments into estimates of changes or levels in:
 - Vehicle hours of service
 - Cost per vehicle hour (peak and off-peak)
 - Ridership (occupancy, trip length)
 - Average revenue per passenger (by distance, peak or off-peak, fare type)

2. Calculate incremental costs and revenues for each segment or alternative.

3. Evaluate changes or service segments according to suitable criteria:
 - Incremental net revenues (revenues exceed costs or cost savings exceed revenue loss).
 - Incremental effect on the systemwide operating ratio (increase or decrease).
 - Incremental contribution to deficit meets some prespecified standard with respect to subsidy per vehicle hour or per passenger.

I - 1 Goals

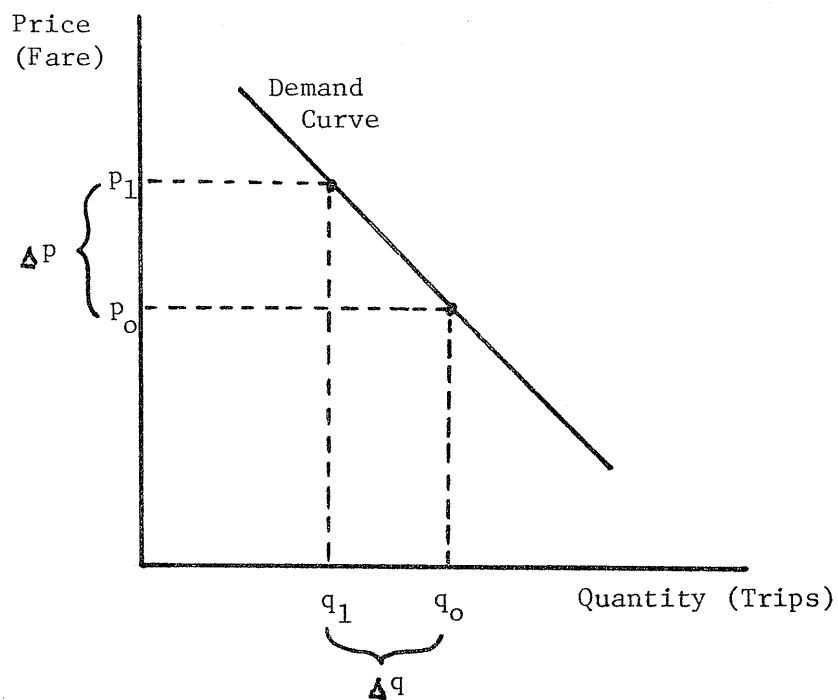
- Efficiency: Most valuable output for society's scarce resources. Evaluated according to willingness-to-pay for output.

- Equity:
 - Benefit Principle: Provide services on basis of contribution to cost.

 - Ability-to-pay: Those with higher income pay larger share of cost relative to service received.

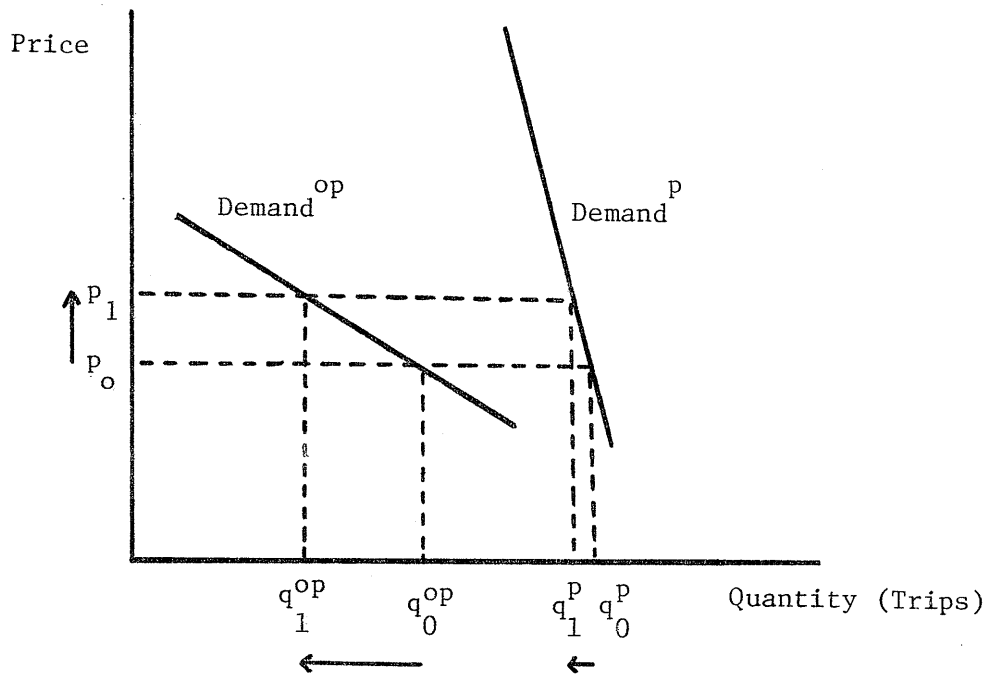
Primary objective in workshop analysis is efficiency.

1 - 2 Demand Curve

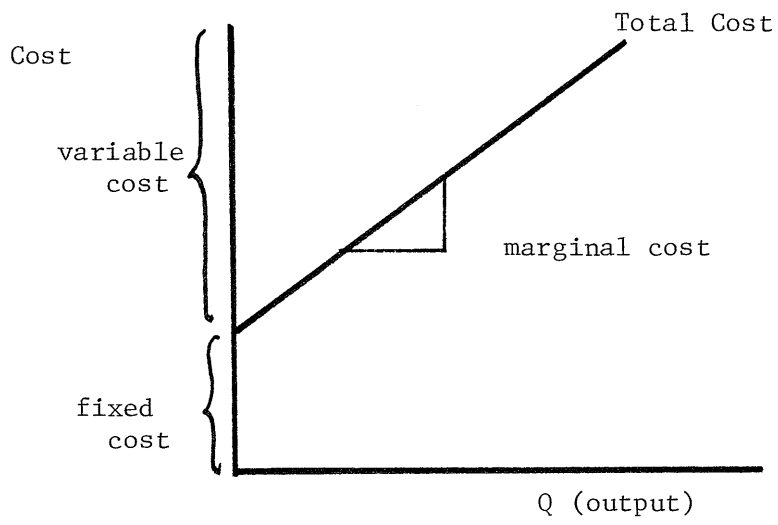


$$\text{PRICE ELASTICITY : } E = \frac{\Delta q/q_0}{\Delta P/P_0} = \frac{\Delta q}{\Delta p} \cdot \frac{P_0}{q_0}$$

1 - 3
Sensitivities of Peak and Off-Peak Ridership



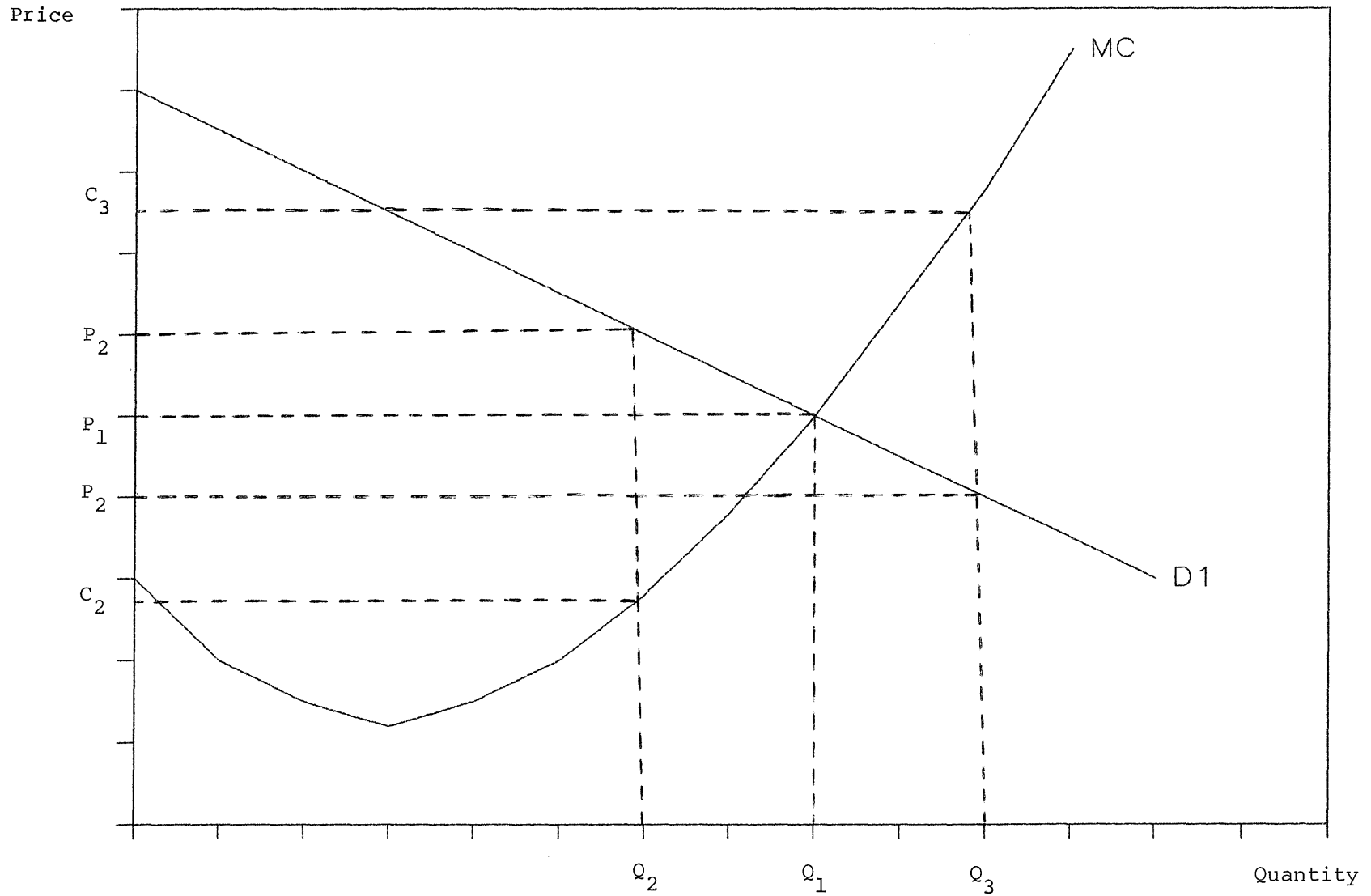
I - 4
Basic Cost Concepts



I-4

- Economic concept of cost is opportunity cost: the value of the output given up by society as a result of diverting resources to the specified purpose.
- Also stated as the value of the resources in their next best use.
- Actual expenditures or price paid are not necessarily equal to cost.
 - e.g., highway wear (no expenditure until replacement)
 - highway space (no price paid; cost is delay)
 - peak operator (requires more than direct cost)
 - depreciation of vehicle (loss of service life)
 - externalities (air and noise pollution)
- Planning concern is with incremental or avoidable costs, or 'marginal' costs.
- Cost estimation can be accomplished by identifying which cost components will be affected by an alternative, and applying a simple 'model.'

I - 5 Efficient Pricing



II - 1 Identifying Submarkets

Submarket Type	Submarket Specification
User	* Demographic -- Age, Sex * Economic -- Income, Occupation * Trip Characteristics -- Purpose, Length
Service	* Operating Environment (e. g., urban vs. suburban) * Service Type (e.g., express vs. local) * Time - of - Day (e. g., peak vs. off-peak) * Mode Type (e. g., rail vs. bus)

II - 2 Inelastic Trips and Users

Non - Discretionary Trips

- * Work
- * Peak Period

Captive Users (Transportation - Disadvantaged)

- * Autoless
- * Young
- * Low Income
- * Disabled

II - 3 User Groups

<u>Submarket</u>	<u>Submarket Group</u>	<u>Price & Service Sensitivity</u>	<u>Comments</u>
AGE	Young Middle Age Senior	Highest Moderate Lowest	More discretion Higher incomes; more choices Most captive
INCOME	Low High	Lower Higher	More captive High auto ownership; high premium on time
AUTO ACCESS	No Car Has Car	Lowest Higher	No substitute options Higher incomes; more choice
TRIP PURPOSE	Work Shop School Medical Recreation	Lowest Higher Lower Lower Highest	Least sensitive in large cities Most sensitive in suburban areas Young tends to be captive Especially low for low-income users Most discretionary trip
TRIP LENGTH	Short Long	Higher Lower	Walk option; fare price high compared to time Typically peak hour, work trips

- Age: Price elasticities fall with age. Based on two cases, the following were estimated: *
 - <16 years: -.32
 - 17-64 years: -.22
 - >64 years: -.14.

- Income: Price elasticities rise with income. From four cases, the following were estimated: *
 - <\$5,000: -.19
 - >\$15,000: -.28.

- Income elasticities do seem to vary be city size, however. In New York City, one study found low income passengers to be most sensitive to fare increases. Where corridors are highly congested and parking is restricted, such as Manhattan, higher income users are fairly insensitive to price changes.*

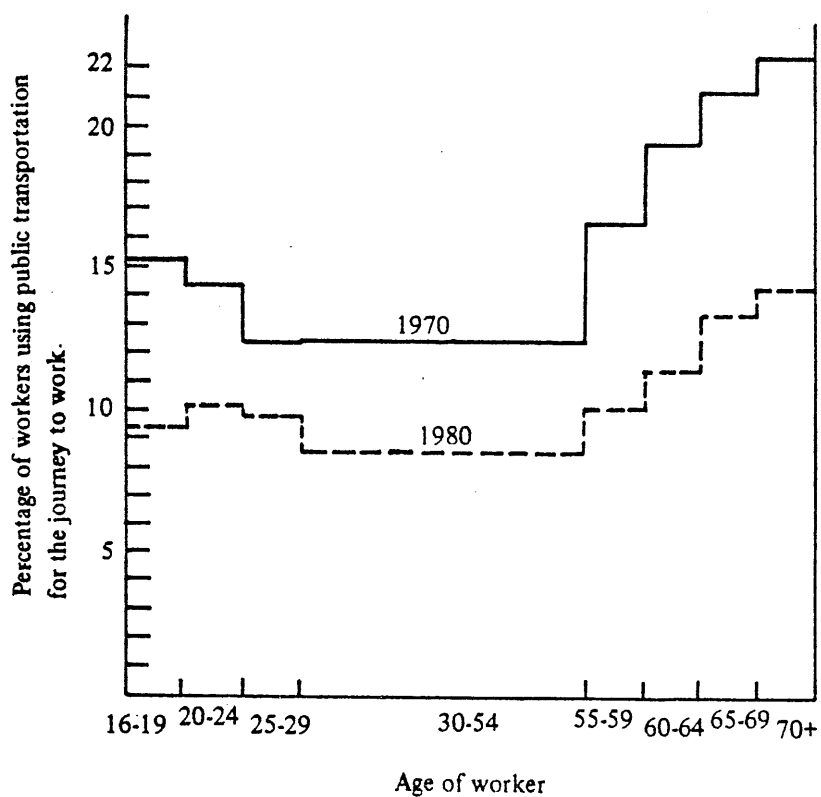
- Auto Availability: This is the strongest indicator of captivity. From two cases, the following were estimated: *
 - no car: -.10
 - car available: -.40.

- Trip Purpose: Work trips are least effected by price changes. Based on six cases, the following were estimated: *
 - work: -.10
 - shop: -.23.

- Trip Length: Short trips are more elastic because there are more travel options (e.g., walking) and fares usually constitute a significant share of total costs (fares plus travel time) to users. A study in London found the following price elasticities: *
 - <1 mile: -.55
 - 1-3 miles: -.29.

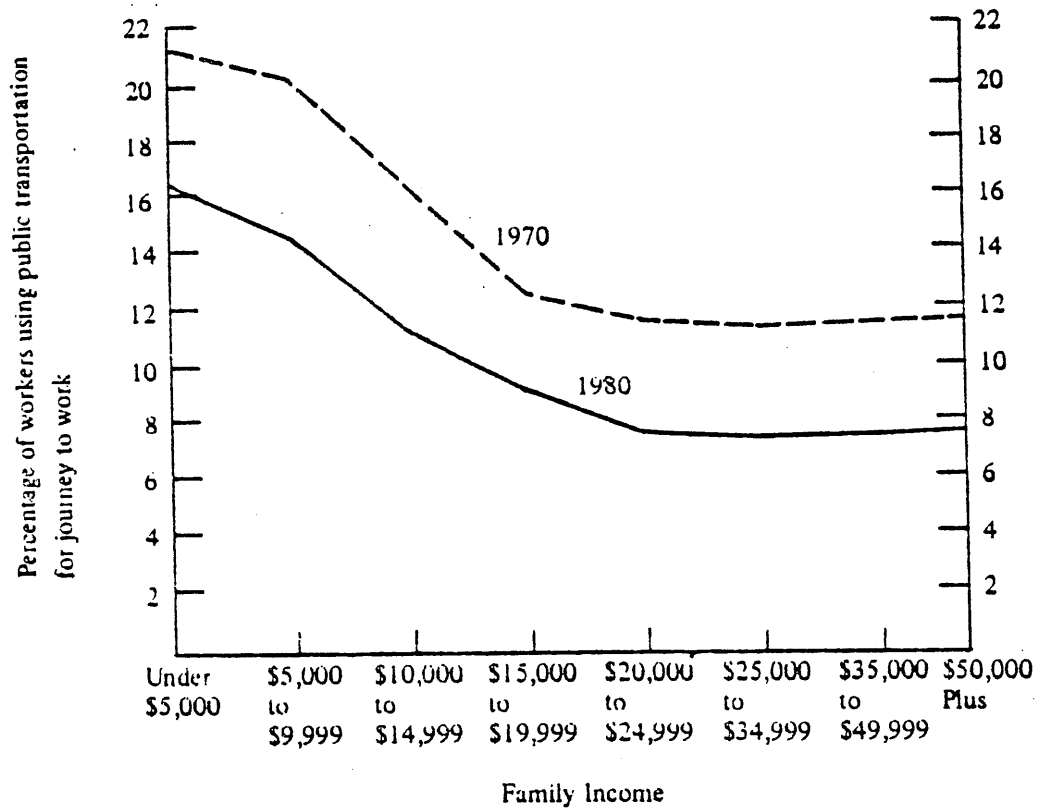
* Source: Ecosometrics, Inc., "Patronage Impacts of Changes in Transit Fares and Services". Report prepared for Urban Mass Transportation Administration, U.S. Dept. of Transportation, 1980.

II - 4 Transit Work Trips by Age



Source: Joint Center for Political Studies, "Demographic Change and Recent Worktrip Travel Trends." Report prepared for the Urban Mass Transportation Administration, U.S. Department of Transportation, 1985.

