PART IV. MEASUREMENT TECHNIQUES

Overview

The benefits tree shows that transit can have a wide variety of consequences. These consequences occur because transit provides an alternative means of travel, because transit provides a means of making trips, because land use can vary and because transit is an enterprise. Each of these categories of consequences leads to other effects, which in turn lead to still more effects. While measurement of all effects at all levels of the tree may appear to be a difficult (if not an impossible) task, there are factors that may make the problem less difficult. The purpose of a given benefits analysis and the nature of the decisions to be made are two important factors in making the process easier.

An understanding of the decision process will help to identify those consequences that should be looked at in detail. Since a decision involves a comparison of alternatives, only those consequences that are likely to be significantly different between alternatives need to be looked at extensively. If a consequence is likely to be the same for all alternatives, it will not make any difference in the decision. The scope of analysis can therefore be reduced.

A second way of simplification is to avoid combining consequences to produce aggregate estimates of benefits. Valuation is often difficult, and it can easily lead to double counting. There is also an "apples and oranges" problem. For example, it is impossible to add prestige to emissions reduction in any meaningful way. If a difference exists and if it is significant, then it should be expressed in the most understandable terms. The most understandable terms for emissions reduction might be tons of pollutants reduced; the most understandable terms for prestige might be a summary of results of an attitudinal survey.

A final way of simplifying the analysis is to use the branching of the tree to get more general indicators. Transit trip making affects lifestyle in a number
of ways, but these effects are very difficult to measure at the lower levels of the
tree. In such a case, it may suffice to indicate the number of people affected
(i.e., the number of new users) as a general indicator, rather than to measure all
lower level effects. The method depends on the decision.

With this background, methods for measuring benefits are suggested in
the remainder of the report. The table on the next page provides suggestions on
how to measure benefits at the first two levels identified in the benefit tree.

**Transit as an Alternative.** The value of having transit available as a
possible alternative (option value) is difficult to estimate. These effects could be
simply described in words or else measured in a general sense; i.e., overall size
of service area or the population of zero automobile households served. More
detailed estimates could be found from looking at the costs (or consumer
surplus) of providing such advantages by means other than transit; i.e., use of
taxicab service in the event of an automobile breakdown.

**Travel by Transit.** Travel related benefits for both automobile users
and transit users can be estimated through an enhanced consumer surplus
technique. This technique can be used to estimate the user effects from savings
in travel time, operating and parking costs, and destination choice that result if
the transit system is changed. The technique is described in greater detail in the
Section H of this report. Consumer surplus also can be used to determine the
land redistribution effects of transit (also explained later in Section I).

Environmental effects of travel occur in several areas of the tree and
could be measured by trip related multipliers. If the number of trips is known
along with some of their characteristics (i.e., length, speed, delay, and vehicle
# Measurement Techniques for Transit Consequences

<table>
<thead>
<tr>
<th>I. Provides Alternatives</th>
<th>Ease of Measurement</th>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Long Term Option</td>
<td>difficult</td>
<td>written comment</td>
</tr>
<tr>
<td>B. Unusual Occurrence</td>
<td>easy</td>
<td>service area size</td>
</tr>
<tr>
<td>C. Independent Living</td>
<td>difficult</td>
<td>difference in C.S. of next best alt.</td>
</tr>
<tr>
<td>D. Recreational Riding</td>
<td>moderate</td>
<td>written comment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>value/trip</td>
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<thead>
<tr>
<th>II. Travel by Transit</th>
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<tbody>
<tr>
<td>A. Fewer Automobile Trips</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Facility Needs</td>
<td>easy</td>
<td>comparison of plan alternative</td>
</tr>
<tr>
<td>2. Environmental Effects</td>
<td>easy</td>
<td>trip related multipliers</td>
</tr>
<tr>
<td>3. User Effects</td>
<td>easy</td>
<td>consumer surplus</td>
</tr>
<tr>
<td>B. Transit Trips</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. User Effects</td>
<td>easy</td>
<td>consumer surplus</td>
</tr>
<tr>
<td>2. Change in Well Being</td>
<td>very difficult</td>
<td>written comments</td>
</tr>
<tr>
<td>3. Change in Life Style</td>
<td>very difficult</td>
<td>written comments</td>
</tr>
<tr>
<td>4. Security</td>
<td>difficult</td>
<td>written comments</td>
</tr>
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<tr>
<th>III. Land-Use/Economic Activity</th>
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<tbody>
<tr>
<td>A. Concentration of Activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Efficiency of Public Services</td>
<td>moderate</td>
<td>written comment</td>
</tr>
<tr>
<td>2. Interpersonal Contacts</td>
<td>very difficult</td>
<td>land-use model</td>
</tr>
<tr>
<td>3. Land Preservation</td>
<td>difficult</td>
<td>written comment</td>
</tr>
<tr>
<td></td>
<td>moderate</td>
<td>comparison of plan alternatives</td>
</tr>
<tr>
<td></td>
<td>moderate</td>
<td>included with consumer surplus</td>
</tr>
<tr>
<td></td>
<td>moderate</td>
<td>included with consumer surplus</td>
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</tbody>
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<tr>
<th>IV. Transit Supply</th>
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<tbody>
<tr>
<td>A. Community Support</td>
<td>very difficult</td>
<td>referenda, budget allocations</td>
</tr>
<tr>
<td>B. Facilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Construction</td>
<td>moderate</td>
<td>input/output</td>
</tr>
<tr>
<td>2. Land-use</td>
<td>easy</td>
<td>plan results</td>
</tr>
<tr>
<td>C. Operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Employment</td>
<td>moderate</td>
<td>input/output</td>
</tr>
<tr>
<td>2. Environmental</td>
<td>easy</td>
<td>transit veh. mil. multipliers</td>
</tr>
<tr>
<td>3. Purchases</td>
<td>easy</td>
<td>input/output</td>
</tr>
</tbody>
</table>

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Measurement of Transit Benefits
type), then estimates can be made of energy, air pollution, and noise consequences. Methods for doing this for air pollution are discussed in Section J. Facility needs related to less automobile travel can be found from comparisons of plan elements.

Transit trip making has many complex consequences; i.e., change in well being, change in lifestyle, and security. It can be argued that these effects will be reflected in net consumer surplus, if the measurement of consumer surplus is calculated so that it incorporates the behavioral nature of travel choice. The calibration of mode choice models and other steps of the travel forecast must be done to represent how travelers consider all aspects of their travel decisions. Traveler behavior would account for the values placed on many of the effects shown in the transit trip making part of the tree.

**Land-Use Consequences.** Effects on land use of transit can be partially measured through a consumer surplus approach, if the modeling structure permits land-use distribution to change. Techniques are given in Section I. Other land-use consequences that result from concentration are more difficult to measure. Efficiency of public services and interaction may need to be described in words. Land preservation could be found from the results of a travel demand/land-use model, as described later.

**Transit Supply Consequences.** The presence of transit has a variety of effects. Transit facility construction and operation employ people and consume resources. In addition, the presence of a transit system can generate local community pride and prestige. Such intangibles are difficult to measure but may be quite significant to a community. Employment impacts can be determined through an input-output analysis or through a direct approach, as described in Section K of this report. Other effects (such as land consumption, environmental effects and purchases) can be found from plan designs.
H. TRAVEL RELATED BENEFITS

Measuring Travel Related Benefits

Travel related benefits are those that result from increased accessibility when a transit system is improved. Benefits can accrue to a transit patron, because a trip can be made with less time, cost or inconvenience by transit than by some other alternative. Benefits can also accrue to an automobile driver or a passenger, because there might be less congestion on some streets due to increased transit usage. Benefits can also accrue to a traveler who might choose to make an additional trip by either mode or might choose to switch modes.

Many past benefits studies have determined that the largest single user benefit from a transportation system improvement is travel time savings. Additional user benefits include savings in costs of fuel, tolls, fares, vehicle ownership, and vehicle maintenance. Intangible user benefits can include the comfort of travel, the ability to make entirely new trips, or to satisfy trip purposes by traveling to better but more distant destinations.

In our largest cities, there has been an increasing interest in transit's impact on traffic congestion. There are two aspects to this impact: (1) the degradation of traffic flow associated with buses mixed with automobiles; and (2) the improvements in traffic flow that might occur if some drivers can be persuaded to take transit. Both of these effects should be components of user benefits.

When dealing exclusively with highway travel, it is sometimes possible to estimate user benefits by adding individual components. For example, by ignoring changes in mode or destination it is possible to compute time saving from a highway improvement by subtracting the "after" total travel time from the "before" total travel time. Transit benefits are far more complicated, so it is easiest to estimate them directly from the net consumer surplus of the system change. If calculated properly, net consumer surplus will include all the cited benefits – both tangible and intangible.
**Essential Ingredients**

User benefits in the form of net consumer surplus can be easily estimated, provided that a good travel forecast has been prepared for the transit alternative and the null alternative. Ideally, the travel forecast should have these features.

a. It must have determined mode split for every possible trip in the transportation system. Planners familiar with travel forecasting will call this a "post distribution" mode split for all origin and destination pairs. The mechanism for computing mode split should be properly sensitive to travel time, travel cost and convenience (including weighted out-of-vehicle time).

b. The spatial distribution of trips should have been sensitive to the amount of transit service, enabling shifts in origin-destination patterns because of transit improvements. Most travel forecasting models do not provide this sensitivity; however, it can often be added with little difficulty. Methods for distributing trips in this way are described in the section, “Technical Issues.”

c. The spatial distribution of trips should be sensitive to the level of congestion on highways. Some travel forecasting models can do this automatically, others cannot. Planners sometimes refer to a forecast with this property as having “elastic-demands.”

d. Trip generation, the choice to travel or not to travel, should be sensitive to the quality of transit service. This could be done in a number of ways, including using automobile ownership forecasts that relate to the extent of transit service.

e. The amount of traffic estimated for each segment of road must be properly sensitive to the amount of congestion on that segment.
Furthermore, the amount of estimated delay on each road segment must accurately reflect the amount of traffic. If both these conditions are satisfied, the forecast is described as having an "equilibrium traffic assignment".

f. The estimate of mode split for each possible trip should be properly sensitive to the amount of congestion on the road network.

g. The procedure should be capable of market segmentation; that is, to incorporate data from user groups with different circumstances.

