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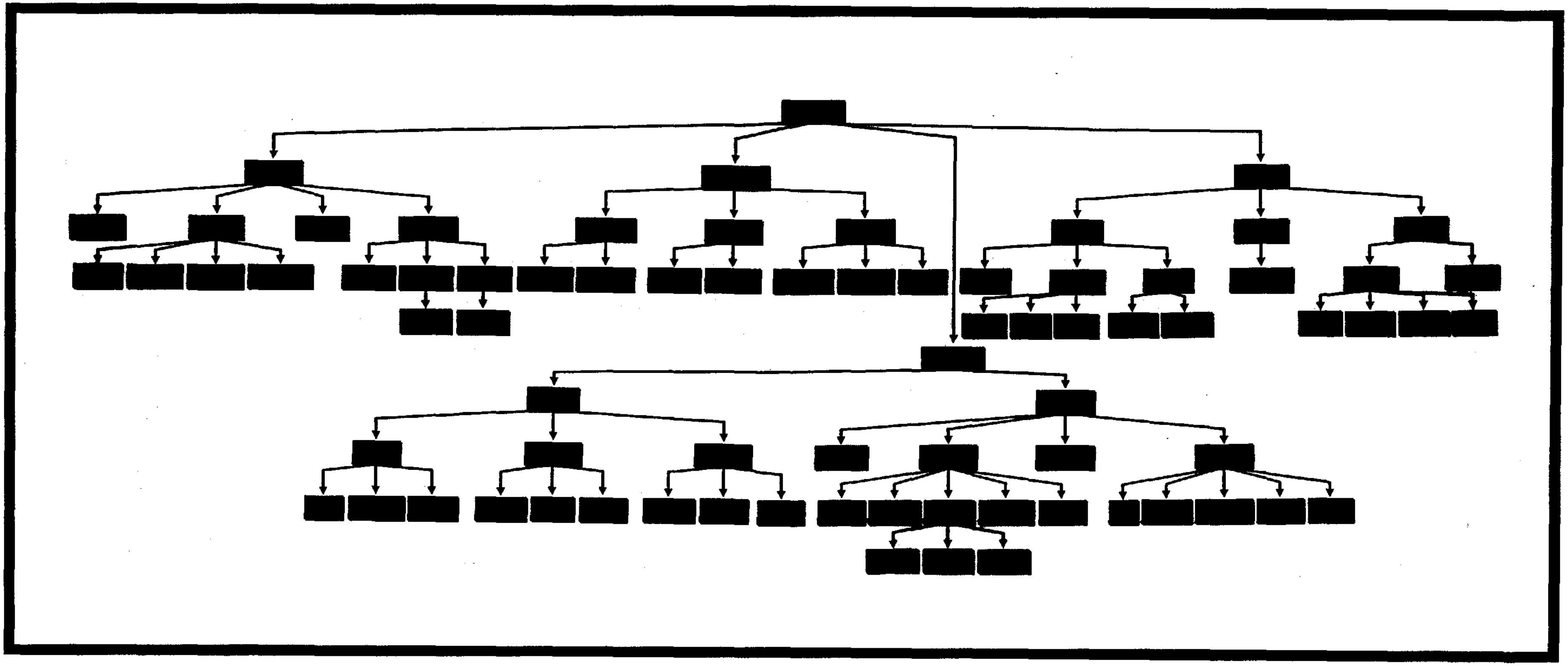
Measurement of Transit Benefits

Prepared by:
The Center for Urban Transportation Studies
The University of Wisconsin—Milwaukee

Final Report
June 1993



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Benefit assessment is done to make decisions, and a general discussion is given of how to view benefits for that purpose. Consequences of transit are illustrated through the use of a benefit tree. Transit service provides an alternative means of travel, results in changes of trip making by automobile to transit, affects land-use activity and leads to direct and indirect employment. These effects lead to still further consequences.

Methods are provided for measuring benefits. These methods include an enhanced consumer surplus approach to measure travel related changes and a land-use redistribution model to identify travel benefits of land-use changes. Techniques for air pollution assessment and for employment impacts are also given in detail.

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PART I: INTRODUCTION

A. BACKGROUND

In recent years there has been an increased interest in public transit at the local level. Many urban areas have undergone substantial reviews of their local transit services and developed ambitious plans for expanding service and for constructing new fixed guideway facilities. This increased local interest often coincides with budget shortages at all levels of government and with increased automobile ownership and usage. Under such conditions this support for transit usually means a larger commitment of local funds. Very often such support is manifested through a referendum or through a major grass roots effort. There is a local perception that the benefits of transit are great — so great that people will accept increased local taxes to pay for them. This has occurred in many cities, but the benefits of transit are still poorly understood. Traditional methods of benefit measurement, with their roots in economic theory, offer only an incomplete understanding how local communities perceive the value of public transit.

An accurate assessment of the benefits of transit service is particularly complex because beneficiaries include the community-at-large, as well as passengers. Local businesses benefit from better transit access; and the community holds certain forms of transit in high esteem, even if only small portions of the population regularly use it. Many automobile drivers feel that transit has an option value; they might need it someday. Moreover, there is the indirect benefit of transit service accruing to society from the increased mobility of the population as a whole.

Conventional methods of measuring benefits, derived from economic theory, provide only partial help in understanding how local citizens value transit or why they are willing to go through considerable effort to increase the amount of service. Typical economic benefit assessments rely on the notion that benefits occur primarily to users and only secondarily to nonusers. Nonuser benefits are added when it can be argued that they result from improved service to users.

These techniques can lead to double counting of benefits if not carefully done. Benefits are usually expressed in monetary units; well-established methodologies are employed for such items as out-of-pocket cost savings, time savings, and accident reduction. Typically these methodologies try to directly relate benefits to these savings by using the difference between the cost of the good and the amount a person is willing to pay for it. In this case, the "good" is either the access provided by transit or one of its many indirect effects.

Transit has unique characteristics that do not fit well with traditional methods of benefit measurement. First, user benefits cannot be easily found because of difficulties in determining the way willingness-to-pay varies across individuals and population segments. A simple time-savings approach, popular in benefit-cost studies of highways, can underestimate user benefits because some individuals can have a large willingness-to-pay, even when the average individual does not. Besides a possible time savings, users can benefit by being able to make trips that would otherwise be foregone, by saving other personal resources, and by being able to make trips to more desirable destinations.

"Transit has unique characteristics which do not fit well with traditional methods of benefit measurement."

Second, transit has comparatively large nonuser benefits. Many people who rarely use transit are its strongest supporters. There may be an option value ("I-might-need-it-some-day"), environmental concerns, sympathy for those who cannot use automobiles, civic pride, or other similarly intangible factors. If people perceive that transit has benefits, then the benefits exist to some extent. This argument is conceptually consistent with notions of consumer surplus, but we possess few means to measure nonuser benefits.

Third, transit may have effects on the location of land development activity. Recent rail transit projects have had significant impacts on the urban areas they serve. Major development projects have been positioned near stations, which lead to overall shifts in regional land-use patterns. Not only can a development project cause a desirable change in the location of activity, it can cause new activity, at least locally. In addition, the resulting concentration of activities can provide agglomeration benefits, such as a reduction in the costs of providing public services when activities are concentrated. Such benefits are seldom explicitly considered in traditional methods, although they are often cited at the local level as important reasons to construct new fixed guideway transit systems. Clearly there is a need to take a fresh and different look at benefits as they relate to transit.

"The measurement of benefits must be comprehensive enough to permit comparisons between alternatives for the purpose of making decisions."

Besides identifying benefits and determining how they are distributed, there are problems associated with measuring them. The measurement of benefits must be comprehensive enough to permit comparisons between alternatives for the purpose of making decisions. The willingness-to-pay criterion might be used to estimate the direct user benefits of transit service. But the methodology should be sensitive to differences among different population segments. For instance, "captive" users are likely to have inelastic demands for transit service, and consequently, their aggregate benefits may be considerably higher than for people with access to other transportation modes.

B. OBJECTIVES

The estimation of benefits from transit investments is a difficult process which can be approached with many different points of view. It is the objective of this report to look at benefits in a broad way to gain a better understanding of why local citizens positively perceive transit services. The report will attempt to provide a comprehensive view of the range of consequences of transit services and to indicate various methods that can be used to assess transit benefits. In addition, comparisons will be made among methods to assess benefits in various communities and to compare benefits from a political viewpoint to those from a technical viewpoint. Guidelines for benefits measurement are provided with examples.

PART II: PRINCIPLES AND ISSUES

C. BASIC VIEW OF BENEFITS

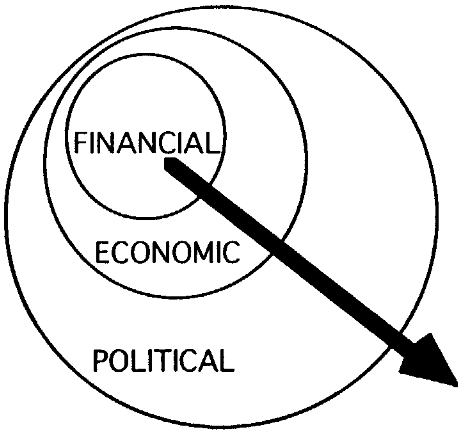
A fundamental understanding of the concept of benefits is important for an understanding of techniques to measure transit benefits. Transit systems have many consequences for a community, ranging from the basic (need for bus stops, purchase of fuel) to direct effects (trips made by transit, employment of workers in transit firms) to indirect effects (changes in land use, independent life styles). These consequences need to be sorted to determine how they relate to one another, whether they are positive or negative, and their relative importance.

"Benefits exist because people believe they are important, whether or not they can be measured . . ."

Benefits can be viewed as those consequences that are valued by some segment of the population. Benefits exist because people believe they are important, whether or not they can be measured (or even if seemingly objective measurement shows them to be nonexistent). Some communities place a high value on public transit even though it is difficult to find significant benefits by methods used for other means of transportation. These communities may be willing to support transit with high local subsidies and/or dedicated local taxes. These communities value transit highly and are collectively "willing-to-pay" a substantial amount of money to support transit. The level of monetary benefits of a transit system in such places must be viewed as being at least as high as the total local expenditures (user costs + subsidies) for transit, maybe substantially higher.

Benefits can be viewed in different ways, and it is essential to distinguish between approaches. Much of the debate about benefits stems from the chosen point of view. Three common viewpoints are financial, economic, or political.

A financial viewpoint includes only those benefits that can be recovered as income. Benefits are those things that contribute to the rate of return on the investment in transit. Returns (benefits of transit) should occur directly to the agency to pay the expense of providing service. External benefits have no value unless they can be "captured" by the transit agency.



"The political process in a democratic system provides a way for a community to express its opinion of what is and what isn't important."

The economic viewpoint of benefits is broader in that benefits can accrue to others and still be of value. This viewpoint uses a willingness-to-pay criteria for benefits; i.e., how much are users and nonusers of a system willing to pay for a service beyond its price? The difference between willingness-to-pay and price can be viewed as a benefit — consumer surplus. The economic view also assumes that the benefits can be measured (or converted) to monetary units. Benefits are derived from an analysis of supply/demand equilibrium and from the behavior of individuals who make choices in an open market condition.

The third viewpoint of benefits is a political one. The political process in a democratic system provides a way for a community to express its opinion of *what is* and *what isn't* important. When duly elected officials make choices, ideally they are expressing the collective feelings of society about the benefits of different governmental activities. The value placed on transit by voters, primarily nonusers, is an indication of the benefits beyond those accruing to users. If a local community willingly taxes itself to spend large sums of money for transit, this implies they feel there are large benefits of transit, irrespective of any quantitative measures. Promotional materials from transit agencies, citizen groups and referenda advocates often include environmental improvements, access to jobs, economic development, better mobility for others, emergency transportation, and enhanced community image/pride as reasons to support transit.

The political process involves tradeoffs and choices and can be a good indicator of community values. However, there are factors that may cause the political process to represent opinion poorly. Lack of open debate, unfair competition between ideas, over-representation of special interests, or consideration of other unrelated issues (e.g., educational policy or low income housing) can inhibit the interpretation of transit decision making as a means of measuring benefits.

Economic Versus Noneconomic Evaluation of Benefits

Benefit-cost analysis is a method of evaluation that, if applied completely and accurately, will select the best projects and best alternatives within projects. Economists have developed benefit-cost analysis to a high degree of sophistication. Nonetheless, there are many aspects of the transit project decision process that cannot be adequately represented in a benefit-cost study. Issues of fairness, health, aesthetics, social interaction, and prestige are difficult to convincingly quantify in monetary terms. Furthermore benefit-cost analysis can mask the tradeoffs between alternatives, their performance and impacts that often become the focus of real world decision making. Difficulties of valuation of benefits, lack of independence of measures, and different viewpoints and goals of decision makers further complicate the process. Finally, other issues (such as land-use impacts and safety) could be quantified in monetary terms, but we often lack the time and resources to do it properly.

This report adopts economic theory where it is of demonstrated value; then broadens that theory to incorporate factors of particular importance to transit projects. Where economic theory does not apply or where it is difficult to implement, other methods are suggested.

This report recognizes that transit decision making is a highly complex process that cannot be replaced by a set of rules or a formula. Techniques are proposed that can be useful to identify the range of transit consequences and their interrelations, to highlight significant tradeoffs between alternatives and to better quantify the effects of transit.

Decision Basis for Benefit Measurement

Benefit analysis is done so decisions can be made. A decision could be for a specific purpose, such as the selection of the best alternative, or for more general reasons, such as to generate support for all transit services. Understanding the nature of decisions is the key to benefit measurement.

Specific decisions involve the comparison of proposed alternatives against a base system. The comparison process is a useful way of dealing with many of the philosophical, conceptual, and mathematical difficulties with benefits measurement. Biases caused by assumptions tend to cancel each other out, since they either have the same effect on all alternatives or have very little differential effect (i.e., it only makes a difference if there is a difference). For example, there may be concern over the choice of an appropriate interest rate, but if all alternatives have roughly the same portion of capital costs and roughly the same time stream of maintenance costs, then interest rates may not make much of a difference in the final decision. Similarly, air quality impacts on health may be very difficult to assess, but all alternatives may have similar effects.

"Understanding the nature of decisions is the key to benefit measurement."

The importance of many of the subjective benefits of transit will be directly related to the type of decision being made. A decision to select a particular technology (i.e., rail versus bus) should include a broader range of benefits than a study of alternative locations of a particular technology. Rail transit is perceived by many civic leaders and elected officials as positively affecting economic development, jobs and civic prestige, while bus transit does not. Rail versus bus decisions may be made at the local level by elected officials considering these factors, but these factors might be ignored at a federal level. Locational decisions, in particular, need not consider quite as many factors, since there may be no differential impact. For example, community prestige may be the same regardless of the chosen location, so it need not be a component of a benefits assessment for that tier of a decision.

National Versus Regional Viewpoints

Benefits of transit from a national point of view may be quite different from those perceived at a regional or local level. As the geographic scope of analysis is increased, shifts from one area to another become internalized and may no longer be viewed as benefits. A benefit at a regional level that involves a taking of activity from another region would be interpreted as a "transfer payment" at a state or national level. Economists, as a rule, prefer to ignore transfer payments in benefit-cost studies. Many important impacts of transit (such as effects of transit on land use, some environmental consequences, employment gains or community prestige) may be of little importance at the national level, since they involve transfers between regions rather than overall national gains. Allocation of money between urban areas is quite a different decision than the local selection of an alternative within a region. Alternative selection would likely emphasize different criteria, including interregional transfers.

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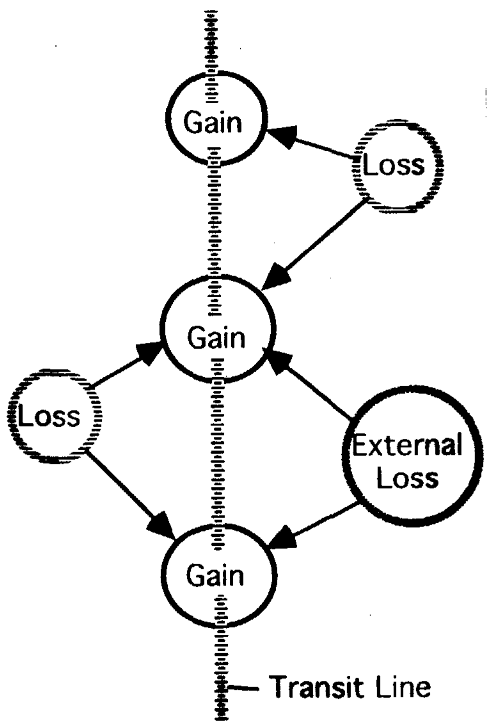
It is important to consider the goals of the investment, especially at higher levels of government. A goal at a high governmental level to maximize return on investment would lead to different choices than a goal to help distressed areas. Different goals may require different alternatives, as well as different decision criteria.

It is crucial that everybody involved understand that the selection of benefits and how they are measured depends upon the viewpoint of those who make decisions. For example, an analysis of interregional transfers can be complicated by fairness issues. Often, a city can successfully argue for more transit funds because it has not received a proportionate share of some other federal program. To be perfectly fair, transfer payments should be considered at the national level, too.



Local Versus Areawide Benefits

The geographic scope of analysis will also affect magnitude or even the existence of benefits at the regional level. For example, it may be important to local officials that employment gains occur in a particular neighborhood or political jurisdiction. From a regional point of view, employment may only shift between subareas for no net gain. Similarly, there could be a gain in employment for one metropolitan region because of transit investment, but this could be offset by losses in other regions. The concept of a "zero sum game" is relevant in national or regional analysis, but for small areas there can be substantial gains in employment.

Another example relates to land value and tax base. Transit investment may result in a shift of values from suburban to centralized locations with no change in the overall tax base. From a regional perspective there is no gain in overall value; whereas, from a more local perspective there could be important benefits.

Of course, there can be other benefits representing overall gains, regardless of geographic scope. For example, some experts may argue that a more centralized land-use pattern may lead to a more efficient use of infrastructure and an increase in the efficiency of interaction between people.

The geographic scope will also affect the relative impact of transit services. A large geographic area with a moderate sized transit change will result in a measured benefit that appears small. However, if the geographic area were made smaller, the impact of transit would appear to be more significant. Consequently, care should be exercised when using relative measurements (percentage change in some overall indicator) to avoid misleading results. The change is the same but the percentage is larger or smaller depending on the size of the area that is used for comparison.

Definition of Null Alternative

Benefits are a relative measurement. They are envisioned as savings that occur as a result of an investment. They are found by comparing the world with a transit change against the world without it. Accordingly, the definition of the base or null alternative is important to the measurement of transit benefits. The definition will depend on the type of analysis. For example, the base alternative for a major fixed guideway proposal may represent the current transit system with minor changes over an extended period, including fleet replacements and minor service improvements.

An occasional study has been performed[1,2] of the impact of having no transit service in a particular community. These studies start with the assumption that transit service has been eliminated, and then they calculate the costs that are incurred (additional travel costs, social services, etc.) as a result. Attempts are made to develop a total cost that includes all impacts of removing the system. Such studies are used to establish a baseline for transit benefits. Similar approaches are widely used, topic by topic, to demonstrate the benefits of an existing transit service. For example, air pollution and energy savings could be calculated by looking at the air pollution reduction per transit trip versus the same trip by automobile. Unfortunately, this approach is not very realistic in that seldom does a community seriously consider the elimination of all transit service. Assessing benefits in this manner would be acceptable only if service might be eliminated in entire areas of a city or parts of a state.

"Benefits . . . are found by comparing the world with a transit change against the world without it."

In all cases there is considerable judgement in definition of the base system. Assumptions about the base system could substantially affect on

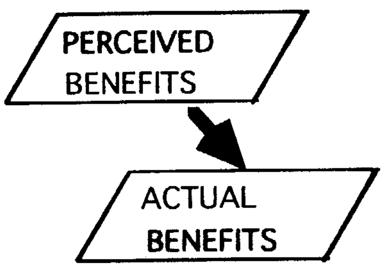
[1]Dockendorf, J., October, 1972.

[2]Urban Institute, June, 1991.

calculated benefits, while other assumptions might have only a minor effect. All assumptions should be made explicit and well documented. Good documentation will enable discussion and lead to more defensible conclusions. Furthermore, sensitivity analysis should be conducted to determine the relative impact of various assumptions on the results of a benefit calculation.