**II -5
Transit Work Trips by Income**

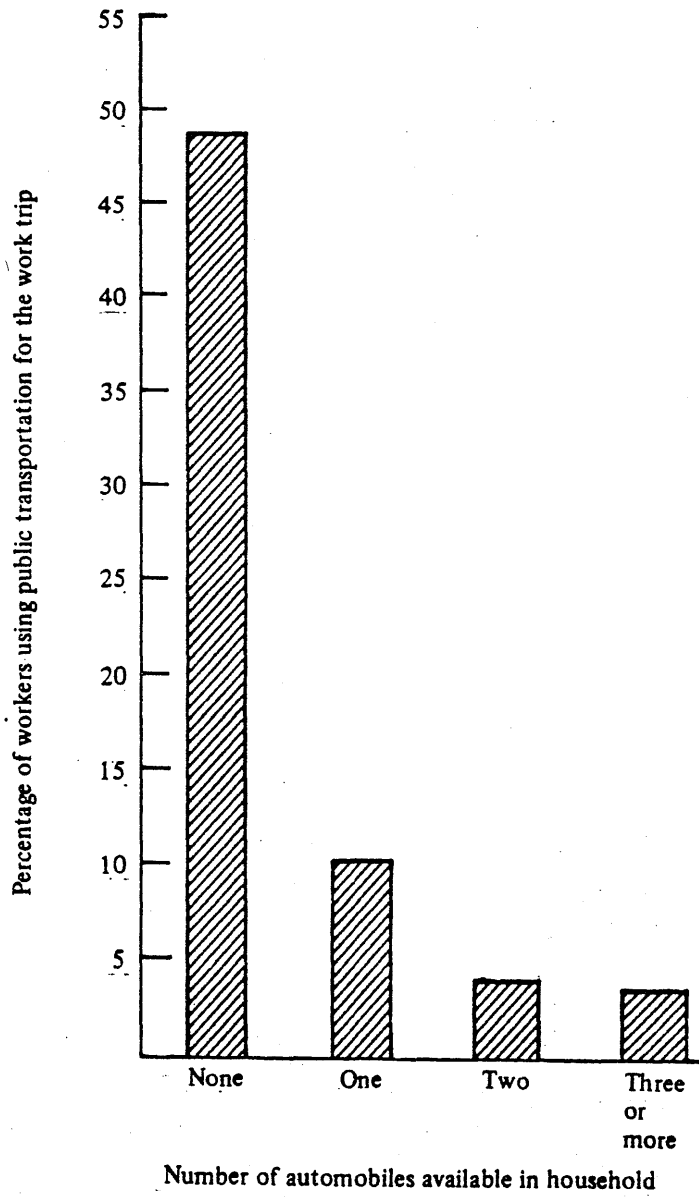


Source: Joint Center for Political Studies, 1985.

II-5

- A strong negative relationship between transit usage and income.
- Families with annual incomes of \$20,000 or more patronize transit the least for work trips.
- The steepest decline in transit usage in 1980 was in the \$5,000 to \$15,000 income range (1980\$s).

II - 6 Transit Work Trips by Auto Availability



Source: Joint Center for Political Studies, 1985.

II-6

- Transit usage for work trips is most strongly related to whether or not someone has a car available.
- While nearly half of families with no auto used transit to get to work in 1980, only 3 percent of those with two or more vehicles patronized transit for work trips.

II - 7 Transit Operating Environment

<u>Type</u>	<u>Submarkets</u>	<u>Price & Service Sensitivity</u>	<u>Service Characteristics</u>	<u>Cost/Rider</u>
	Density:			
	Low	High	High speeds, long headways, circuitry	High
	High	Low	Slower, more frequent, more crowded	Low
LAND USE	Composition:			
	Single-Use	High	Long headways, circuitous routing	High
	Mixed-Use	Low	Slower, more frequent	Low
	Intrasuburban	Higher	High speeds, long headways, circuitry	High
	Intraurban	Lowest	Slower, more frequent, most ubiquitous	Low
LOCATIONAL SETTING/ CORRIDORS	Intra-CBD	Highest	Slowest, most frequent, most congested	Low
	Suburb-to-City	Varies	Express, radial, limited-stop, fast	High
	City-to-Suburb	Varies	Less frequent, circuitous, cross-town	High

II - 8
Locational Changes in Work Trips

Type of Journey-to-Work Trip	Percent of Work Trips		
	1960	1970	1980
Within the central city	47.2	37.6	31.7
Central city to suburbs	5.2	7.5	6.6
Suburbs to central city	17.1	18.6	19.8
Within the suburbs	<u>30.5</u>	<u>36.3</u>	<u>41.9</u>
Total	100.0	100.0	100.0

Source: Philip N. Fulton, "Changing Journey-to-work Patterns: The Increasing Prevalence of Commuting Within the Suburbs in Metropolitan America", Paper presented at the Annual Meeting of the Transportation Research Board, Washington, D.C., January, 1986.

II - 9
Percent of 1980 Work Trips by
Mode

Type of Journey-to-Work Trip	Percent				Total
	Drive Alone	Carpool	Public Trans- portation	Other Means or Worked At Home	
Within the central city	56.1	16.3	16.1	11.5	100.0
Central city to suburbs	69.3	22.1	5.6	3.0	100.0
Suburbs to central city	68.1	22.2	8.0	1.8	100.0
Within the suburbs	<u>69.7</u>	<u>17.8</u>	<u>1.6</u>	<u>10.9</u>	<u>100.0</u>
Total	64.9	18.4	8.0	8.7	100.0

Source: Philip N. Fulton, 1986.

**II - 10
Service Submarkets**

Type	Submarkets	Price/ Service Sensitivity	Service Characteristics
Service:	Radial Express	Higher	High speed, limited stop, long headways
	Local, regular	Lower	Slower, more frequent, more crowded
Mode Type	Conventional Bus	Higher	More flexible, lower density markets
	Heavy rail	Lower	Less flexible, higher density markets
Time-of-day	Peak	Lower/Higher	More frequent, more crowded
	Off-peak	Higher/Lower	Less frequent, less crowded

II - 11 Modal Options

	Private	For-Hire	Public or Common Carrier
<u>Modes:</u>	Automobile Motorcycle Bicycle Walking	Taxi Jitney Dial-a-ride Charter bus	Conventional Bus Light Rail Heavy Rail
<u>Best Operating Environment:</u> Density Trip Patterns Trip Purpose	Low - medium Dispersed All	Low Dispersed Business, medical, Shop	Medium - high Concentrated Radial Work, shop, business
<u>Price/Trip:</u>	Automobile travel price is high and low travel time	Generally high travel price and moderate travel time	Generally low travel price and high travel time

Source: Vucan R. Vichic, "Urban Passenger Transport Modes." In George E. Gray and Lester A. Hoel, Public Transportation: Planning, Operations, and Management. Englewood Cliffs, New Jersey: Prentice-Hall, p. 69.

II - 12
**Average Travel Time for Work
 Trips**

Mode of Transportation	Average Travel Time
Automobile	20.8 Minutes
Other private vehicle	22.7 Minutes
Autos plus other private vehicles	21.1 Minutes
Bus or streetcar	37.8 Minutes
Subway or elevated trains	47.4 Minutes
Railroad	63.8 Minutes
Taxi	18.6 Minutes
All public transportation	42.2 Minutes
Walked only	10.2 Minutes
All Modes	22.5 Minutes

Source: Joint Center for Political Studies, 1985.

III - 1
Key Factors in Mode Choice

- Money Price
 - * Fixed
 - * Variable
- Time
 - * In Vehicle
 - * Waiting
 - * Walking
 - * Transfer
- Travel Characteristics
 - * Reliability
 - * Comfort
 - * Security
 - * Flexibility
 - * Privacy

III - 2 User Cost Calculation

<u>Cost Component</u>	<u>Transportation Type</u>		
	<u>Bus</u>	<u>Car</u>	<u>Walking</u>
Fixed	0	2.00	0
Variable	1.50	2.00	0
Time	45 min.	15 min.	2 Hrs.

Total Cost
With Time
Valued At:

\$1.00 per hr.	\$2.25	\$4.25	<u>\$2.00</u>
\$4.00 per hr.	<u>\$4.50</u>	\$5.00	\$8.00
\$8.00 per hr.	\$7.50	<u>\$6.00</u>	\$16.00

Variable Cost
With Time
Valued At:

\$1.00 per hr.	\$2.25	\$2.25	<u>\$2.00</u>
\$4.00 per hr.	\$4.50	<u>\$3.00</u>	\$8.00
\$8.00 per hr.	\$7.50	<u>\$4.00</u>	\$16.00

III - 3 Elasticity

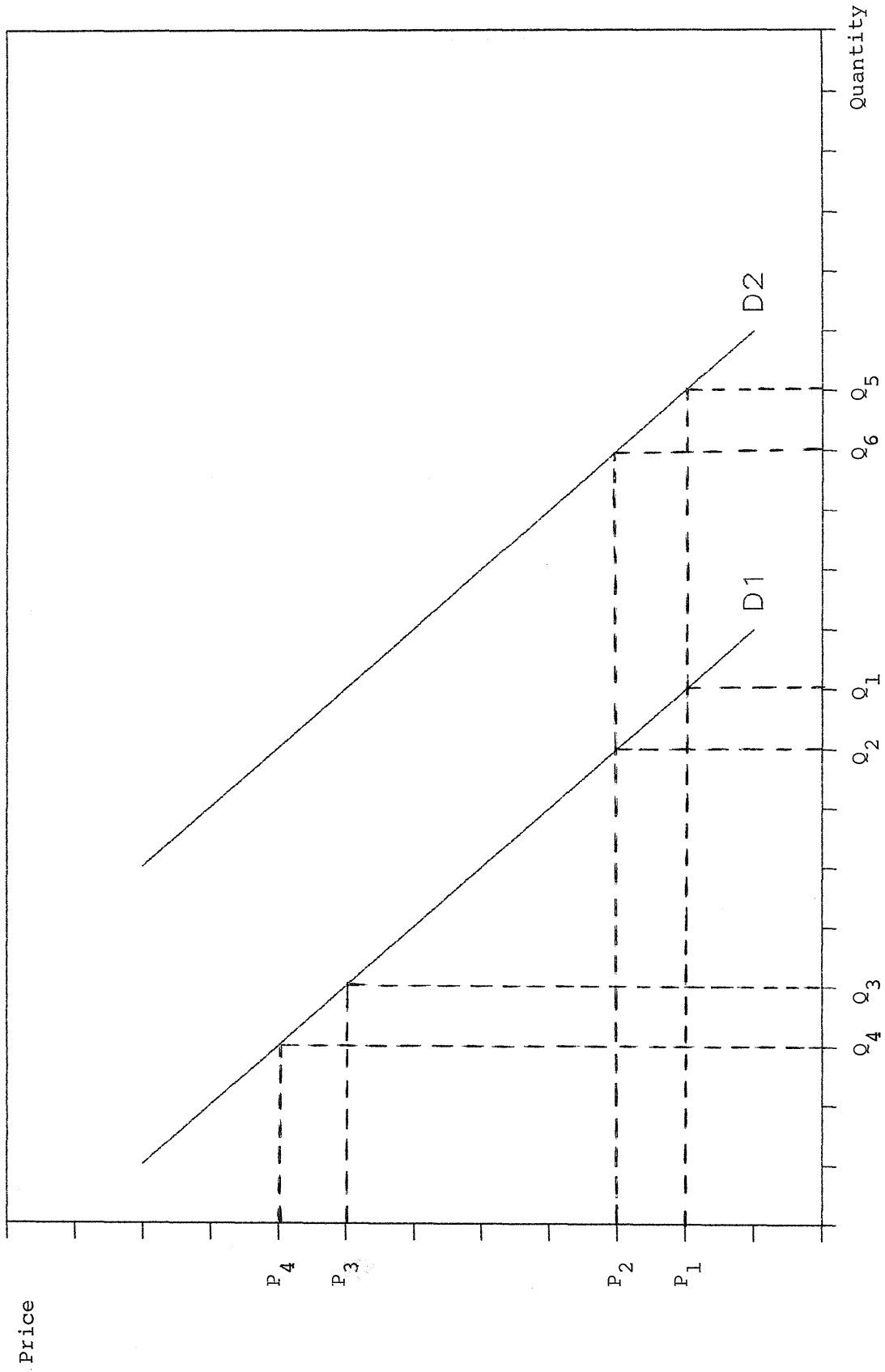
Definition: Elasticity is the percentage change in quantity divided by the percentage change in price

$$= (\Delta Q/Q) / (\Delta P/P)$$

$$= (\Delta Q/\Delta P) / (P/Q)$$

Elasticity	< 1	Inelastic
	= 1	Unit Elastic
	> 1	Elastic

III - 4 Elasticity and Slope



III - 5 Revenue and Elasticity

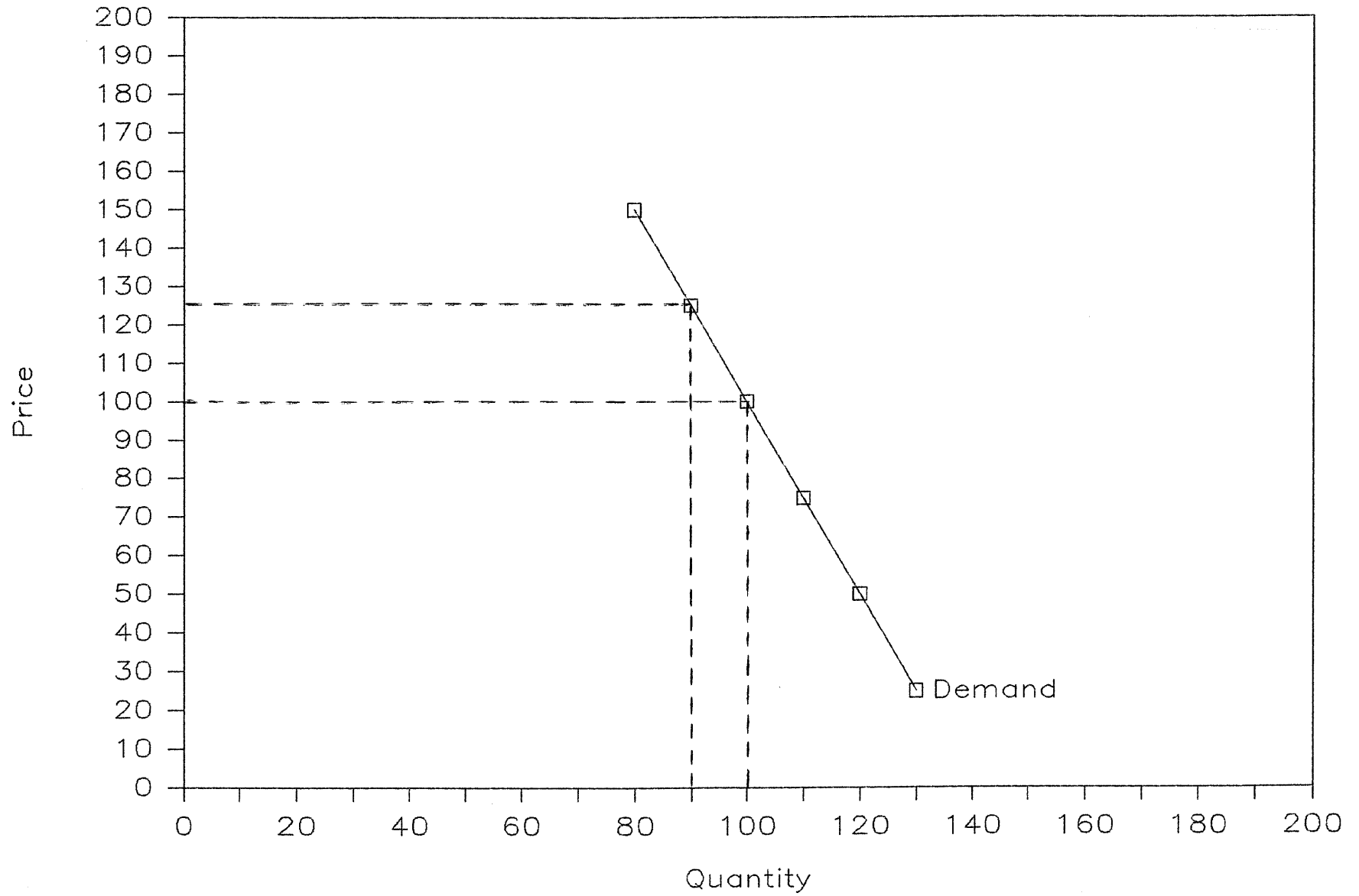
- Revenue = $P * Q$
- As P goes up, Q goes down; and vice versa

- Inelastic:
 - $\% \text{ change } Q < \% \text{ change } P$
 - The change in P dominates, so revenue rises and falls with P

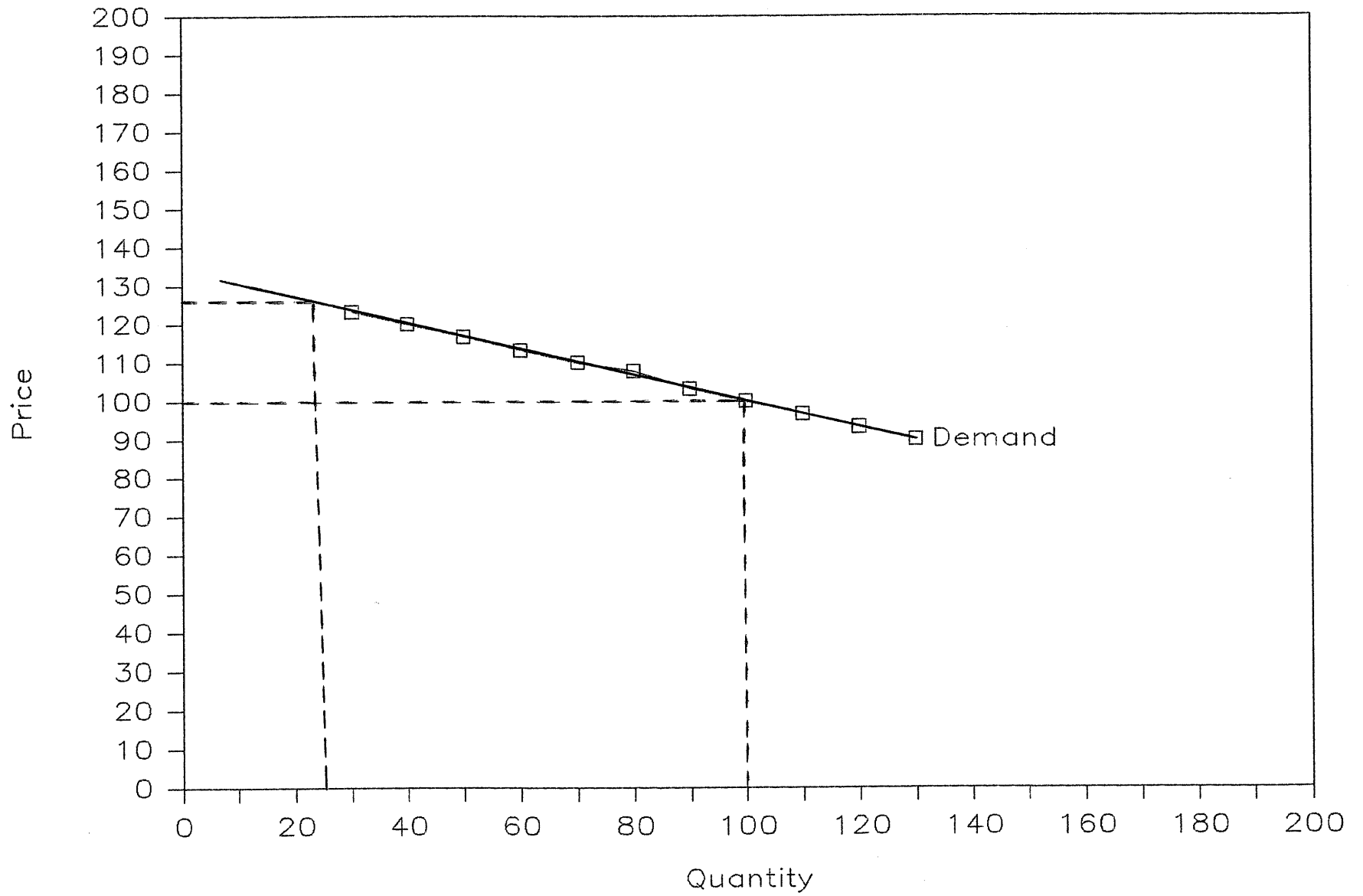
- Elastic:
 - $\% \text{ change } Q > \% \text{ change } P$
 - The change in Q dominates and changes in revenue are in the opposite direction from changes in P .