The essence of this approach is to use behavioral travel choice models as the indicator of willingness-to-pay and the basis for benefit measurement.

Procedures for creating such a forecast have been developed over the past several years, and are already available in off-the-shelf travel forecasting packages. The essence of this approach is to use behavioral travel choice models as the indicator of willingness-to-pay and the basis for benefit measurement. Additional elements may be needed, depending upon the nature of the transit system modification and upon its long-term effects on urban development.

A ballpark estimate of user benefits can sometimes be made with a less-than-ideal travel forecasting model. Such a rough estimate is not always desirable as some benefits may be underestimated; the method will be explained later in this chapter.
Travel Benefits asMeasured by an Enhanced Consumer Surplus

Economists tell us that benefits of any public project can be ascertained by calculating net consumer surplus. Consumer surplus is the difference between the amount an individual is willing to pay for a good and the amount the individual actually pays. For example, consider a commuter line that now carries 500 riders. One particular commuter might be willing to pay $5 for travel from his suburban home to his work place, but the rail operator only charges $4. The $1 difference is the commuter's current consumer surplus. Any decrease in fare would further increase this commuter's consumer surplus. Net consumer surplus can be estimated very easily when there aren't any changes in travel behavior. A reduction in fare to $3 would increase this commuter's surplus by another $1 to a total of $2. The net increase in consumer surplus for all current riders is exactly $500.

Net consumer surplus is more difficult to estimate when there are behavioral changes. Continuing with the previous example, assume that after the fare decrease there was an increase in ridership on the commuter line of 100 new riders. It is reasonable to assume that each new rider had a willingness-to-pay of somewhere between $3 and $4. A rider with a willingness-to-pay of less than $3 wouldn't choose to ride; a rider with a willingness-to-pay of greater than $4 would already be riding. Without any further knowledge of the new riders we can only split the difference and assume the average willingness-to-pay of the new riders is $3.50. The average net consumer surplus for a new rider is $0.50, or $50 for all 100 new riders. The total net consumer surplus of the fare reduction is $550 ($500 for the old riders and $50 for the new riders).

A person's decision to switch to transit normally consists of more than cost issues. The potential rider also considers in-vehicle time, out-of-vehicle time, comfort, and convenience. The forecast of travel must include all of these elements of the choice process, properly weighted.
MEASUREMENT TECHNIQUES

When doing a complete benefits calculation, it is also essential to consider losses in consumer surplus elsewhere in the system – on other transit routes or on highways. The above example would be totally correct only if the new riders had not been already making the same trip by some other means.

Clearly, benefits still can accrue when there aren't any changes in fare, such as with improved headways, elimination of transfers, faster speeds, or line extensions. Some service improvements can decrease the duration of the trips; other service changes improve the convenience of trips. It is important to include these nonmonetary changes in any estimate of consumer surplus.

Disutility Measures

For any given transit trip it is possible to calculate a comprehensive measure of its costs and inconveniences, called the trip's "disutility". Disutility is most easily interpreted when it is expressed in units of automobile riding time. A typical disutility function would look like:

\[
\text{Disutility} = \text{automobile riding time} + \\
\text{(transit riding time)}\text{(transit riding weight)} + \\
\text{(walking time)}\text{(walking weight)} + \\
\text{(waiting time)}\text{(waiting weight)} + \\
\text{(transfer time)}\text{(transfer weight)} + \\
\text{initial wait penalty} + \text{first transfer penalty} + \\
\text{second transfer penalty} + \\
\text{fare}/\text{(value of time)} + \\
\text{(tolls + parking costs +} \\
\text{vehicle operating costs)}/\text{(value of time)} + \\
\text{(vehicle ownership costs)}/\text{(value of time)} .
\] (H.1)
In this equation, the value of time is the rate at which travelers would be willing to trade money for time savings. Typical values of weights and penalties are shown in Table H.1. These values could also differ by trip purpose and by market segment to represent different levels of importance for different types of trips.

Equation H.1 deals exclusively with time, cost and convenience issues. Additional terms could be provided for other significant elements of comfort, such as protection from inclement weather and privacy, if they were factors in traveler choices.

### Table H.1. TYPICAL WEIGHTS AND PENALTIES FOR TRAVEL DISUTILITY

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Transit Riding Weight</td>
<td>$1 + 2.0 \times \text{ (fraction of person time standing)}$</td>
</tr>
<tr>
<td>Walking Weight (good weather)</td>
<td>1.3</td>
</tr>
<tr>
<td>Waiting Weight</td>
<td>1.9</td>
</tr>
<tr>
<td>Transfer Weight</td>
<td>1.6</td>
</tr>
<tr>
<td>Initial Weight Penalty</td>
<td>8.4 minutes</td>
</tr>
<tr>
<td>Transfer Penalty (first or second)</td>
<td>23 minutes</td>
</tr>
<tr>
<td>Value of Time</td>
<td>0.167 to 0.333 of the average wage of choice riders</td>
</tr>
</tbody>
</table>

The only vehicle ownership costs that should be included in Equation H.1 are those that can be attributed to a single trip. It has been found that travelers do not correctly perceive the full value of their vehicle ownership costs while making mode choice decisions, so this term is sometimes omitted. However, it may be that a user regularly chooses transit to avoid ownership of a
second car. In that case the ownership cost of an automobile should be included in the automobile disutility equation for those who consider this a factor.

Travelers have a willingness-to-pay in units of travel time. They will choose to ride only if the disutility of travel (in time units) is less than their willingness-to-pay (in time units). Consequently, travelers possess a consumer surplus of disutility in time units. This disutility may be mathematically expressed as a time savings or converted to monetary units by multiplying by the value of time.

\(^{13}\) Horowitz, Alan J., 1980, pp. 175-182.
Calculation of Enhanced Consumer Surplus

This enhanced measure of consumer surplus is illustrated in Figure H.1 for a single trip. A demand curve shows the relationship between numbers of trips and trip disutility, expressed in time units. Point 1 represents the original disutility and number of riders taking the trip. Point 2 shows a new disutility and the number of riders after a service change, such as shortening the headway. Because of the service improvement, more people have chosen to take this trip. Some new riders switched from the automobile, some new riders have changed their choice of destination, and some new riders are making an entirely new trip. \( T_1 \) is the original disutility and \( T_2 \) is the new disutility. All the old riders receive a windfall consumer surplus of \( T_1 - T_2 \). This windfall is illustrated as the shaded area A. New riders have a net consumer surplus shown in the shaded area B. The new riders' net consumer surplus is an almost triangular area. Consequently, the total consumer surplus can be found from the roughly trapezoidal, combined area:

\[
Net \ Consumer \ surplus = (T_1 - T_2) \times \frac{Q_1 + Q_2}{2} \tag{H.2}
\]

More precisely, net consumer surplus may be found by subdividing the shaded area into several flat and wide trapezoids and adding their areas, as shown in Figure H.2. This process of finding the area of several smaller trapezoids can be expressed mathematically as,

\[
Net \ Consumer \ Surplus = - \int_{T_1}^{T_2} Q(T) \, dt \tag{H.3}
\]
Figure H.2. Approximating the net consumer surplus integral with flat trapezoids.

Figure H.3. Effect of a transit system improvement on net consumer surplus for automobile users.
where \( Q(T) \) is ridership as a function of disutility. Because of the integral sign, Equation 3 looks more complicated than it really is. Integral calculus is never actually used to perform such a computation. Instead, we would simply divide the service change into several small increments and compute the net consumer surplus with Equation H.2 as each increment is applied.

In a multimodal transportation system it is necessary to sum the net consumer surplus over all possible modes. For example, it is likely that highway traffic would decline slightly as the result of the service improvement illustrated in Figure H.1. The demand curve for the highway is shown in Figure H.3. It is seen that the disutility of travel declines slightly, due to congestion relief, but the number of automobile passengers also declines. Consequently, there is a small net consumer surplus to highway travelers (shaded area).

Total net consumer surplus for the whole system can be found from this relationship,

\[
Net \ Consumer \ Surplus = - \sum_m \sum_i \sum_j \int_{T_{mij}} Q(t) \, dt \quad (H.4)
\]

for all modes \((m)\), all origins \((i)\) and all destinations \((j)\). As before, the integral is performed by summing the areas of flat, wide trapezoids.
A Numerical Example

Consider the network of Figure H.4 and the accompanying data. There is one origin, one destination, and two modes – bus and automobile. There are 1400 person trips made between the origin and destination during the peak hour, of which 50 trips are captive to transit. The remaining 1350 travelers have a choice of modes. Transit disutility will be reduced, on average, from 50 minutes to 40 minutes by a variety of service improvements. The practical capacity of the road is 650 vehicles per hour and the average number of passengers per automobile is 1.2. The trip takes, on average, 20 minutes under uncongested conditions by automobile.