A sensitivity analysis is relatively easy to do, compared to the effort of the original benefits calculation. A base case is defined with a set of assumed values of parameters. Then each parameter is varied independently by a fixed percentage above and below its assumed value. The relative change in benefits per change in parameters (a type of elasticity measure) can be calculated. This process is completed for all parameters having some uncertainty as to their value. The result is an indication of the importance of each assumption. A good sensitivity analysis creates considerable insight into the nature of the system being analyzed and frequently helps generate additional options that might be more efficient or have more benefits.

Perceived Versus Measured Benefits



"Benefits occur because people believe them to be important."

Benefits occur because people believe them to be important. People are willing to pay a certain price for something because they believe it to have positive effects. The perceptions of people as well as the actual characteristics of the good must be considered. Benefits that are perceived may be much different from ones that can be measured, and there could be important perceived benefits that are impossible to measure. For example, there may be a strong perception on the part of the community that transit substantially reduces lung disease from air pollution. Calculations of air quality impacts may show very little actual change in community health. Nonetheless, the perceived substantial benefit for health will be an important factor in the debate that leads to decisions. In this case, the real benefit is what is believed to exist, not the measurement.

A similar example relates to the community image of transit. Residents of an urban area and their elected officials may feel that their community needs a certain form of transit to enhance the status and image of the community. As a result they decide to increase their taxes to support the system. The actual level of benefit from community image is nearly impossible to measure; nonetheless, it is a determining factor in the decision. The level of the overall perceived benefit could be interpreted to be as at least as large as the amount of local money spent on the system.

Over time, the real benefits of a system will prevail over perceived benefits, if there are major differences. As people gain experience with a system, they see the actual benefits. Sometimes there is disappointment in the system; in other cases people might be pleasantly surprised.

Double Counting

There are four basic steps in benefit assessment. First, benefits must be identified, then measured, then valued and then combined. As one proceeds through these steps, possibilities of misrepresentation increase. Questions of double counting arise in the processes of valuation and combination.

Double counting of benefits is a serious and complex issue. As a rule one does not want to count the same thing twice when calculating benefits. Double counting should be avoided, especially when benefits are compared to costs for the purpose of making build or no build decisions. Double counting tends to inflate benefits, resulting in unnecessary investments.

For example, benefits calculations may include savings from reductions in accident costs and changes in vehicle operating cost. If vehicle operating costs include an insurance component, there would be a double counting because accident costs and insurance measure the same thing. Similar problems can occur between energy savings, fuel taxes and vehicle operating costs, because fuel use is counted several times.

Similarly, it is generally agreed among economists that travel time savings and land value increases can involve a double counting of benefits. Land may change its value as a result of greater accessibility as time savings are capitalized. Including both items in a benefit total, without careful consideration, could lead to an inflated view of benefits. The issue becomes complicated, however, because land may change in value because of other effects of transit not related to user time and cost savings. Land values may increase because of better visibility, better pedestrian access to retail at stations or economies of scale. Thus, a portion of land value increments could be legitimately added to time savings benefits, while the remainder should not.

Double counting cannot be totally avoided. The simplest way to overcome many of the problems with double counting is not to add benefits together. Consequences of transit can be displayed for each alternative, and these consequences need not be combined. The information can then be interpreted and compared by decision makers who are making tradeoffs in their minds to reach a conclusion. Some factors will be ignored while others are given high value as these decisions are reached. It is essential not to over-represent a given benefit by providing several redundant measures.

Venn diagrams, or similar graphical techniques, can be used to show double counting where it exists.

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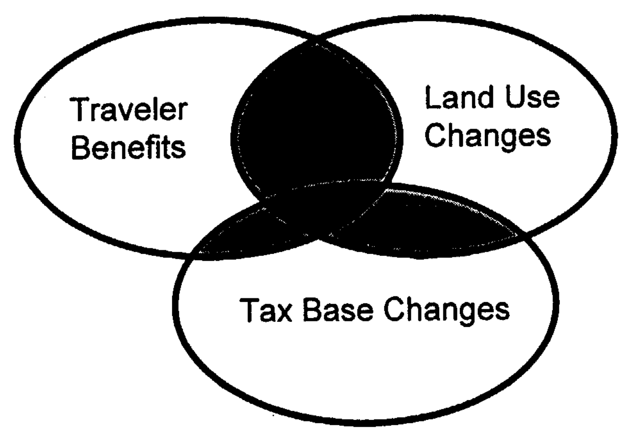


Success Should be Consistent with Positive Benefits

Benefit measurement must be intuitively correct. Intuitively correct answers may not always come from some measurement techniques. For example, shifts of trips from automobile to transit could lead to counter-intuitive results when only time-savings are used as the benefit indicator. More travel by transit may show up as a negative benefit, because transit trips generally take more time than automobile trips. Thus a transit alternative that attracts large numbers of automobile trips could do poorly in a benefits evaluation if total travel time is used as a measure of success. A negative time savings benefit is counter to the goal of increasing transit use and misrepresents what will happen. Other effects, such as changed automobile ownership costs and reduced parking difficulties, may have been ignored and should be identified, as well.

"Benefit measurement must be intuitively correct."

Better and more intuitively correct measurement techniques are available. Later, this report will discuss an enhanced consumer surplus measure that more realistically expresses user benefits and accounts for behavior factors in travel choice.

D. TECHNICAL ISSUES IN BENEFIT MEASUREMENT

Beyond the issues raised earlier in this chapter there are technical issues that affect how the benefits are interpreted and affect the underlying validity of their measurement. Three of the more general technical issues relate to the size of the universe, aggregation of benefits and standardization.

Size of the Universe

The *universe* is defined by the limits of the system, usually delineated by geographical boundaries. The size of the universe can make a big difference to the perceived magnitude of benefits. The definition of the universe is especially important when relative measures are used, such as percentage reduction in air pollution or energy use or the percentage change in trips to a locale. If the size of the universe is large, the relative magnitude of transit induced change will appear to be small. Measures of this sort can be misleading since there would be larger impacts in smaller areas or different time periods. It is better to simply report the magnitude of the effects and allow comparison between alternatives rather than putting them on a relative scale. Different individuals can then interpret whether or not they are significant, based on their magnitude rather than on the choice of the size of the universe.

Aggregation of Benefits

If nonmonetary benefits are to be combined, the choice of the mathematical formulation will affect results. Generally, benefits are combined using a linear function, by adding individual benefits put in some common set of units such as dollars or time. The use of a linear function assumes that each benefit is independent (unrelated) of all other benefits. Since some benefits are invariably related to others a simple linear sum could seriously misrepresent the overall effect of an alternative. Other mathematical forms can be used. For example, weights can be used as exponents with the combination of benefits being the product of each benefit raised to its power. This formulation has a different effect on the combination, since it tends to emphasize differences — magnifying high scores and diminishing low scores.[3] The resulting nonlinear preference function may be more consistent with intuitive preferences than a linear form. Reasonable arguments can be made for either approach (linear or multiplicative), and it is sometimes difficult to make a choice. Sensitivity analysis should be used to determine the differences.

A second, and perhaps better, approach is to avoid aggregation except in cases where the decision to combine factors is obvious. *Tradeoff analysis* can be used to provide a basis for decision without the need for aggregation.

"A . . . better approach is to avoid aggregation . . . ."

Standardization

Benefits are measured on different scales and need to be placed on a standard scale if they are to be combined. Several standardization methods exist. Examples are standardization by range, standardization by mean, and standardization by mean and standard deviation. Standardization by range sets the upper and lower limits of all indicators on the same scale, say 0 to 100. Standardization by mean sets the mean values at the same point, say 50, while use of standard deviation also standardizes the dispersion of data. Since the nature of data may differ for each indicator, choice of a method may affect the outcome. Sensitivity analysis can help reduce the effect of a given standardization method on the aggregate benefit measure.

[3] Alexander, E., and E. Beimborn, June, 1987, p. 37.

E. INTERPRETATION OF BENEFITS

Once a set of benefits has been identified and measured, they should be interpreted to build confidence in the analysis. The process of benefit measurement always involves a series of simplifications, omissions and assumptions that must be examined to determine their effects on the results. The interpretive phase could involve several activities.[4]

Break-even Analysis

Break-even analysis tells how much better the best alternative is over the second-best. Such an analysis is often easy to perform. An important question is addressed: Are the differences between the best and second-best alternatives significantly large so that they are not within the range of differences that might be expected from the data and procedures used? Such an analysis would be conducted by comparing marginal costs versus gains. The marginal gain of the best plan over the second-best plan should be examined in relation to the process used to delineate the differences in the plans. If the differences are beyond the range of variance due to the forecasting techniques, there should be a greater degree of confidence in the best plan.

Sensitivity Analysis

As mentioned earlier, the purpose of sensitivity analysis is to identify the effects of the various parameters and assumptions used in the forecasts and in the evaluation. The results of the forecasting procedures may be very sensitive to some parameters and insensitive to others. The sensitivity analysis can be

[4]Beimborn, E., Oct., 1977, p. 25.

directed at the alternatives themselves or at the data processing effort. In the first case, the sensitivity of the choice of the best alternative to the procedure used to define a benefit measure is examined. In the second case, the sensitivities of the forecast to the data used and parameters of the forecasting techniques are examined. Obviously, the latter case would involve considerably more effort that the former. Data and parameter sensitivity would usually involve the following steps: (a) identify the parameters used in the forecasts; (b) examine the range of values used; (c) review the process used to set parameter values for the forecasts; (d) estimate the possible range of values the parameter could have as the result of statistical, conceptual, or assumption errors; and (e) determine how these errors would be carried through the process and how they might have a differential effect on the various alternatives.

Analysis for Contingencies

A contingency is an event whose occurrence is possible but not probable. For example, the effects of severe long-term shortages in petroleum-based fuels, the effects of major changes in population growth, or the effects of major shifts in land-use patterns might be viewed as contingencies. Because of the uncertainty of the future, it is desirable to examine how well the best alternative performs under contingent situations. Such an analysis would usually involve the following steps: (a) identify the contingent situations, (b) develop scenarios as to how they would occur, (c) forecast the performance of the best alternative under the contingent situations, and (d) compare the performance of the best alternative under normal and contingent situations.

Impact and Incidence Analysis

The impact (upon whom) and the incidence (at what period in time) of the costs and gains associated with the best alternatives should be examined. The costs and gains for two plans may be very similar in the aggregate but very dissimilar in their effects on those who receive them or the times in which they occur.

Implementation Feasibility

The relative ease with which a plan can be implemented should be examined. A superior plan with a low probability of successful implementation might be rejected in favor of a lesser plan with a higher probability of successful implementation. In addition, plans might be combined to increase implementation probabilities, or efforts might be made to reduce barriers to implementation (when barriers can effectively be identified).

Qualitative Analysis

Qualitative analysis is a catchall that would include a careful examination of the best choice considering factors omitted in the analysis, assumptions made, factors that could not be quantified, uncertainties, and the results of the other phases of interpretation.

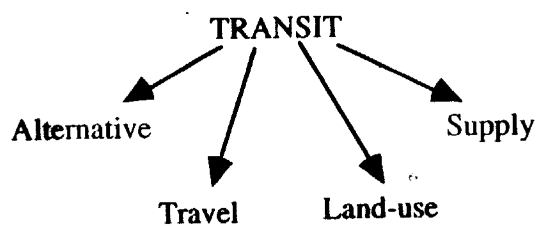
PART III: A FRAMEWORK FOR BENEFIT ANALYSIS

F. CONSEQUENCES OF TRANSIT

The topic of transit benefits is widely discussed in technical literature, trade journals and the popular press. Advocates for transit offer transit benefits as a basis for expanded service and/or increased public expenditures for transit. Benefits frequently cited include air pollution reduction, congestion relief, energy savings, strengthened central cities, land value gains, and reduced automobile dependency. In many cases, these benefits are calculated and, sometimes, combined to present a strong case for transit expansion. There is little consistency in how benefits are combined. Methods for doing calculations vary widely, and the results can often be misleading.

Despite the large amount of prior work on transit benefits, there have been few systematic efforts to deal with the interrelationships between different benefits nor have there been many attempts to provide a comprehensive picture of transit benefits. This section of the report provides a framework for understanding the interrelationship of benefits of transit service. The framework takes the form of a tree diagram.

The Benefit Tree



The benefit tree provides a display of what might happen as the result of transit service. Because transit exists, there are certain consequences. These consequences may not necessarily be benefits but merely impacts resulting from the improvement of a transit system. Impacts can be significant or insignificant depending on the chosen viewpoint, the scope of analysis and the nature of the base alternative.

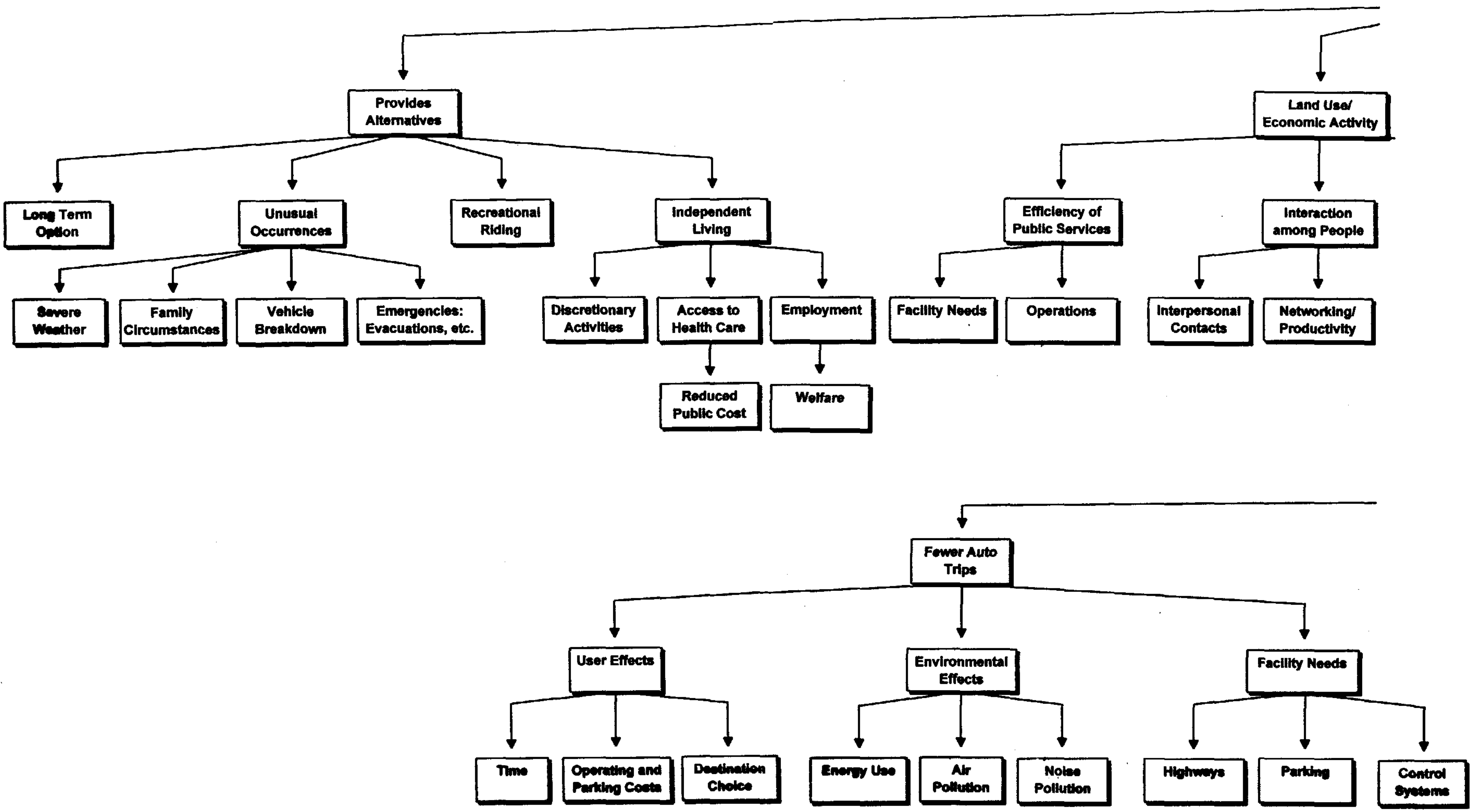
First, transit provides an alternative means of travel that may or may not actually be used by any given individual. Because transit exists, people have options available for travel for unusual occurrences, for the future when a person may not be able to use an automobile, or for the transit dependent.

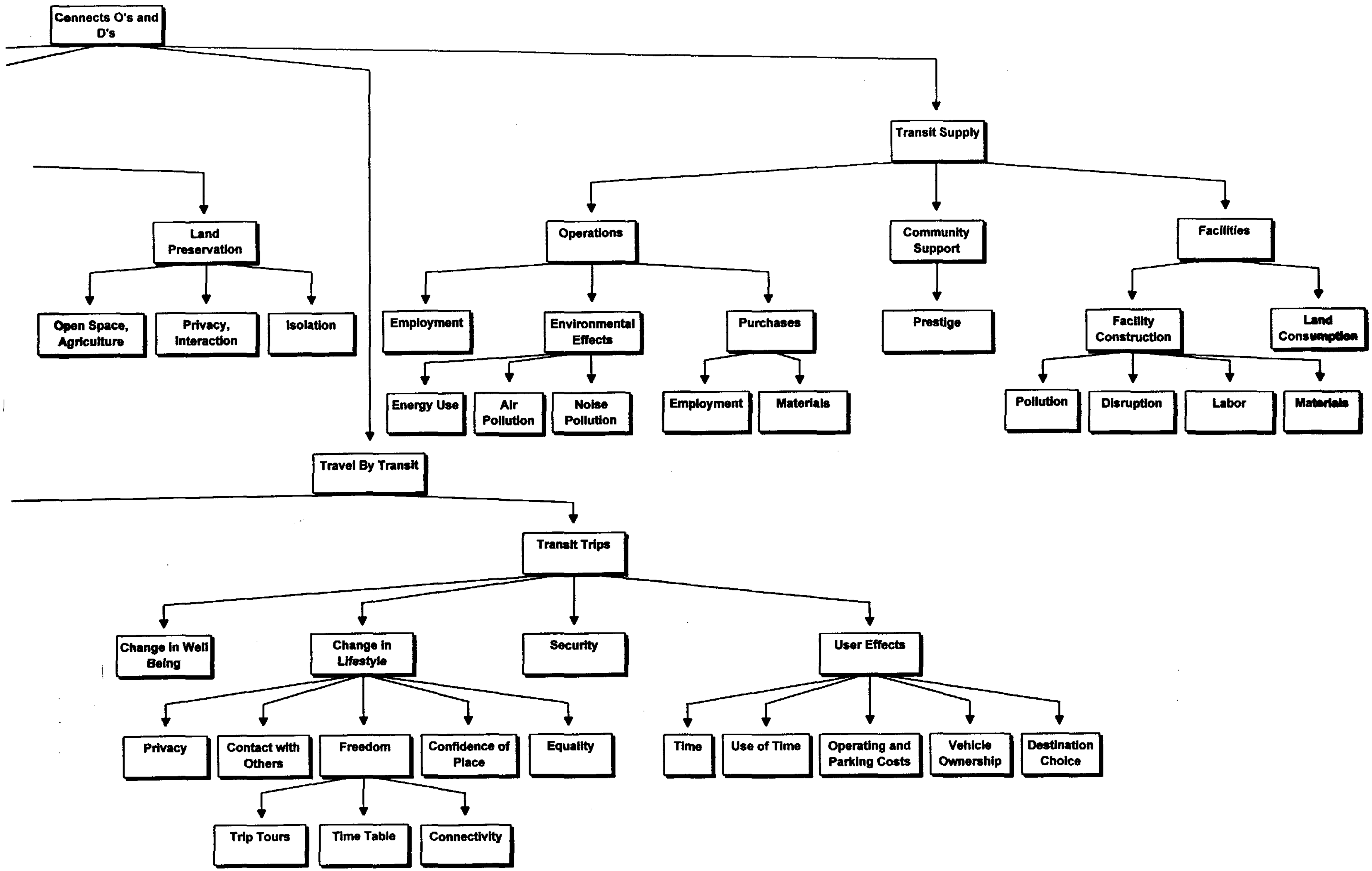
Second, trip making occurs, which can result in a shift between automobile and transit travel or trips by persons who could not otherwise travel. Trip making, in turn, results in changes in user resources (time, cost, etc.), changes in facility needs, environmental effects and so forth.