- Unit Elastic:
 - $\% \text{ change in } Q = \% \text{ change in } P$
 - Revenue is constant as price changes.

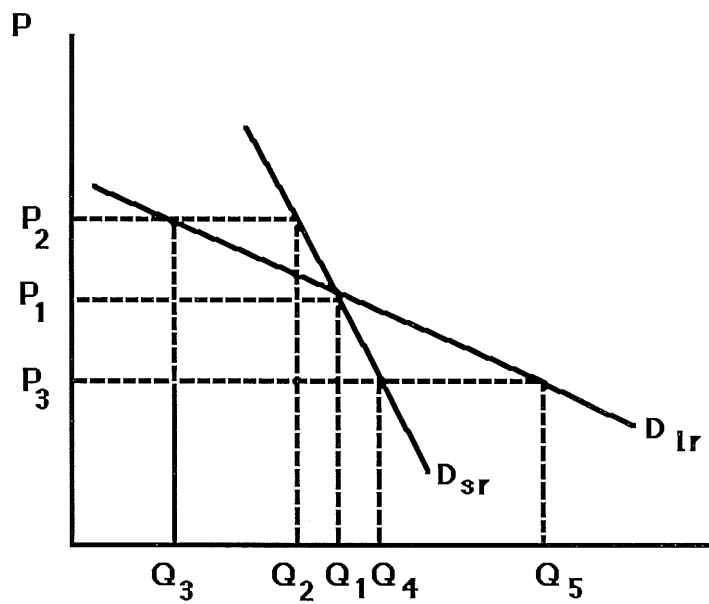
III - 6 Inelastic Demand



III - 7 Elastic Demand



III - 8
All Elasticities are Greater in Long
Run



III - 9
Responses to Price Increases

All Prices Rise

- *Walk
- *Carpool
- *Single Car
- *Stay Home

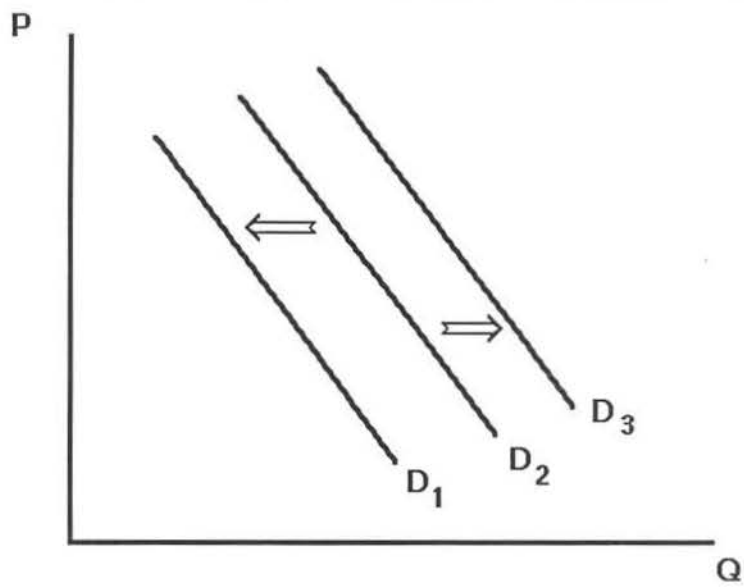
Only Peak Price Rises

- *Travel At Off Peak
- *All of Above

Long Run

- *Move Residence
- *Change Jobs
- *Buy Car

III - 10
Demand Shifts



III - 11
Shift Factors

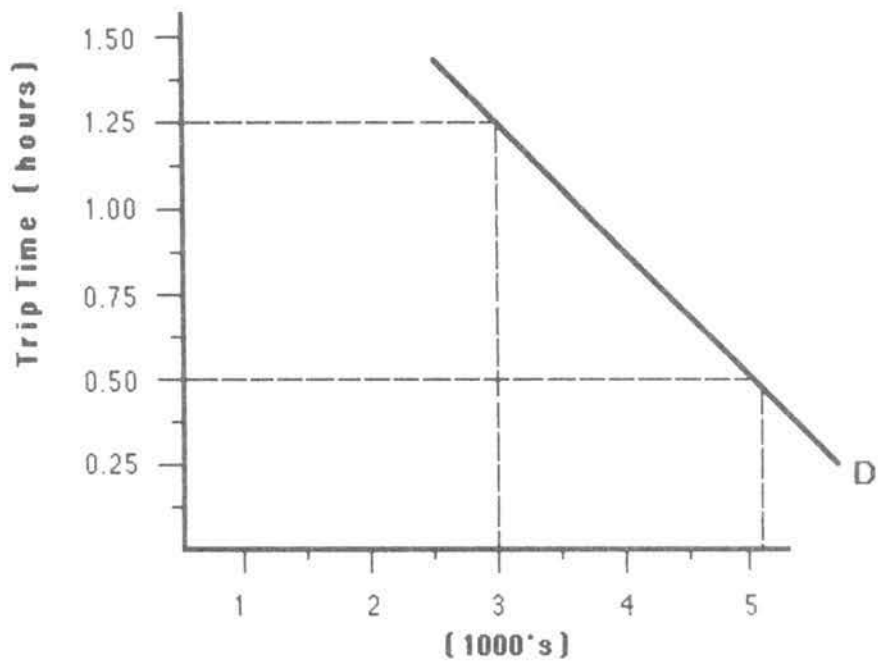
- * Taste
- * Income
- * Price of Alternatives
- * Availability of Alternatives
- * Location Patterns
- * Value of Time
- * Service Characteristics

III - 12 Estimates of Service Elasticities

	Peak	Off-Peak	All Hours
Headway Elasticities			
Bus	-0.37	-0.46	-0.47
Commuter Rail	-0.38	-0.65	-0.47
Vehicle-Miles Elasticities			
Bus	+0.33	+0.63	+0.68
Rapid Rail	+0.10	+0.25	+0.55
Total Travel-Time Elasticities			
Bus	-1.03		-0.92
Bus and Rapid Rail		-0.59	
In-Vehicle-Time Elasticities			
Bus (Quasi-Experimental)	-0.29	-0.83	
Bus (Non-Experimental)	-0.68	-0.12	
Rapid Rail	-0.70		
Bus and Rapid Rail	-0.30		-0.27
Commuter Rail			-0.59
Total Out-of-Vehicle Time Elasticities			
Bus and Rapid Rail			-0.59
Walk-Time Elasticities			
Bus	-0.26	-0.14	
Wait-Time Elasticities			
Bus and Rapid Rail	-0.20	-0.21	-0.54
Transfer-Time Elasticities			
Bus and Rapid Rail	-0.40		
Number-of-Transfer Elasticities			
Bus		-0.59	

Source: Lago, Armando M., Mayworm, Patrick, and McEnroe, J. Matthew, "Transit Service Elasticities," Journal of Transport Economics And Policy 15,2 (May 1981), pp. 99-119.

III - 13
Demand as a Function of Service
Characteristics



III - 14
Other Modes

- * Congestion Increases Time Cost
- * Gasoline Prices Increase
- * Rain Makes Walking Unpleasant
- * Bicycles Provided With
Separate Paths.

Availability May Also
Be Very Important

- * Gasoline Shortages
- * Parking Availability

III - 15
Cross-Price Elasticity of Demand

Definition: % change in Q
divided by the %
change in the
price of another
good.

Positive value implies
goods are substitutes.

Negative value implies
goods are complements.

III - 16
Income Elasticity of Demand

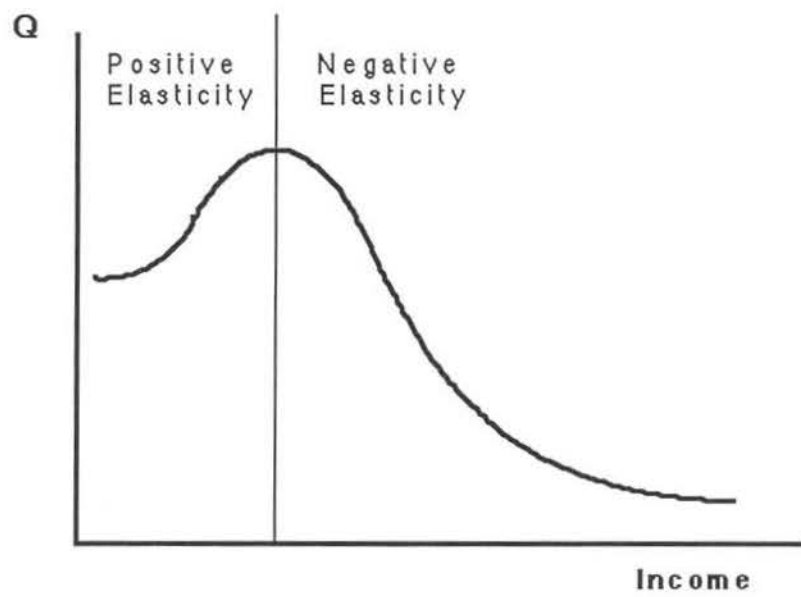
Definition: % change in Q divided
by the % change in
income

A positive value defines a
"normal" good.

A negative value defines
an "inferior" good.

Transit has a negative income
elasticity of demand.

III - 17
Income Elasticity of Transit
Demand

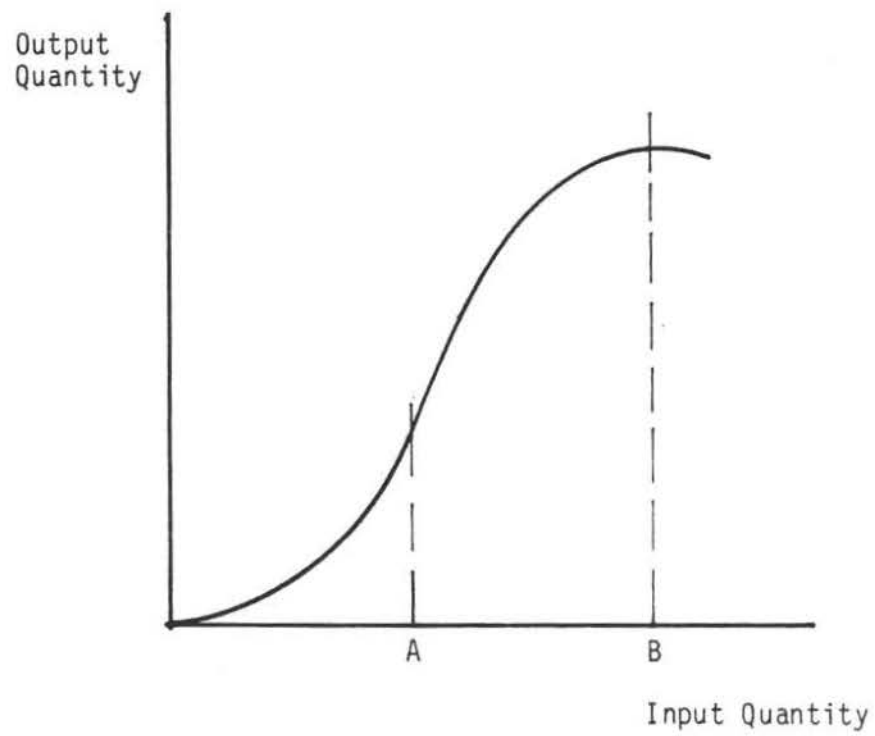


IV - 1 Cost Distinctions and Terms

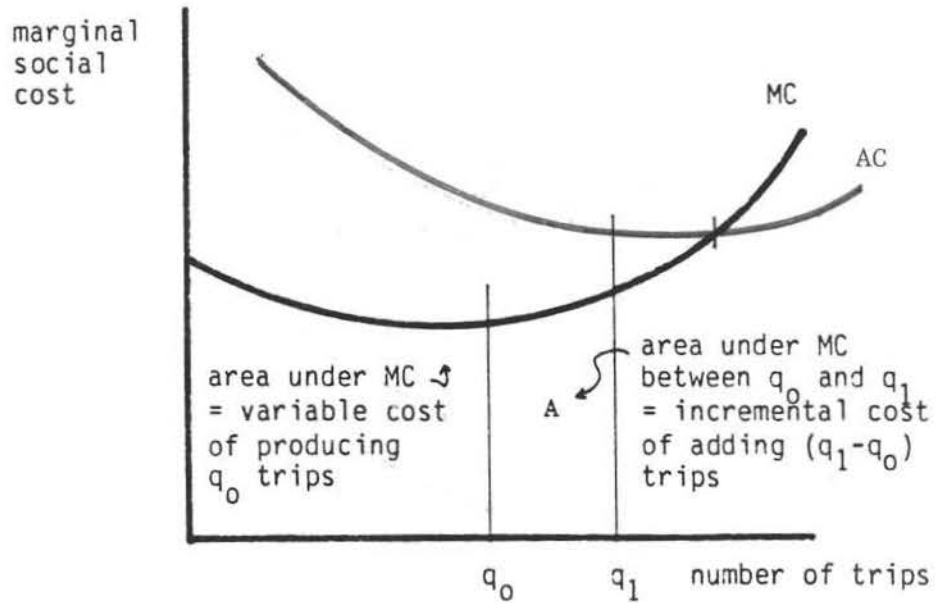
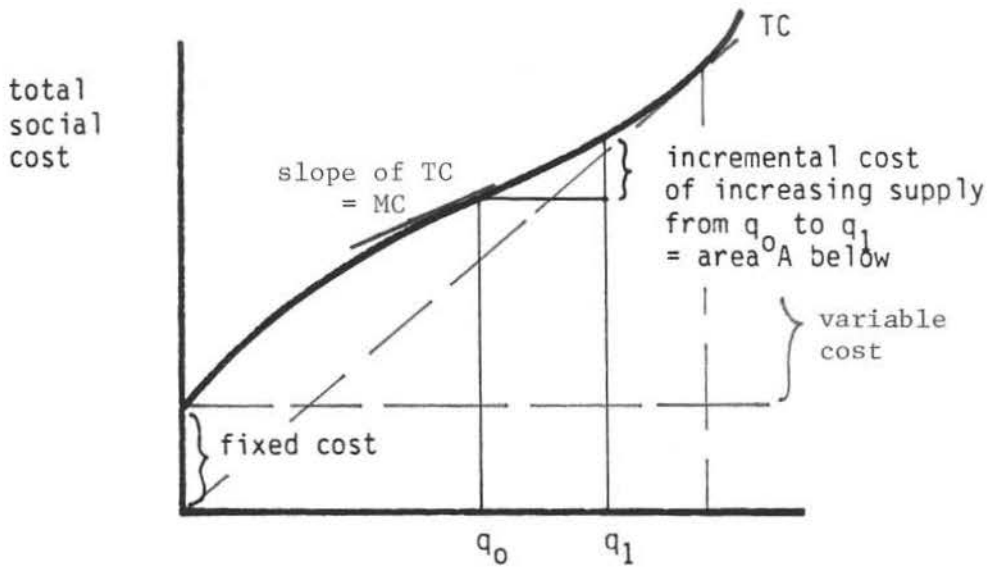
Terms

Capital	vs. Operating	Lifetime greater than one year
Variable	vs. Fixed	Varies with output (output = service, passengers)
Marginal	vs. Average	Effect of a one-unit change in output
Incremental	vs. Total	Effect of an alternative, relative to a base case
Avoidable	vs. Sunk	Only avoidable costs are of interest
Short Run	vs. Long Run	Short run is temporary or transitional
Production	vs. Deployment	Two phases in transit service supply

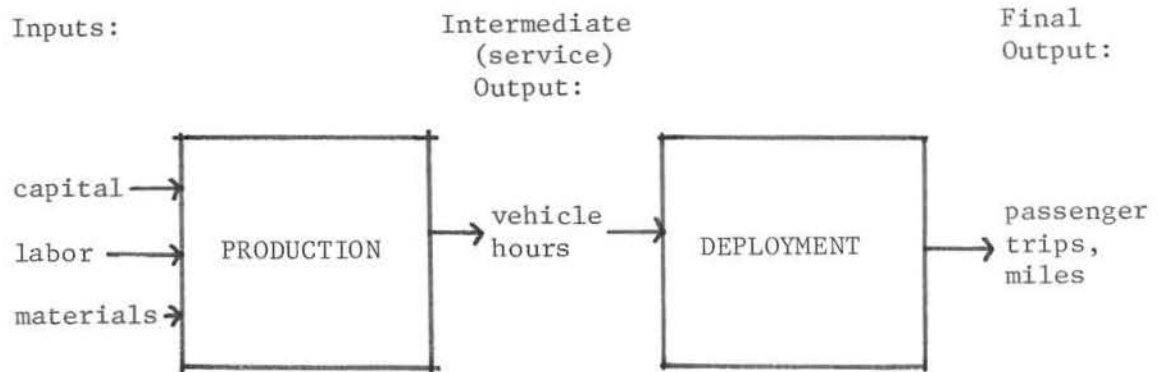
IV - 2
A Production Function, with One
Input