The disutility by automobile, $T_a$, can be estimated from the BPR travel time/volume formula:14

$$T_a = (\text{uncongested travel time}) \times [1 + 0.15 \times (\text{volume/practical capacity})^4]$$

so

$$T_a = 20 \times [1 + 0.15 \times (\text{volume}/650)^4] \qquad (H.5)$$

The number of travelers choosing the bus can be estimated by adding the captive riders to those choice riders who chose transit:

$$Q_b = (\text{Captive Riders}) + (\text{Choice Travelers}) \times P_b \qquad (H.6)$$

Where $P_b$ is the fraction of choice travelers who chose transit. The remaining travelers go by automobile. The fraction of choice travelers choosing the bus may be found from the logit model:

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MEASUREMENT TECHNIQUES

\[ P_b = \frac{\exp(-\alpha T_b)}{\{\exp(-\alpha T_b) + \exp(-\alpha T_a)\}} \] (H.7)

where \( \exp( ) \) is the exponential function and \( \alpha \) is a constant that is individually calibrated for each transit system. From earlier work, it has been determined that a good value of \( \alpha \) for this example is 0.06.

These relationships permit a simultaneous solution of transit ridership and automobile disutility. Because the equations are rather complicated, it is easiest to find the solution iteratively with a spreadsheet. The before and after solutions are shown in Table H.2.

<table>
<thead>
<tr>
<th></th>
<th>Bus</th>
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<tbody>
<tr>
<td></td>
<td>Disutility</td>
<td>Passengers</td>
<td>Disutility</td>
</tr>
<tr>
<td>Before</td>
<td>50.0</td>
<td>357</td>
<td>29.6</td>
</tr>
<tr>
<td>After</td>
<td>40.0</td>
<td>462</td>
<td>26.3</td>
</tr>
<tr>
<td>Change</td>
<td>-10</td>
<td>+105</td>
<td>-3.3</td>
</tr>
</tbody>
</table>
The results of Table H.2 can be easily confirmed by substituting these results directly into Equations H.5, H.6 and H.7. In general, results such as those in Table H.2 would be outputs of rather complex simulation that incorporates the necessary feedback loops.

Using Equation H.1, the consumer surplus for the system can be computed:

\[
\text{Net Consumer Surplus Transit} = (50 - 40)(357 + 462)/2
\]

\[= 4095 \text{ person minutes}\]

and

\[
\text{Net Consumer Surplus Automobile} = (29.6 - 26.3)(1043 + 938)/2
\]

\[= 3269 \text{ person minutes}\]

for a total of 7364 person minutes.

This example assumed that the only effect of a transit improvement is to shift people from automobile to bus. New trips, had they existed, could have been easily handled within this framework. For example, if the service change generated 40 new transit trips, their consumer surplus would be 40 times their average improvement in disutility:

\[= 40 \times (50 - 40)/2\]

\[= 200 \text{ person minutes}\]

The net consumer surplus would then be 7564 person minutes.
A popular method of evaluating improvements in highways is the computation of time savings. This method assumes that demand is inelastic; i.e., the pattern of trip making will be unchanged and the only effect will be a savings in time for certain travelers. This assumption assures that net consumer surplus can be computed by subtracting the total automobile time after the change from the total automobile time before the change. However, when there are important changes in demand due to choice of mode or of destination, time savings fails to measure properly net consumer surplus. In the previous example, a disutility savings in time units can be computed as

\[
\text{Time savings} = (29.6 \times 1043) + (50 \times 357) - (26.3 \times 938) - (40 \times 462)
\]

\[
= 5573 \text{ person minutes of savings.}
\]

In this case, time savings underestimates the benefit of the transit service improvement.

A conventional time savings calculation underestimates the benefits of the service change because it simply penalizes travelers who switch to transit. These travelers appear to be making an irrational decision in choosing a mode with a higher disutility. However, a close inspection of each travelers’ decision process would undoubtedly reveal a strong predisposition toward transit of those that switched. The traveler's origin or destination may have been particularly well located for a transit trip; or the traveler may be able to avoid the purchase of an automobile; or the traveler may have some personal circumstance that makes automobile driving unattractive. A time savings calculation would only make sense if we possessed highly detailed personal information about every traveler. Such information is impossible to get.
Unlike time savings, net consumer surplus takes the mode choice decision at face value as a description of choice behavior. Since mode choice models are developed to represent consumer behavior, it should logically follow that they also can be used to determine how much the traveler benefits when that behavior takes place. If a person chooses a different travel behavior, there must be a net positive benefit (or a smaller loss).

**Value of Time**

Values of time have been tabulated for many different travel situations. A majority of studies establishing a value of time have done so by statistical analysis of mode split data. Statistical procedures have varied, yielding varied results. However, the bulk of values of time fall between 12.5% and 50% of the prevailing wage rate. Many transit studies have adopted standard values of time – one third of the wage rate for work trips and one-sixth of the wage rate for non-work trips. A value of time would permit conversion of disutility (in time units) back to dollar units.

For example, assume all the travelers in the previous example are going to work and they all make $12 per hour. The value of time is then $4 per hour (one-third of the wage rate) and there are 245.45 hours of consumer surplus for a total of $981.80 worth of benefits.

Economists have confirmed that different people have different values of time while traveling; for example, high wage earners benefit more from a time savings than low wage earners. This line of reasoning can produce the controversial conclusion that the best transit systems are those that serve high income people. Systems that serve low income individuals (often minorities) achieve less monetary benefits because of their lower values of time. A strict measure of monetary benefits must include this income variation. For this
reason, it is suggested that planners resist converting disutility benefits to dollar benefits when comparing alternatives or when choosing an alignment. Otherwise, the evaluation methodology could lead to discriminatory results.

Market Segmentation

A traveler's response to a transit system change would normally vary by the traveler's life circumstances. For example, a large family with only a single automobile would be unlikely to sell it, even if transit service is made very convenient. A small family with many automobiles might be more inclined to cast off a redundant vehicle. Such life circumstances could affect the net consumer surplus of a transit system improvement. These persons would have a larger disutility function with components for vehicle operation costs and ownership costs.

The best way of accounting for life style is to segment the market for transit service within the travel forecast. At the very least, a distinction should be made between “captive” and “choice” riders. Other variables in a segmentation scheme could include income, automobile availability, and family size. It is best if the segmentation scheme be kept consistent throughout all forecasting model steps – trip generation to mode split.

Aggregation Issues

Economists have argued about the practice of aggregating a small amount of time savings for each traveler across a large number of travelers to get a large net benefit. Some economists feel that the saving of a very small amount of time (e.g., a fraction of a minute) is of no practical value, so it must have a
very low benefit. Other economists state that small time savings should be counted anyway.

The practice of discounting small, individual time savings assumes that travelers are instantly granted these savings and have no means of adjusting their lifestyles to them. It further assumes that the travel patterns are identical across alternatives. Neither of these assumptions are valid. A time savings, regardless of its size, is beneficial.

Enhanced Consumer Surplus without a Travel Forecasting Model

The effect of many service changes can be roughly estimated in numerous ways; for example, the similar route method, elasticity method, and the pivot point method. The elasticity method is particularly popular for small, short-term service changes to individual bus routes. Elasticity may be defined as the percentage change in output divided by the percentage change in input, so long as the changes are small. For example, assume a bus route had a reduction in headways from 25 minutes to 20 minutes and this resulted in a route ridership increase from 3000 to 3300. Thus, there was a 10 percent increase in ridership associated with this 20 percent reduction in headway. The elasticity, in this case, was -0.5. Some typically found values of elasticity are reproduced in Table H.3. Although elasticity values can be adopted from other cities, local knowledge is strongly preferred.

The benefits of a small, short-term service change can be easily estimated from Equation H.2. We should use Equation H.3 for a large service change, because the typical assumption of constant elasticity implies a nonlinear demand curve. In other words, larger service changes should be arbitrarily broken into a series of smaller service changes for the purposes of benefits calculation.
Consider an example of another route. The current ridership is 2400 with a headway of 30 minutes. The headway is to be reduced in half. Assume that each 1 minute reduction in headway results in a 0.5 minute reduction in average waiting time and further assume that each reduction of 1 minute of waiting time results in a 1.9 minute reduction in disutility (see Table H.1). Furthermore assume that the headway elasticity is constant across the whole reduction. The calculations are illustrated on Table H.4. Again, the result has units of person minutes. This calculation did not assume a value for disutility for any given rider; only differences in disutility were used.

The disadvantages of an elasticity model relate to its simplicity. It is only approximate, ignoring local circumstances and peculiarities of existing service. It cannot be used to determine the impact on other parts of the transportation system (for example, reductions in congestion on the highway as a result of service change), so consumer surplus from elasticity models excludes some possible benefits.