Third, transit accessibility makes land more or less valuable, causes shifts in life styles, preserves open space, affects interaction among people, and affects the efficiency of certain public services.

Fourth, transit exists as an enterprise that employs people in its operation and construction. It too uses resources.

The benefit tree shows how consequences are related. The tree is divided into five branches. Vertically, the tree grows in specificity from top to bottom. Double counting occurs when benefits are included at multiple levels on the tree. Some benefits can be quantified, others cannot.


Provides Alternatives
Long Term Option
Unusual Occurrences
Recreational Riding
Independent Living
Severe Weather
Family Circumstances
Vehicle Breakdown
Emergencies: Evacuations, etc.
Discretionary Activities
Access to Health Care
Employment
Reduced Public Cost
Welfare
Land Use/ Economic Activity
Efficiency of Public Services
Interaction among People
Facility Needs
Operations
Interpersonal Contacts
Networking/ Productivity
Fewer Auto Trips
User Effects
Environmental Effects
Facility Needs
Time
Operating and Parking Costs
Destination Choice
Energy Use
Air Pollution
Noise Pollution
Highways
Parking
Control Systems



Connects O's and D's
Transit Supply
Land Preservation
Operations
Community Support
Facilities
Open Space, Agriculture
Privacy, Interaction
Isolation
Employment
Environmental Effects
Purchases
Prestige
Facility Construction
Land Consumption
Energy Use
Air Pollution
Noise Pollution
Employment
Materials
Pollution
Disruption
Labor
Materials
Travel By Transit
Transit Trips
Change in Well Being
Change in Lifestyle
Security
User Effects
Privacy
Contact with Others
Freedom
Confidence of Place
Equality
Time
Use of Time
Operating and Parking Costs
Vehicle Ownership
Destination Choice
Trip Tours
Time Table
Connectivity

Transit as an Alternative — Branch 1

Transit provides alternatives to those who regularly use automobiles or for those who have no other option but public transportation, as shown in Branch 1 of the tree. When good transit service exists people need not be solely dependent upon their automobiles. A benefit accrues to the entire population, even those who never use transit, because transit provides an option for travel.

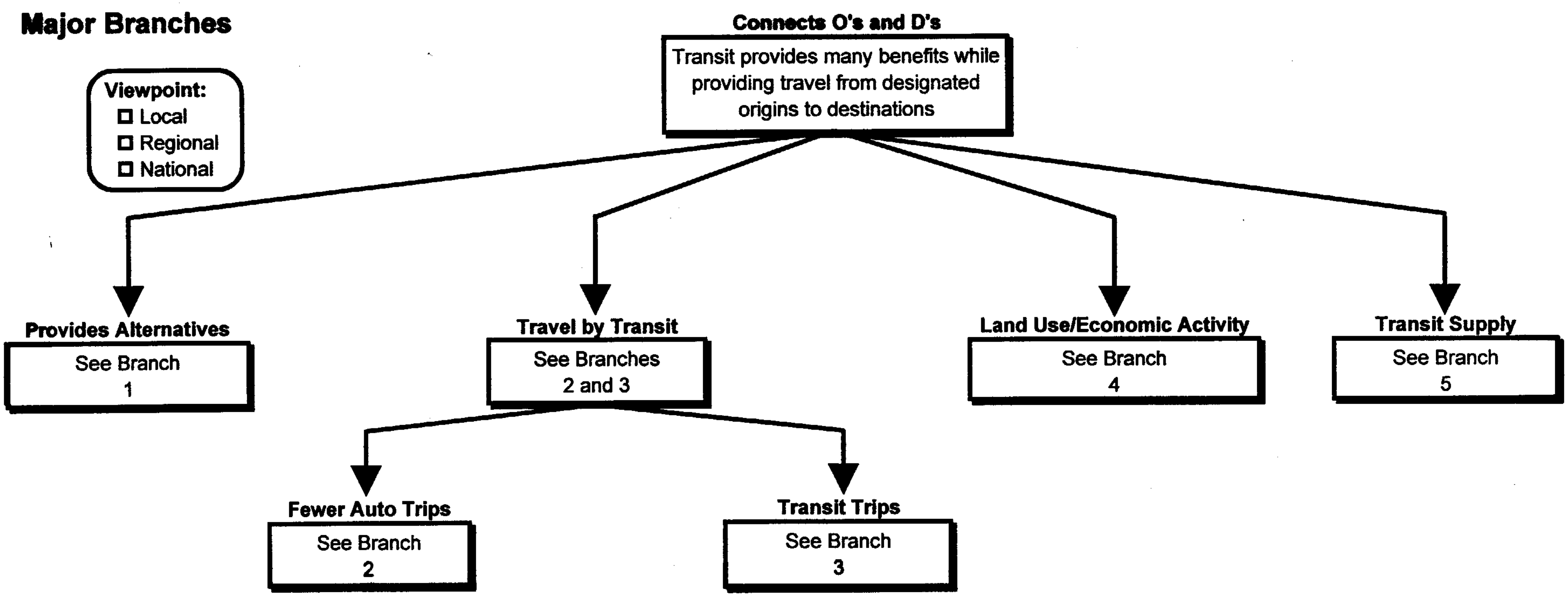
Transit as a Long Term Option. Transit provides a form of mobility insurance. It is available whenever other forms of transport are not. People will see value in having a transit system, even though they may not need to use it right now, feeling they may need it at some time in the future when they are no longer able to drive an automobile.

"Transit provides a form of mobility insurance."

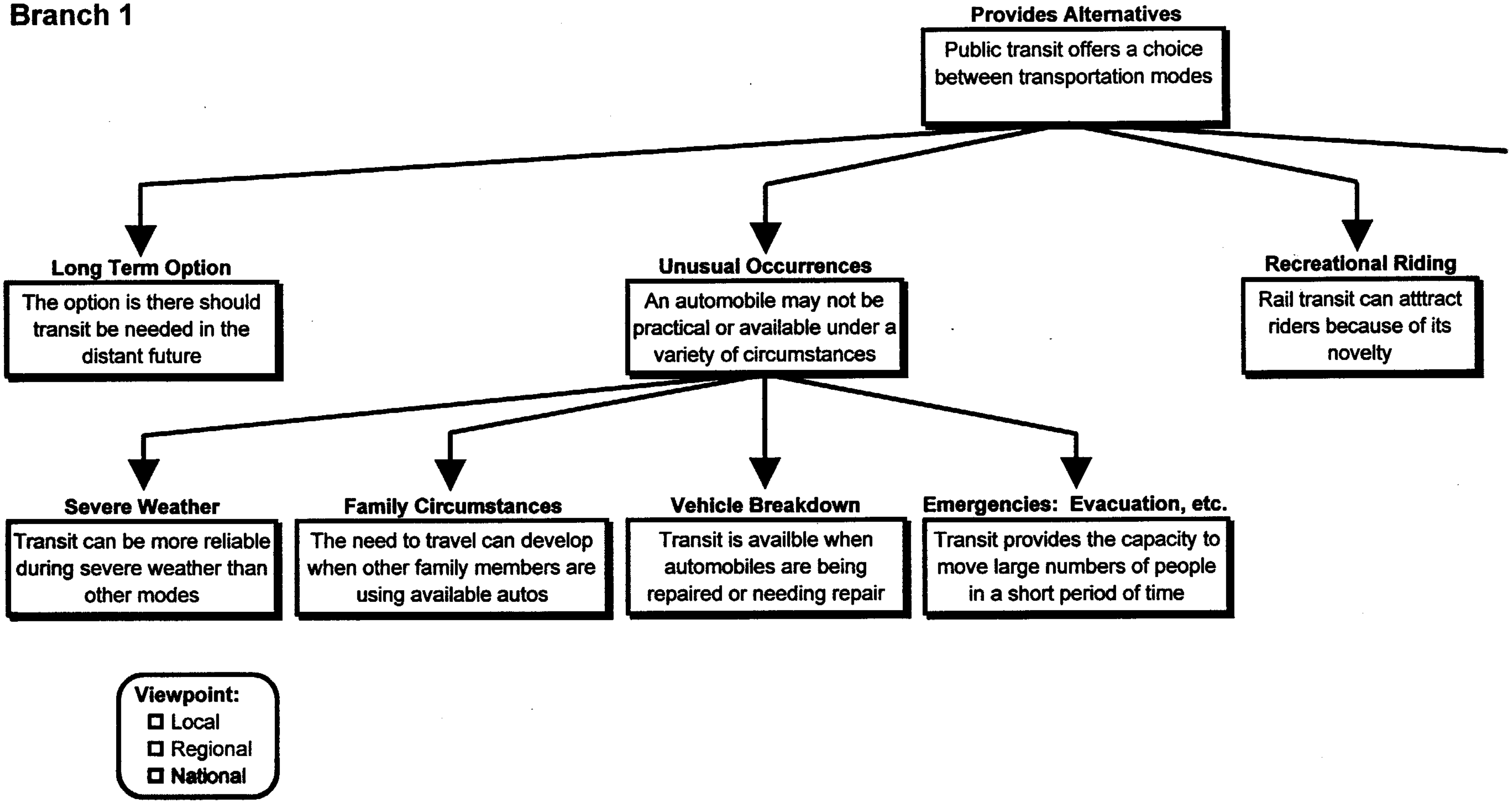
Unusual Occurrences. Unusual occurrences, such as severe weather, fuel shortages, family emergencies, vehicle breakdowns, community emergencies, and evacuations, temporarily increase society's dependence on transit. In these cases, benefits of transit are large even though the probability of the occurrence is small. In the event of a major disaster (such as floods, earthquakes, and hurricanes), transit has provided mobility for large numbers of people and enabled communities to resume normal operations sooner.

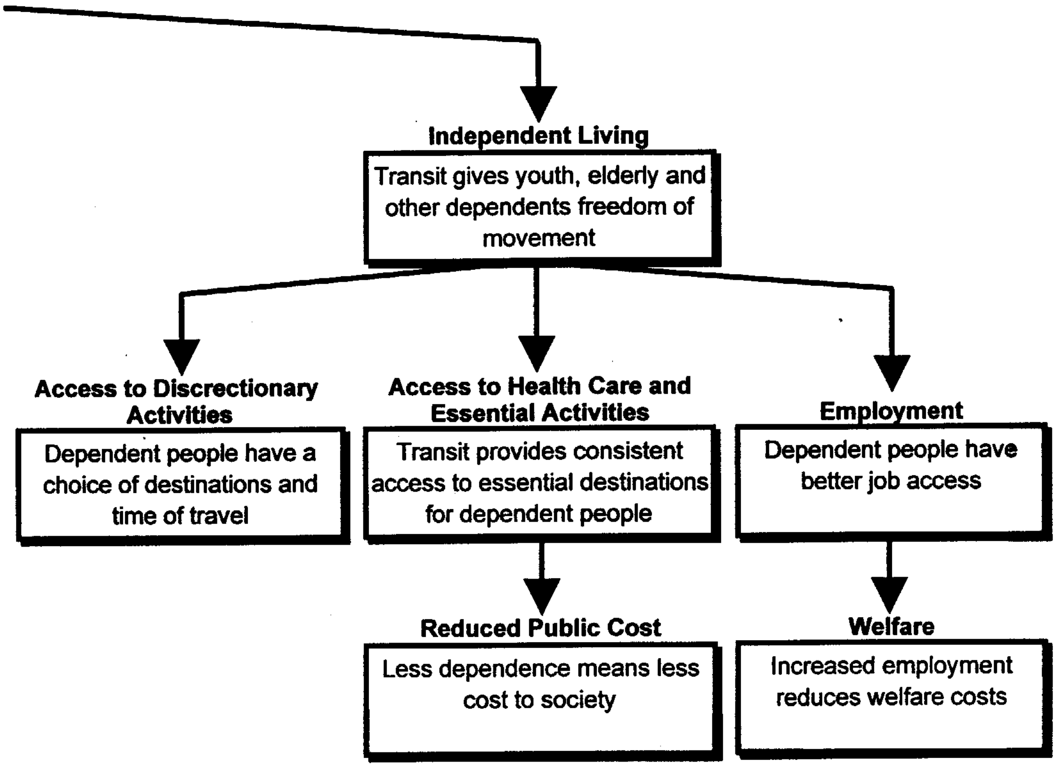
Independent Living. Transit provides the elderly and disabled, as well as those unable to drive for other reasons, freedom to travel without relying on others. This permits them to live independently, to have good access to discretionary activities (such as social events and recreation), as well as essential activities (such as employment, health care, education and shopping). The benefits to them and to others can be far greater than the consumer surplus of the trip itself. If transit service were not available, the costs of providing alternative services might be very high. Access to various activities, including health care and employment, not only allows for an individual's independence, but reduces public cost.

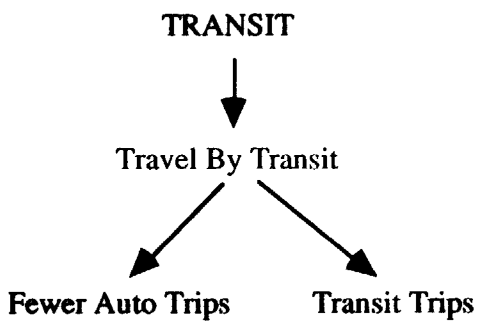
Recreational Riding. Transit can be a form of recreation in many cities, such as San Francisco, where tourists enjoy riding the cable cars or historic vehicles. People may be attracted to the city for other activities (conventions, shopping, fairs, exhibitions, sporting events, etc.) because of the novelty of the transit system.



Branch 1


Provides Alternatives
Public transit offers a choice between transportation modes
Long Term Option
The option is there should transit be needed in the distant future
Unusual Occurrences
An automobile may not be practical or available under a variety of circumstances
Recreational Riding
Rail transit can atttract riders because of its novelty
Severe Weather
Transit can be more reliable during severe weather than other modes
Family Circumstances
The need to travel can develop when other family members are using available autos
Vehicle Breakdown
Transit is availble when automobiles are being repaired or needing repair
Emergencies: Evacuation, etc.
Transit provides the capacity to move large numbers of people in a short period of time
Viewpoint:
Local
Regional
National


Independent Living
Transit gives youth, elderly and other dependents freedom of movement
Access to Discrectionary Activities
Dependent people have a choice of destinations and time of travel
Access to Health Care and Essential Activities
Transit provides consistent access to essential destinations for dependent people
Employment
Dependent people have better job access
Reduced Public Cost
Less dependence means less cost to society
Welfare
Increased employment reduces welfare costs



Travel Related Consequences — Branches 2 and 3

Transit directly benefits both transit and automobile users as a result of trip making and associated saving in user time and cost. Furthermore, it can lead to savings in the cost of providing transportation facilities and in negative environmental consequences of travel.

Transit User Effects. The most obvious benefits of a transit improvement are reductions in the time, cost and inconvenience of transit trips as shown in Branch 3 of the tree. The magnitude of the benefits can be estimated by analyzing choice behavior; if people make a choice to use transit it is because they feel that they will personally benefit from the transit trip. Such benefits can be measured by looking at the attributes of alternative choices and the choice behavior and by observing the differences between them. These effects relate to savings in personal resources, such as time and cost. Some savings may be long run and others may relate to an individual trip. For example, if one member of a household regularly uses transit to travel to work, the household may avoid the purchase of an automobile. Avoiding a car purchase can have substantial benefits over that of a single trip. So-called captive users can have a high benefit since their alternative would be not to travel.

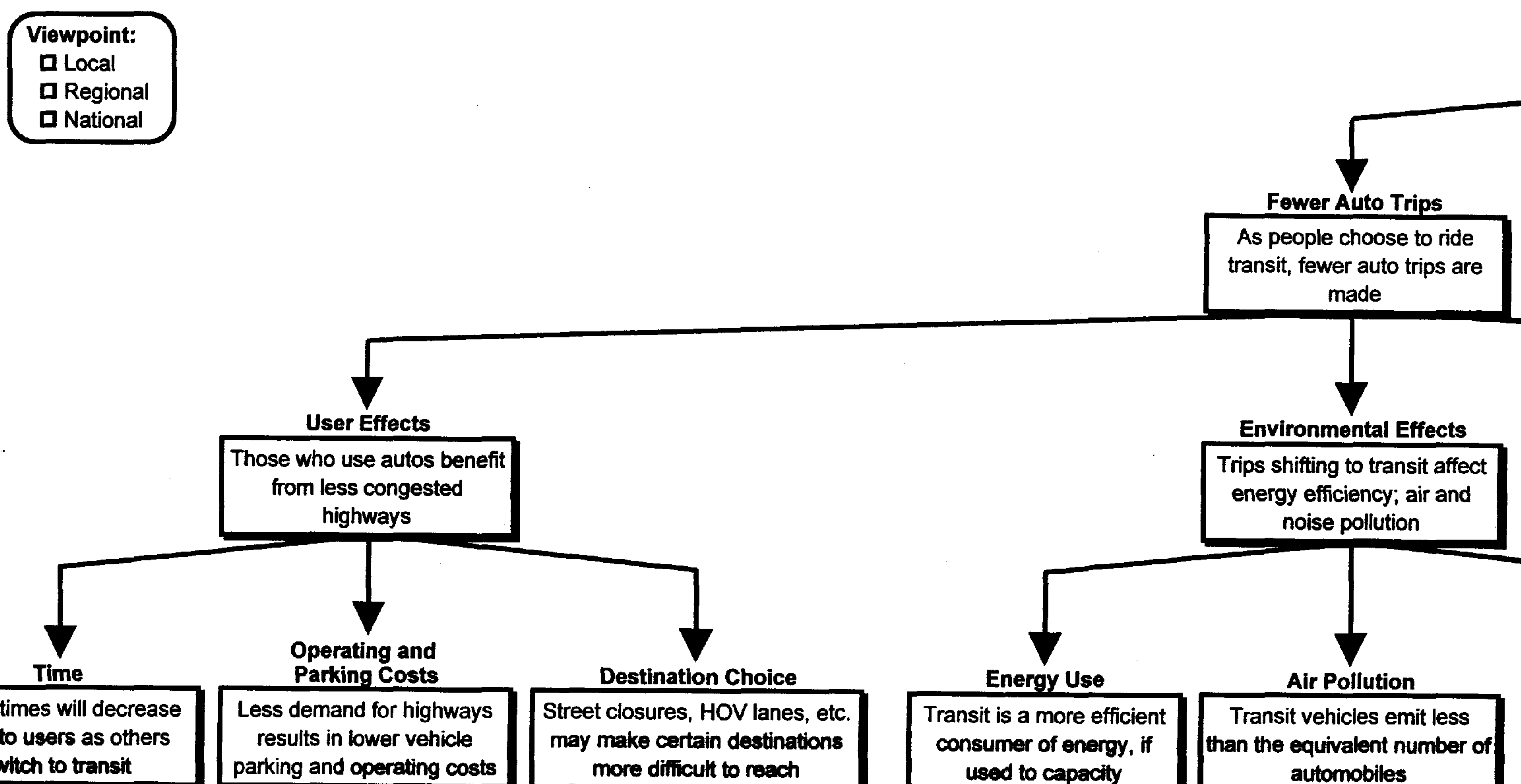
Change in Well Being and Security. Shifts of trips to or from transit carry with them changes in user safety, security and feelings about self. Automobile travel and transit travel differ in accident and security experiences. Assessment of these benefits are further complicated by differences between perceived and actual conditions. Users of transit may feel they are helping the environment and society through their transit use and have positive feelings about their personal choice.