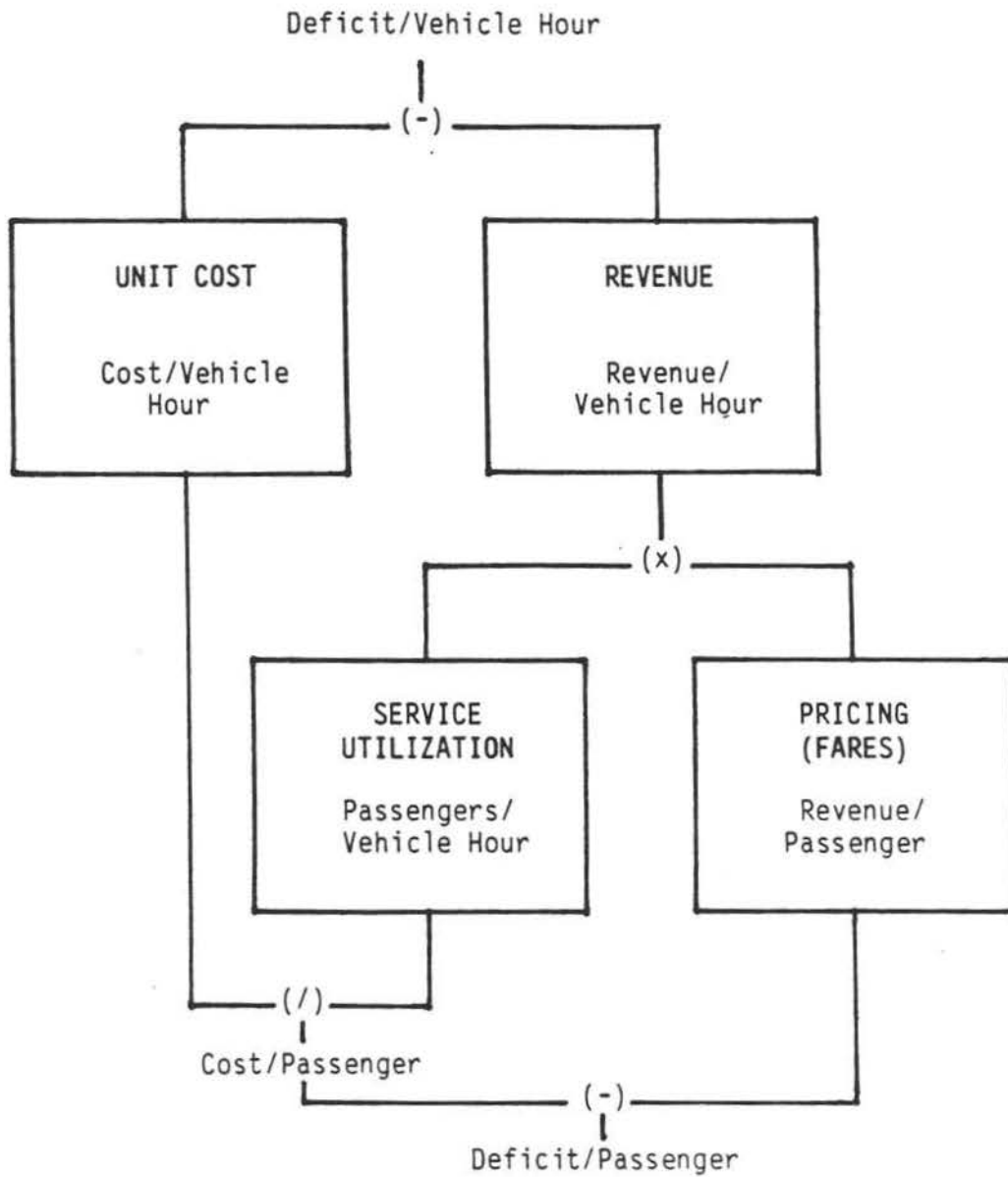
IV - 3 Total, Marginal, and Average Cost Functions



IV - 4 Two Phases in Supply of Transit Services



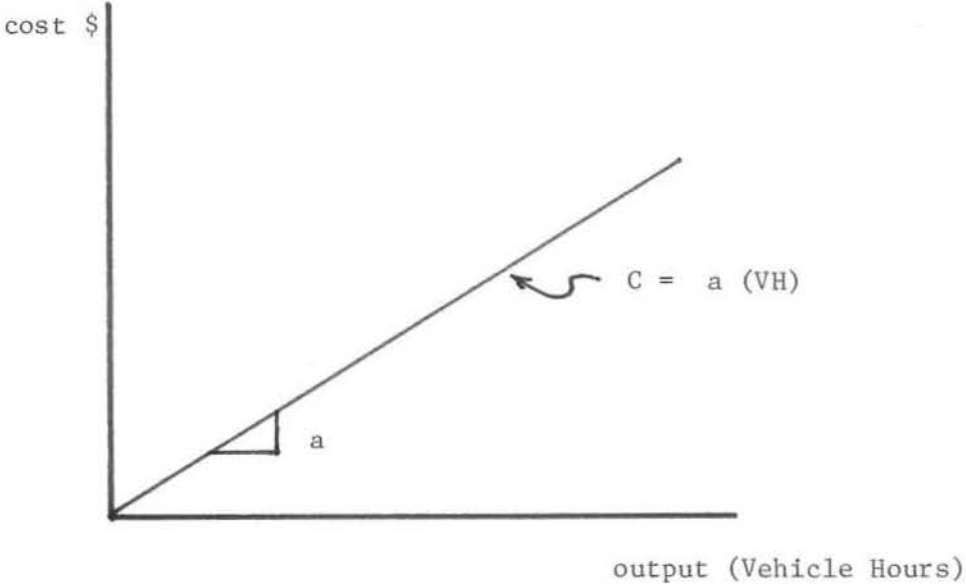
IV - 5
Summary Cost and Performance
Measures



IV-5

- Measure of production phase is unit cost, per vehicle hour.
- Measure of deployment phase is revenue per vehicle hour.
- Revenue side can be broken into two components, passengers/hr and revenue/passenger.
- All relationships are identities, i.e., true by definition.
- Only three of the seven are needed to mathematically determine the others.
- Deployment has generally small impacts on cost per vehicle hour.
- In the literature on transit performance indicators, unit cost is sometimes referred to as "efficiency" and utilization as "effectiveness".

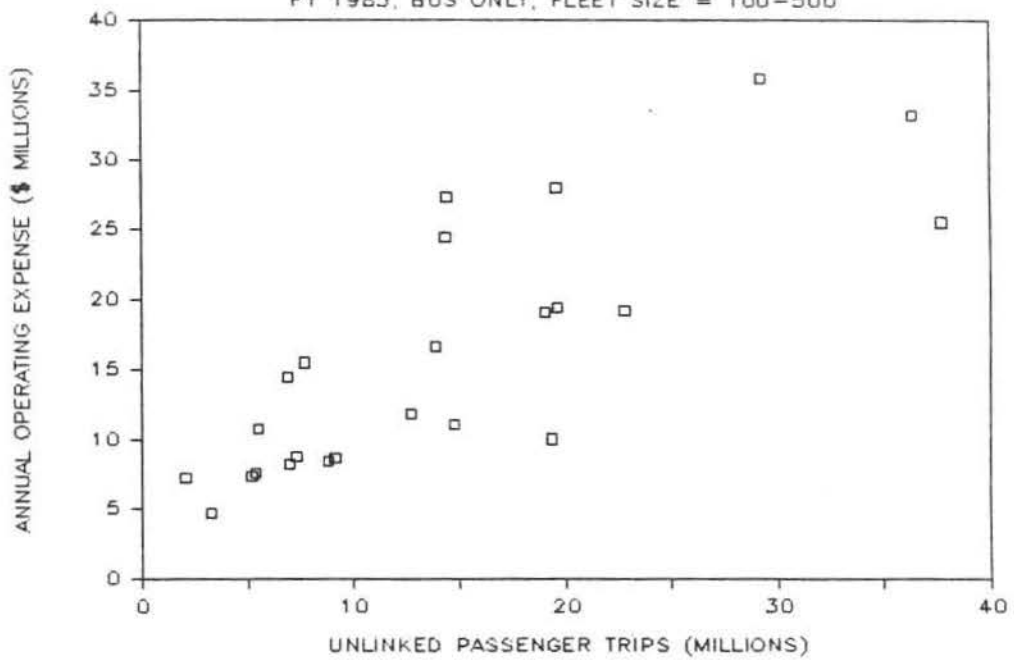
IV - 6
Simple Empirical Cost Function



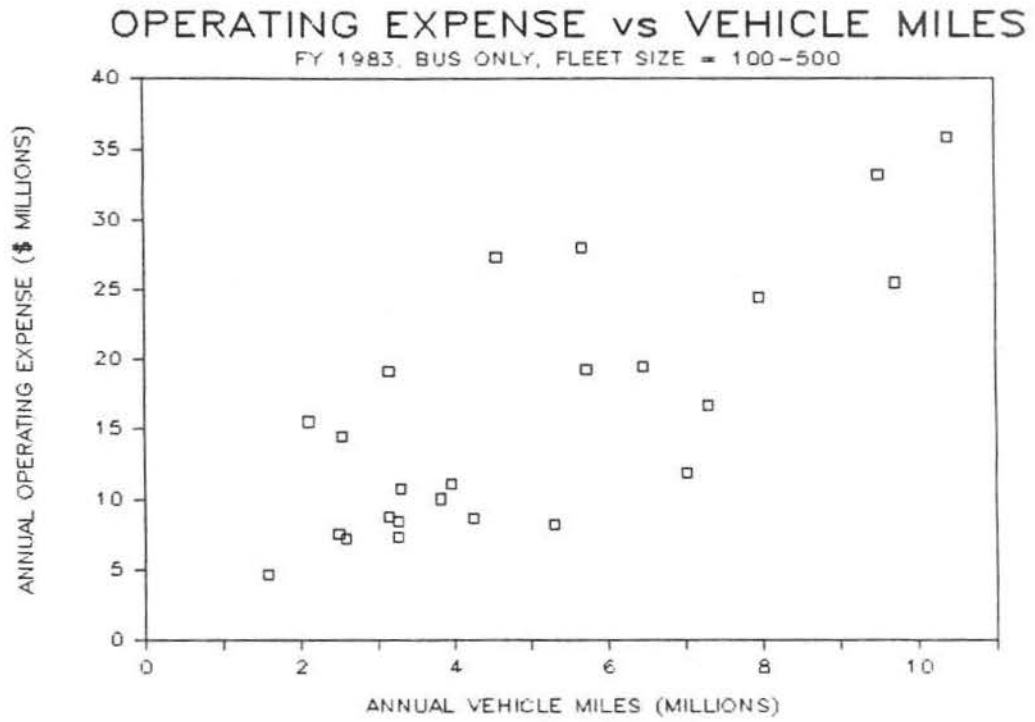
IV -7 Relationship Between Cost and Passengers

OPERATING EXPENSE vs PASSENGERS

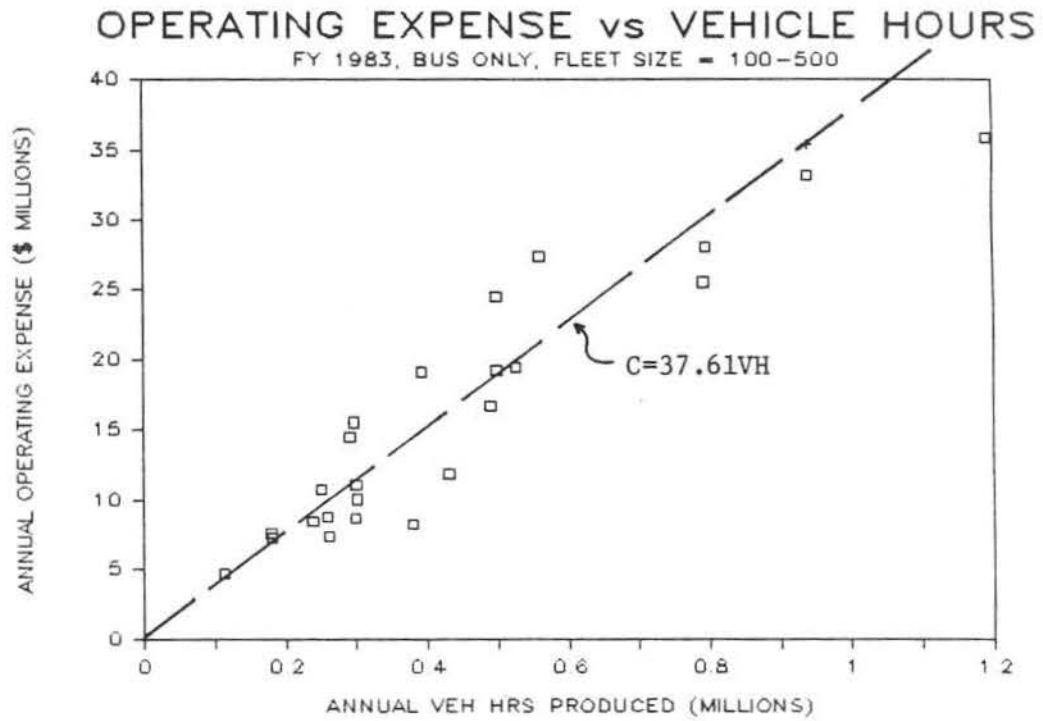
FY 1983, BUS ONLY, FLEET SIZE = 100-500



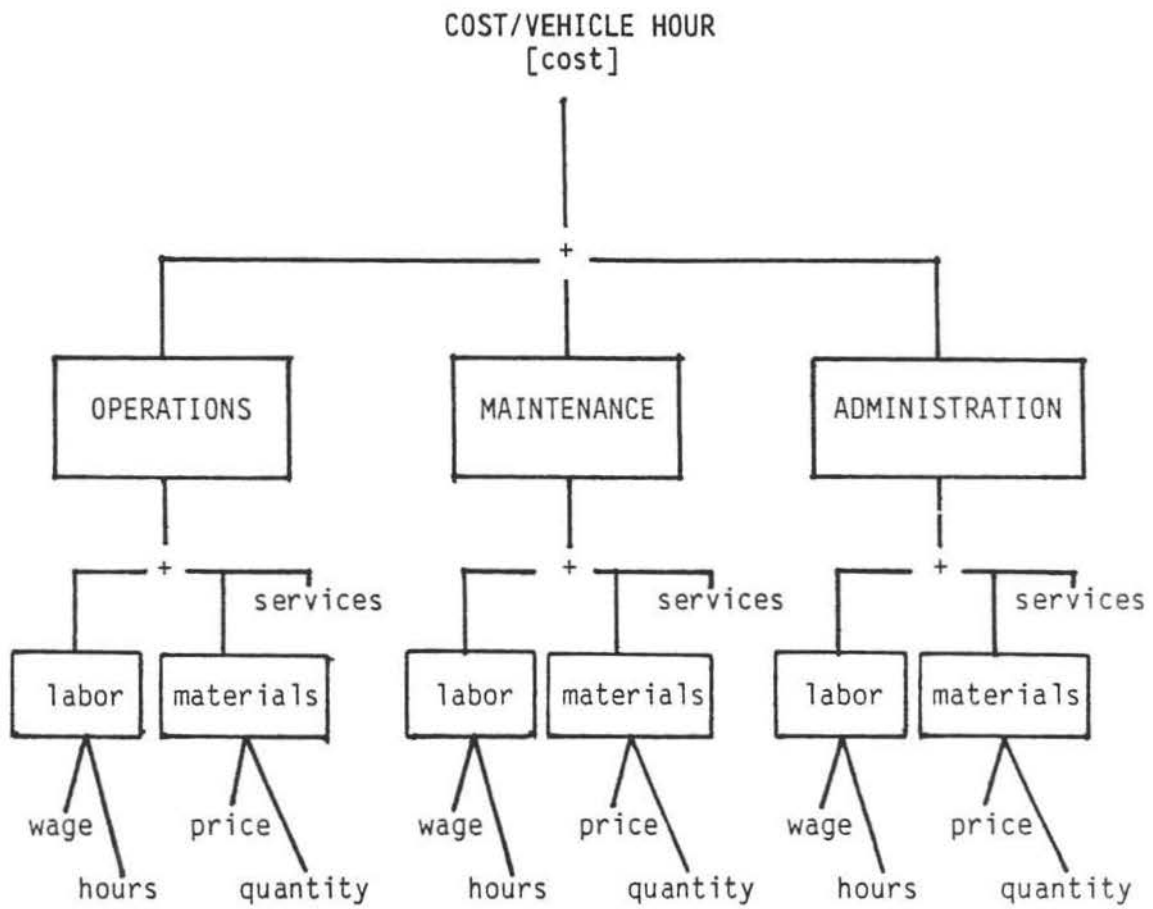
IV - 8 Relationship Between Cost and Vehicle Miles



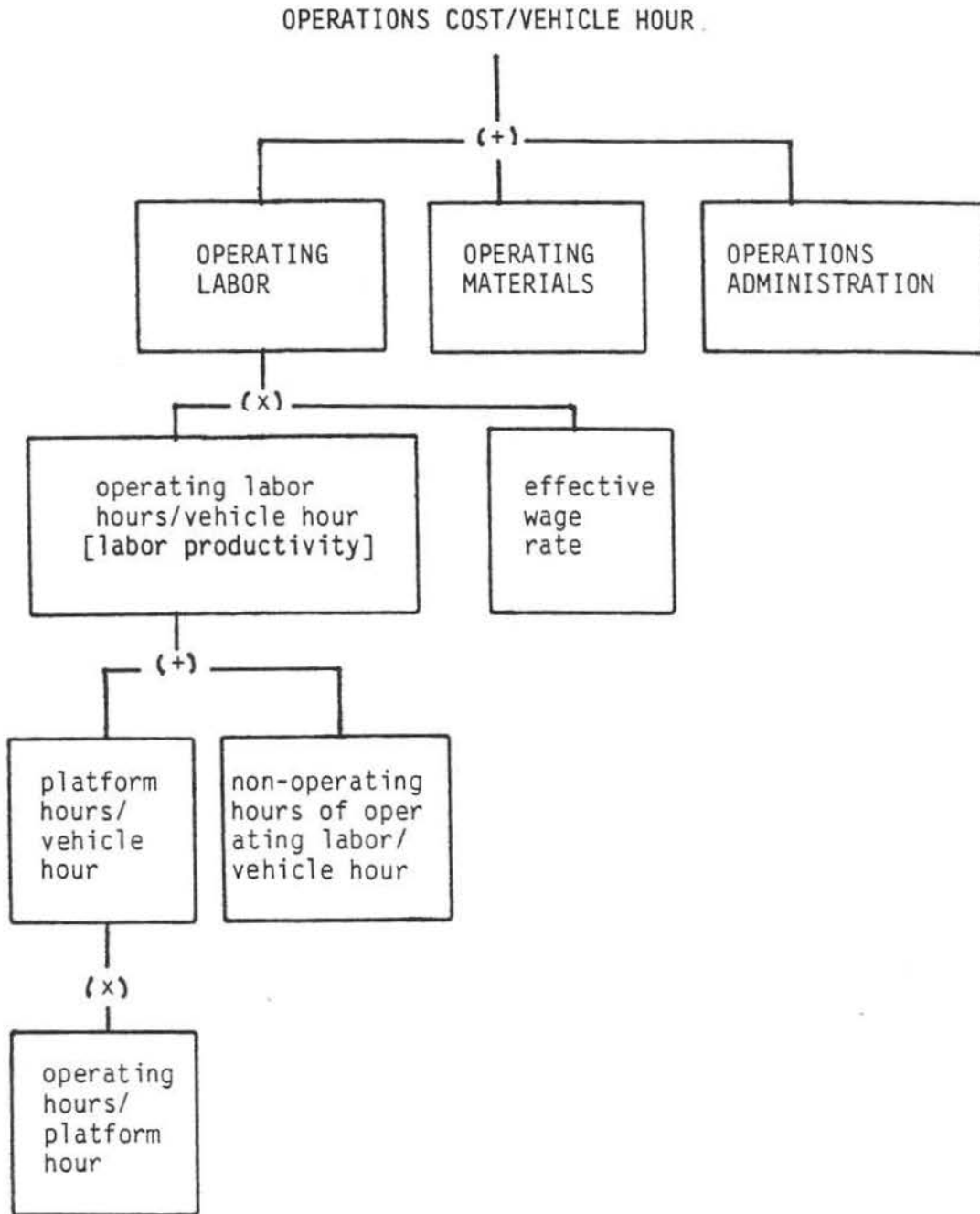
IV - 9 Relationship Between Cost and Vehicle Hours