<table>
<thead>
<tr>
<th>Table H.3. TYPICAL VALUES OF ELASTICITY FOR TRANSIT SERVICE CHANGES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bus Fare</strong></td>
</tr>
<tr>
<td><strong>Rapid Rail Fare</strong></td>
</tr>
<tr>
<td><strong>Headway</strong></td>
</tr>
<tr>
<td><strong>Bus Miles</strong></td>
</tr>
<tr>
<td><strong>Households within Service Area</strong></td>
</tr>
</tbody>
</table>

## Table H.4. CONSUMER SURPLUS WITH ELASTICITIES

<table>
<thead>
<tr>
<th>Headway Reduction</th>
<th>Change in Disutility</th>
<th>Before Ridership</th>
<th>After Ridership</th>
<th>Net Consumer Surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 to 25 min</td>
<td>4.75 min</td>
<td>2400</td>
<td>2600</td>
<td>9975</td>
</tr>
<tr>
<td>25 to 20 min</td>
<td>4.75 min</td>
<td>2600</td>
<td>2817</td>
<td>12865</td>
</tr>
<tr>
<td>20 to 15 min</td>
<td>4.75 min</td>
<td>2817</td>
<td>3052</td>
<td>13939</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>36779</td>
</tr>
</tbody>
</table>
Technical Issues

A travel forecast that can properly measure enhanced consumer surplus is no more difficult to run than a conventional forecast, provided care is taken to compute the necessary values of disutility and demand for all modes. The types and amount of data, calibration requirements, and necessary expertise are essentially unchanged. However, there are certain technical and procedural questions that must be dealt with.

Equilibrium Assignment Issues. When computing consumer surplus, it is important that automobile disutility be consistent with the amount of traffic along the path from origin to destination. In addition, the amount of traffic should be sensitive to possible variations in mode split and the distribution of trips, both of which depend upon automobile disutility. This consistency is sometimes referred to as an elastic demand-equilibrium assignment. Planners have developed different methods for obtaining such equilibrium solution, but one particular method has been demonstrated to be the most practical with travel forecasting models currently in use by the majority of transportation planning agencies.

This method of obtaining an equilibrium assignment is illustrated in Figure H.5. Figure H.5 contains the same steps as a traditional travel forecast. However, Figure H.5 differs from traditional travel forecasting by including a feedback loop, so that the trip distribution and mode split steps can be based upon the highway disutilities that are appropriate for the amount of traffic congestion. (If there is an effect that goes back to trip generation, then the feedback loop should extend to that step as well.) Critical to the feedback loop is an averaging step. At this step the traffic volumes from all previous all-or-nothing traffic assignments are averaged together. Then new disutilities on each link are obtained. An unweighted average typically works well.
Figure H.5. Combined-Steps Methods of Travel Forecasting
Variations in the order of steps in Figure H.5 are sometimes justifiable to handle special planning situations.

A. Transit disutilities are usually assumed to be unrelated to the amount of congestion on the highway network. It might be useful to include traffic congestion in transit disutilities if congestion relief is the principal reason for implementing the service change. However, the service change must be quite large to affect significantly the total level of benefits.

B. Land-use is usually assumed to be independent of the amount of congestion on the highway network or the quality of service on the transit system. If either of these assumptions are invalid, then the feedback loop must include the land-use step. More will be said about land-use effects later in this report.

**Composite Disutilities.** Most travel forecasts find the distribution of trips throughout the community with a model step that excludes information about the quality of transit service. Consequently, such a forecast will not be properly sensitive to changes in transit service. Forecasters have sometimes included transit service into the trip distribution step by computing composite disutilities between origins and destinations that account for both highway and transit service. The following composite cost function has been found to provide the correct amount of sensitivity:

\[ T_{cij} = \frac{\ln[\exp(-\alpha T_{bij}) + \exp(-\alpha T_{aij})]}{-\alpha} \]

where \( T_{cij} \) is the composite disutility from origin \( i \) to destination \( j \), \( T_{bij} \) is the disutility by transit, \( T_{aij} \) is the disutility by automobile and \( \alpha \) is the same parameter from the mode split model that appeared in Equation H.7. For example, in the case study community the trip...
from downtown to the Golden Meadows Apartments has a transit disutility of 40 minutes and an automobile disutility of 15 minutes. With an \( \alpha \) value of 0.06, the composite disutility is

\[
T_{cij} = \ln \left[ \exp(-0.06 \times 40) + \exp(-0.06 \times 15) \right] / -0.06 = 11.64.
\]

The composite disutility is always smaller than the smallest value of its components.

**Approximating the Net Consumer Surplus Integral with Trapezoids.**
Transit service changes can be either discrete or continuous. An example of a discrete service change would be the addition of a new rail station. An example of a relatively continuous service change would be an improvement in headways. It would make sense to compute the net consumer surplus of only part of a headway improvement, but it would make little sense to compute the net consumer surplus of only part of a new station. For discrete service changes, there can be only two possible valid forecasts with and without the change. Consequently, net consumer surplus must be computed by Equation H.2, recognizing that a slight overestimate in benefits is possible.

For continuous service changes, the calculation of net consumer surplus can be more precise. The service change can be arbitrarily divided into several increments and the net consumer surplus computed for each increment, as the area of a flat trapezoid. The sum of the net consumer surpluses for each increment is the total net consumer surplus. The major drawback to subdividing service changes in this manner is the added computation time necessary to evaluate each amount of intermediate service.

**Need for a Realistic Null Alternative.** Net consumer surplus is always calculated between a before case and after case. The most relevant before case is the null alternative, i.e., the most likely state of the community without the service change. The null alternative is not necessarily the current state of affairs.
The null alternative could include growth or decline, redistribution of activities, or natural changes in the character of the community. Good null alternatives are difficult to construct, but they are essential to a valid calculation of consumer surplus.

A TSM (transportation system management) alternative is not a null alternative; a TSM alternative, by itself, can have significant benefits over the current state of affairs. It would be better to look at consumer surplus between different sets of alternatives; i.e., TSM versus null, proposed versus null, proposed versus TSM, etc. That way the net benefits versus costs can be determined.

**Adding Net Consumer Surpluses Across Alternatives.** Net consumer surpluses across alternatives are not usually additive. For example, the net consumer surplus between alternative X and alternative Y, \( C_{xy} \), can be calculated by designating one of the alternatives to be the null alternative. A similar calculation can be done between alternatives Y and Z, yielding \( C_{yz} \). However, \( C_{xz} \) is not the sum of \( C_{xy} \) and \( C_{yz} \), unless alternative Y is a subset of alternative Z.

Similarly, the net consumer surplus of half an alternative is not half the net consumer surplus of the full alternative. For example, a proposal is made to add two light rail lines. Three alternatives need to be considered: Line One by itself; Line Two by itself; and Lines One and Two together. The net consumer surplus for Line One cannot be added to the net consumer surplus of Line Two to get the consumer surplus of both lines together.
Avoiding Double Counting

The notion of consumer surplus encompasses all user benefits, including all direct manifestations of these benefits. Because it is such a broad measure, care must be taken to avoid double counting. Some areas where double counting could occur are as follows.

**Land Value Increments.** Land value increments which are consequences of greater accessibility by transportation system users should not be counted. This is frequently the case. Those land value increments that are due entirely to agglomeration effects could conceivably be counted, but they are difficult to isolate. For example, a more dense land-use pattern would lead to lower costs of public utilities. These are properly counted as benefits. When measuring land value increments that essentially result from a redistribution of activities (such as agglomeration effects) it would be necessary to count both gains and losses throughout the community. The size of the study area selected will affect this, since the losses could occur outside your study area while gains occur inside. Since losses are particularly difficult to ascertain, it is best to avoid counting land value increments as benefits except those that can be attributed to higher density.

**Vehicle Operating Costs.** Vehicle operating costs include the costs of fuel, maintenance, insurance, and depreciation. Since the vehicle operating costs are included -- explicitly or implicitly through calibration -- in a good mode split model, they should have already been included in net consumer surplus.

Benefits not Included in Consumer Surplus

Consumer surplus only measures the benefits of system changes that are perceived by users during their daily trip making. Consumer surplus does not take into account benefits to individuals that are not immediately perceived, long-term benefits,
benefits to society at large, benefits due to a favorable redistribution of economic activity or land use, and benefits from preserving scarce natural resources. Many of these benefits are discussed in other sections of this report.
I. LAND-USE EFFECTS OF TRANSIT

Introduction

Many people believe that the benefits stemming from land-use changes induced by improved transit services are quite significant; however, the existence of these benefits has been difficult to demonstrate accurately, although almost every newly published environmental impact statement for local transit improvement cites these benefits.

Some researchers have recently adopted a contrary opinion: that travelers will tend to undercut the benefits of transit system improvements by varying their behavior to take advantage of the new supply.

Our goal in this section is to construct a prospective, analytical procedure for assessing the impacts of transit on land use, which can allow forecasts and comparisons of land-use/travel-efficiency consequences of various options of transit improvement. This goal could be achieved if the procedure has these features: (1) the procedure must be simple, straightforward, cheap and easy to understand and operate by a potential user; (2) it must be sensitive to transportation facility variables, including transit variables; (3) the accessibility variables in the procedure should reflect "elastic" disutilities of each link; (4) the outputs of the procedure could be easily analyzed in terms of consumer surplus and other trip-making benefit indicators. In this chapter, we will:

- briefly explain the theories of residential location and elastic-demand equilibrium assignment;

- construct a procedure to forecast land-use changes induced from improved transit services;
– introduce the methods of measuring the benefits that result when land use is allowed to change; and finally,

– present an example of the approach using Wausau, Wisconsin.