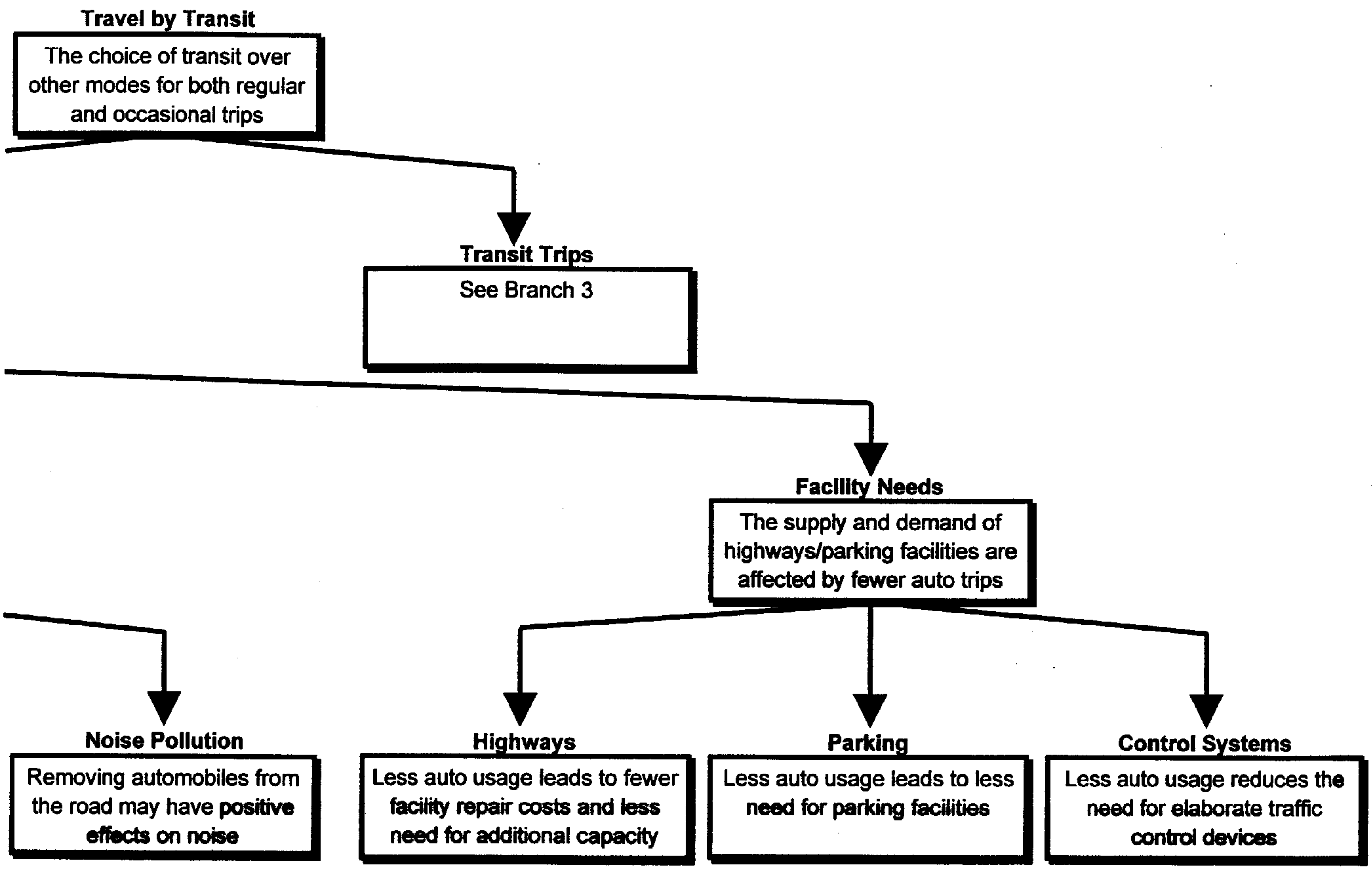
Change in Lifestyle. Transit riders come in closer physical contact with other riders, allowing for more interaction within the same community. Levels of privacy, frequency of contact with strangers, and equity are all affected. Some of these consequences can be viewed as benefits, others as disbenefits, depending on the point of view. Interaction increases familiarity with others, and it presents opportunities for networking, better communications, and understanding. Transit use can encourage a different life style. Travel by transit also affects users' freedom and their confidence in the ability to get places, to travel independently, and to travel punctually. For some this change is negative, while many people view it positively.

Automobile Related Benefits. Transit travel also provides benefits to both users and nonusers by decreasing the number of automobiles on highways as shown in Branch 2. Fewer automobile trips may mean less need for expanded highways, less parking facilities and less traffic control needs. Fewer automobile trips mean less energy use, less land consumption, and less accidents. Reduced automobile trip making affects the time and cost of meeting travel needs for remaining automobile users.

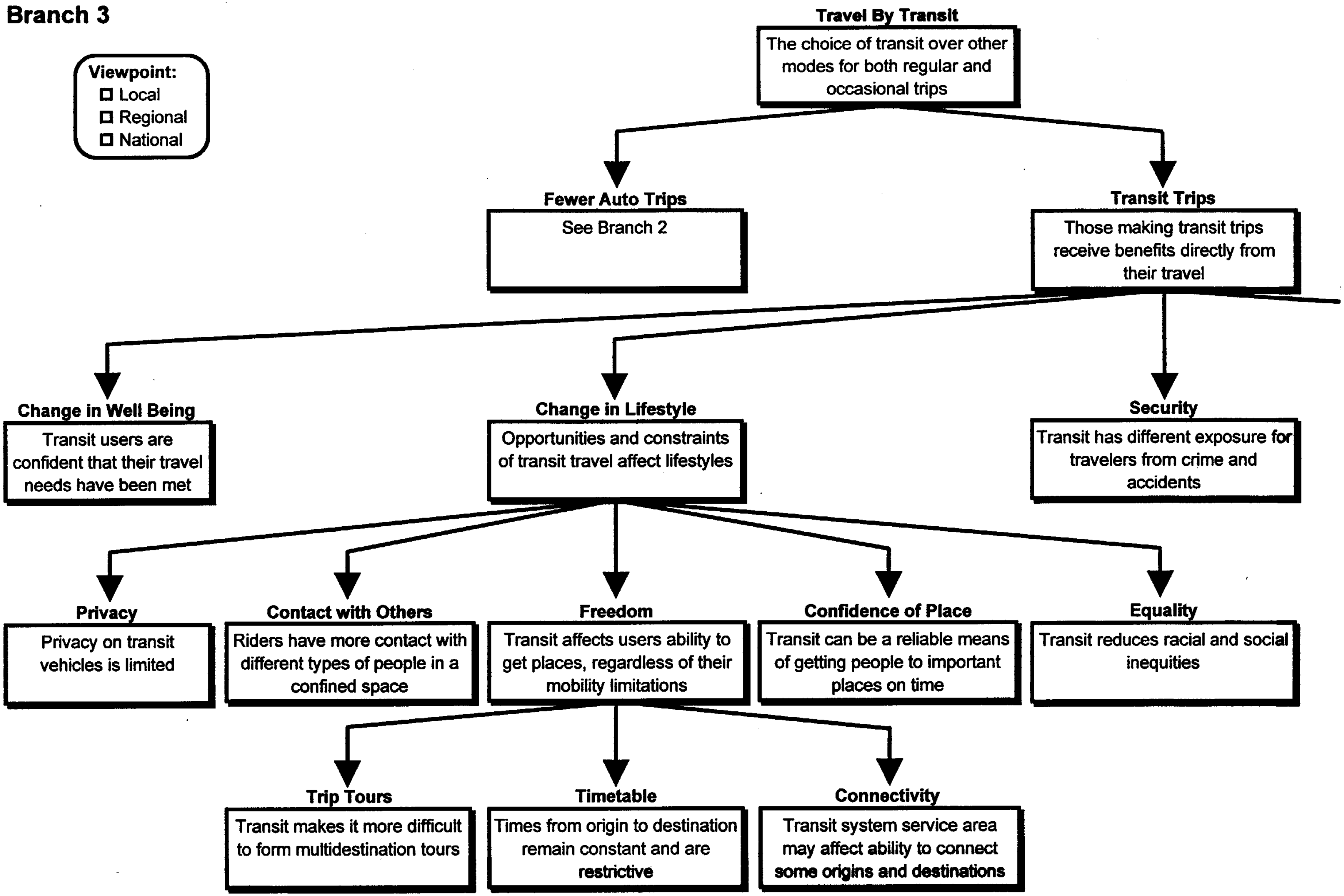
Environmental Effects. Shifts of travel between automobile and transit lead to a healthier environment. Reductions in overall travel lead to lower air pollutant emissions, reduced noise levels and other effects.

Branch 2

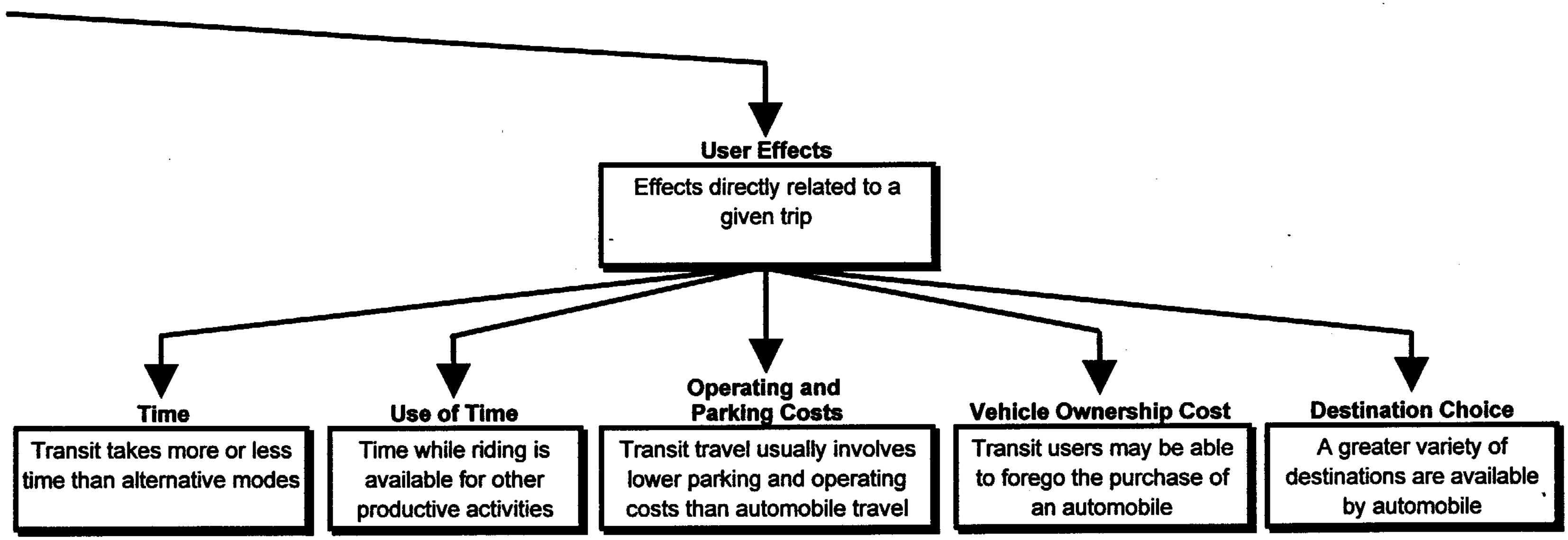

Viewpoint:
Local
Regional
National
Fewer Auto Trips
As people choose to ride transit, fewer auto trips are made
User Effects
Those who use autos benefit from less congested highways
Environmental Effects
Trips shifting to transit affect energy efficiency; air and noise pollution
Time
Travel times will decrease for auto users as others switch to transit
Operating and Parking Costs
Less demand for highways results in lower vehicle parking and operating costs
Destination Choice
Street closures, HOV lanes, etc. may make certain destinations more difficult to reach
Energy Use
Transit is a more efficient consumer of energy, if used to capacity
Air Pollution
Transit vehicles emit less than the equivalent number of automobiles


Travel by Transit
The choice of transit over other modes for both regular and occasional trips
Transit Trips
See Branch 3
Facility Needs
The supply and demand of highways/parking facilities are affected by fewer auto trips
Noise Pollution
Removing automobiles from the road may have positive effects on noise
Highways
Less auto usage leads to fewer facility repair costs and less need for additional capacity
Parking
Less auto usage leads to less need for parking facilities
Control Systems
Less auto usage reduces the need for elaborate traffic control devices

Branch 3

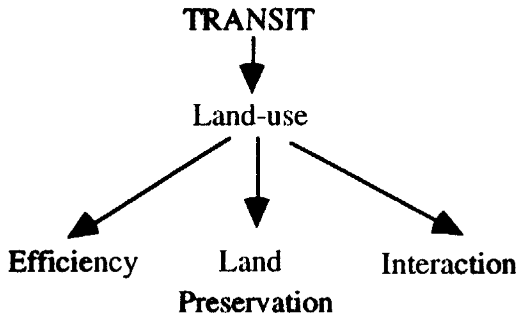


Viewpoint:
☐ Local
☐ Regional
☐ National
Travel By Transit
The choice of transit over other modes for both regular and occasional trips
Fewer Auto Trips
See Branch 2
Transit Trips
Those making transit trips receive benefits directly from their travel
Change in Well Being
Transit users are confident that their travel needs have been met
Change in Lifestyle
Opportunities and constraints of transit travel affect lifestyles
Security
Transit has different exposure for travelers from crime and accidents
Privacy
Privacy on transit vehicles is limited
Contact with Others
Riders have more contact with different types of people in a confined space
Freedom
Transit affects users ability to get places, regardless of their mobility limitations
Confidence of Place
Transit can be a reliable means of getting people to important places on time
Equality
Transit reduces racial and social inequities
Trip Tours
Transit makes it more difficult to form multidestination tours
Timetable
Times from origin to destination remain constant and are restrictive
Connectivity
Transit system service area may affect ability to connect some origins and destinations


User Effects
Effects directly related to a given trip
Time
Transit takes more or less time than alternative modes
Use of Time
Time while riding is available for other productive activities
Operating and Parking Costs
Transit travel usually involves lower parking and operating costs than automobile travel
Vehicle Ownership Cost
Transit users may be able to forego the purchase of an automobile
Destination Choice
A greater variety of destinations are available by automobile

Land-Use and Economic Consequences

Transit affects land-use and economic activity in different ways than highway systems. Generally, transit can sustain more concentrated land-use patterns. An evaluation of land-use and economic activity is complex. Some of the land value and economic changes occur because of savings in user travel time and cost, while other land-use changes are shifts of activity from one location to another. Care should be taken in the interpretation of these effects, especially if they are combined with others. Increases in economic activity can lead to increases in land values.



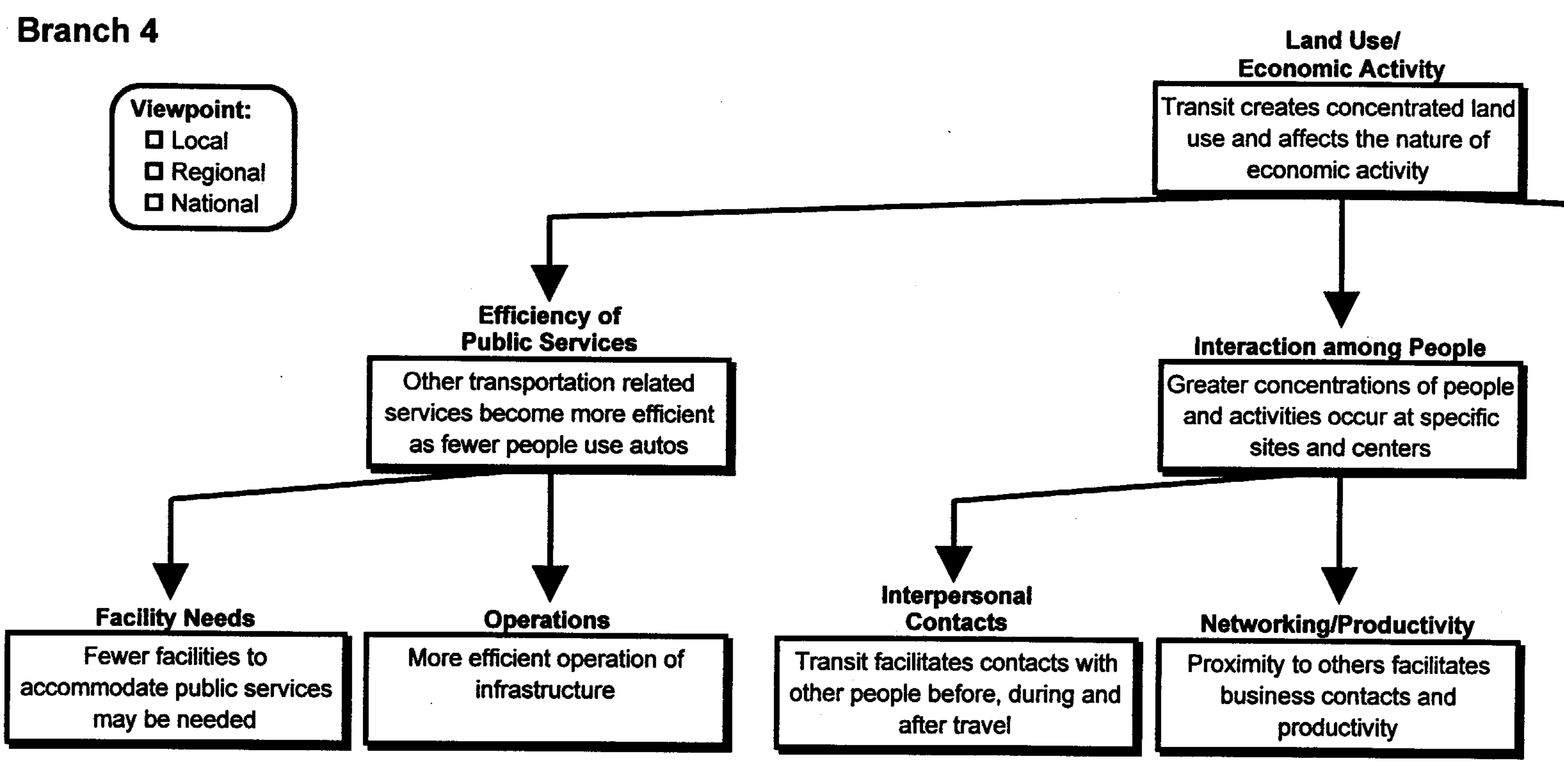
Land-Use Consequences. With concentrations of activities, public services become more efficient. There is a reduced need for sewer, water, and other utilities with higher densities. Services such as police and fire protection may become more efficient with less land area to cover. Furthermore, operating costs of these services may become smaller per unit of delivered service because of the concentration of activity.

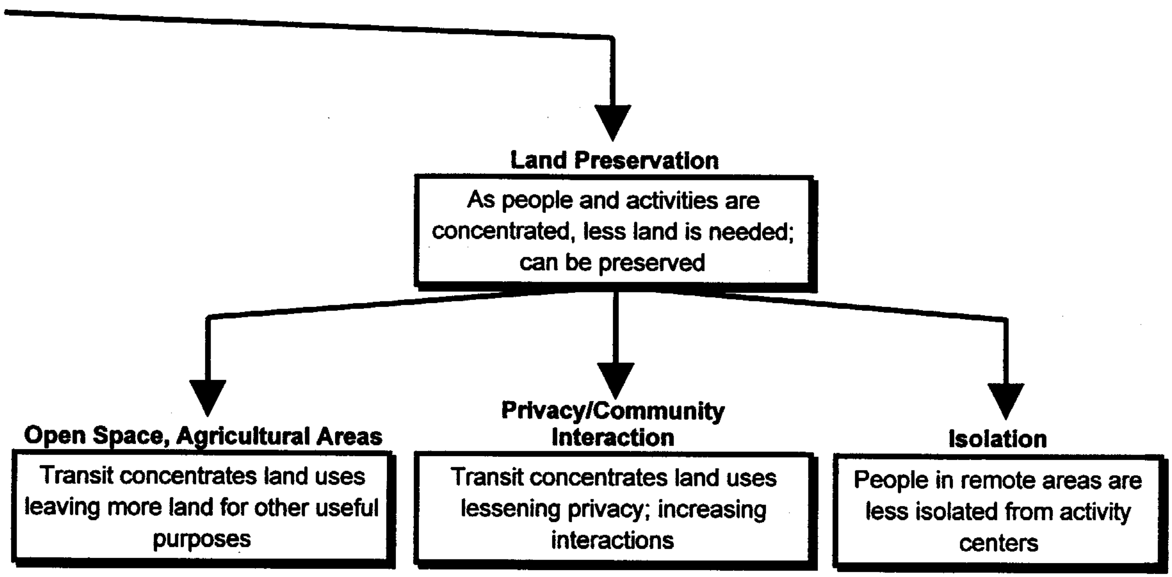
A concentrated land-use pattern also can lead to more interpersonal contacts, increased networking, productivity and community interaction. Communities with high levels of transit service and concentrated land use ("Eurocity") have very different levels of interaction than places that are automobile dominated, and lower densities ("horizontal city"). These effects could be positive or negative depending on how they occur. Increased interactions could have a synergistic effect on the destructive effect (say, from more crime) depending on many factors.