IV - 10 Components of Service Production Cost



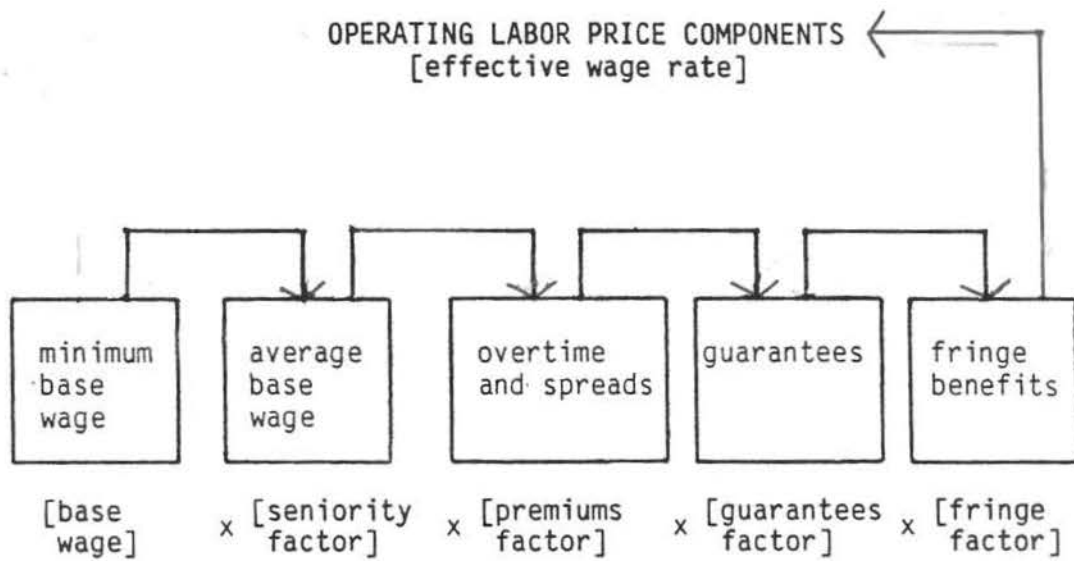
IV - 11 Components of Operations Cost



IV-11

- Details of Operations (Transportation) costs.
- Total operating labor hours per vehicle hour is operating labor productivity.
- Total compensation per operating labor hour is "wage" rate (includes fringe benefits).
- As with other components of cost, these are defined to be identities, whether multiplicative or additive.
- Fuel consumption per hour might be affected by speed (e.g., express) or terrain.
- Both labor productivity and labor compensation are affected by many factors. Service changes might affect productivity through peak/base distribution and compensation through overtime.

IV - 12
Components of Operating Labor
Costs

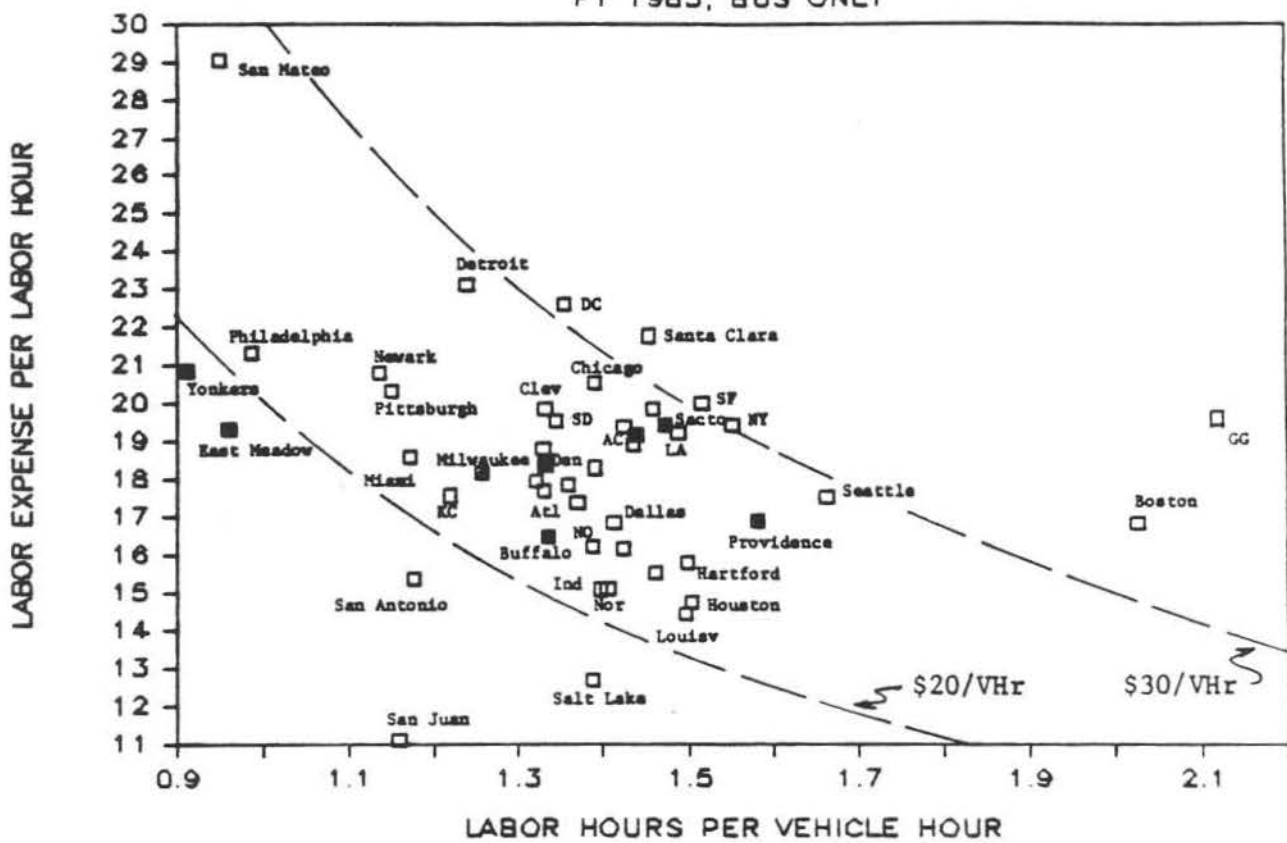


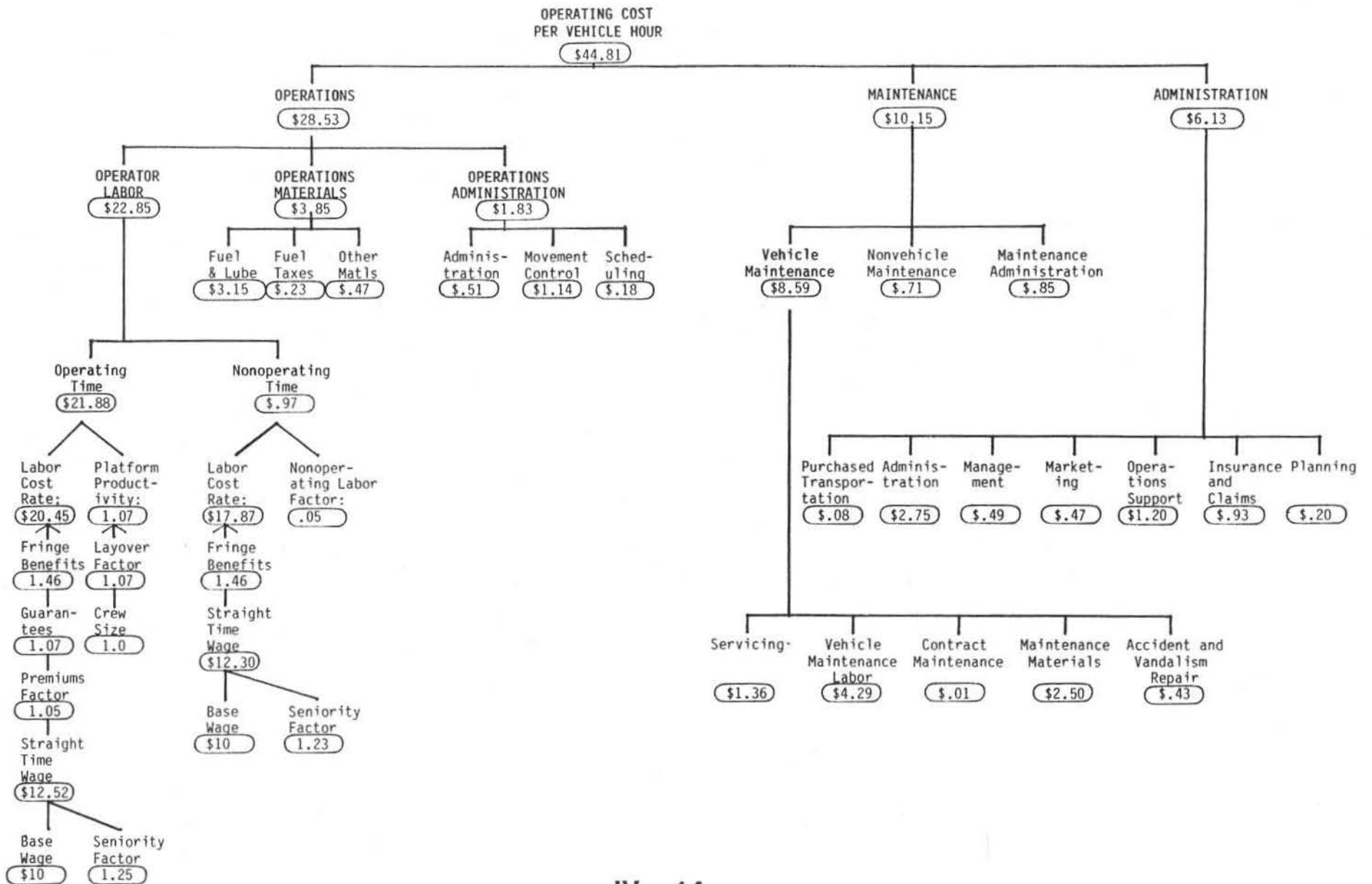
IV-12

- Operating labor compensation rate can be broken into several components, each of which may be affected differentially by policy or service changes.
- Ratio of average pay rate to base (or top) rate is "Seniority" factor, reflecting experience of operators.
- Spread premiums and overtime are partly a consequence of amount of peaking; also reliability, work rules, etc.
- Guarantees are payments for time not actually worked, and therefore amount to additional compensation rather than lower productivity.
- Example: use of part time operators reduces non-operating labor hours (productivity), reduces fringe payments (compensation), and reduces spread penalties (compensation), but increases accidents (inexperience), training costs (non-platform time), absenteeism (guarantees and overtime), and turnover (some administrative costs).

IV -13
 Relationship Between Operating
 Labor Productivity and Wage
 Rates

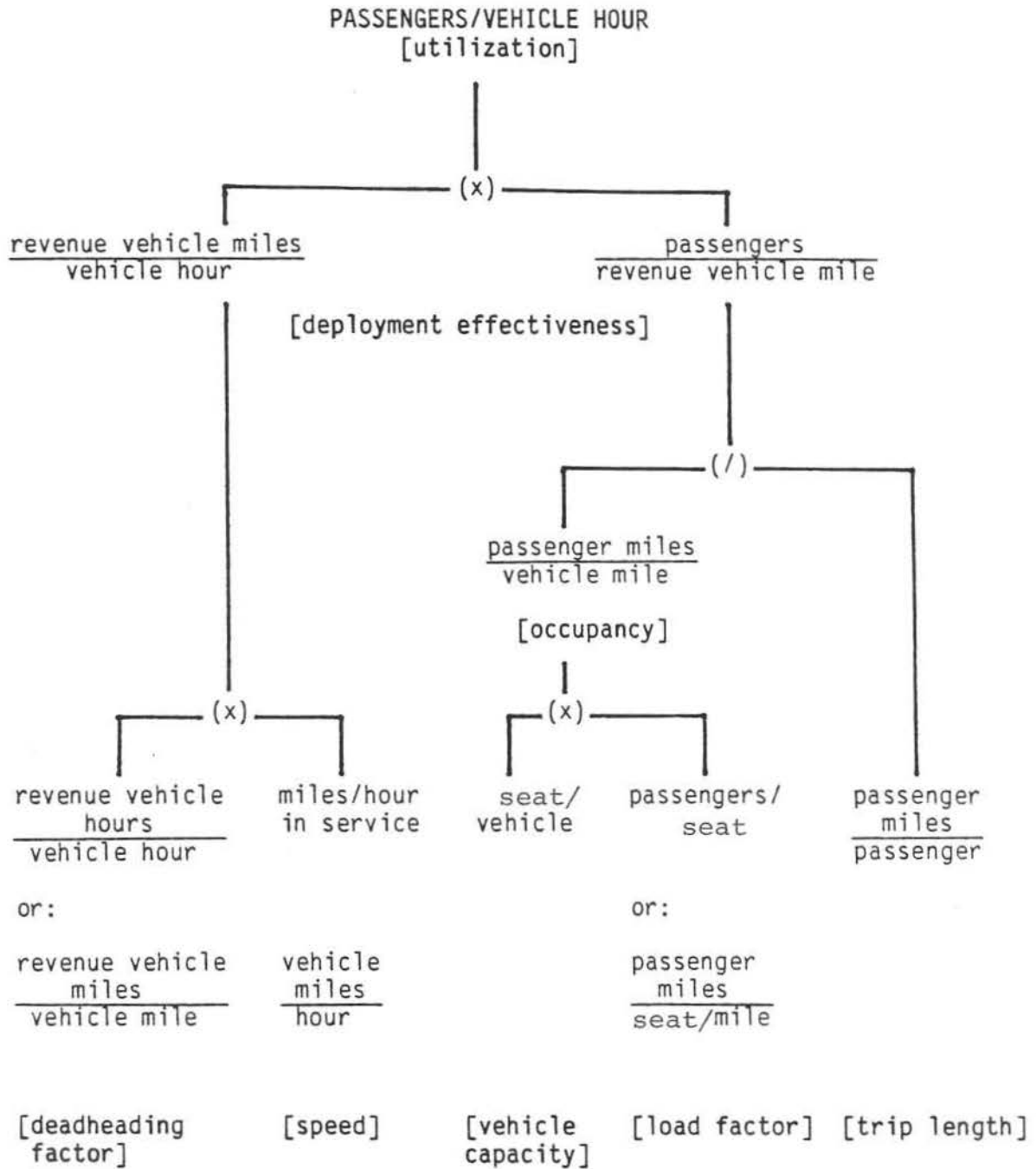
OPERATIONS LABOR PRODUCTIVITY
 FY 1983, BUS ONLY