**Background on Residential Location Models**

There are two kinds of "behavioral models" of urban land use and transportation. The first group can be called "Residential Location Models". The second group is called "Land-Use Models". Residential location models assume that work places have fixed locations, but residences can move around in response to both transportation variables and location attraction variables. A land-use model contains not only a residential location model, but models of industrial and service location. It would attempt to allocate residential, industrial, and services activities consistently with each other and consistently with transportation supply; and to resolve conflicts over available land for these activities. The most popular land-use model was first built by Ira Lowry of the Rand Corporation in 1964.\(^{15}\) In recent years, this model has been refined and improved, so that it has become quite sophisticated. For example, Lowry-Wilson derivatives are capable of describing 90% of the variation in regional activity distributions.\(^{16}\)

The major difference between a residential location model and a land-use model is how they deal with service sectors. A residential location model always assumes services as a "fixed," exogenous factor. In a Lowry-type model, services are defined as those employers who derive their income from within the

\(^{15}\)Lowry, I. S., 1964.

\(^{16}\)Putman, S. H., 1979.
region and who are sensitive to the locations of their customers. Services are further subdivided into two classes: those that serve people and those that serve businesses.

A residential location model is used here. Residential location models, in general, have the following advantages in operation over a land-use model.

- It can use exactly the same zone system as the travel forecasting model.

- Calculations are faster and computer requirements are modest.

- Because fewer types of activities are moving spatially, it is easier to keep track of what the model is doing.

Consequently, a residential location model has lower costs, is faster, and is easier to master. We have adopted this type of model as one theoretical concept for assessing the land-use benefits induced from transit service improvement.

The simplest residential location model is a form of the gravity model. In this situation, trips are produced at the work place and attracted to home. Thus, work-based home trips originating at zone i and ending at zone j are:

\[
T_{ij(whb)} = a_i w_j f(t_{ij}) \left( \frac{\sum_j w_j f(t_{ij})}{\sum_j w_j f(t_{ij})} \right)
\]

Where:

- \( w_j \) is the residential attractiveness of zone j;
MEASUREMENT TECHNIQUES

e_i is the employment in zone i;

t_{ij} is the disutility of travel from zone i to zone j; and

f(t_{ij}) is a deterrence function value for a trip from zone i to zone j, often called a friction factor.

This equation includes three rationales:

– Workers tend to locate their residences near their work places, provided other factors are the same;

– Zones with relatively greater attractiveness tend to attract a relatively larger proportion of worker's residences, provided other factors are the same; and

– The measure of closeness, disutility, includes both the quantity and quality of transportation system.

Residential Attractiveness. The strongest single measure of residential attractiveness, w_j, is the zone's residential developable area. Other attributes of the zone (such as amenities, quality of schools, prestige, safety and zoning) may also be included. If necessary, the attractiveness can be easily adjusted by multiplying the residential developable area with a factor for land-use controls, amenities and community characteristics. DRAM^{17} (disaggregate residential allocation model) is a popular example of a residential location model with an expanded measure of attractiveness.

^{17}Ibid.
**MEASUREMENT TECHNIQUES**

**Employment.** Total employment, e, for each zone includes both "basic" industrial employment and service employment.

**Disutility of Travel.** Disutility, as previously discussed, is always expressed in units of time but may include cost and inconvenience factors, as discussed before under consumer surplus. Disutility includes travel between zones as well as within the zone (intrazonal disutility). Intrazonal disutility could be found by this formula:

\[ t_{ii} = 0.75 \times t_m D^{1/2} \]

Where \( t_m \) is the disutility necessary to travel one mile, and \( D \) is the gross area of the zone in square miles.

**Deterrence Function.** The concept of deterrence function is similar to a friction factor in traditional travel forecasting. The most popular deterrence function is of the form,

\[ f(t_{ij}) = \exp(-\beta t_{ij}) \]

where \( \beta \) can be empirically derived or set.

If we assume that there is exactly one trip home for each worker, the number of workers residing in a zone is simply equal to the total home-based work trips in that zone. The population can be easily derived from this number, by multiplying by the population to employment ratio. Dwelling units can be found by a similar method.
Elastic-Demand Equilibrium

Demand must have some elasticity. Within an ideal travel forecasting model the spatial distribution of trips should be sensitive to the level of congestion on highways. Practically speaking, on a highway the level of congestion affects its disutility in terms of riding time and operating costs. Consequently, highway disutility determines its travel patterns in terms of demand.

Traffic demand, in turn, results in the level of congestion. The three elements -- congestion level, disutility and traffic demand have an inseparable relationship. This can be expressed in the following formulas:

\[ Q = D \{T, x, \phi\} \]

and

\[ T = S \{Q, v, \} \]

where

- \( Q \) is the travel volumes per unit time;
- \( D\{\} \) is the demand;
- \( x \) is a set of exogenous variables;
- \( T \) is the disutility;

---

A good solution method for these interrelated formulas is the equilibrium travel forecasting method outlined earlier in this report. Land-use distribution also depends on the disutilities of each link, so an ideal land-use forecasting model should be sensitive to the changes in disutilities. The procedure for finding an equilibrium land-use/travel solution is discussed in the following section.

**Land-Use Forecasting Procedure**

The land-use forecast model consists of two interrelated parts: a land-use forecast and a travel forecast. Solving them together allows calculation of users’ benefits from forecasted levels of highway use and transit ridership. The procedure is illustrated in Figure I.1. This procedure differs from a conventional travel forecast principally by the nested feedback loops between land use and travel, as well as for travel equilibrium. Those loops assure that residential location properly reflects the level of congestion on the highway network.
Benefits Assessment

As transit services improve, travelers gain additional travel options and the composite disutilities will decline correspondingly. From the earlier discussion, we know that the following formula has been found to be a good expression of composite disutilities:

\[ T_{cij} = \ln \left[ \exp(-\alpha T_{bij}) + \exp(-\alpha T_{αιj}) \right] / -\alpha \]

where

- \( T_{cij} \) is the composite disutility from zone i to zone j
- \( T_{bij} \) is the disutility by transit
- \( T_{αιj} \) is the disutility by automobile, and
- \( \alpha \) is a parameter that can be empirically derived.

This equation tells us that the composite disutilities are always less than automobile disutility. Consequently, if we use the composite disutilities to replace automobile disutility in the land-use model and travel forecasting model, we can easily tell the differences in their results. The differences are the benefits induced by the transit services in land use. In the same way, we can also compare various alternatives of transit improvements. In this manner it is possible to obtain an overall consumer surplus that includes benefits to transit users, benefits to highway users and benefits to both groups as a result of land-use shifts.

With these procedures, we can measure two types of benefits that occur from land-use changes induced from transit services. The first type compares
MEASUREMENT TECHNIQUES

the disutilities and travel patterns of the null alternative with those of an improved alternative based on the projected land-use redistribution from null alternative. An example will be given later. Another type compares the disutilities and travel patterns under the projected land-use changes of the null alternative with those under the projected land-use changes of an improved alternative. The first type simply compares the benefits caused by improved transit service itself. The second type compares not only the benefits caused by improved transit service itself, but the benefits caused by land-use changes induced by improved transit services. The difference between these two is the land-use effects of an improved alternative.

The benefits could be measured in terms of consumer surplus, amount of congestion relief and trip length. If we hold total trip productions constant in the travel forecasting model, then the users' benefits are totally attributable to modal shifts and travel pattern changes. The benefits caused by entirely new trips are not included, but could be in a more sophisticated modeling framework that relates trip generation to improvements in the transit system.

**Consumer Surplus.** The net consumer surplus from land-use changes induced from improved transit services include both benefits to automobile users and benefits to transit users. As transit service improves, both disutilities for automobile and transit will decline. They could be reduced further if trip lengths become shorter, as well. Net consumer surplus is calculated by the method described earlier in Section H.

**Congestion Relief.** Congestion relief can be measured by observing the volume-to-capacity (v/c) ratio changes on each link. The categories of v/c ratio can be set, for example, 0-0.5, 0.5-1.0, 1.0-1.5, 1.5-2.0 and more than 2.0. (Volume to capacity ratios greater than 1.0 are possible when "capacity" is defined as being LOS C conditions, as is commonly done in travel forecasting.)
models.) The numbers of link directions that fall in each category can be counted. The comparisons of these numbers suggest the benefits gained.

**Trip Lengths.** The trip length distribution can be found by observing the percentage of trips in each time length interval. The comparison of the lengths before and after transit service improvement is another means of seeing users' benefits induced by improved transit services.

The benefits that occur from land-use changes induced from improved transit services not only include these users' benefits but also nonusers' benefits, as described earlier. Nonusers' benefits of land-use changes are quite complex. These benefits might include economic aggregation effects, preservation of scarce urban lands, increased walking and bicycling, efficiency of urban renewal and infrastructure, etc. To quantify all these benefits would be beyond the scope of this report or (indeed) beyond the scope of a typical benefits assessment. However, the procedure shown here provides a good starting point for the further studies.
MEASUREMENT TECHNIQUES

An Example – Wausau, Wisconsin

Wausau, a city in central Wisconsin, has been selected as a case study site. It is a city with two modes – bus and automobile. For the purpose of assessing the benefits, we set the null alternative for our comparison to the existing networks of both modes. We designed two alternatives. The design alternative A is upgrading existing transit system headway from 30 minutes to 15 minutes. Alternative B is resetting transit fare from 50 cents to zero and system headway to five minutes. Also, three different growth scenarios were set for the analysis to test the marginal benefits by allowing land-use changes under different levels of congestion. The first scenario is the existing city (low congestion). The second growth is 1.5 times more activity than now. The third scenario is two times more activity, and it results in a very congested network. The QRS II (Windows Version) software package was used for the travel forecasts. A detailed explanation of the process used for this analysis is given elsewhere.19

Results: Land-Use Redistribution. A comparison of the dwelling unit redistribution due to transit changes was conducted for both design alternatives. Zonal trip production was defined as the sum of the number of employees in each sector (retail and non-retail). Zonal trip attraction was defined as the zonal net developable area. An exponential model was used for trip distribution. Parameters for the trip distribution model, $\beta$, were adopted from a previous land-use study ($hbw = 0.12$, $hbnw = 0.11$, $nbh = 0.11$). The conversion factor from home-based work trips to dwelling units was set to 1.5. The time period of travel was set on the peak hour (5 PM). Results are given after three full land-use iterations (outer loop).