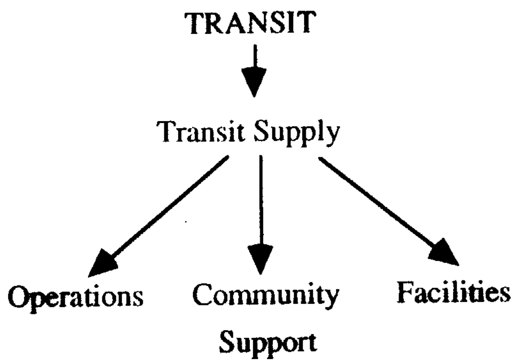
Concentrations of activity also lead to more preservation of open space for agriculture and natural areas. Concentration has effects on the value of land at a specific location. While the net change in land value for all land in an urban region may not change, it could increase substantially in areas of activity concentration.

It is important to separate those effects on land use that are related to better accessibility from effects due to concentration. Travel time and cost savings and better accessibility can be the cause of land value changes. Thus, double counting can occur if both are added to a benefit measure.

Economic Consequences. Economic activity and employment levels at a location may be impacted through job creation or job shifts. Increased economic activity often results in an increased tax base. A concentration of economic activities could produce higher employment levels at a locale and, thus, a more equitable tax base.


Branch 4
Viewpoint:
Local
Regional
National
Land Use/ Economic Activity
Transit creates concentrated land use and affects the nature of economic activity
Efficiency of Public Services
Other transportation related services become more efficient as fewer people use autos
Interaction among People
Greater concentrations of people and activities occur at specific sites and centers
Facility Needs
Fewer facilities to accommodate public services may be needed
Operations
More efficient operation of infrastructure
Interpersonal Contacts
Transit facilitates contacts with other people before, during and after travel
Networking/Productivity
Proximity to others facilitates business contacts and productivity


Land Preservation
As people and activities are concentrated, less land is needed; can be preserved
Open Space, Agricultural Areas
Transit concentrates land uses leaving more land for other useful purposes
Privacy/Community Interaction
Transit concentrates land uses lessening privacy; increasing interactions
Isolation
People in remote areas are less isolated from activity centers



Transit Supply Consequences

Finally, the existence of transit, by itself, has benefits and impacts as shown in Branch 5 of the tree.

Community Support and Prestige. At the local level many people feel that a transit system (particularly a fixed guideway system) adds to the prestige of the city, perhaps qualifying their city for "world class" status. Prestige cannot be quantified, but it can be of critical importance when decisions are made at the local level. People may support transit because they have a general belief that it makes a positive contribution to the environment and to society.

Facilities. Facilities and their construction cause temporary or permanent impacts that may constitute either benefits or disbenefits. Jobs are created through construction and materials consumption if the construction is a new activity for an area. Construction can be temporarily disruptive, including loss of customers for some businesses, spot congestion, and general inconvenience. Facilities consume vacant land or productive land. Land near stations can become good sites for secondary developments.

Operations. Transit agencies employ people, consume resources and make purchases as a result of their operations. These activities are multiplied as their impact is felt through the local economy.

Use of Benefits Tree — An Example

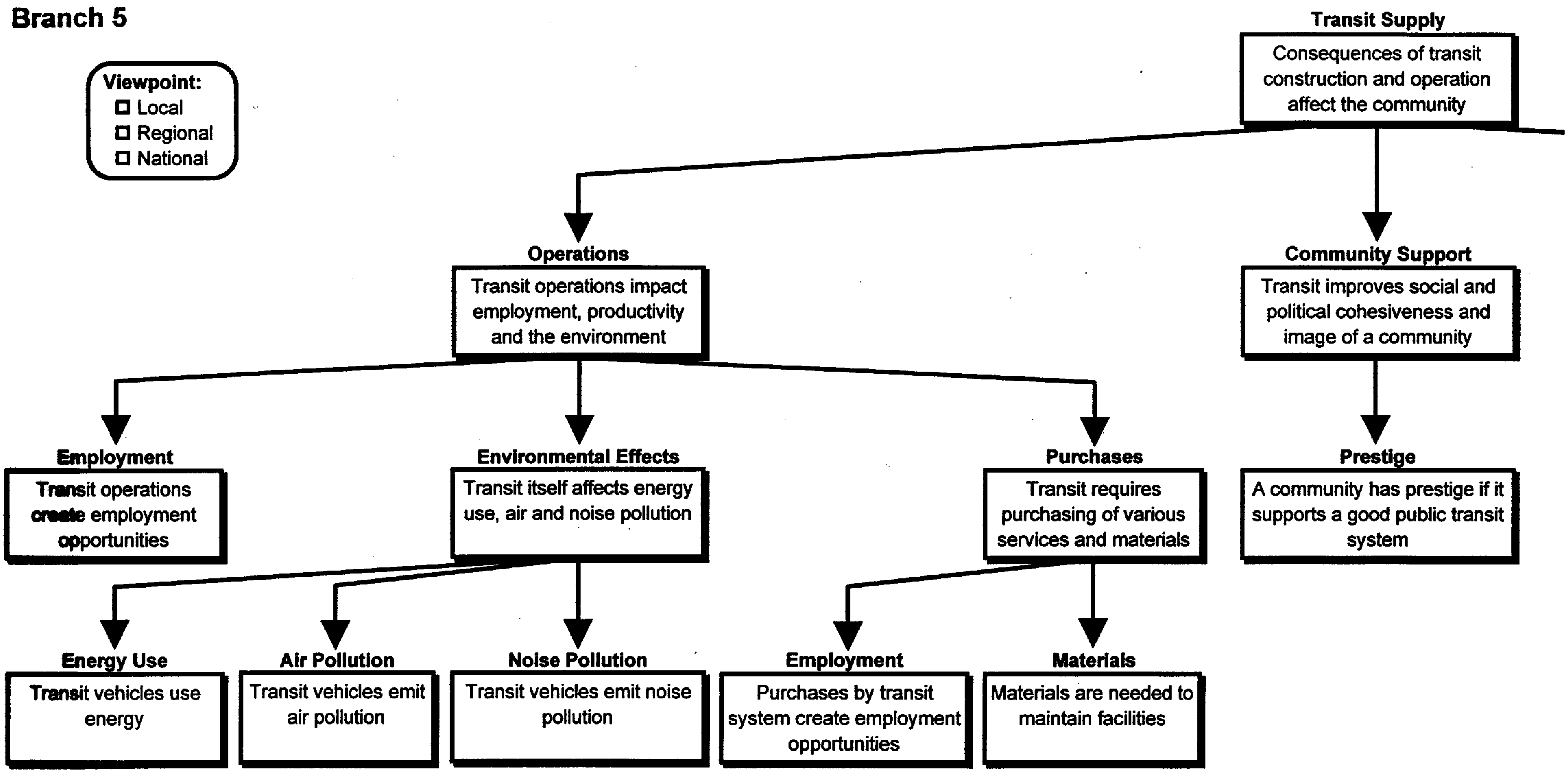
The benefits tree can be used to identify and display the potential benefits of a transit alternative. This would be done by first identifying those boxes on the diagram where it appears that a transit alternative will be significantly different from the null alternative. Only those consequences generate benefits or disbenefits. Each remaining box would then be filled out with numerical or descriptive information to describe the effect.

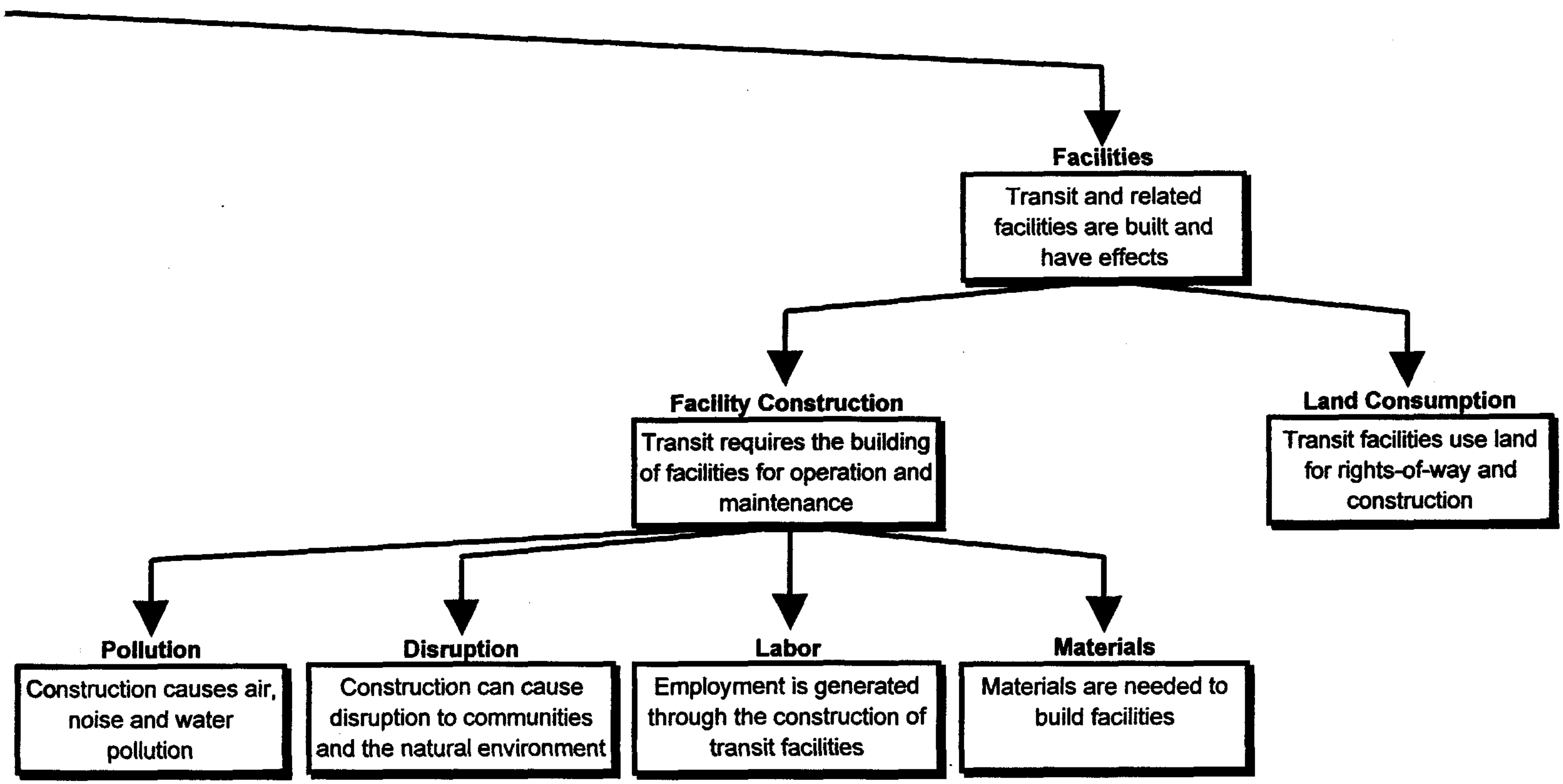
It is important to understand that measures at one level could include measures at lower levels. Thus, benefits should not be combined across levels since double counting can occur. Rather, the tree is a way of displaying how the pieces fit together, and as a way of comparing alternatives.

The example shows Branch 5 of the tree, transit supply, as filled out for a rail transit alternative as compared to the null alternative, an all bus system. Plan design and travel demand analysis lead to the determination that the rail alternative requires 30 light rail vehicles to operate on 20 miles of track. Operations and construction require the resources shown in the tree. A fully filled out tree could illustrate all consequences and help focus decision making on key tradeoffs between alternatives and aid in the selection of a locally preferred alternative. *This example uses the viewpoint of a local decision rather than a national decision.* As such, consequences that have differential effects at the local level are included. Decisions at other levels of government may use different factors.

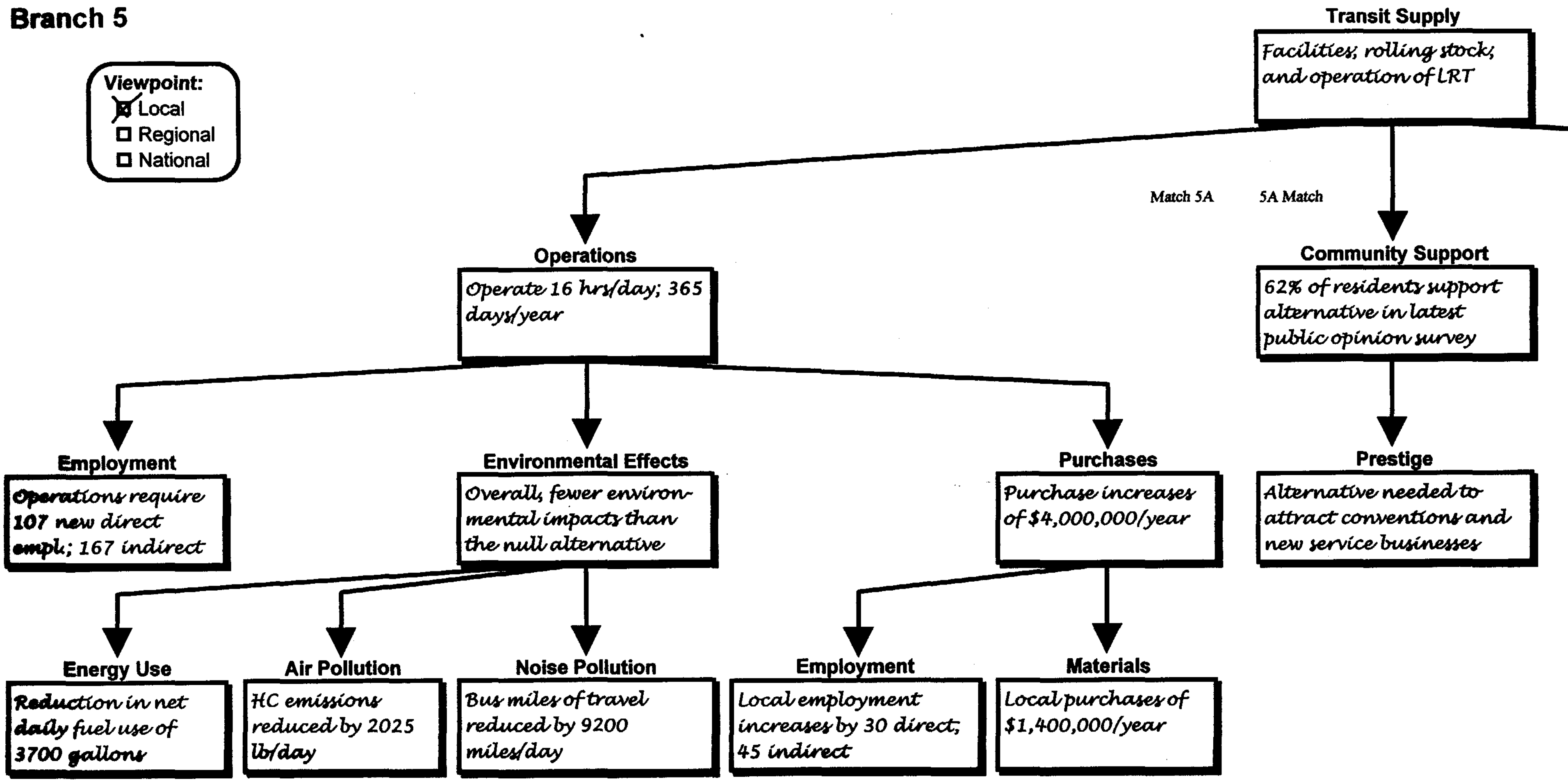
To facilitate use of the tree, a blank version of the tree is included as an appendix to this report. A soft-copy version is also available (as Excel spreadsheet files) upon request from the Center for Urban Studies at the University of Wisconsin—Milwaukee (414-229-5787).

Branch 5

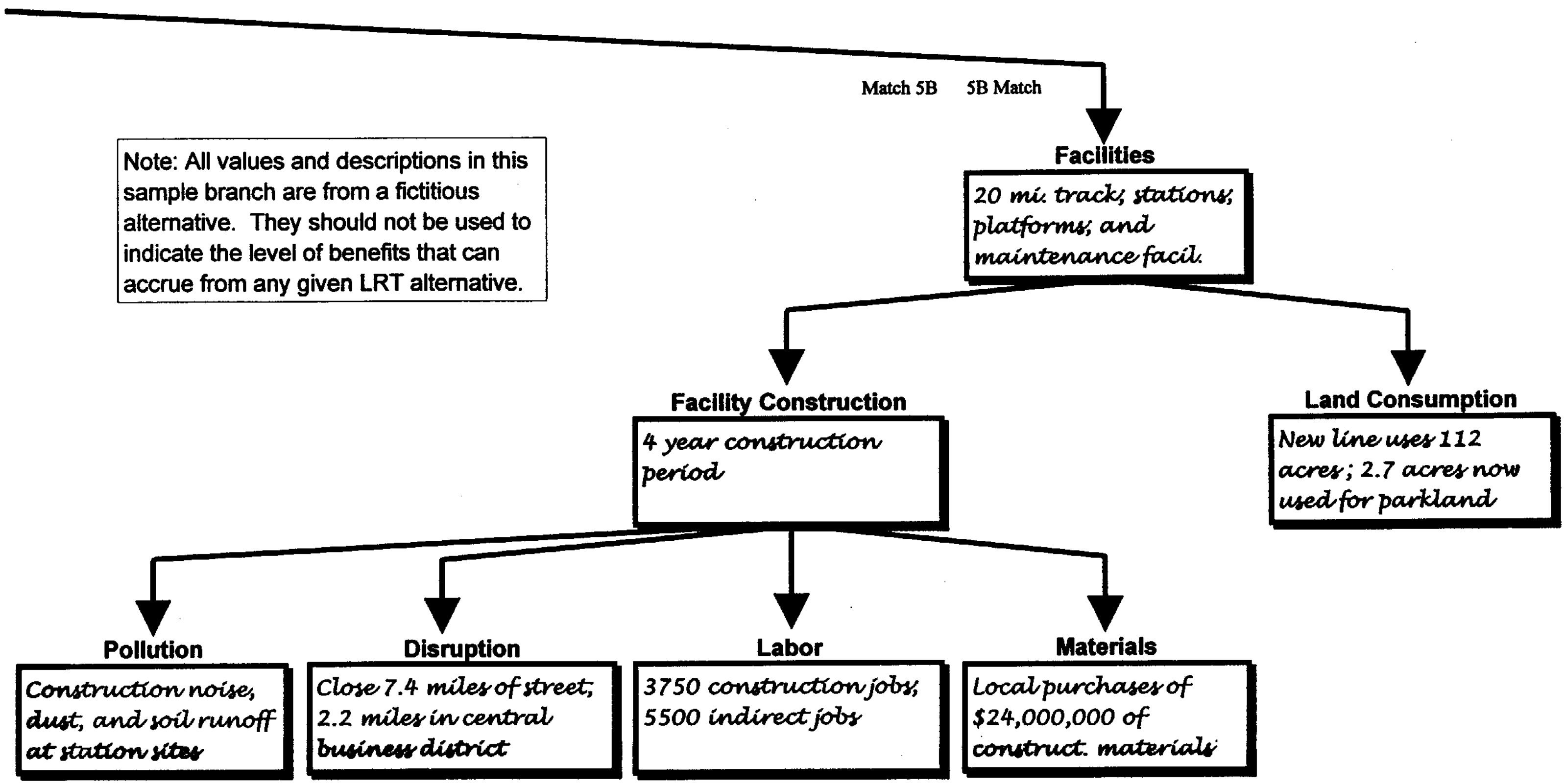

Viewpoint:
Local
Regional
National
Transit Supply
Consequences of transit construction and operation affect the community
Operations
Transit operations impact employment, productivity and the environment
Community Support
Transit improves social and political cohesiveness and image of a community
Employment
Transit operations create employment opportunities
Environmental Effects
Transit itself affects energy use, air and noise pollution
Purchases
Transit requires purchasing of various services and materials
Prestige
A community has prestige if it supports a good public transit system
Energy Use
Transit vehicles use energy
Air Pollution
Transit vehicles emit air pollution
Noise Pollution
Transit vehicles emit noise pollution
Employment
Purchases by transit system create employment opportunities
Materials
Materials are needed to maintain facilities


Facilities
Transit and related facilities are built and have effects
Facility Construction
Transit requires the building of facilities for operation and maintenance
Land Consumption
Transit facilities use land for rights-of-way and construction
Pollution
Construction causes air, noise and water pollution
Disruption
Construction can cause disruption to communities and the natural environment
Labor
Employment is generated through the construction of transit facilities
Materials
Materials are needed to build facilities

Branch 5



Viewpoint:
Local
Regional
National
Transit Supply
Facilities, rolling stock, and operation of LRT
Match 5A
5A Match
Operations
Operate 16 hrs/day; 365 days/year
Community Support
62% of residents support alternative in latest public opinion survey
Employment
Operations require 107 new direct empl.; 167 indirect
Environmental Effects
Overall, fewer environ-mental impacts than the null alternative
Purchases
Purchase increases of $4,000,000/year
Prestige
Alternative needed to attract conventions and new service businesses
Energy Use
Reduction in net daily fuel use of 3700 gallons
Air Pollution
HC emissions reduced by 2025 lb/day
Noise Pollution
Bus miles of travel reduced by 9200 miles/day
Employment
Local employment increases by 30 direct; 45 indirect
Materials
Local purchases of $1,400,000/year


Match 5B
5B Match
Note: All values and descriptions in this sample branch are from a fictitious alternative. They should not be used to indicate the level of benefits that can accrue from any given LRT alternative.
Facilities
20 mi. track; stations; platforms; and maintenance facil.
Facility Construction
4 year construction period
Land Consumption
New line uses 112 acres; 2.7 acres now used for parkland
Pollution
Construction noise, dust, and soil runoff at station sites
Disruption
Close 7.4 miles of street; 2.2 miles in central business district
Labor
3750 construction jobs; 5500 indirect jobs
Materials
Local purchases of $24,000,000 of construct. materials

G. STATE OF THE PRACTICE

Benefit Measurement in Transit Studies

This section describes the benefits typically identified in various planning and other technical documents for new transit systems. The description only reflects what is felt to be important by local agencies as they analyze alternative systems and propose systems for implementation.