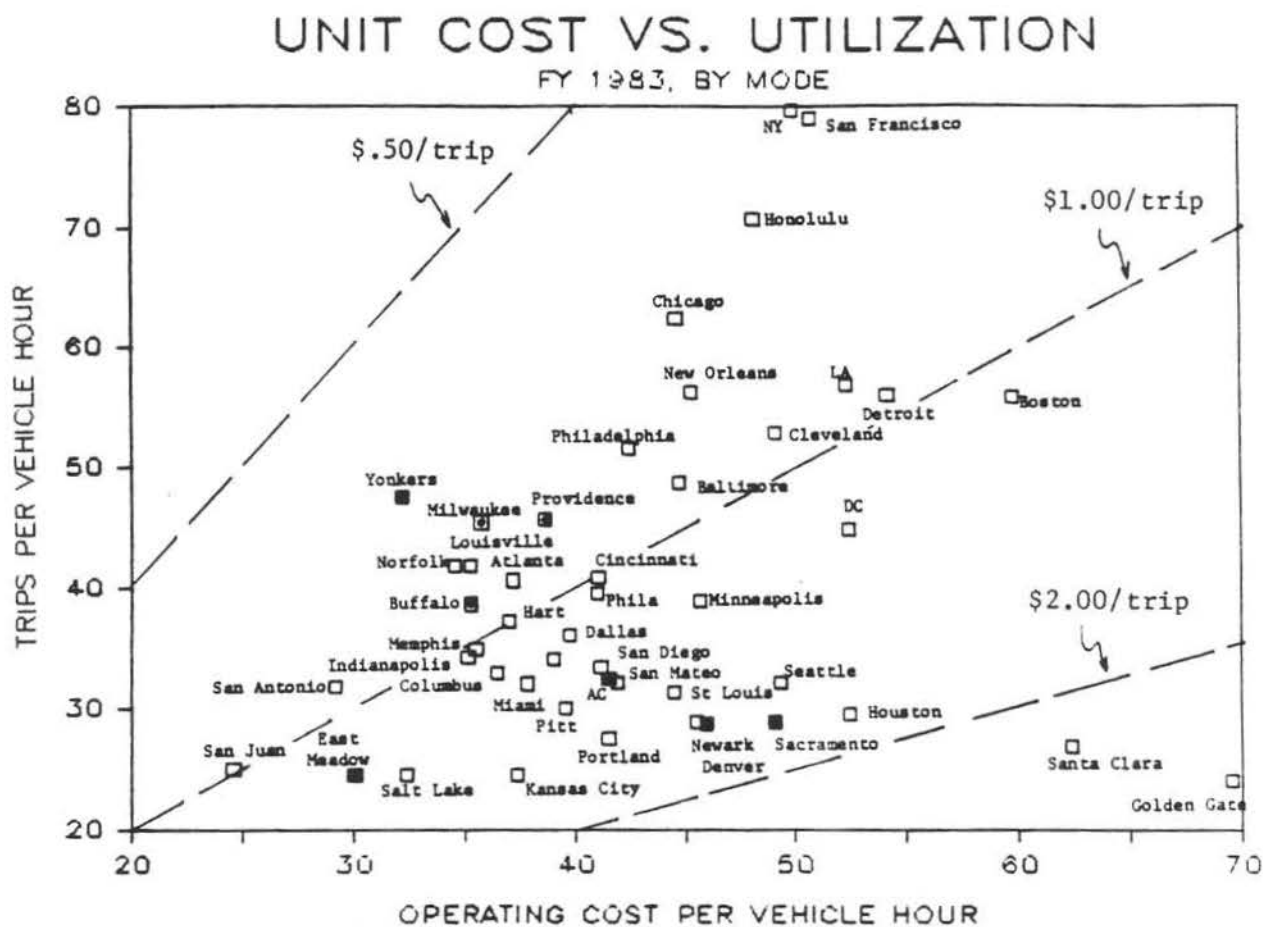


IV - 14
Detailed Disaggregation of Operating Costs

IV - 15 Components of Service Utilization



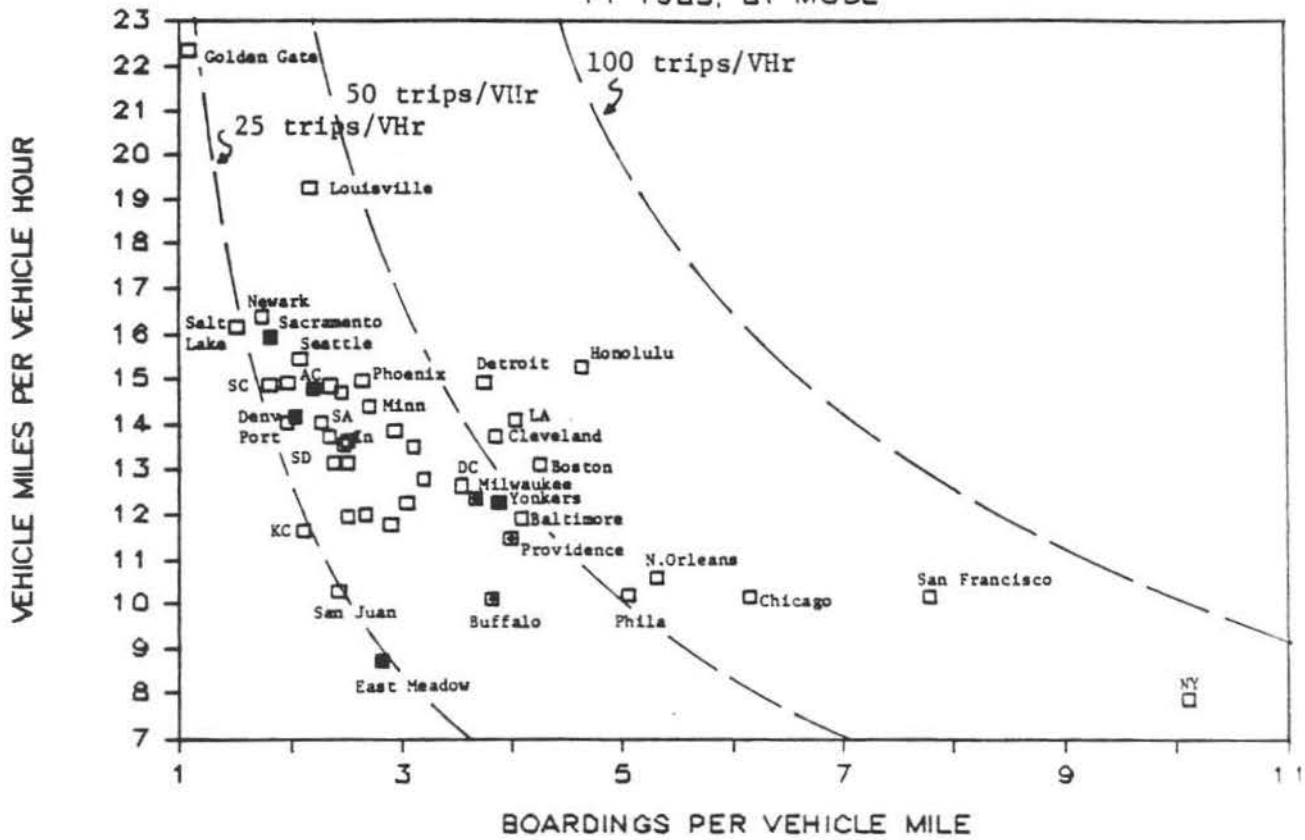
IV - 16
Relationship Between Cost and
Utilization



IV - 17
 Relationship Between Boardings
 and Speed

BOARDINGS VS. SPEED

FY 1983, BY MODE



IV - 18
Components of Capital Cost



DEPRECIATION

Consumption of the service life of
a capital asset, e. g. , wear and tear

$$\text{Cost} = \frac{\text{value}}{\text{remaining life}}$$



OPPORTUNITY COST

Income foregone by retaining a
capital asset rather than selling it

(old bus is cheaper than new one)

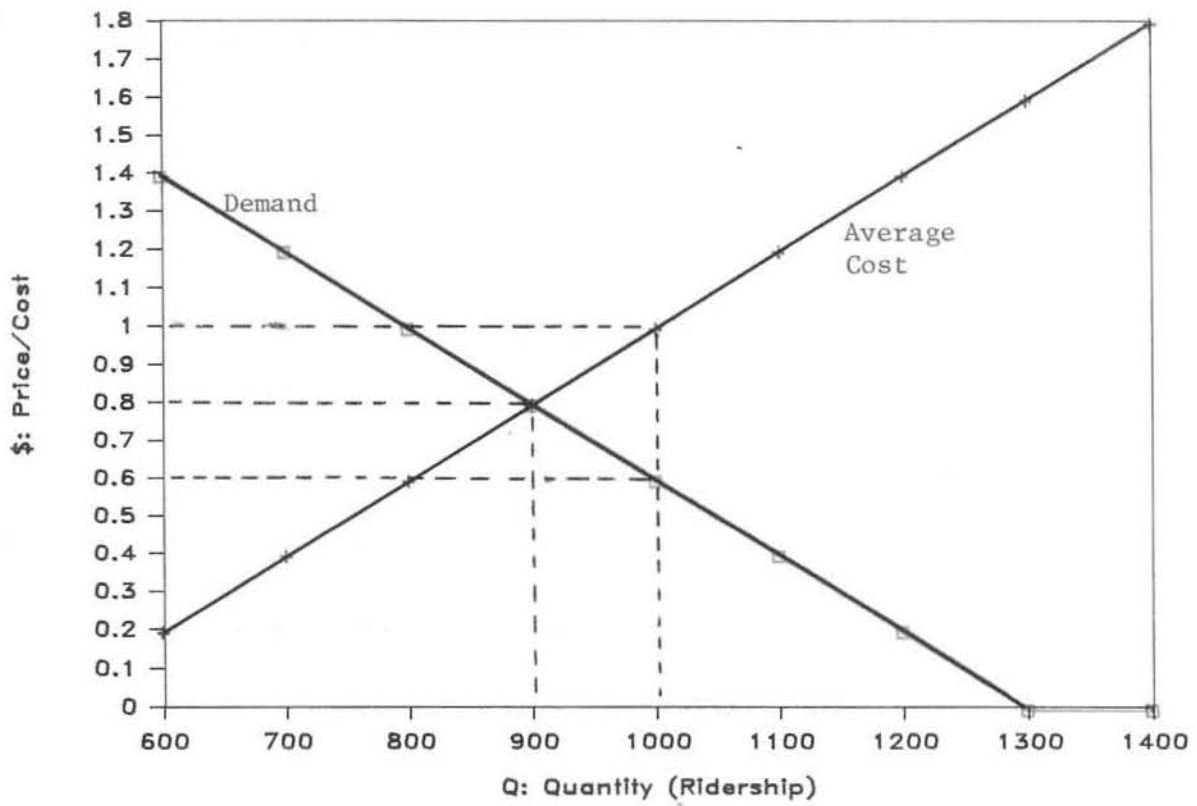
IV - 19
Calculation of Peak versus
Off-Peak Unit Costs

	Total or Average	Peak	Off-Peak
Vehicle hours	100	40	60
Operating labor hrs	150	84	66
Productivity (Lab.Hr/Veh.Hr)	1.5	2.1 ^b	1.1 ^a
Operating Labor \$	2250	1307	943
Operating Labor \$ per labor hour	15	15.56 ^d	14.28 ^c
Maintenance Cost (\$)	1000	480	520
Maint. \$/veh. hr.	10	12.00 ^e	8.67 ^f
All other costs per vehicle hr.	10	10 ^g	10 ^g
TOTAL OPERATING COST per vehicle hour	42.50	54.68	34.38
Capital Depreciation per vehicle hour	4	4 ^h	4 ^h
Capital Opportunity cost per veh. hr.	1.75	4.37 ⁱ	0 ⁱ
TOTAL COST/VEH HR	48.25	63.05	38.38

IV - 20 Bus Costing Example

	Base	Extension		
DAILY RIDERS:			Pass/VeHr	
Peak	1800	1500	90.0	60.0
Offpeak	200	500	20.0	25.0
Total	2000	2000	66.7	44.4
VEHICLE HOURS OF SERVICE:			Pass/VehMi @	
Peak	20	25	Speed (mph) =	15
Offpeak	10	20	6.00	4.00
Total	30	45	1.33	1.67
			4.44	2.96
UNIT COSTS OF SERVICE (\$/VeHr):			Occupancy @	
Peak	63.05	63.05	Trip Length =	4
Offpeak	38.38	38.38	24.0	16.0
			5.3	6.7
			17.8	11.9
CAPITAL AND OPERATING COST:				
Peak	1,261	1,576		
Offpeak	384	768		
Total	1,645	2,344		
COST PER PASSENGER:				
Peak	0.70	1.05		
Offpeak	1.92	1.54		
Average	0.82	1.17		
REVENUE PER PASSENGER:				
Peak	\$0.60	\$1.00		
Offpeak	\$0.60	\$0.50		
Total Peak	1080	1500		
Total Offpeak	120	250		
Average	0.60	0.88		
PERFORMANCE EVALUATION:			Deficit/VeHr	
Peak Deficit/Pass	0.10	0.05	9.05	3.05
Offpeak Deficit/Pass	1.32	1.04	26.38	25.88
Total Deficit	445	594		
Avg Deficit/Pass	0.22	0.30		

V - 1 Impacts of Fare Increase



- Assume:

Fare elasticity = FE = $-.3$

Current ridership = $q_0 = 1,000$

Current fare = $p_0 = \$.60$

All other things, including service characteristics, are held constant. Diseconomies of scale (average costs are increasing).

- Compute:

Current revenue = $R_0 = (q_0)(p_0) = \$600$

Current average

cost = $AC_0 = \$1.00/\text{rider}$

Current total cost = $C_0 = (AC_0)(q_0) = \$1,000$

Current deficit = $D_0 = R_0 - C_0 = \$400$

Current cost

recovery ratio = $R_0/C_0 = .60$.

- Efficient fare: What is the ridership and cost impact of increasing fares to $$.80$?- Ridership Impact: $\Delta q = (FE)(\Delta p)(q_0)/p_0 = (-.3)(.2)(1000)/.6 = -100$

New ridership = $q_1 = q_0 + \Delta q = 1000 - 100 = 900$.

- Revenue Impact: Change in revenue = $\Delta R = (q_1)(p_1) - (q_0)(p_0) = (900)(.80) - (1000)(.6) = \120

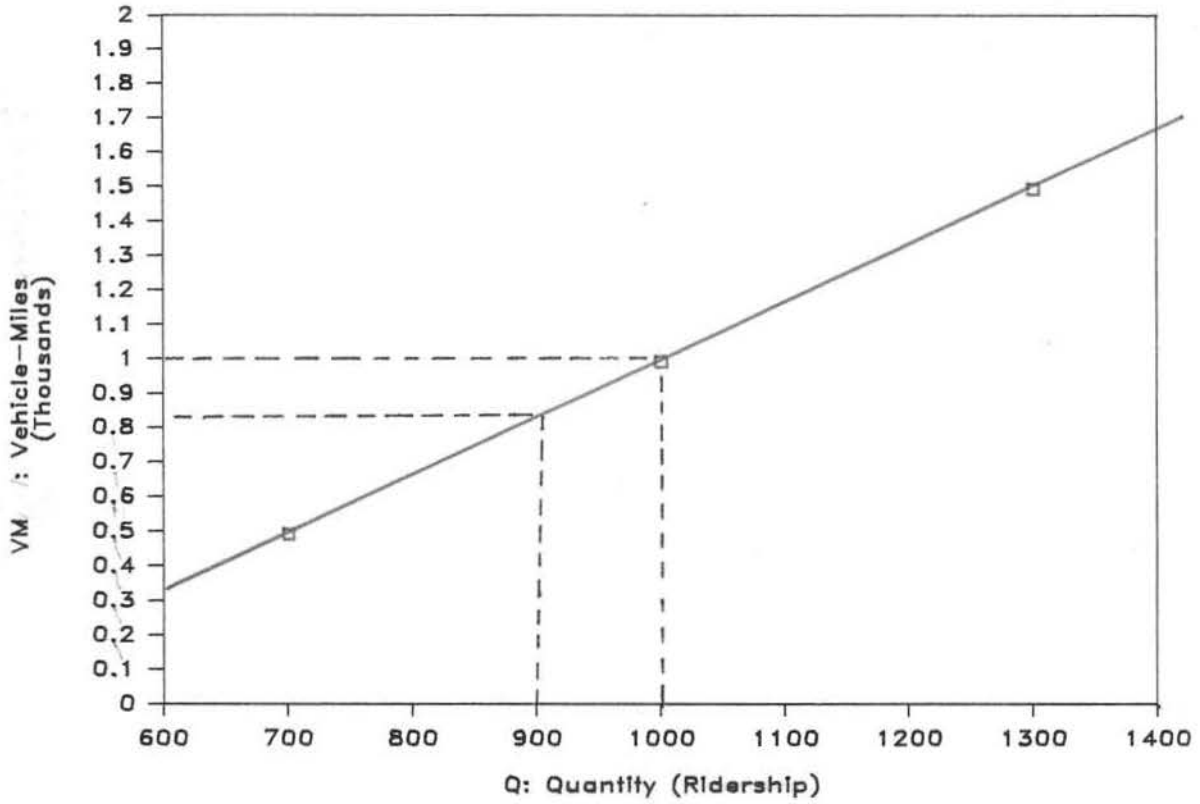
New revenue = $R_1 = R_0 + \Delta R = 600 + 120 = \720 .

- Cost Impact: New average cost = $AC_1 = .80$

New total cost = $C_1 = (AC_1)(q_1) = (.8)(900) = \720 .

- Deficit Impact: New deficit = $R_1 - C_1 = \$720 - \$720 = 0$
New cost recovery ratio = $R_1/C_1 = 1$.

V - 2
Service Change Equivalent of Fare
Increase



- Assume: Service elasticity = $SE = +.60$
 Current vehicle miles = $VM_0 = 1,000$
 Current ridership = $q_0 = 1,000$
 All other things, including price, are held constant.
- Equivalent service change: What is the equivalent service change with respect to ridership of increasing fares to \$.80?

$$\begin{aligned} \text{- Service impact: } \Delta VM &= (\Delta q)(VM_0)/(SE)(q_0) \\ &= (-100)(1000)/(+.60)(1000) \\ &= -167 \end{aligned}$$

$$\text{New vehicle-miles} = VM_1 = VM_0 + \Delta VM = 1000 - 167 = 833$$

Thus, cutting daily services from 1,000 to 833 vehicle-miles is comparable to increasing fares from 60 cents to 80 cents in terms of ridership impact.

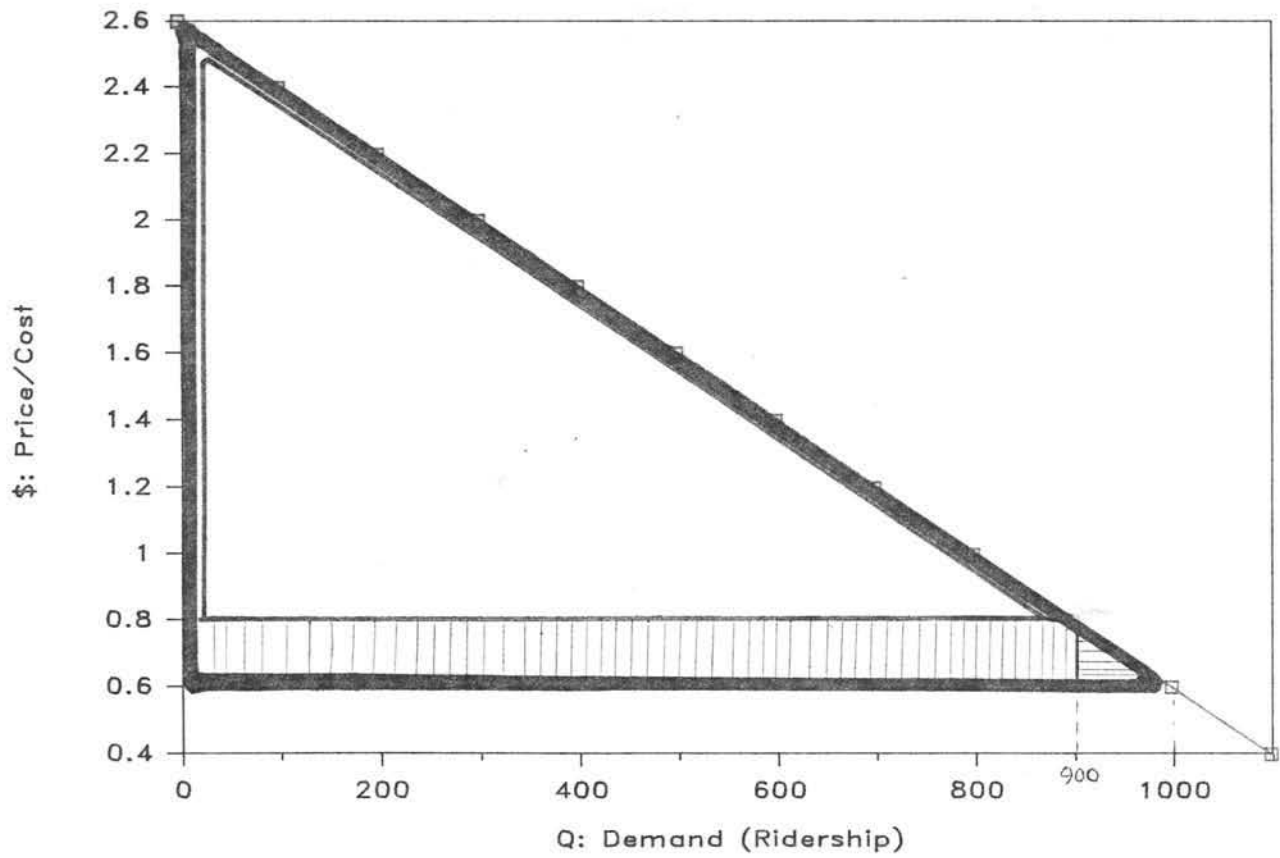
- Note, however, that since fare is unchanged, a deficit remains:
 New Revenues = $(900)(\$.6) = \540
 Costs = $\$720$
 New Deficit = $\$720 - \$540 = \$180$
- Equivalent service change: What is the equivalent service change with respect to the deficit level of increasing fares to \$.80?

$$\begin{aligned} \text{- Service impact: } \Delta VM &= (\Delta q)(VM_0)/(SE)(q_0) \\ &= (-200)(1000)/(+.60)(1000) \\ &= -333 \end{aligned}$$

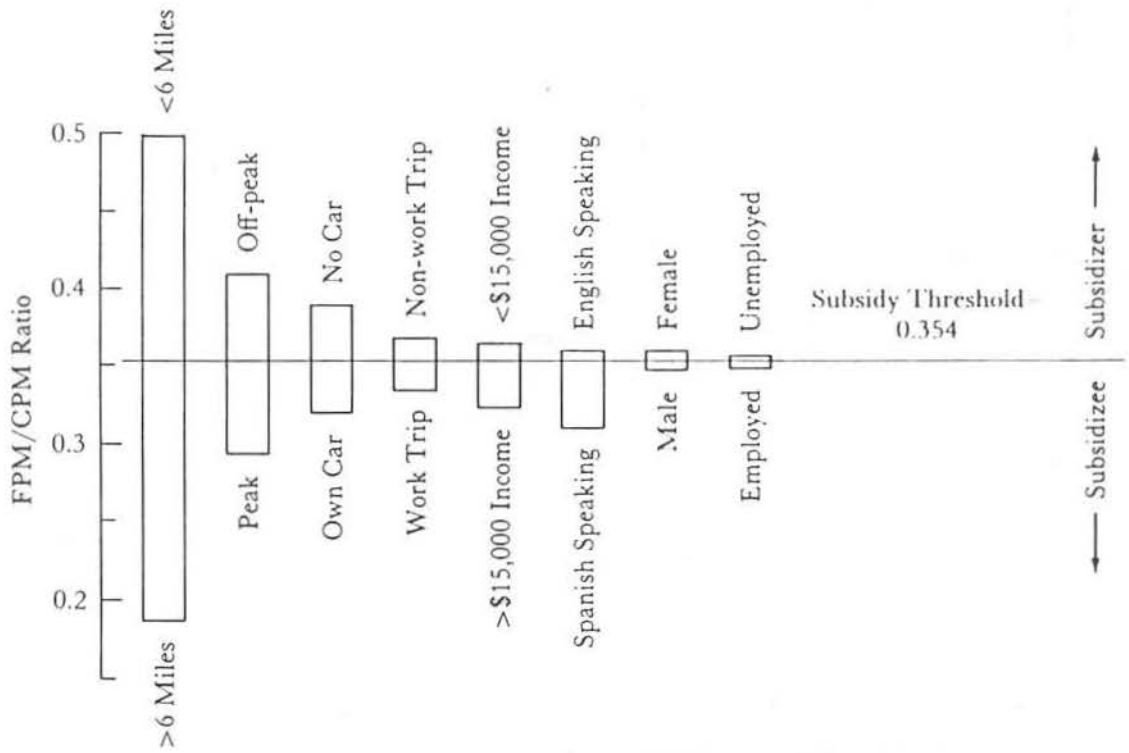
$$\text{New vehicle-miles} = VM_2 = VM_0 + \Delta VM = 1000 - 333 = 667$$

- Deficit Impact:
 New Revenues = $(800)(\$.60) = \480
 New average cost = $\$.60$
 New Costs = $(800)(\$.60) = \480
 New deficit = $\$480 - \$480 = \emptyset$.