The maps of Wausau on the following pages show how land redistribution changes under each of the alternatives. Each map shows the

change in the number of dwelling units per zone. In the first map (alternative A) there are relatively small changes in population, with growth in the central area and some population loss at the fringes. Under alternative B, there are similar shifts but in greater numbers. Population gains in areas served by transit average 0.77% under alternative A and 2.29% under alternative B. Losses of population in areas not served by transit were 1.83% with alternative A and 5.04% with alternative B.

**Consumer Surplus.** On the basis of our land-use forecasting results and corresponding travel forecasting results, the enhanced consumer surpluses under three growth scenarios were computed. The results are contained on Tables I.1 and I.2. Units are minutes of disutility. The results are found by comparing the land-use redistribution under the null alternative with that of alternatives A and B. The study shows that the more congested the network, the more consumer surplus for both highway and transit users under both alternatives. Total consumer surplus increases from 2,097 minutes with Alternative A with existing travel demand to 5,696 minutes when demand is doubled. Alternative B, which has very low headways and zero bus fares, has significantly larger consumer surplus than alternative A, reaching a total of 17,118 minutes with the high demand scenario. The land redistribution step has a relatively minor impact on consumer surplus. The total consumer surplus decreases by 11.1% with alternative A and by 4.3% with alternative B under existing demand; increases by 2.6% with alternative A and shows no change with alternative B under a demand level 1.5 times the existing; and increases by 12.6% with alternative A and shows no change with alternative B when demand is twice existing. Thus, land-use redistribution has an effect in a range of no more than +/- 13% for the cases studied.
Land use changes with Alternative B.

Land use changes with Alternative A.
### Table I.1. Consumer Surplus with Land Redistribution

<table>
<thead>
<tr>
<th>Growth Scenario</th>
<th>Highway CS</th>
<th>Transit CS</th>
<th>Total CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>35</td>
<td>196</td>
<td>2,063</td>
</tr>
<tr>
<td>1.5 times more</td>
<td>383</td>
<td>740</td>
<td>3,221</td>
</tr>
<tr>
<td>2 times more</td>
<td>1,021</td>
<td>2,192</td>
<td>4,675</td>
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### Table I.2. Consumer Surplus without Land-Use Redistribution

<table>
<thead>
<tr>
<th>Growth Scenario</th>
<th>Highway CS</th>
<th>Transit CS</th>
<th>Total CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>93</td>
<td>245</td>
<td>2,239</td>
</tr>
<tr>
<td>1.5 times more</td>
<td>294</td>
<td>694</td>
<td>3,220</td>
</tr>
<tr>
<td>2 times more</td>
<td>1,176</td>
<td>2,129</td>
<td>4,880</td>
</tr>
</tbody>
</table>

*Measurement of Transit Benefits*
Congestion Relief. The attached charts indicate the level of congestion relief for home-based work trips as transit service improves. Generally, the model shows a reduction in the pattern of vehicle trips operating on congested links and or increase in the portion on lower v/c links. This congestion relief results from the shift of trips to transit and a reduction of automobile trips. Effects are relatively minor for alternative A and somewhat larger for alternative B.

Trip Length. The attached figures show that transit improvement will increase the percentage of shorter trips and decrease the percentage of longer trips in the network, which makes the distribution of the trip length flatter under every scenario. The differences between alternatives are relatively small and occur mostly with the shorter length trips.

Conclusions. It is possible to determine the effects of land-use changes and transit systems changes through an enhanced consumer surplus approach. Such a technique looks at overall weighted travel times by mode and permits land use to shift in response to transit improvements. For the example tested the largest benefits accrue to transit users, with additional benefits to automobile users. Land-use benefits were relatively small in the examples we tested and can be positive or negative. Benefits were only slightly negative for existing levels of urban activity. The technique is relatively easy to apply and can be useful to help interpret land-use and travel consequences of transit investment.
J. AIR POLLUTION REDUCTION BENEFITS

With the passage of the 1990 Clear Air Act Amendments, local agencies are placing greater emphasis on the potential for transit to reduce emissions from automobiles. Unfortunately, the true air quality benefits of a transit alternative cannot be easily quantified and expressed in dollar terms. To do so the analyst must confront all the messy measurement issues (health benefits, reductions in loss of life, impact on the natural environment, aesthetics) of air pollution reduction.

The question of intangible air quality benefits of transit has largely been solved by the setting of the National Ambient Air Quality Standards. A joint political/scientific/economic decision has been made that these standards are beneficial. Furthermore, metropolitan areas are developing strategies that include transit to achieve these standards through reductions of emissions. Thus, the benefits of transit can be measured by how well an alternative helps achieve emission goals compared to other methods.

If transit reduces emissions with less cost or difficulty than other methods, then there is a benefit from the transit related reduction. There are three basic approaches to reducing emissions; these are: (1) reduce emissions through better vehicle technology, (2) reduce emissions through behavior control on automobile drivers or land use that lead to fewer vehicle miles of travel, and (3) increase vehicle occupancies through use of alternative modes, including transit.

All three methods at least require a good procedure to determine vehicular emissions. A recommended procedure for emissions measurement is discussed later in this section.
Methods of Measuring Benefits

**Vehicular Controls.** If monetary benefits are essential to the analysis, then the most expedient method of measuring them is to find the costs of achieving emission goals by means other than transit. If the goals are modest and the technology exists, then benefits assessment is a simple matter of finding the price of the pollution control technology – cleaner fuels and vehicles, more inspection and maintenance, better vapor recovery, etc. – and determining how much of these technologies are needed to reach the goal.

**Behavioral Controls.** If the goals are difficult to reach and cannot be met without changing travel behavior, then there are other strategies including travel behavior that can achieve the same effect as improving transit service. There are a wide variety of techniques that are being discussed to do this. These strategies usually take the form of controls that have negative effect on consumer surplus. For example, higher gasoline taxes would have the effect of reducing automobile travel throughout the region by eliminating trips, shortening trips and causing a change in mode split.

A general method of evaluating air quality constraints can be constructed from these principles. First, determine an equivalent fuel tax to bring emission reductions to the same level as a transit alternative. (Other methods besides a gasoline tax could be used if they were felt to be the most reasonable alternative to transit.) A gasoline tax is useful for comparison in that it affects all automobile travelers and can be easily added to the travel choice equations. It is a surrogate for other techniques that would have the same effect on the disutility equations. The tax would be introduced in the disutility function for the trip distribution and mode split steps. Second, measure the change in consumer surplus (it should be negative), by the methods discussed earlier.
Consider the sample problem from the discussion of consumer surplus. Suppose it has been determined that automobile disutility must increase by ten minutes to have the same emissions reductions as an improved transit alternative (i.e., the transit users' disutility decreases an average of ten minutes in the alternative). With a value of time of $4.00 per hour and a fuel use rate of one-half gallon per trip, this disutility increase is equivalent to a tax of $1.33 per gallon (10 * 4.00 * 2 / 60). Thus,

\[ T_a = 20 \times [1 + 0.15 \times (\text{volume/650})^4] + 10. \]

The changes in travel are summarized in Table J.1.

<table>
<thead>
<tr>
<th></th>
<th>Bus</th>
<th>Automobile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disutility</td>
<td>Passengers</td>
</tr>
<tr>
<td>Before Tax</td>
<td>50.0</td>
<td>357</td>
</tr>
<tr>
<td>After Tax</td>
<td>50.0</td>
<td>439</td>
</tr>
</tbody>
</table>

Note that the tax has been set so that the after-tax mode split is the same as from the headway reduction in the previous example. The net enhanced consumer surplus is -6636 minutes (from the trapezoidal area). There is gain in tax revenue equivalent to 9380 minutes of travel, but this revenue is considered a transfer payment and should be ignored.
In this example, the disbenefit of a gasoline tax is almost as large in magnitude as the benefit of the headway reduction. However, to count it as a benefit for transit requires an argument that draconian traffic controls are unavoidable without transit. Such an argument could be made in a few large cities, but certainly not everywhere.

**Meeting Transit's Emission Goals.** From a decision maker's viewpoint, either of the previous two methods is complex and abstract. The establishment of emission goals has the advantage of simplifying the decision process – we possess a direct means of determining if the transit alternative is successful. Since there are no compelling reasons to try to produce an overall benefit measure, it is only necessary to compute for each alternative the percentage of the goal achieved.