A list of benefits and impacts was compiled from Alternatives Analysis/Environmental Impact Statements for major transit investments. Within the AA/EIS's, the government requires certain impacts to be quantified including air and noise pollution, travel times, land value, employment, etc. Local agencies can add other factors to this list and elaborate on required items in order to make their case more convincing.

AA/EIS's provide evidence of which benefits are of greatest importance to each community. One city may emphasize quality of life while another may emphasize travel time savings.

Fifteen alternative analyses, environmental impact statements and economic impact assessments were reviewed. Results from this analysis are given in a table on the following pages. Cited benefits are indicated, as well as whether an effort was made to quantify the benefits. The categories for the benefits were developed from the benefit tree as discussed previously. A reading of the AA/EIS's reveals that communities cite a wide variety of benefits. There are a few differences between cities. None of the cities considered the option value of transit, while most considered the reduction in automobile trips, land preservation and transit operations as benefits. The cited benefits can be discussed in terms of the four major branches of the benefits tree: transit as an alternative, travel related changes (Branches 2 and 3), land-use/economic effects, and transit supply.

Transit as an Alternative

That transit provides an alternative means of travel to the automobile was seldom mentioned in the EIS's. This consequence provides options, greater flexibility, and travel insurance for short term emergencies or long term changes in life style. Better accessibility for the elderly and disabled was discussed in only three statements. The Southeastern Pennsylvania Transportation Authority (SEPTA) commented on the importance of transit to the elderly and handicapped. "For the handicapped, SEPTA services, including paratransit, provide a vital link to jobs, health care, recreation, church, shopping and visiting."[5] SEPTA believes the elderly and disabled use mass transit more frequently than any other cross-section of the population. It addressed the option value of transit by discussing whether proposed routes consider the needs of elderly and handicapped.

Travel Related Consequences

These two branches involve what AA/EIS's refer to as "Transit Oriented" benefits. They include accessibility, comfort, congestion, parking, safety/security, travel times, value of time, and VMT charges. These effects result from changes in trip making and are dealt with extensively in the AA/EIS's. Nearly all the reports reviewed provide estimates of facility needs, environmental effects, and user savings.

Of these factors, accessibility, congestion, safety and security were rarely quantified. However, travel times, changes in vehicle miles of travel (VMT), parking effects, and value of time were nearly universally quantified. Fourteen of the

[5]U. S. Department of Transportation, June 1991, p. 4-12.

BENEFITS	**CITY** Atlanta	Chicago	Cleveland	Dallas	Detroit	Harris County, TX	Los Angeles	Honolulu
I. Provides Alternatives								
A. Long Term Option								
B. Unusual Occurrences								
C. Independent Living								
D. Recreational Riding								
II. Travel By Transit								
A. Fewer Auto Trips								
1. Facility Needs								
2. Environmental								
3. User Effects								
B. Transit Trips								
1. User Effects								
2. Change Well Being								
3. Change in Lifestyle								
III. Land Use/Economic Activity								
A. Concentration Of Activity								
1. Efficiency of Public Services								
2. Interpersonal Contacts								
3. Land Preservation								
4. Open Space								
B. Economic Activity								
1. Employment Impact								
2. Land Values								
IV. Transit Supply								
1. Community Support								
2. Facilities								
3. Operations								

***Darker shaded area indicates a quantified benefit**

BENEFITS	**CITY**						
I. Provides Alternatives	**Miami Kendall**	**Miami Metromov**	**SE Penn**	**St. Louis**	**San Mateo County, CA**	**Toronto**	**Tucson**
A. Long Term Option							
B. Unusual Occurrences							
C. Independent Living							
D. Recreational Riding							
II. Travel By Transit							
A. Fewer Auto Trips							
1. Facility Needs							
2. Environmental							
3. User Effects							
B. Transit Trips							
1. User Effects							
2. Change Well Being							
3. Change in Lifestyle							
III. Land Use/Economic Activity							
A. Concentration Of Activity							
1. Efficiency of Public Services							
2. Interpersonal Contacts							
3. Land Preservation							
4. Open Space							
B. Economic Activity							
1. Employment Impact							
2. Land Values							
IV. Transit Supply							
1. Community Support							
2. Facilities							
3. Operations							

*Darker shaded area indicates a quantified benefit fifteen EIS's quantitatively analyzed VMT, travel time, value of time, and parking. Air quality, energy and noise pollution are quantified in every document, as these are required items for an AA/EIS. Issues of transit travel (such as change in well-being and in lifestyle) were superficially mentioned in only one EIS as possible spin-off effects of an efficient transit system. The methods for measuring these benefits were as follows.

Facility Needs. **Parking** losses are calculated by the number of parking spaces destroyed so that the land can be used for track or other transit facilities. Parking losses may also occur from coordinated planning efforts to reduce the amount of traffic in downtown corridors and to promote transit ridership. The documents reviewed did not discuss reductions in highway facility needs that might result from an increased transit ridership.

Environmental Effects. Environmental effects are the primary subject of an EIS. **Air Quality** indexes are derived from standard formulas, measured in units of carbon monoxide emission levels by transit line and (in some cases) regionally. This method of quantification is consistent throughout the various environmental impact statements. **Noise impacts** are compared between alternatives and are measured in units of decibels. **Energy consumption** is calculated across alternatives and is measured in units of British Thermal Units (BTU) for each alternative.

User Effects. User effects occur to both automobile users and to transit riders. They are frequently combined in two overall measures: travel time and vehicle-miles-traveled. **Travel time savings** are estimated in person-minutes of in-vehicle travel for alternative transit system(s) as compared to a base system. These methods treat all components of travel time (waiting, transfer, travel, etc.) with equal weight. Travel time savings are sometimes converted into monetary units to obtain a dollar value of time savings. Changes in traveler cost (e.g., automobile operating costs, parking and transit fares) are seldom included.

Congestion is measured in vehicle miles traveled (VMT). The reports reason that more vehicle miles traveled has greater potential for congested highways and arterials. There is a prevailing view that a reduction in VMT is a principal benefit of transit. **Accessibility** as it relates to transit dependent riders (such as the poor, elderly, and handicapped) is measured in the travel time it takes to reach a work based and/or a nonwork based destination.

Change in Well Being. The effects of the transit system on the general well being of its users, their safety and their security are seldom mentioned in the documents. One report discussed this topic, saying,

> Better transit service within the downtown would enhance the convenience of region-serving transit service. This could reduce the use of automobiles for commuting to the Central Area and could encourage people to make longer trips by unifying the C.A. into a unified whole . . . .[6]

The Central Ohio Transit Agency generated accident statistics to determine the relative safety of each alternative to the null alternative.[7] **Social Interaction** is generally not considered, but some EIS's discuss how neighborhoods will be affected by transit systems. Interaction effects are evaluated by how much a neighborhood will be divided by transit facilities. **Quality of Life** may be quantified in ways important to a specific community, but differs from place to place. For example, COTA quantified the "quality of life" issue as the need to provide better

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[6]Alternatives Analysis and Draft Environmental Impact Statement Central Area Circulator, Chicago, Illinois, August 1991, p. 5-2.

[7]Economic Impacts of COTA on Central Ohio, January, 1988, p. 27, table 17.

access for the poor, elderly and handicapped to reach job destinations, leading to fewer welfare recipients.[8]

Change in Lifestyle. Similarly, the effects of transit on the lifestyle of users were seldom discussed. Transit users have different levels of privacy, contact with others, freedom of movement and confidence in being able to get places than automobile users. Only a limited discussion of these consequences appeared in one of the documents reviewed, where it was stated,

> Better transit service within the downtown will encourage people to make longer trips by unifying the Central Area into a more coherent whole, allowing them [people] access to jobs that were not convenient to them before, and encouraging people to venture farther within the downtown during lunch and in the evening.[9]

Land-Use/Economic Consequences

Concentration of Activity. Concentrating activities causes greater efficiency of public services, increased interpersonal contacts and preservation of land. Of these items, only land preservation and employment impacts were discussed by all reports. **Efficiency of Public Services** was mentioned in 13 reports with comments such as "The LRT alternatives generally reduce these times [transit travel times] by at least 10 minutes . . . ."[10] **Interpersonal contacts** are not mentioned in any of

[8]Economic Impacts of COTA on Central Ohio, January, 1988, p. 32.

[9]Alternatives Analysis and Draft Environmental Impact Statement Central Area Circulator, Chicago, Illinois, August, 1991, p. 1-9.

[10]Tasman Corridor, Santa Clara County, California, May, 1991, pp. 4-7.

the reports. **Land preservation and open space**, however, were discussed in fourteen of the fifteen reports reviewed. Preservation of parklands and wetlands were most often mentioned, calculating the amount of potentially endangered wetlands or flood plains. Preservation was rarely quantified, but the Honolulu EIS quantified the preservation of a potentially endangered butterfly population.

Economic Effects. Transit is often advocated as a way to persuade developers to build commercial, industrial, and residential sites within certain corridors. AA/EIS's attempt to measure the amount of economic activity that will occur and the potential impacts new developments will have on the region's economy. Several different methods of **employment** analysis were implemented depending upon the preference of the city or region. Variations of the input-output analysis for employment impacts are commonly used. Also, multipliers calculated by the Bureau of Labor Statistics are frequently used to determine potential employment. For example, the Colma BART station FEIS/FEIR calculated employment impacts by using the 1982 *I-O Model and Economics Multipliers for the San Francisco Bay Region.* The reports are unclear whether the employment impacts represent real gains or simple shifts from within or outside the region.

Land Value is directly related to economic development; attempts were made to determine the cost of land once a transit system is implemented or expanded. Land close to the transit centers may increase in value. Both negative and positive impacts could occur from this kind of development. Land value effects are rarely quantified. Only the St. Louis EIS made a minimal effort to quantify such benefits based on tax revenues: "EWGCC estimates that LRT will potentially attract $532.1 million in development . . ."[11] The amount of potential development was usually discussed but there are too many unknowns to permit quantification.

[11]5-29, St. Louis.

Transit Supply

Consequences of an expanded transit system are discussed but not necessarily quantified. **Community support** (added prestige or "world class" city) is sometimes mentioned. For example, according to the Metropolitan Atlanta Rapid Transportation Authority,

> Rapid rail transit represents a major public investment which has and will continue to greatly influence Atlanta's future development pattern. The region will continue as one of the nation's pivotal distribution points linking the United States and the world with the rapidly growing Southeastern market.[12]

Employment Impacts of facility construction are cited in every AA/EIS. Very often this is done by estimating the employment activity per year during construction. Effects on employment for operations are also given. Generally it is felt by the community that such jobs are a local gain since they are new to the area. Whether such jobs are shifts from other areas and whether more jobs would be created by investing funds in other activities are seldom mentioned.

[12]MARTA, Transit Station Areas Update, August, 1986, p. 15.

Local Use of Benefit Measures

Visits were made to different cities around the country to gain a better understanding of transportation decision making and the role of benefits analysis. Cities were selected where expansion of the transit system has been a significant local issue and where extensive analysis has been or is being made of the benefits of transit. The purpose of these visits was to examine how analytical estimates of benefits were used in decision making and to identify critical factors that lead to the choice of particular courses of action. This effort also looked into the role of referenda as a way to gain a community expression of transit benefits, to determine whether one could estimate overall perceived benefits by looking at how much a community was willing to tax itself voluntarily to support transit.

In each community, interviews were conducted to understand better the technical and political arguments for and against the transit expansion. In-depth interviews were held with staff members of transit agencies, local government, and metropolitan planning agencies, and with citizens and the academic community. A large number of documents were also obtained, including planning documents and promotional information that helped to understand the social, political and philosophical history of transportation decision making. There was good agreement among those interviewed about the key political issues and the areas of dispute.

Issues of Debate

In the communities we visited we found diverse opinions on the general value of transit and even more disagreement on specific projects. This disagreement is especially evident where the issue of building a rail system is a point of local controversy. In these places transit, in general, may have widespread support but particular parts of rail system proposals can be seriously questioned.

A FRAMEWORK FOR ANALYSIS

Debates over courses of action tend to center on benefit issues. Advocates believe there are substantial benefits of transit investment, while those people opposed doubt that such benefits exist. In most cases, these opinions existed independently of any attempts to quantify benefits. Studies that measured benefits were ignored or discredited or cited as authoritative depending on one's position on the proposed project. In most places we visited benefits were a matter of belief rather than an agreed fact. Furthermore, many benefits cited were intangible and difficult or impossible to measure.

"Debates over courses of action tend to center on benefit issues. Advocates believe there are substantial benefits of transit investment, while those people opposed doubt that such benefits exist."

The strongest criticisms come from those who believe that rail development cannot possibly be cost effective. In a role reversal, some critics are accusing political leaders of being too visionary, of not appreciating the obstacles to a successful system, and of placing too much faith in travelers' willingness to adapt to the changing transportation system. Technical analysis used to justify rail programs have been challenged by opponents, saying that the positive results were predetermined by the chosen methods. The critics have taken a conservative position relative to the potential benefits of a rail program, suggesting that most of the benefits are small and that overall non-quantified benefits do not exist. They say that it would be better to spend the money on bus services that can blend with the automobile-oriented life style of the community. Advocates, on the other hand, place high weight on nonquantified consequences and are optimistic on other effects.

In the cities visited those interviewed felt that the community supported transit principally because of the promise of congestion relief. Concerns about air pollution and energy consumption were also expressed in some locations. Supporters of transit included downtown interests, who believed that the center of the city could not experience any future growth without an increase in transportation system capacity. Comparisons to other "world class" cities were made in several of the cities we visited. Transit was seen as an important factor in civil pride and prestige. However, it was also mentioned in several cities that transit was supported by people who feel that they would not personally use it. In other words, their view was that people want transit so that other people can ride it.

These reasons for transit support in some cities appear to be based on frustration with the highway system. Transit was presented as a palatable way of solving seemingly intractable problem of traffic congestion. It was mentioned in several places that the city once had a fine streetcar system and things were better then. Lacking tangible evidence that a rail system would actually mitigate today's traffic problems, decision makers accepted this contention as an act of faith.

In some places the issue of socioeconomic status of riders was mentioned. There was a general agreement that trains have more status than buses. They can attract a better class of rider because of the promise of personal safety, comfortable seats, smoother ride, and attractive surroundings. Asked why these same attributes couldn't be given to buses, it was stated by one person that a better bus environment could not be maintained, given the type of people taking the bus. A decision has been made to create trains for affluent travelers, leaving buses as they were for poor people.

Socioeconomic status is also affecting route alignments. There is a discernible tendency to locate rail lines away from richer areas and near poorer areas, somewhat undercutting the objective of increasing the proportion of affluent riders. The desire to serve poorer areas is understandable; poorer areas already have a demonstrated need for transit. The desire to avoid rich areas is perplexing. Interviewees suggested that the rich do not envision taking transit themselves, but fear an increase in crime in their neighborhoods by "those" people who do take transit. Another impediment to providing rail transit in rich neighborhoods is a perception by some individuals that it is visually unattractive and noisy.

Role of Political Process

Transit planning, especially for new rail systems, is fundamentally a political process, assisted by technical analysis. Our experience was that most local planners do not feel it necessary to evaluate the benefits of its rail program because they have received a mandate for the program in the form of a clear political mandate and/or successful referenda. The decision makers are all actors in the political process, and they decide which parts of the transit program receive funding.

Transit is seen by some elected officials as a means of revitalizing the community, containing sprawl, and encouraging growth in high density corridors. There exists a strong belief in the cities visited that they have a dynamic community, rapidly changing in both its urban form and its demographics. The vision of rail transit development is that it can help reshape the community into a more efficient one and that it can overcome the almost complete dependence on highway transportation.

"Transit planning, especially for new rail systems, is fundamentally a political process, assisted by technical analysis."

Transit relies on key elected officials for its support. If these key officials lose elections or leave office, there can be significant changes in direction. Projects are dropped or scaled back as other issues gain emphasis. The level of benefits may remain the same, but different people pursue other political objectives.

In some cases support for transit occurs because of a compromise between highway goals, environmental interests and other factors. Some level of transit investment is needed to gain support for overall transportation programs that include substantial investment in other modes of transportation. Furthermore support of advocates for environmental protection is obtained by supporting transit in exchange for compromises in development policy. Transit is another issue that mixes into an overall package of programs assembled by elected officials. When the overall picture is explained, the level of effort for transit can make more sense than if transit is looked at by itself. Transit decision making is part of local politics, and it cannot be replaced by objective technical analysis.

The political process is sensitive to good technical analysis and systems can be modified or designed differently as a result of objective measures. However, technical analysis that conflicts with strongly held beliefs will tend to be discredited and ignored. Transit decision making is dominated by intangibles that do not lend themselves to quantification and is done as part of a process of compromise and tradeoffs with other needs.

"The political process is sensitive to good technical analysis and systems can be modified or designed differently as a result of objective measures. However, technical analysis that conflicts with strongly held beliefs will tend to be discredited and ignored."

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.

"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."

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 type),

MEASUREMENT TECHNIQUES FOR TRANSIT CONSEQUENCES

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

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 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 as Measured 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.