V - 3 Distributive Impacts of Efficient Price

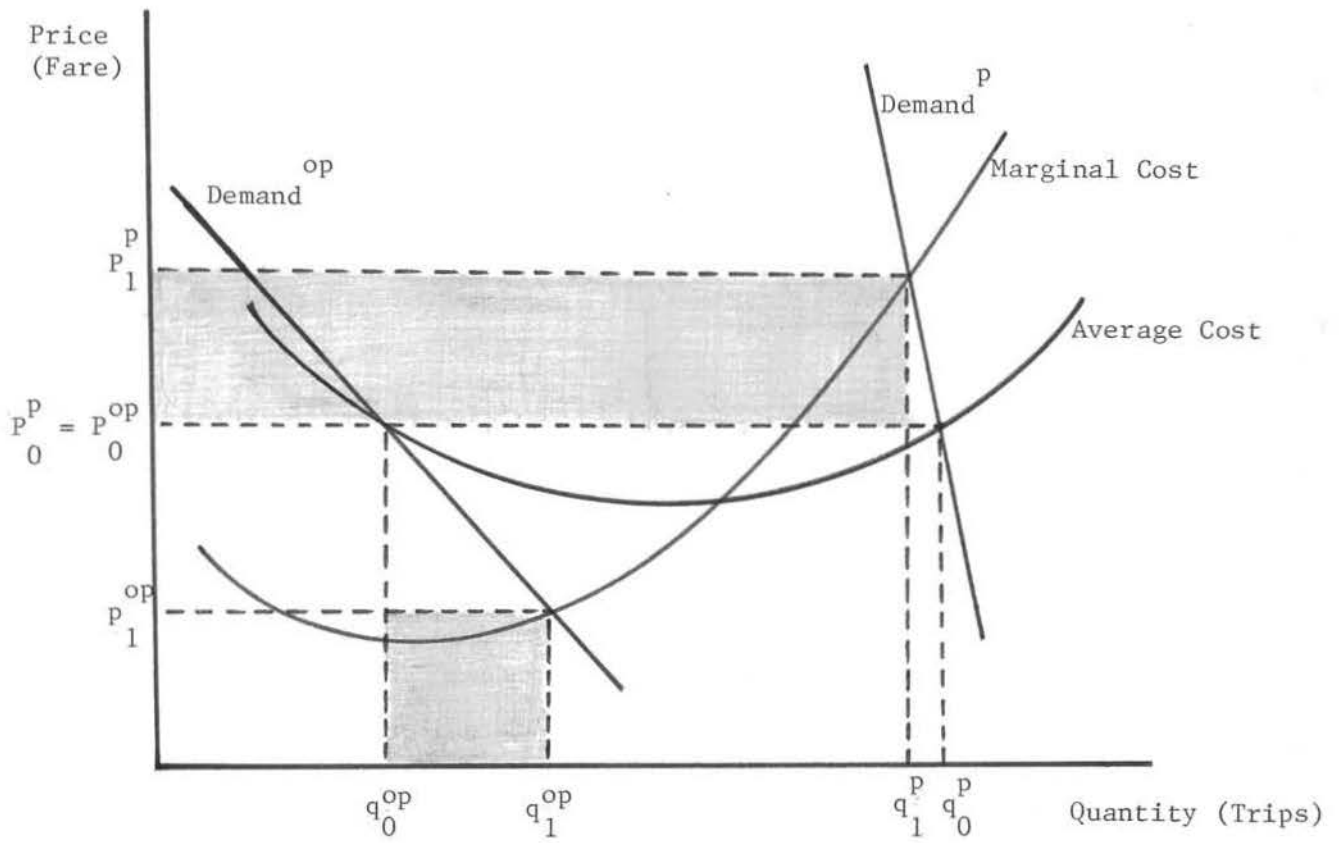


V - 4 Equity Analysis for San Diego Transit



Source: Robert Cervero, "Transit Cross-Subsidies", Transportation Quarterly, July, 1982.

V - 5 Differential Fares



GROUP PRESENTATION PROBLEM

For the policy options described in the following pages, choose one alternative to the existing service to analyze and present to the "Board". Presently, 40-passenger buses operate along the Westway corridor of Metropolis, a medium-size west coast city. Metropolis is the financial, retail, and distributional hub for a large agricultural and forest product region. It is experiencing a healthy growth rate of 2 percent per year. Several large high-technology firms, moreover, have moved to Metropolis within the past five years.

Presently, buses operating along the Westway corridor feed into residential neighborhoods and then provide line-haul connections to the regional downtown. Generally, middle-income, white-collar workers who are employed in downtown patronize services along the corridor. A flat fare of 60 cents is charged along the twenty-mile service corridor.

Metropolis Transit, the regional transit agency, presently recovers around 40 percent of its costs through the farebox. The Board wishes to increase this to over 50 percent within the next two years in response to declining state and federal operating assistance. The board's overriding objective is to introduce various services and pricing changes that are efficient and that promise to reduce deficit levels.

Groups of four persons (or less) are to choose one of the following four policy options being considered by Metropolis Transit's board:

- * Change in service levels: substitution of articulated for conventional buses, holding capacity constant.
- * Change in capacity: increase in capacity using articulated buses, holding headways constant.
- * Change in service design: conversion from a standard to a feeder/line-haul route design.
- * Change in fares: switch from a flat to a peak/off-peak fare structure.

Each group presentation must contain a specific recommendation (pro or con), and must take no more than fifteen minutes. The recommendation must be analytically sound, and buttressed by supporting documentation.

Group Presentation Problem

POLICY OPTION 1: Change in Services Using Articulated vs. Standard Buses

The Board wants to know whether the changeover from standard to articulated buses along the Westway corridor would be an efficient move. No changes in capacity are being sought; rather, the board is interested in knowing whether large buses operating on slightly longer headways are more cost-effective than conventional buses operating more frequently. Given the changes in travel time that would result from a conversion to articulated buses, would the articulated bus policy be an efficient, deficit-reducing one?

POLICY OPTION 2: Change in Service Quality by Expanding Capacity

Another policy option the board is interested in is the efficiency potential of increasing capacity while keeping headways constant. This would involve the conversion to 60-passenger articulated buses that operate as frequently as standard 40-passenger buses. The major benefit to users would be an increase in the probability of getting a seat from .80 (before the conversion to articulated buses) to 1.0 (after the conversion to articulated buses). Using available cost and elasticity information, would this be an efficient strategy for the Westway corridor?

POLICY OPTION 3: Service Design Options

Conventional 40-passenger buses operating along the Westway corridor presently circulate through residential neighborhoods to pick up passengers and then provide mainline connections to downtown (e.g., standard collection). Thus, no transfers are necessary under the current arrangement. The Board is considering converting to a feeder/line-haul arrangement (whereby passengers would now have to transfer at designated transit centers) at a cost savings of 10 percent. Under this arrangement, 20-passenger vans would serve as feeders and conventional buses would provide the line-haul connections. Using cost and travel time data provided, is the conversion from a standard collection to a feeder/line-haul service an efficient policy?

POLICY OPTION 4: Peak/Off-Peak Fare Differential

Given differences in costs of peak versus off-peak services, the board is interested in possibly converting from the present flat fare system to one involving a time-of-day differential. What might be an appropriate differential? Indicate how you allocated fixed and variable costs in arriving at this differential. What would be the likely ridership and fiscal impact of this fare differential? What might be the equity and fare collection implications of switching from a flat to a peak/off-peak fare structure?

Cost Data For Westway Corridor

Type of Service

<u>Cost Component:</u>	<u>Standard Collection (Non-transfer service)</u>	<u>Feeder and Line Haul (Transfer Required)</u>
Capital	\$1,000,000	\$900,000
Maintenance	500,000	450,000
Labor	2,000,000	1,800,000
Other	500,000	450,000
Total	\$4,000,000	3,600,000

Cost Per Hour

<u>Vehicle Type:</u>	<u>Labor</u>	<u>All other</u>
Articulated (60 Passenger)	\$20.00	\$30.00
Conventional (40 Passenger)	20.00	20.00
Vans (20 Passenger)	20.00	10.00

Time-of-Day Characteristics

<u>Submarket:</u>	<u>Hours of Operation</u>	<u>Passengers</u>	<u>Labor Cost</u>
Peak	50,000	2,000,000	\$1,300,000
Base	50,000	1,000,000	700,000
Total	100,000	3,000,000	2,000,000

Passenger Data For Westway Corridor

Elasticities

	<u>Price</u>	<u>Travel Time</u>	<u>Seat Probability</u>
Peak	-0.2	-1.0	0.5
Off-peak	-0.4	-0.6	0.5

Average Trip Times

<u>Service Type:</u>	<u>Conventional Bus</u>	<u>Articulated Bus (Same Capacity)</u>	<u>Articulated Bus (Same Schedule)</u>
Standard	25 minutes	28 minutes	25 minutes
Feeder	10 minutes	10 minutes	10 minutes
Line-haul	20 minutes	22 minutes	20 minutes

Fare = \$0.60

- Cost minimization in production is only one aspect of economic efficiency. Another major issue is creating the right mix of outputs.
- There are also differences between short term and long term evaluations of efficiency. Many production decisions are fixed in the short term but can be varied in the future, and consumers often take time to adjust to changes.
- Many people think of efficiency as trying to create the biggest pie using society's limited resources.
- Formal evaluations of efficiency can be done using cost-benefit analysis. However, many actions can improve efficiency without use of a formal analysis. Many choices regarding the service characteristics and production decisions in transit can both improve efficiency and lower operating deficits.
- Efficiency concerns must be tempered by some concern for equity, but the two are often not in conflict. Further, there are a variety of equity principles to consider.

- The efficient quantity occurs when willingness-to-pay by consumers (as measured by the demand curve) is equal to the opportunity cost of providing the services (as measured by the marginal cost curve). Hence, an efficient pricing scheme is to set price equal to marginal cost.

- If price is too high (P_2) people will not take trips that are worth more than the cost of providing them. If price is too low (P_3), then the value of additional trips is less than the cost of providing them (C_2). Hence, an efficient pricing scheme is to set price equal to marginal cost.

- Marginal cost pricing maximizes net benefits.

- Relevant money price in the choice of transit mode is different for short run and long run decisions. Many expenditures occur whether or not a particular trip is made on a particular mode, but they may be variable in terms of general mode choice. Once the general decisions are made they influence the cost of a particular trip. An automobile trip is very expensive if the car must be rented for the one trip, but if a car is owned the cost of one more trip is often small.

- Fixed expenditures may include the basic ownership costs of a car or the cost of a transit pass.

- Variable expenditures may include: parking fees, fuel, higher insurance and depreciation for auto; and zone fares or peak surcharges for transit.

- Time is the most important non-monetary expenditure in mode choice. People are willing to pay more in order to shorten trip time. The amount they are willing to pay will vary by person and over how the time is spent, such as waiting or traveling.

- The differences in choice of mode as a function of value of time and fixed versus variable cost can be quite significant. The example shows how this choice is made in terms of the perceived total cost to the passenger. The last set of figures relate to a person who already owns a car.

- Car ownership is influenced by perceived need for it for recreation and shopping trips as well as for commuting.

- Mode choice is also strongly influenced by collection and distribution options. People who must drive to a transit stop are more likely to use auto for the entire trip than those who can make entire trip without an auto.

- Elasticity is a measure of how responsive consumers are to a change in a parameter such as price. If they are very responsive then elasticity will be high, and if they are not very responsive then elasticity will be low. Low values of elasticity are those near zero. Values between zero and one are termed inelastic, and values from one on up are elastic.

- Elasticity usually varies as one moves along a demand curve. However, we usually depict an elastic demand curve as being relatively flat and an inelastic one as being relatively steep.

- The negative relationship between price and quantity mean that elasticities calculated from the formula will have a negative sign. By convention the sign is treated as positive for price elasticity, but the sign is important for other elasticities.

- Elasticity varies along a straight-line demand curve, and it varies with the level of demand.

- The changes in price from P_1 to P_2 and from P_3 to P_4 are equal. The changes in quantity from Q_1 to Q_2 , from Q_3 to Q_4 , and from Q_5 to Q_6 are also equal to each other. Yet the three elasticities will differ.

- $(\Delta Q / \Delta P) * (P_1 / Q_1) < (\Delta Q / \Delta P) * (P_3 / Q_3)$

- $(\Delta Q / \Delta P) * (P_1 / Q_1) > (\Delta Q / \Delta P) * (P_1 / Q_5)$

- The relationship between price and revenue is very important in terms of understanding the options to raise revenue from the farebox. Because of the loss in ridership as fare increases, revenue will not rise in proportion to price. However, because most of the price elasticities are low for transit, there is significant opportunity to raise revenue from this source.

- In cases where the elasticity is high there is an opportunity to raise revenue by lowering fare. Such cases are rare in transit.

- The changes in quantity will often require that capacity be raised or lowered. This usually changes service characteristics such as average waiting time, and this may in turn require additional analysis. Thus, if demand is elastic then lowering fare will cause more people to ride and increase revenue; however, if this happens with no change in capacity, there is likely to be crowding and other problems.

- With unit elastic demand, price and quantity changes offset each other to leave revenue unchanged.

- The figure illustrates the affect on revenue of an increase in price when demand is inelastic. The initial loss in quantity is likely to increase over time since demand is more elastic in the long run than it is in the short run; however, if long run demand is also inelastic then revenue will still rise.

- The initial price is \$1.00 and the quantity demanded at that price is 100. This gives revenue of \$100.00.

- The rise in price to \$1.25 causes a decline in quantity to 90. Thus revenue increases to \$112.50 rather than \$125.

- There is a ten percent change in quantity in response to a twenty-five percent change in price, so the elasticity is calculated as 0.4 which is inelastic.

- In the case of elastic demand, the same rise in price is more than offset by the fall in quantity. In this example, the rise in price to \$1.25 causes quantity to fall to 25. Hence revenue declines to \$31.25. If this is a short run curve than revenue will decline even more in the long run since the curve will be more elastic.

- The quantity change is calculated as seventy-five percent while the price change is still twenty-five percent. Hence, the elasticity measure is 3.0 which is very elastic.

- One factor which makes demand curves elastic is the existence of good substitutes. The low elasticity of demand for transit is an indication that people who use transit do not consider the alternatives to be good substitutes.

- Demand curves are more elastic in the long run because of the time people have to make adjustments in their behavior. Thus, if transit fares rise, it may not make sense to run out and buy an automobile; but it may raise the probability that a person will choose to buy an automobile in the near future. Once the auto is purchased, transit use will stop.
- Other factors also take some time to adjust. Once a new route is opened it may become more advantageous for certain types of activity to locate near the route. The new development may take significant time to complete, but it may alter the number of potential riders along the route.
- When the price rises to P_2 the initial change in quantity is only to Q_2 . Thus, the measured elasticity is likely to be small. Over time people adjust their behavior to reflect the change in price, and quantity falls to Q_3 . The calculated elasticity may still be inelastic, but it will be more elastic than the elasticity calculated on the basis of the initial change.
- A price drop to P_3 causes an initial quantity increase to Q_4 and an eventual increase to Q_5 . Even if it is still inelastic, the long run elasticity will be higher than the short run elasticity.

- Analysis of the loss in ridership associated with a fare increase can give some idea of why the demand for transit tends to be inelastic. The most direct response is to simply stop making trips. However, many riders do not consider this a viable option since they ride to work or other important destinations.

- The alternative methods of making the trip are often very different from transit. The decision to use a car is much more expensive in money terms although it has other advantages. Other modes are also not close substitutes in the sense of being almost like transit.

- One advantage of a peak period increase rather than a general fare increase is that it may shift some of the riders to off-peak times, although this effect is usually small.

- The price of transit is not likely to have much influence on some of the major long run adjustments people can make, but it may tip decisions for some percentage of the population.

- A demand curve shows the relationship between price and quantity holding everything else constant. Changes in almost anything else may cause the demand curve to shift. A shift in the demand curve means that either more or less will be purchased at any given price to the consumer.

- Shifts in the demand curve due to other factors may be much more significant than the changes in quantity of rides due to a change in price of transit.

- Since such changes occur with price held constant, the changes in quantity are not mitigated by changes of price in the opposite direction. Changes in revenue are simply changes in quantity times price.

- Some things that might cause a positive shift in the demand for transit are:
 - Higher gasoline prices or parking costs.
 - Increased speed of transit service.