**Technical Issues**

**Determining Emission Rates.** Those agencies responsible for meeting obligations under the Clean Air Act are required to estimate emissions by procedures established by the Environment Protection Agency. For consistency, it is important that similar procedures be used when evaluating the air quality benefits of transit. EPA supplies software, MOBILE, for emission calculations. However, it is not practical to run MOBILE for each and every link in a large highway network. Instead, it is necessary to use MOBILE to develop a table of emission factors that vary by speed and by facility type, assuming facilities differ in their vehicle mix, trip length and cold start characteristics. The table should have every integer value of speed. It is also possible to express the outputs of MOBILE in the form of a polynomial:
emission rate for a facility = \[ \sum_{n=1}^{N} a_i \cdot \text{speed}^n \cdot 1, \]

where the \( a_i \)'s are empirical coefficients and \( N \) is the number of terms for good accuracy. You can fit this function to emission rates for integer values of speed using the linear regression capabilities of a good spreadsheet program. Expect to need five or six terms for a good match to the original emission estimates. An equation that fits MOBILE 4.1 hydrocarbon emissions for the year 2002 in Wisconsin is:

\[
\text{emissions} = 7.72 - 0.5744s + 0.01983s^2 - 0.00032s^3 + 0.0000019454s^4
\]

where \( s \) is link speed.

**Determining Volumes and Speeds.** As indicated in a previous section, the travel forecast must be sensitive to the amount of congestion on highways. Most travel forecasting models will deliver estimates of speed on each link. Some models will also provide estimates of delay at intersections. Still others will combine intersection and link delay in some manner. Given the variety of ways speed can be computed, it is important to express speeds in a manner consistent with MOBILE. In essence, MOBILE only deals with link speeds. Any delay at intersections, either within the link or at its ends, must be included in the link speed estimate. Some travel forecasting models may require special computer routines to postprocess the estimates of link speeds and intersection delays.

Many travel forecasting models use relations for link speeds that are designed for good convergence of traffic assignment algorithms, but are unrealistic from the standpoint of urban traffic. The most defensible set of traffic delay relations are contained in the 1985 Highway Capacity Manual (HCM). It is strongly suggested that the speeds from the forecasting model be checked against those from the HCM. Even better, it is suggested that speeds be
completely recalculated using procedures adopted from the HCM. Even better still, select a travel forecasting model that uses the correct traffic relations in the first place.
Many supporters of transit systems promote their alternative as a way to create jobs, help the local economy, rejuvenate downtowns and alleviate a plethora of urban ills. Most transit planning studies provide an estimate of employment impacts of construction of transit facilities and operations. However, no particular method of employment calculation prevails.

When ascertaining employment benefits, several caveats must be considered, one of them being that employment changes may merely represent a transfer of job locations. Thus, these "benefits" may more accurately be referred to as employment "impacts". For example, land-use and employment changes may be generated from the moving of a shopping district to a transit station from some other location. The total employment is unchanged, but it is at a different place.

Employment from transit facility construction will generate some local employment but will also attract workers skilled in construction from other activities. In a recent review of employment impacts of light rail projects, Marc Levine concludes,

...no studies have yet demonstrated that major rail transit investments have stimulated structural (i.e., lasting beyond the immediate stimulus of the construction phase) net increases in a given region's employment, productivity, output, or real-estate development... Typically, transportation policies promote local employment at the expense of job creation elsewhere, refocusing economic activity around transit investments rather than creating net aggregate growth....

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When considering the actual employment benefits of transit, it is important to compare transit employment with employment in other sectors. Does transit create more jobs than would occur if the funds were left untaxed in the economy? Does transit provide a significant amount of job creation different from highway construction or other capital-intensive projects? Are the created jobs low wage or high wage? What types of jobs are needed immediately to stimulate the local economy? Before one can properly determine the impacts of transit upon employment, all of these questions must be accurately answered with the proper analytical methods.

Employment impacts of transit investments can be calculated by performing Input-Output analyses or by using multipliers provided by the Bureau of Labor Statistics or the Department of Commerce. Various Input-Output analysis procedures (abbreviated I-O) include those devised by the Regional Science Research Institute, INPLAN, and others. Each model should be considered for its reliability, ease of use, cost, and the types of areas used in its comparative analysis (i.e., region versus region, region versus nation, central city versus region, etc.).

Input-Output Analysis

Input-Output analysis tracks business (public or private) spending patterns in the basic (export) and nonbasic (local) sectors of the economy. The gain or loss of regional income per unit of final sales for regional goods and services can be obtained from these industrial spending patterns. The analysis includes all final sales to consumers as well as sales to inputs of production.

The basic principle of Input-Output analysis is that the total economic activity within a nation, state or region involves the production of intermediate goods and services that lead to the production of final goods and services. An
increase in the demand for a final product will likewise increase the outputs of many intermediate goods and services that either directly or indirectly are required to produce the initial product. Thus, increases in total economic activity are reflective of an increase in the demand for a final product. The advantage of Input-Output analysis is its ability to produce economic impact multipliers for desired industries.

In the case of transit systems, I-O analysis shows where its money, ultimately, is spent, whether it be to industries within the region or industries outside the region. Exact changes in employment for the region may be obtained this way. For example, if a city decides to build a light rail line, some employment will be generated in that city in the form of retail or construction. However, job creation will also be stimulated in other areas – other states or foreign countries – for example at locations where light rail equipment is built. Input-Output analysis simultaneous considers all of these effects.

Input-Output analysis uses the following terms:  

- Intermediate Suppliers – those who purchase inputs used in production for the outputs they supply. These products are then sold to other intermediate suppliers or final purchasers.

- Primary Suppliers – those who do not need to purchase inputs to process what they supply (such as labor). Payments to primary suppliers do not generate interindustry sales. Rather, they are considered final sales.

- Intermediate Purchasers – those who buy suppliers' outputs that will be further used in the production process.

– Final Purchasers – those who buy suppliers' outputs in their final forms for final use. Intermediate input purchases are generated by the demands of final purchasers.

An I-O model divides the economy into many industrial sectors, broadly characterized as intermediate and primary suppliers and intermediate and final purchasers. Intermediate suppliers refine the raw materials in the production process (produce the component parts for the next higher stage in the assembly process) that, in turn, sell to intermediate and final purchasers or to factors of final production. Primary suppliers provide the labor and raw materials to the production process; therefore, they do not purchase any inputs to make what they supply. On the purchasing side, intermediate purchasers purchase goods from intermediate suppliers for continued processing. Final purchasers are consumers who buy the finished product from intermediate suppliers. The level of demand by consumers for final goods is determined exogenously (i.e., outside the model). The demand for outputs (such as all consumption of a transit system) can be converted into employment impacts.

Three major assumptions of input/output analysis must be understood before an interpretation of input/output impacts may be accurately completed:

1. Direct requirement coefficients are average relationships.

2. Inputs and outputs are directly proportional; i.e., as inputs are doubled so are outputs. Therefore, estimated economic impacts may be overstated.

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3. There is no substitution of production inputs. Input sources from a region cannot be substituted for input sources from outside the region.

**An Example.** Input-Output analysis uses three tables. These tables are referred to as the transactions table, direct requirements table and total requirements table. Data regarding total flows of goods and services among suppliers and purchasers during a given year are recorded in the transactions table. These flows are expressed in monetary units and are considered sales transactions between suppliers and purchasers.

From the transactions table the direct requirements table can be derived. Here are recorded the inputs from different suppliers required by each intermediate purchaser for each unit of output that the purchaser produces.

Finally, the total requirements table is derived from the direct requirements table. This table records the total purchases of direct and indirect inputs required throughout the economy per unit of output sold to final purchasers by the intermediate suppliers.

An example of how the procedure works can be shown for a simple case where the economy involves three intermediate sectors—manufacturing, transportation and construction, and one primary sector—households. In the following example, for simplicity the transportation sector is given a net increase in size without decreasing other sectors. In a more realistic analysis, it would be necessary to decrease other local sectors in order to account for the taxes necessary to fund the transit project. Initial data for transactions is shown in the first table. This shows which sectors purchase from other sectors. For example, the manufacturing sector sells $350,000 of its production to the manufacturing sector, $730,000 to the transportation sector, $50,000 to construction and $1,370,000 to households for a total sales (output) of $2,500,000. Similar data is also given for the other sectors.
Table K.1. REGIONAL SALES TRANSACTION TABLE
(in thousands of monetary units)

<table>
<thead>
<tr>
<th></th>
<th>Manufacturing</th>
<th>Transportation</th>
<th>Construction</th>
<th>Households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>350</td>
<td>730</td>
<td>50</td>
<td>1370</td>
</tr>
<tr>
<td>Transportation</td>
<td>40</td>
<td>150</td>
<td>75</td>
<td>1735</td>
</tr>
<tr>
<td>Construction</td>
<td>30</td>
<td>350</td>
<td>200</td>
<td>1920</td>
</tr>
<tr>
<td>Households</td>
<td>580</td>
<td>770</td>
<td>2175</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>2000</td>
<td>2500</td>
<td>5025</td>
</tr>
</tbody>
</table>

Table K.2. REGIONAL DIRECT-REQUIREMENTS TABLE

<table>
<thead>
<tr>
<th></th>
<th>Intermediate Purchasers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manufacturing</td>
</tr>
<tr>
<td>Intermediate Suppliers</td>
<td>Manufacturing</td>
</tr>
<tr>
<td></td>
<td>Transportation</td>
</tr>
<tr>
<td></td>
<td>Construction</td>
</tr>
<tr>
<td></td>
<td>Households</td>
</tr>
<tr>
<td>TOTAL DIRECT INPUTS</td>
<td>1.0000</td>
</tr>
</tbody>
</table>
The rows within the transaction table show the distribution of each supplier’s sales to intermediate and final purchasers. The columns show the distribution of each purchaser's purchases from intermediate and primary suppliers. Total Inputs will equal total Outputs. The numbers for intermediate suppliers are based on sales totals for a given accounting period.