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:

$$\begin{aligned}\text{Disutility} = {} & \text{automobile riding time} + \\ & (\text{transit riding time})(\text{transit riding weight}) + \\ & (\text{walking time})(\text{walking weight}) + \\ & (\text{waiting time})(\text{waiting weight}) + \\ & (\text{transfer time})(\text{transfer weight}) + \\ & \text{initial wait penalty} + \text{first transfer penalty} + \\ & \text{second transfer penalty} + \\ & \text{fare}/(\text{value of time}) + \\ & (\text{tolls} + \text{parking costs} + \\ & \text{vehicle operating costs})/(\text{value of time}) + \\ & (\text{vehicle ownership costs})/(\text{value of time}) \quad . \end{aligned} \tag{H.1}$$

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

Transit Riding Weight	1 + 2.0 x (fraction of person time standing)
Walking Weight (good weather)	1.3
Waiting Weight	1.9
Transfer Weight	1.6
Initial Weight Penalty	8.4 minutes
Transfer Penalty (first or second)	23 minutes
Value of Time	0.167 to 0.333 of the average wage of choice riders

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.[13] 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:

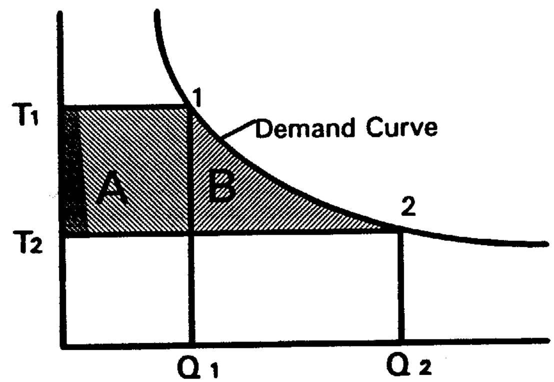


Figure H.1. Calculating net consumer surplus from a demand curve.

$$\text{Net Consumer surplus} = (T_1 - T_2) * (Q_1 + Q_2)/2 \quad . \tag{H.2}$$

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,

$$\textit{Net Consumer Surplus} = -\int_{T_1}^{T_2} Q(T)dt \tag{H.3}$$

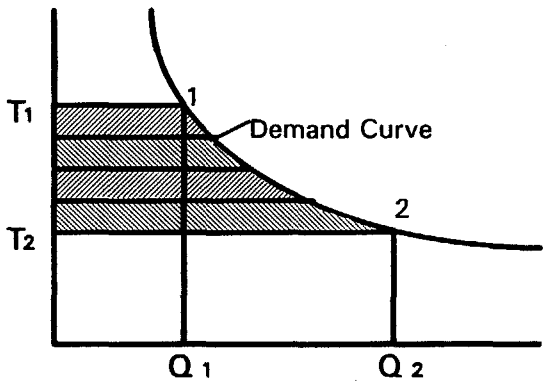


Figure H.2. Approximating the net consumer surplus integral with flat trapezoids.

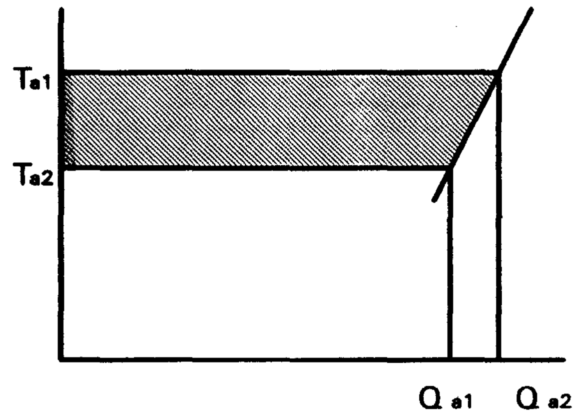


Figure H.3. Effect of a transit system improvement on net consumer surplus for automobile users.

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,

$$\textit{Net Consumer Surplus} = -\sum_m \sum_i \sum_j \int_{T_{1mij}}^{T_{2mij}} Q(t)\, dt \,, \tag{H.4}$$

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.

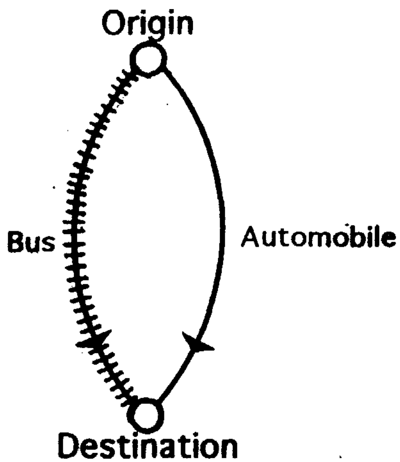


Figure H.4.

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

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

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

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

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:

[14]Federal Highway Administration, Report HHP-24/R8-83, August 1973.

$$P_b = \exp(-\alpha\ T_b) \;/\; \{\exp(-\alpha\ T_b) + \exp(-\alpha\ T_a)\} \qquad \text{(H.7)}$$

where exp() is the exponential function and α is a constant that is individually calibrated for each transit system. From earlier work, it has been determined that a good value of α 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 H.2. CHANGES IN TRAVELER DISUTILITY AND BEHAVIOR

	Bus		Automobile	
	Disutility	Passengers	Disutility	Passengers
Before	50.0	357	29.6	1043
After	40.0	462	26.3	938
Change	-10	+105	-3.3	-105

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.

Relationship of Enhanced Consumer Surplus to Time Savings

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.

"If a person chooses a different travel behavior, there must be a net positive benefit."

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 H.3. TYPICAL VALUES OF ELASTICITY FOR TRANSIT SERVICE CHANGES	
Bus Fare	-0.4
Rapid Rail Fare	-0.2
Headway	-0.5
Bus Miles	0.9
Households within Service Area	1.0

Source: "Travel Response to Transportation System Changes," FHWA, 1981.

Table H.4. CONSUMER SURPLUS WITH ELASTICITIES

Headway Reduction	Change in Disutility	Before Ridership	After Ridership	Net Consumer Surplus
30 to 25 min	4.75 min	2400	2600	9975
25 to 20 min	4.75 min	2600	2817	12865
20 to 15 min	4.75 min	2817	3052	13939
Total				36779

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.

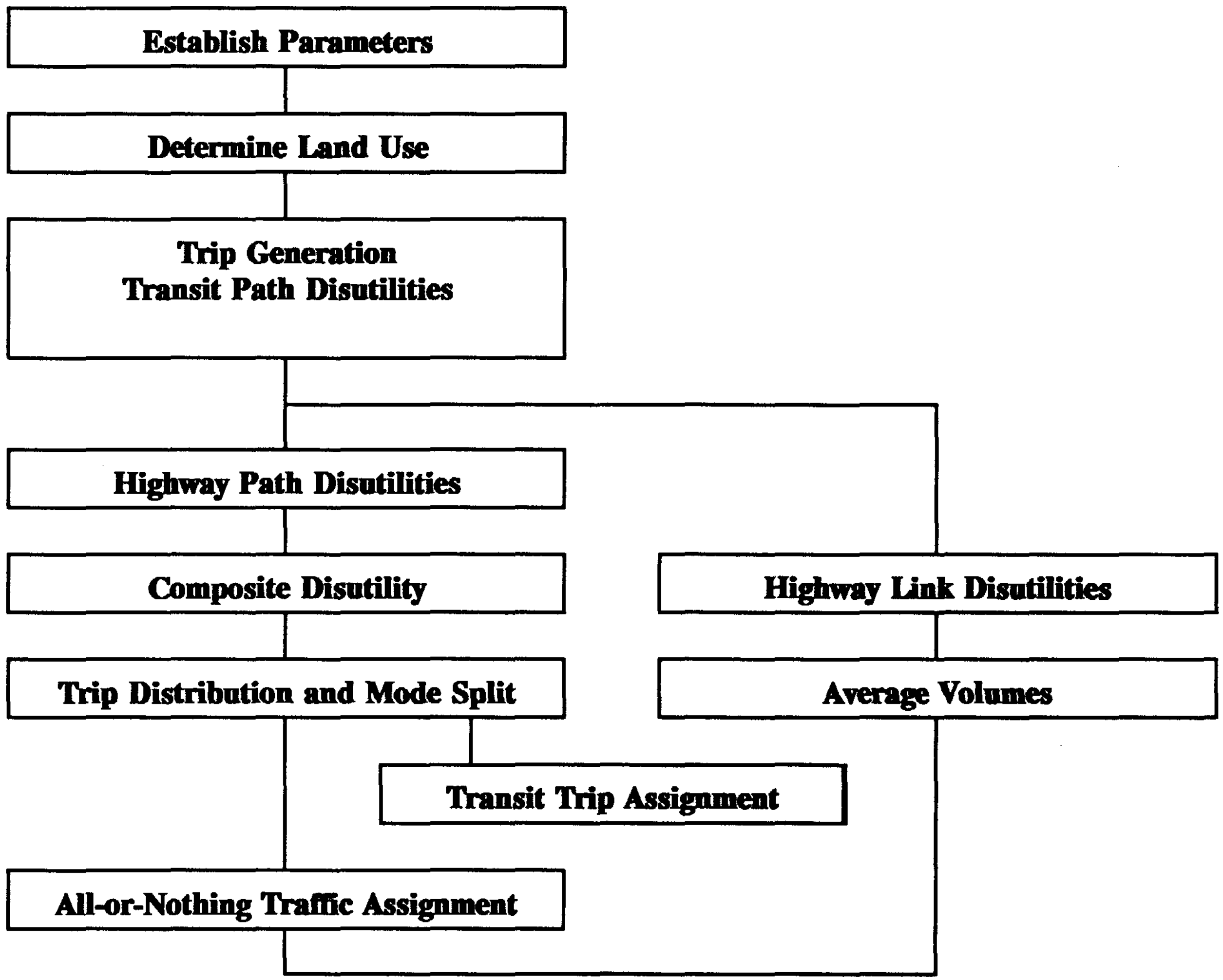


Figure H.5. Combined-Steps Methods of Travel Forecasting

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:

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

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 α 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 α value of 0.06, the composite disutility is

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

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 region

[15]Lowry, I. S., 1964.

[16]Putman, S. H., 1979.

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:

$$T_{ij(wbh)} = e_i \, w_j f(t_{ij}) \;/\; (\sum_j w_j \, f(t_{ij}))$$

Where:

w_j is the residential attractiveness of zone j;

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.*

Employment. Total employment, e_i, 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 β 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:[18]

$$Q = D\{T, x, \phi\}$$

and

$$T = S\{Q, v, f\}$$

where

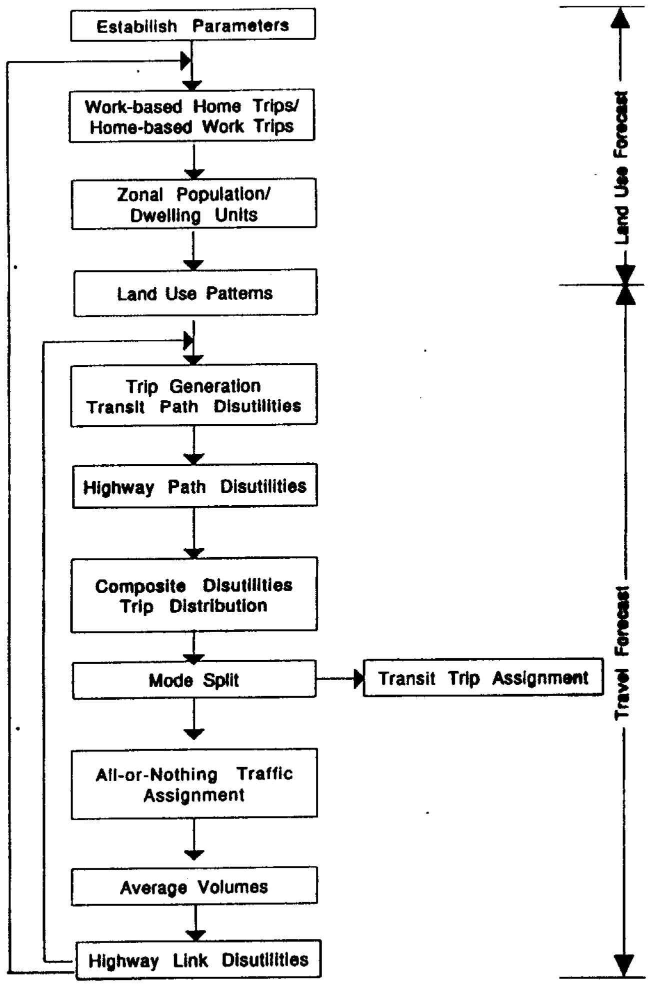
Q is the travel volumes per unit time;

D{ } is the demand;

x is a set of exogenous variables;

T is the disutility;

[18]Williams, H. C. W. L., *et al.*, 1991, pp. 253-279.



Framework of the Model

Figure I.1

S{ }   is the cost function

v   is a set of policy variables influencing modal costs

ϕ, f are sets of parameters influencing the demand for and cost of travel, respectively.

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:

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

where

T_{cij} is the composite disutility from zone i to zone j

T_{bij} is the disutility by transit

T_{aij} is the disutility by automobile, and

α 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 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.

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]

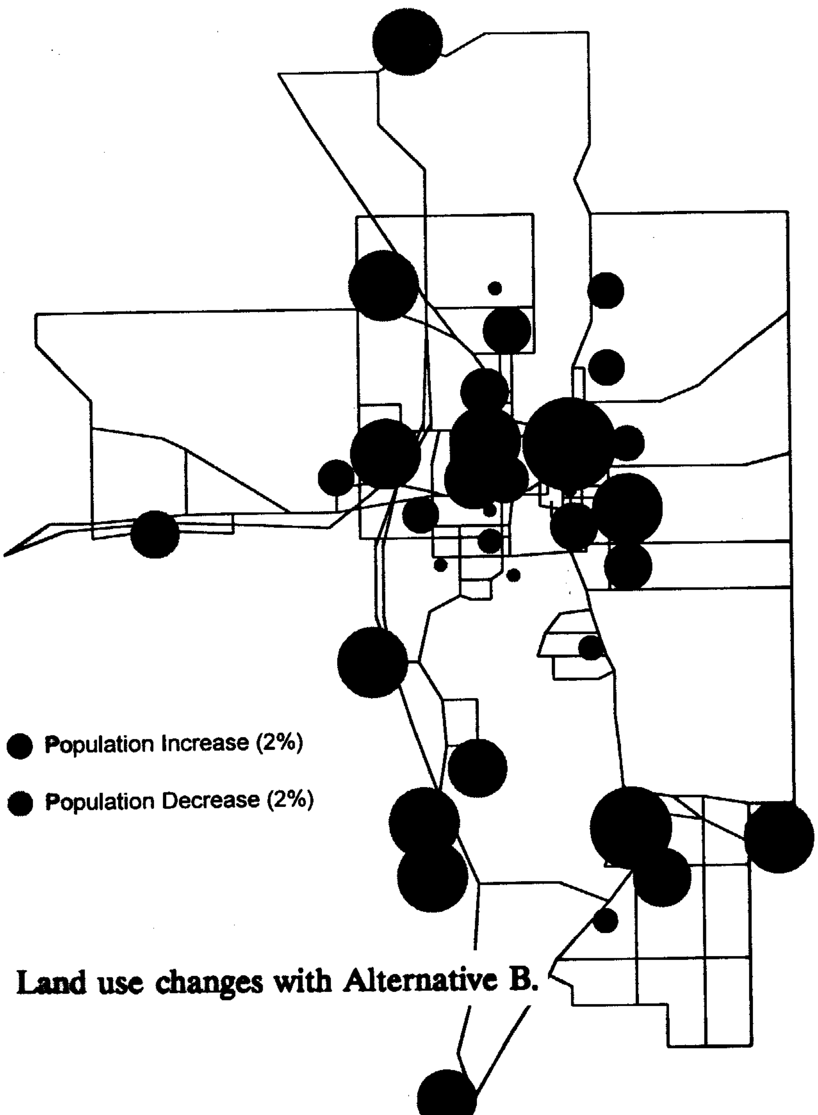
Results: Land-Use Redistribution. A comparison of the dwelling unit redistribution due to transit changes was conducted for both design alternatives. Zonal trip production was defined as the sum of the number of employees in each sector (retail and non-retail). Zonal trip attraction was defined as the zonal net developable area. An exponential model was used for trip distribution. Parameters for the trip distribution model, β, were adopted from a previous land-use study (hbw = 0.12, hbnw = 0.11, nhb = 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

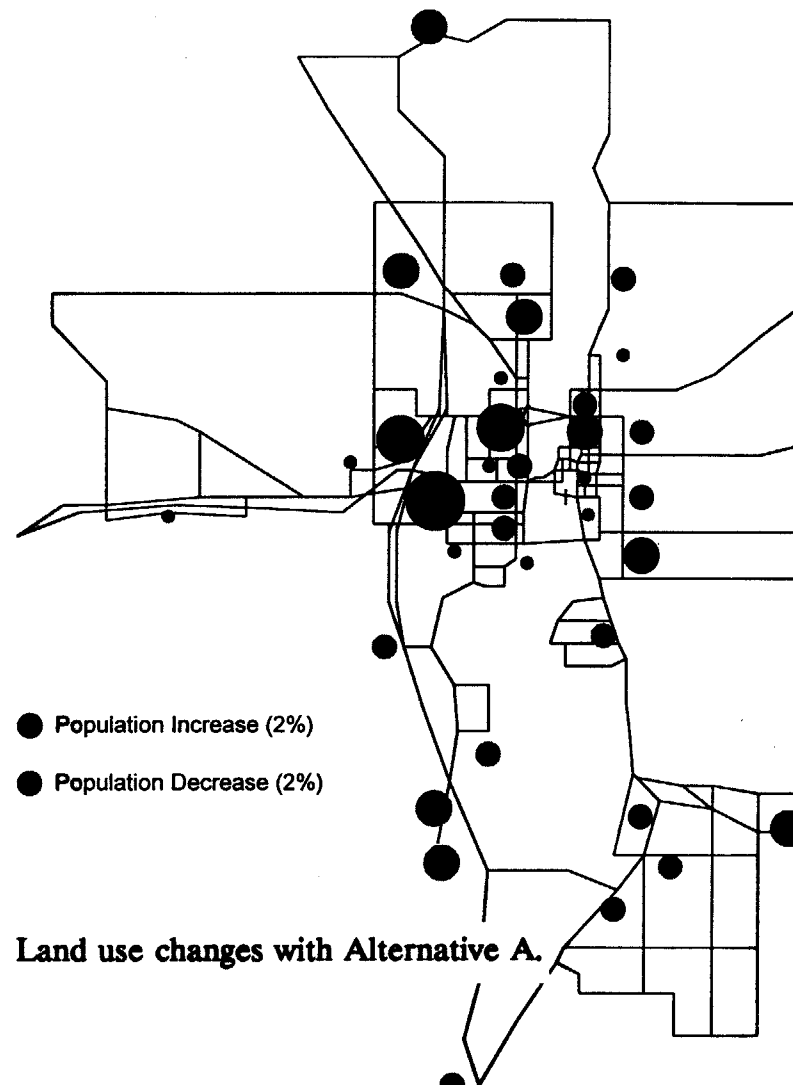
[19]Gong, Zejun, March 1993.

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.