- Negative shifts in the demand for transit might be caused by:
 - Lower gasoline prices or parking costs.
 - More dispersed locations of employment and residences.
 - More problems with crime or crowding on transit.

- Three general categories of shift factors are those relating to income, those relating to the price and availability of alternatives, and those relating to the characteristics of the transit service which is available.

- Service elasticities are higher than price elasticities, although they are still inelastic.
- Most of the estimated elasticities relate to time, but other service characteristics are likely to be important also.

- The second major factor in changing the demand for transit is the cost of other modes. As they become more convenient or less expensive to use, passengers are likely to shift to them. Factors which make alternatives less attractive or more expensive in turn increase the demand for transit services.

- The money cost of the other mode may not be the best measure of its influence on the demand for transit. For example, increases in transit demand during the oil crises of the 1970's were associated with increases in the price of gasoline. However, the major impact was probably the difficulty in getting gasoline at that price. Because of the long lines, many people who would have been willing to pay the price for gasoline chose to conserve it and take the bus. Thus, the true price was higher than the measured price.

III - 15
Cross-Price Elasticity of Demand

Definition: % change in Q
divided by the %
change in the
price of another
good.

Positive value implies
goods are substitutes.

Negative value implies
goods are complements.

- The concept of cross-price elasticity of demand is useful in summarizing the relationship between transit and the other modes. The magnitude of the cross-price elasticity tells us how responsive demand for transit is to changes in the prices of these other modes.

- The cross-price elasticity of demand for auto trips with respect to transit prices is estimated to be very small. This means that auto ridership is relatively insensitive to transit pricing policy.

- Estimates of the cross-price elasticity of demand for transit with respect to changes in the cost of automobile commuting are somewhat higher. This indicates that there is potential to affect the demand for public transit by increasing the perceived cost of automobile commuting.

III - 16
Income Elasticity of Demand

Definition: % change in Q divided
by the % change in
income

A positive value defines a
"normal" good.

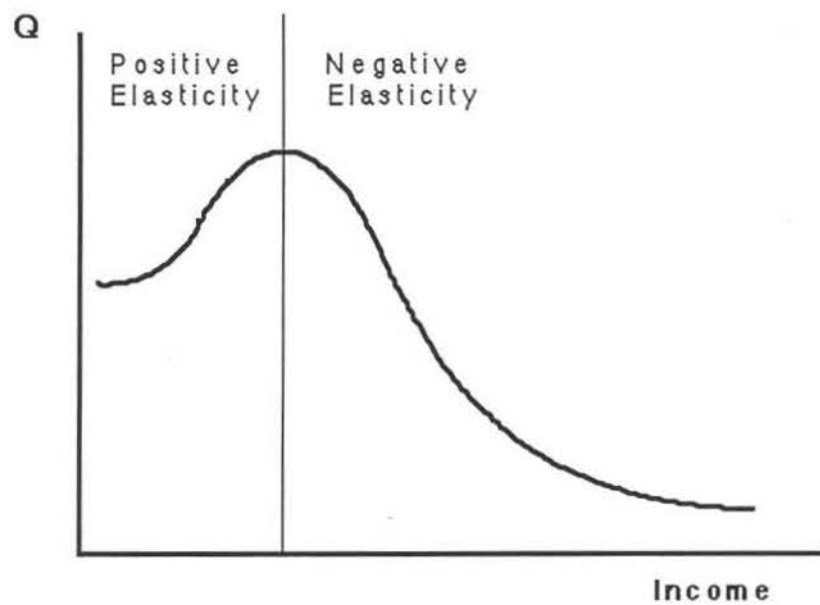
A negative value defines
an "inferior" good.

Transit has a negative income
elasticity of demand.

- The final factor which has a major impact on the demand for transit is income. We define the income elasticity of demand as the percentage change in quantity divided by the percentage change in income. While the magnitude of this elasticity can tell us how responsive demand for transit is to changes in income, the most interesting part of this number is the sign. If the sign is positive then consumption of the item increases as income increases, and the good is a "normal" good. However, for some goods the amount consumed tends to decrease as income increases. These are termed "inferior" goods. Generally an inferior good is one which has a higher quality replacement which is used as income increases.

- The income elasticity measure for transit show it to be an inferior good. People tend to switch to automobiles as their income increases.

III - 17
Income Elasticity of Transit
Demand



- At very low income levels, demand for trips does not seem very sensitive to changes in income, hence there appears to be little relationship between income and transit demand. As income increases but remains low, people make more trips and many of the additional trips are on mass transit. Beyond some point, however, the increase in trips is likely to result in some other mode being used and transit use on average declines.

III-10
Income and Transit

- * Changes in automobile ownership
Fixed cost drops from mode
choice calculation
- * Higher income implies that person
places a higher value on time.
- * More likely to choose non-central
location.

- As income increases people are more likely to buy automobiles. The income elasticity of demand for this good is positive. Once the automobile is owned it becomes more attractive for use in commuting.

- One reason people buy automobiles as their income increases is that they place greater value on their time. Hence, they are willing to incur greater monetary expenditures to reduce their time spent traveling.

- People are also more likely to choose non-central locations for their residences as their incomes increase. Transit is at a relative disadvantage in serving such markets.

- Many of the factors which lead to a decline in the demand for transit as income increases might be offset by changes in the type of service provided. For example, the higher value placed on time means that efforts to reduce the time cost of transit may be more effective in attracting this group than efforts aimed at keeping fares low. Also, changes in travel patterns may make more flexible transit options more attractive.

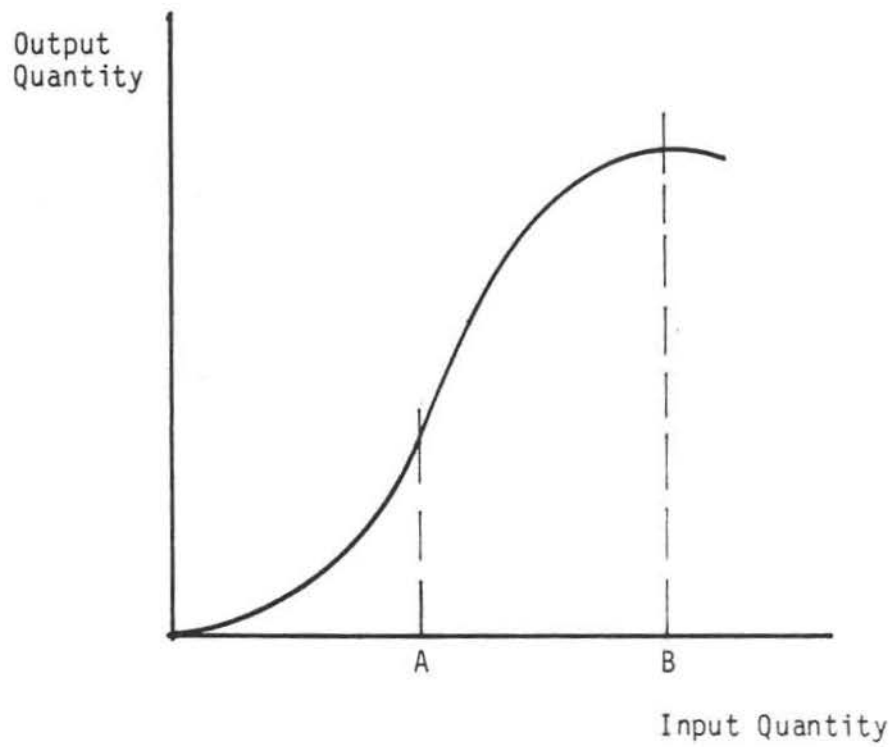
IV - 1 Cost Distinctions and Terms

Terms

Capital	vs. Operating	Lifetime greater than one year
Variable	vs. Fixed	Varies with output (output = service, passengers)
Marginal	vs. Average	Effect of a one-unit change in output
Incremental	vs. Total	Effect of an alternative, relative to a base case
Avoidable	vs. Sunk	Only avoidable costs are of interest
Short Run	vs. Long Run	Short run is temporary or transitional
Production	vs. Deployment	Two phases in transit service supply

- These terms express basic concepts in understanding costs.
- The terms are not interchangeable, e.g., capital is not the same as fixed, marginal is not the same as incremental.
- All relevant costs are avoidable, in the opportunity cost sense; if they are not avoidable, they are not relevant.
- Because most proposed changes (other than explicitly experimental tests or demonstrations) are not temporary, long run costs are usually applicable.
- Cost side of transit service has a service production component and a service deployment or utilization component.

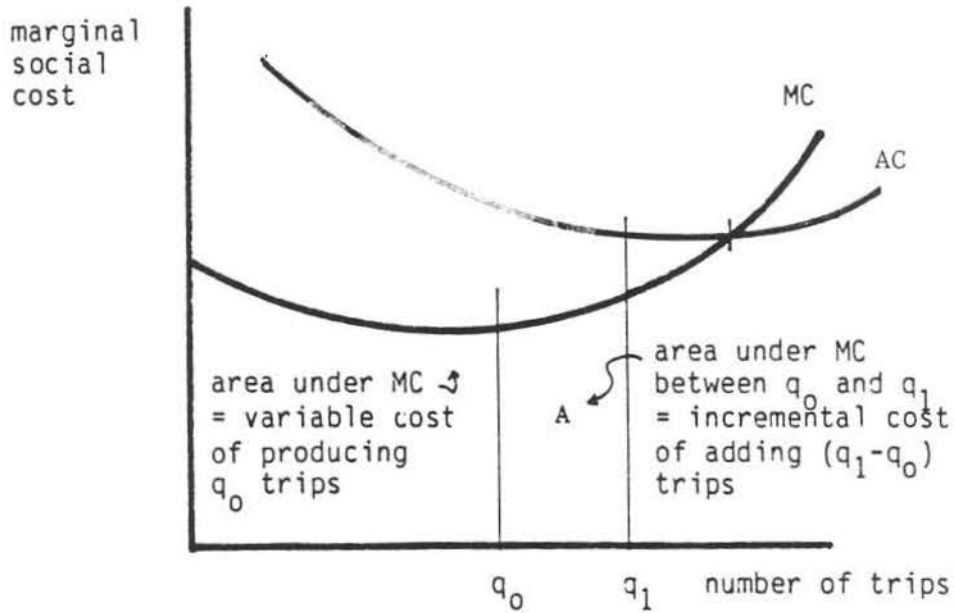
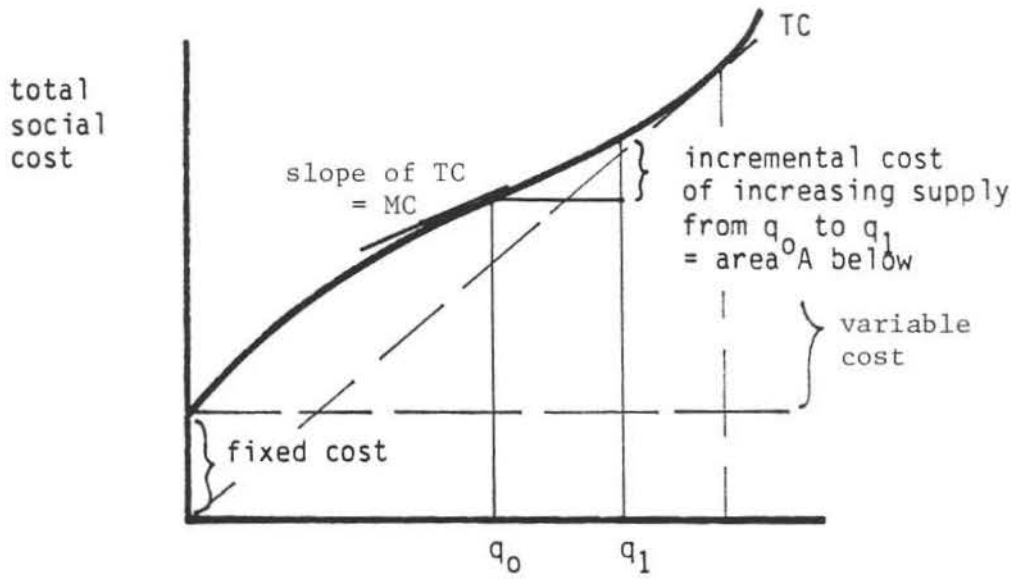
IV - 2
A Production Function, with One
Input



IV-2

- Production function transforms "physical" inputs into physical (or service) output.
- Inputs are capital, labor, and materials.
- For any given input, its marginal productivity tends to be high at low levels of input, its productivity declines as more of it is used, and eventually the input cannot add anything more to output.
- Production function is determined by technology and the productivity with which it is used (waste, or lack of it).

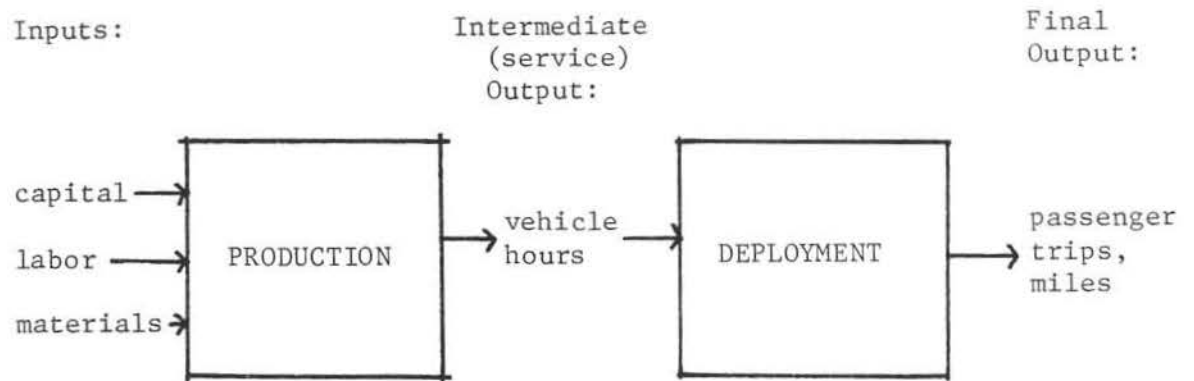
IV - 3 Total, Marginal, and Average Cost Functions



IV-3

- Cost function combines production function with prices of inputs.
- Optimum mix of inputs includes tradeoffs between prices of inputs and productivities.
 - Capital versus maintenance tradeoffs.
 - Vehicle size versus operating labor tradeoff.
 - Automation versus labor tradeoff.
- Average cost = total cost divided by output quantity.
- Marginal cost = slope of total cost function; MC is not affected by fixed costs.
- Variable costs change depending on the amount of service produced; fixed costs do not.

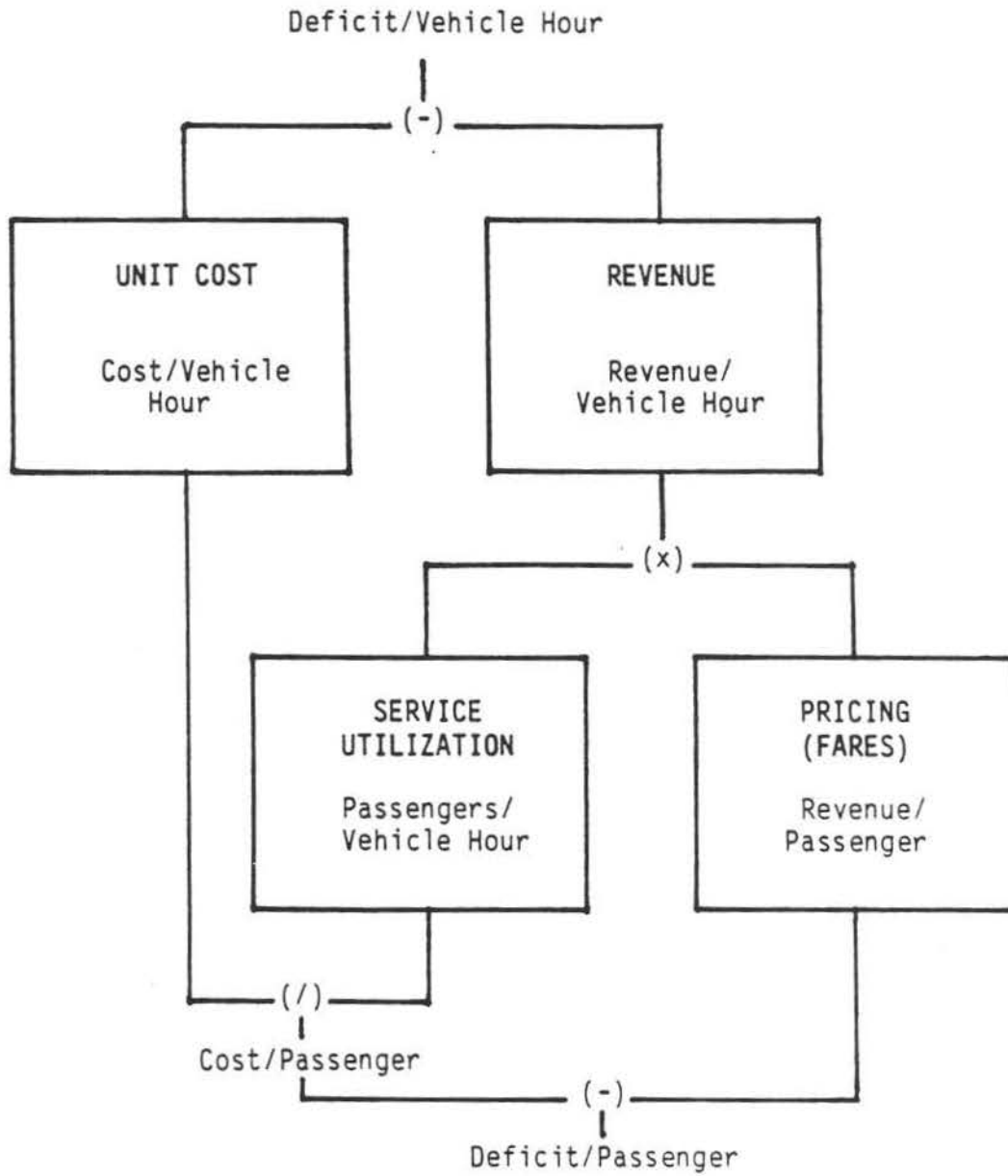
IV - 4 Two Phases in Supply of Transit Services



IV-4

- Process of transforming inputs into passengers carried can be usefully broken into two phases: production and deployment.
- Service output in vehicle hours assumes a time distribution, i.e., blocks of vehicle hours by time period.
- Speed is considered a deployment factor.

IV - 5 Summary Cost and Performance Measures



IV-5

- Measure of production phase is unit cost, per vehicle hour.
- Measure of deployment phase is revenue per vehicle hour.
- Revenue side can be broken into two components, passengers/hr and revenue/passenger.
- All relationships are identities, i.e., true by definition.
- Only three of the seven are needed to mathematically determine the others.
- Deployment has generally small impacts on cost per vehicle hour.
- In the literature on transit performance indicators, unit cost is sometimes referred to as "efficiency" and utilization as "effectiveness".