Next coefficients must be derived to calculate the direct inputs required for any level of demand for the output of any intermediate industry. This is done by dividing each number within the intermediate purchaser column by the total inputs for that column. For example, the coefficient for transportation as a portion of manufacturing output using column A of Table K.1 is $1000 = 0.04$. These coefficients are shown in Table K.2 as the input/output table.

If the level of purchase in a sector is estimated for a future year, the direct inputs for other sectors can be found using the table. For example, suppose the transportation sector purchased $450,000 of goods and services, this would break down to $166,500 from transportation ($0.0365 \times $450,000), $36,000 from manufacturing ($0.075 \times $450,000), $81,000 from construction ($0.175 \times $450,000) and $175,500 from households ($0.385 \times $450,000). This provides the direct inputs only. Since each sector in turn needs inputs from the other sectors, further analysis is needed to get the total picture.

The derivation of a total requirements table that shows the effect of a change on all sectors is shown in Tables K.3, K.4, and K.5. These tables show how a sale of $1.00 works its way through the economy. Table K.3 shows how $1.00 of manufacturing sales is distributed to the four sectors. Initially (columns B-E), the $1.00 is spread according to the I-O table on the first round to the other sectors (0.35 to manufacturing, 0.04 to transport, 0.03 to construction and 0.58 to households). These amounts are totaled in column E. In the second round the totals are multiplied by the coefficients in the I-O table. For example, the numbers in the manufacturing column in the second round are the totals in column E times the coefficients from the I-O table.
### Table K.3. REGIONAL TOTAL-REQUIREMENTS CONSTRUCTION TABLE

<table>
<thead>
<tr>
<th></th>
<th>First Round Intermediate Purchasers</th>
<th>Second Round Intermediate Purchasers</th>
<th>Third Round Intermediate Purchasers</th>
<th>Total Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manufacturing</td>
<td>Transportation</td>
<td>Construction</td>
<td>Total</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.3500</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.0000</td>
<td>0.0460</td>
<td>0.0000</td>
<td>0.0400</td>
</tr>
<tr>
<td>Construction</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0500</td>
</tr>
<tr>
<td>Households</td>
<td>0.0000</td>
<td>0.5800</td>
<td>0.0000</td>
<td>0.5800</td>
</tr>
<tr>
<td></td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

### Table K.4. REGIONAL TOTAL-REQUIREMENTS CONSTRUCTION TABLE

<table>
<thead>
<tr>
<th></th>
<th>First Round Intermediate Purchasers</th>
<th>Second Round Intermediate Purchasers</th>
<th>Third Round Intermediate Purchasers</th>
<th>Total Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manufacturing</td>
<td>Transportation</td>
<td>Construction</td>
<td>Total</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.2550</td>
<td>0.3850</td>
</tr>
<tr>
<td>Transportation</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.2500</td>
<td>0.0750</td>
</tr>
<tr>
<td>Construction</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.1750</td>
<td>0.1750</td>
</tr>
<tr>
<td>Households</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.3850</td>
<td>0.3850</td>
</tr>
<tr>
<td></td>
<td>0.0000</td>
<td>1.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

### Table K.5. REGIONAL TOTAL-REQUIREMENTS CONSTRUCTION TABLE

<table>
<thead>
<tr>
<th></th>
<th>First Round Intermediate Purchasers</th>
<th>Second Round Intermediate Purchasers</th>
<th>Third Round Intermediate Purchasers</th>
<th>Total Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manufacturing</td>
<td>Transportation</td>
<td>Construction</td>
<td>Total</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0200</td>
<td>0.0200</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0300</td>
<td>0.0300</td>
</tr>
<tr>
<td>Construction</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0800</td>
<td>0.0800</td>
</tr>
<tr>
<td>Households</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.8700</td>
<td>0.8700</td>
</tr>
<tr>
<td></td>
<td>0.0000</td>
<td>1.0000</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

**Measurement of Transit Benefits** 118
Similar calculations are done for the other sectors. These are summed again in column I and multiplied by the coefficients again in the third round. For example, the numbers in column J are as follows:

- Manufacturing to manufacturing = 0.1377 * 0.35 = 0.0482
- Transportation to manufacturing = 0.1377 * 0.04 = 0.0055
- Construction to manufacturing = 0.1377 * 0.03 = 0.0041
- Households to manufacturing = 0.1377 * 0.58 = 0.0799

This is then carried to a third round following the same procedures. Results of the three rounds are summed in the final column that shows that every dollar of demand in manufacturing will result in sales of $1.54 in manufacturing, $0.06 in transportation, $0.06 in construction and $0.93 in households, or a total requirement of $2.59 from all suppliers.
Table K.6. INPUT-OUTPUT INTERMEDIATE PURCHASERS TRANSACTION TABLE

<table>
<thead>
<tr>
<th>Intermediate Suppliers</th>
<th>Manufacturing</th>
<th>Transportation</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5428</td>
<td>0.5892</td>
<td>0.0486</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>0.0653</td>
<td>1.1099</td>
<td>0.0370</td>
</tr>
<tr>
<td>Construction</td>
<td>0.0588</td>
<td>0.2253</td>
<td>1.0948</td>
</tr>
<tr>
<td>Primary Suppliers</td>
<td>0.9286</td>
<td>0.9128</td>
<td>0.9868</td>
</tr>
<tr>
<td>TOTAL REQUIREMENTS</td>
<td>2.5955</td>
<td>2.8372</td>
<td>2.1672</td>
</tr>
<tr>
<td>(ALL SUPPLIERS)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Similar procedures are followed to get the requirements for the transportation and construction sectors in Tables K.4 and K.5. The results are summarized in Table K.6. This gives the impact of expenditures by sector and can be used to calculate the economic effects of expenditures in the different sectors of the economy. For example, suppose a new transportation facility was proposed that would require $45,000,000 in construction and an annual additional operating cost of $4,000,000 per year. Using the requirements table this would have the following impacts from construction:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Requirement</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>0.0486 * $45,000,000 =</td>
<td>$2,188,204</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.0370 * $45,000,000 =</td>
<td>$1,665,371</td>
</tr>
<tr>
<td>Construction</td>
<td>1.0948 * $45,000,000 =</td>
<td>$49,264,661</td>
</tr>
<tr>
<td>Households</td>
<td>0.9868 * $45,000,000 =</td>
<td>$44,408,014</td>
</tr>
<tr>
<td><strong>Total Effect</strong></td>
<td>=</td>
<td><strong>$97,526,250</strong></td>
</tr>
</tbody>
</table>

The following impacts occur annually from operations:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Requirement</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>0.0486 * $4,000,000 =</td>
<td>$194,000/year</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.0370 * $4,000,000 =</td>
<td>$148,000/year</td>
</tr>
<tr>
<td>Construction</td>
<td>1.0948 * $4,000,000 =</td>
<td>$4,379,200/year</td>
</tr>
<tr>
<td>Households</td>
<td>0.9868 * $4,000,000 =</td>
<td>$3,947,200/year</td>
</tr>
<tr>
<td><strong>Total Effect</strong></td>
<td>=</td>
<td><strong>$8,668,800/year</strong></td>
</tr>
</tbody>
</table>

These dollar amounts could be converted to jobs by dividing the average cost per job for each of the sectors.
Strengths and Weaknesses

Input-Output analysis yields a more precise measure of economic well being compared to other economic base analyses. I-O analysis makes it easier to find which sectors have the strongest influence on the economy. It is a powerful tool for identifying different types of regional economic activities and linkages. Furthermore, computer software for input-output analysis is readily available. One can use different assumptions to derive multipliers, thereby allowing for a comparison of multipliers and providing for more accuracy in interpretation.

Input-Output analysis, however, is not extremely descriptive of specific economic impacts. The process of carrying out an analysis is time consuming, and the most helpful computer software packages tend to be expensive.

The Direct Approach

A more basic technique to determine job impacts is to inventory the inputs to the production of transit systems. It is the reverse of input-output analysis. Instead of tracking the linkages of production through an input-output table, the analyst tries to account for all the inputs supplied to produce the final good, such as a bus or light rail car. For example, if a city wants to find the number of jobs generated by a bus system extension, it would find where the buses were assembled and then where each part of the bus was made. By tracing these items a count of the number of workers used to build the parts could be completed. This approach to determining employment impacts requires special data preparation, since a computer package is unavailable. It is not possible by this method to determine if impacts are true gains in employment.
It is recommended that an Input-Output analysis be completed, as well, to understand the intricate intraregional industry linkages that occur between sectors. Only I-O will help the analyst more accurately determine how one sector influences another and how employment will shift by the interactions of these sectors.

**Productivity of Transit Investments**

Some people may argue that the government can be more economically productive by investing money in public projects other than transit. Where exactly should the government invest its money to obtain the greatest economic gains? David Alan Aschauer in his report for the Federal Reserve Bank of Chicago entitled, “Is Public Expenditure Productive?” finds through statistical analysis that in fact, “… core infrastructure consisting of streets and highways, airports, electrical and gas facilities, mass transit, water systems, and sewers should possess greatest explanatory power for productivity … weight should be attributed to public investment decisions - specifically, additions to the stock of nonmilitary structures such as highways, streets, water systems, and sewers-when assessing the role the government plays in the course of economic growth and productivity improvement.”

This work is somewhat controversial and others have different opinions. There is dispute as to whether transit investments are significant in terms of net employment increases. From a local perspective, many decision makers believe there are tangible benefits for the local economy through employment gains, even if at the expense of other sectors or areas.

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