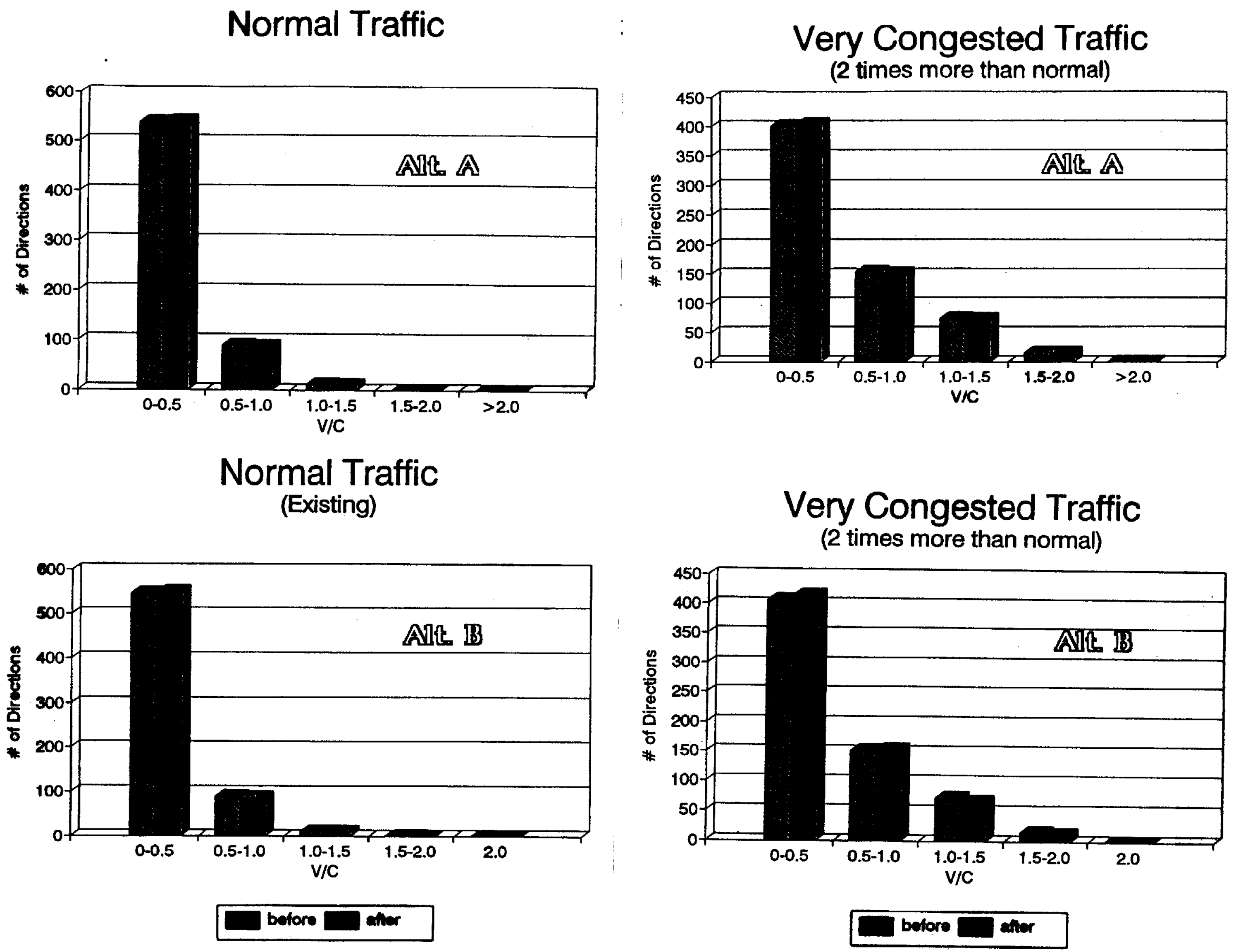
Table I.1. CONSUMER SURPLUS WITH LAND REDISTRIBUTION						
	Highway CS		Transit CS		Total CS	
Growth Scenario	Alt. A	Alt. B	Alt. A	Alt. B	Alt. A	Alt. B
Existing	35	196	2,063	6,502	2,097	6,697
1.5 times more	383	740	3,221	10,679	3,603	11,419
2 times more	1,021	2,192	4,675	14,926	5,696	17,118

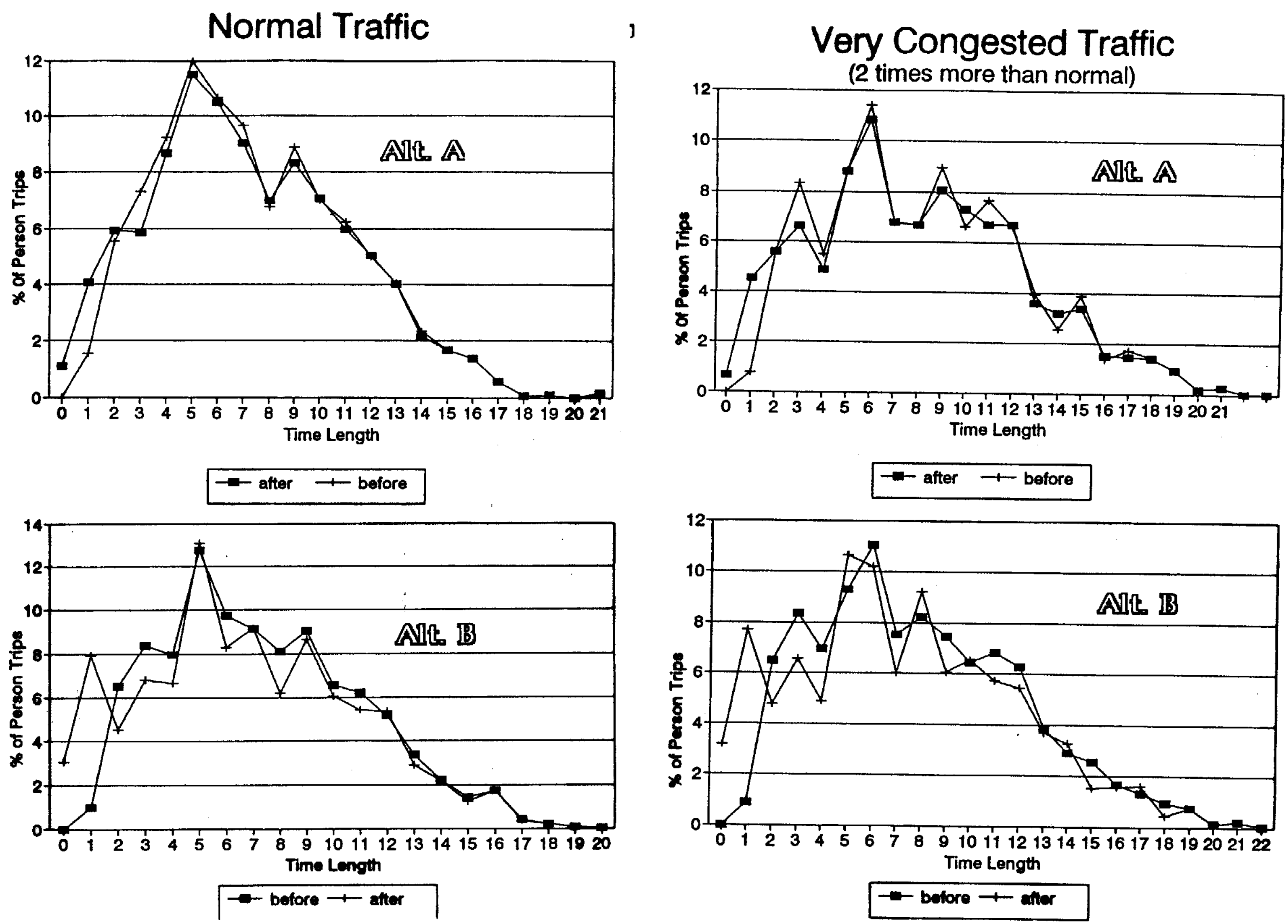
Table I.2. CONSUMER SURPLUS WITHOUT LAND-USE REDISTRIBUTION						
	Highway CS		Transit CS		Total CS	
Growth Scenario	Alt. A	Alt. B	Alt. A	Alt. B	Alt. A	Alt. B
Existing	93	245	2,239	6,742	2,332	6,987
1.5 times more	294	694	3,220	10,675	3,513	11,368
2 times more	1,176	2,129	4,880	14,925	5,055	17,054

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.


Normal Traffic
600
500
400
300
200
100
0
# of Directions
Alt. A
0-0.5
0.5-1.0
1.0-1.5
1.5-2.0
>2.0
V/C
Very Congested Traffic
(2 times more than normal)
450
400
350
300
250
200
150
100
50
0
# of Directions
Alt. A
0-0.5
0.5-1.0
1.0-1.5
1.5-2.0
>2.0
V/C
Normal Traffic
(Existing)
600
500
400
300
200
100
0
# of Directions
Alt. B
0-0.5
0.5-1.0
1.0-1.5
1.5-2.0
2.0
V/C
before
after
Very Congested Traffic
(2 times more than normal)
450
400
350
300
250
200
150
100
50
0
# of Directions
Alt. B
0-0.5
0.5-1.0
1.0-1.5
1.5-2.0
2.0
V/C
before
after


Normal Traffic
Very Congested Traffic
(2 times more than normal)
Alt. A
Alt. A
Alt. B
Alt. B
% Of Person Trips
% of Person Trips
Time Length
after
before
before
after

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 J.1. CONSUMER SURPLUS INFORMATION FOR FUEL TAX DECREASE

	Bus		Automobile	
	Disutility	Passengers	Disutility	Passengers
Before Tax	50.0	357	29.6	1043
After Tax	50.0	439	36.3	938

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 are 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:

$$\textit{emission rate for a facility} = \sum_{n=1}^{N} a_i(\textit{speed})^n ,$$

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, to 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.

K. EMPLOYMENT BENEFITS AND IMPACTS

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. . . . [20]

[20]Levine, 1992, p. 10.

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:[21]

- *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.

[21]Bendavid-Val, 1991, p. 88.

- *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) which, 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.[22]

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.

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

[22]Bendavid-Val, 1991.

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.

The rows within the transaction table show the distribution of each suppliers's sales to intermediate and final purchasers. The columns show the

Table K.1. REGIONAL SALES TRANSACTION TABLE (in thousands of monetary units)

	Manufacturing	Transportation	Construction	Households
Manufacturing	350	730	50	1370
Transportation	40	150	75	1735
Construction	30	350	200	1920
Households	580	770	2175	0
	1000	2000	2500	5025

Table K.2. REGIONAL DIRECT-REQUIREMENTS TABLE

		Intermediate Purchasers			
		Manufacturing	Transportation	Construction	Households
Intermediate Suppliers	Manufacturing	0.3500	0.3650	0.0200	0.2726
	Transportation	0.0400	0.0750	0.0300	0.3453
	Construction	0.0300	0.1750	0.0800	0.3821
	Households	0.5800	0.3850	0.8700	0.0000
TOTAL DIRECT INPUTS		1.0000	1.0000	1.0000	1.0000

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 40 ÷ 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 * $450,000), $36,000 from manufacturing (0.075 * $450,000), $81,000 from construction (0.175 * $450,000) and $175,500 from households (0.385 * $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 totalled 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

		First Round Intermediate Purchasers				Second Round Intermediate Purchasers				Third Round Intermediate Purchasers				
		Manufacturing	Transportation	Construction	Total	Manufacturing	Transportation	Construction	Total	Manufacturing	Transportation	Construction	Total	Total Sales
Manufacturing	1.0000	0.3500	0.0000	0.0000	0.3500	0.1225	0.0146	0.0006	0.1377	0.0482	0.0065	0.0004	0.0551	1.5428
Transportation	0.0000	0.0400	0.0000	0.0000	0.0400	0.0140	0.0030	0.0009	0.0179	0.0055	0.0013	0.0006	0.0074	0.0653
Construction	0.0000	0.0300	0.0000	0.0000	0.0300	0.0105	0.0070	0.0024	0.0199	0.0041	0.0031	0.0016	0.0089	0.588
Households	0.0000	0.5800	0.0000	0.0000	0.5800	0.2030	0.0154	0.0261	0.2445	0.0799	0.0069	0.0173	0.1041	0.9286
		1.0000	0.0000	0.0000	1.000	0.3500	0.0400	0.0300	0.4200	0.1377	0.0179	0.0199	0.1755	

Table K.4. REGIONAL TOTAL-REQUIREMENTS CONSTRUCTION TABLE

		First Round Intermediate Purchasers				Second Round Intermediate Purchasers				Third Round Intermediate Purchasers				
		Manufacturing	Transportation	Construction	Total	Manufacturing	Transportation	Construction	Total	Manufacturing	Transportation	Construction	Total	Total Sales
Manufacturing	0.0000	0.0000	0.3650	0.0000	0.3850	0.1278	0.0274	0.0035	0.1586	0.0555	0.0093	0.0008	0.0656	0.5892
Transportation	1.0000	0.0000	0.7500	0.0000	0.0750	0.0146	0.0056	0.0053	0.0255	0.0063	0.0019	0.0011	0.0094	1.1099
Construction	0.0000	0.0000	0.1750	0.0000	0.1750	0.0110	0.0131	0.0140	0.0381	0.0048	0.0045	0.0030	0.0123	0.2253
Households	0.0000	0.0000	0.3850	0.0000	0.3850	0.2117	0.0289	0.1523	0.3928	0.0920	0.0098	0.0331	0.1349	0.9128
		0.0000	1.0000	0.0000	1.0000	0.3650	0.0750	0.1750	0.6150	0.1586	0.0255	0.0381	0.2222	

Table K.5. REGIONAL TOTAL-REQUIREMENTS CONSTRUCTION TABLE

		First Round Intermediate Purchasers				Second Round Intermediate Purchasers				Third Round Intermediate Purchasers				
		Manufacturing	Transportation	Construction	Total	Manufacturing	Transportation	Construction	Total	Manufacturing	Transportation	Construction	Total	Total Sales
Manufacturing	0.0000	0.0000	0.0000	0.0200	0.0200	0.0070	0.0110	0.0016	0.0196	0.0068	0.0020	0.0002	0.0091	0.0486
Transportation	0.0000	0.0000	0.0000	0.0300	0.0300	0.0008	0.0023	0.0024	0.0055	0.0008	0.0004	0.0004	0.0016	0.0370
Construction	1.0000	0.0000	0.0000	0.0800	0.0800	0.0006	0.0053	0.0064	0.0123	0.0006	0.0010	0.0010	0.0025	1.0948
Households	0.0000	0.0000	0.0000	0.8700	0.8700	0.0116	0.0116	0.0696	0.0928	0.0113	0.0021	0.0107	0.0241	0.9868
		0.0000	0.0000	1.0000	1.0000	0.0200	0.0300	0.0800	0.1300	0.0196	0.0055	0.0123	0.0373	

Manufacturing to manufacturing	=	0.35 * 0.35 = 0.1225
Transportation to manufacturing	=	0.35 * 0.04 = 0.0140
Construction to manufacturing	=	0.35 * 0.03 = 0.0105
Households to manufacturing	=	0.35 * 0.58 = 0.2030

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

		Manufacturing	Transportation	Construction
Intermediate Suppliers	Manufacturing	1.5428	0.5892	0.0486
	Transportation	0.0653	1.1099	0.0370
	Construction	0.0588	0.2253	1.0948
	Primary Suppliers	0.9286	0.9128	0.9868
TOTAL REQUIREMENTS (ALL SUPPLIERS)		2.5955	2.8372	2.1672

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:

Manufacturing	0.0486 * $45,000,000	=	$2,188,204
Transportation	0.0370 * $45,000,000	=	$1,665,371
Construction	1.0948 * $45,000,000	=	$49,264,661
Households	0.9868 * $45,000,000	=	$44,408,014
Total Effect		=	$97,526,250

The following impacts occur annually from operations:

Manufacturing	0.0486 * $4,000,000	=	$194,000/year
Transportation	0.0370 * $4,000,000	=	$148,000/year
Construction	1.0948 * $4,000,000	=	$4,379,200/year
Households	0.9868 * $4,000,000	=	$3,947,200/year
Total Effect		=	$8,668,800/year

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."[23] 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.

[23]Aschauer, 1988.

PART V: RECOMMENDED PRACTICE

A review of existing practice of benefits evaluation suggests that improvements are needed. It is essential that an evaluation be consistent with community values and with observed travel behavior. The following list of major findings and recommended procedures should serve as a set of guidelines for any benefits analysis. Detailed explanations are found in earlier chapters.

Major Findings

Transit decision making is dominated by intangibles that do not easily lend themselves to quantification. Some of the most important benefits of transit are community pride, health effects of pollution, potential for urban redevelopment, equity of transportation service, and its option value.

The political decision process cannot be replaced by an objective technical evaluation scheme. The political process for transit decision making is firmly entrenched. Further, the political process is too complex, too fluid and too subjective to be replicated by an objective evaluation procedure.

> **The political decision process is sensitive to good analysis, but may not respond as the analyst desires.** Good technical analysis is always worthwhile and is appreciated by many political decision makers. However, decision makers will reject any technical analysis that fails to confirm their beliefs or fails to convince them that their beliefs are incorrect.
>
> **The results of any technical evaluation procedures must be intuitively correct.** Any deviation from intuition will be quickly recognized and will undermine the acceptance of the analysis.

Benefit-cost analysis should not be the sole basis for decision making. Benefit-cost analysis is scientific, but it is only meaningful where the effects of a project can be compared with goods on an open market. Many of the important impacts of transit alternatives do not have comparable goods.

> **Strict application of benefit-cost analysis could be discriminatory.** A transit alternative could serve either high income individuals or low income individuals or some combination. Low income individuals have less money they are willing to pay, so their benefits would be less. Transit alternatives that tend to serve high income individuals would be preferred by a benefit-cost analysis, thereby overriding important equity benefits.

Some notions from benefit-cost analysis can be modified and enhanced for the purposes of quantifying some benefits. User benefits can be readily measured by methods similar to those of benefit-cost analysis. In particular, an enhanced consumer surplus approach provides a realistic way of expressing benefits as related to choice behavior.

There are many interrelated benefits, leading to problems of double counting. Double counting can be explicit or implicit. It is the responsibility of the planner to avoid double counting and to indicate where unavoidable double counting occurs.

Combining of transit consequences can be misleading and can create more problems than it solves. Attempts to create a single measure of transit benefits that incorporates all possible consequences are subject to significant problems of double counting and require assumptions that are difficult to justify. It is best to simply highlight significant differences among alternatives and let decision makers choose among the alternatives according to their educated judgement as to what is best for the community.

RECOMMENDED PRACTICE

Evaluations of benefits in environmental impact statements or in alternatives analyses are superficial. Agencies need to become more aware of good evaluation methodologies and use the methodologies in their studies. Many agencies still need to recognize the importance of EIS's and AA's to their decision making.

The benefits of transit improvements are larger in communities where highway congestion is severe. Simulations of transit systems, using state-of-the-art techniques, show that user benefits associated with better transit increase rapidly with the level of congestion on highway networks. Increases with congestion are seen in both benefits to transit users and benefits to highway users.

> **User benefits from a transit improvement remain almost as large when long-term effects of urban redevelopment are included in the analysis.** Some researchers have claimed that reallocation of activities can severely undercut benefits gained from transit system improvements. When residential relocation is allowed in a travel simulation, user benefits achieved are sometimes smaller, but not significantly. A concentration of activities occurs with improved transit service. This concentration is associated with numerous benefits, including better utilization of existing infrastructure, preservation of open space and more economical services.

Recommended Procedures

Use the benefit tree to identify important impacts and to help identify sources of double counting. The benefit tree is a comprehensive listing of potentially positive impacts of transit service improvement. Not all impacts may be realized in any given community. Two impacts in close proximity on the benefit tree may constitute double counting, especially if one of the impacts is directly above the other.

Avoid aggregation of benefit measures. Aggregation destroys information. Transit decision making is complex, and that complexity must be apparent to decision makers. Each decision maker has a different way of weighing benefits; no aggregation scheme can possibly represent every set of weights.

Perform sensitivity and contingency analyses. Both sensitivity analysis and contingency analysis help protect against uncertain future events. These techniques will help assure that the best alternative is selected, even if predictions of the future are faulty.

Quantify as many benefits as possible. Quantification facilitates comparisons of alternatives, permits sensitivity analysis, and helps eliminate ambiguities.

> **Use a broad-based measure of consumer surplus for travel related benefits.** This report describes a direct measure of overall improvement in society, termed enhanced consumer surplus. It encompasses time savings, comfort and convenience. It is also nondiscriminatory. Enhanced consumer surplus can be measured with readily available travel forecasting methodologies.
>
> **Examine changes in efficiency of land uses.** Efficiencies occur because of regional changes in land use and because of local concentrations of activities. The effect of regional changes can be incorporated in enhanced consumer surplus. Local concentrations are difficult to predict, but their impacts of infrastructure efficiency may be significant.
>
> **Quantify air quality impacts.** A simple and direct method of quantifying air quality impacts is to compute emissions reductions from an alternative and compare them to mandated emission reduction goals.
>
> **Avoid using employment impacts as benefits, unless it can be clearly demonstrated that the employment would be greater than the null alternative.**

A common pitfall in benefits studies is to count employment shifts as gains. It would take a very sophisticated analysis to demonstrate a net increase in employment for most transit improvements.

Describe benefits that are not quantified. An objective description of a benefit should be provided, even if the benefit cannot be calculated. It is a mistake to omit valid benefits that do lend themselves to a particular evaluation scheme.

Tell how quantified benefits are calculated. The quantification of some benefits can be technically complicated. Nonetheless, it is important to explain the methodologies used in doing the calculation, including any assumptions made. Techniques must be explained in a manner understandable to a decision maker; otherwise it is best to avoid quantification.

Present information in a manner that facilitates decision making. It is important to treat decision makers with respect and honesty. Information must be presented in a clear and concise manner, avoiding hidden assumptions and highlighting those issues that are salient or controversial.

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APPENDIX: BLANK BENEFIT TREE

The following pages contain a full-sized, blank benefit tree. This tree is identical to the one presented in Section F, except that descriptions of the consequences have been removed. The tree can be photocopied and assembled. There are six different graphics — the tree top and five major branches. As a guide to assembly, match points have been indicated. When assembled the match points should appear as follows.

Match 5A   5A Match

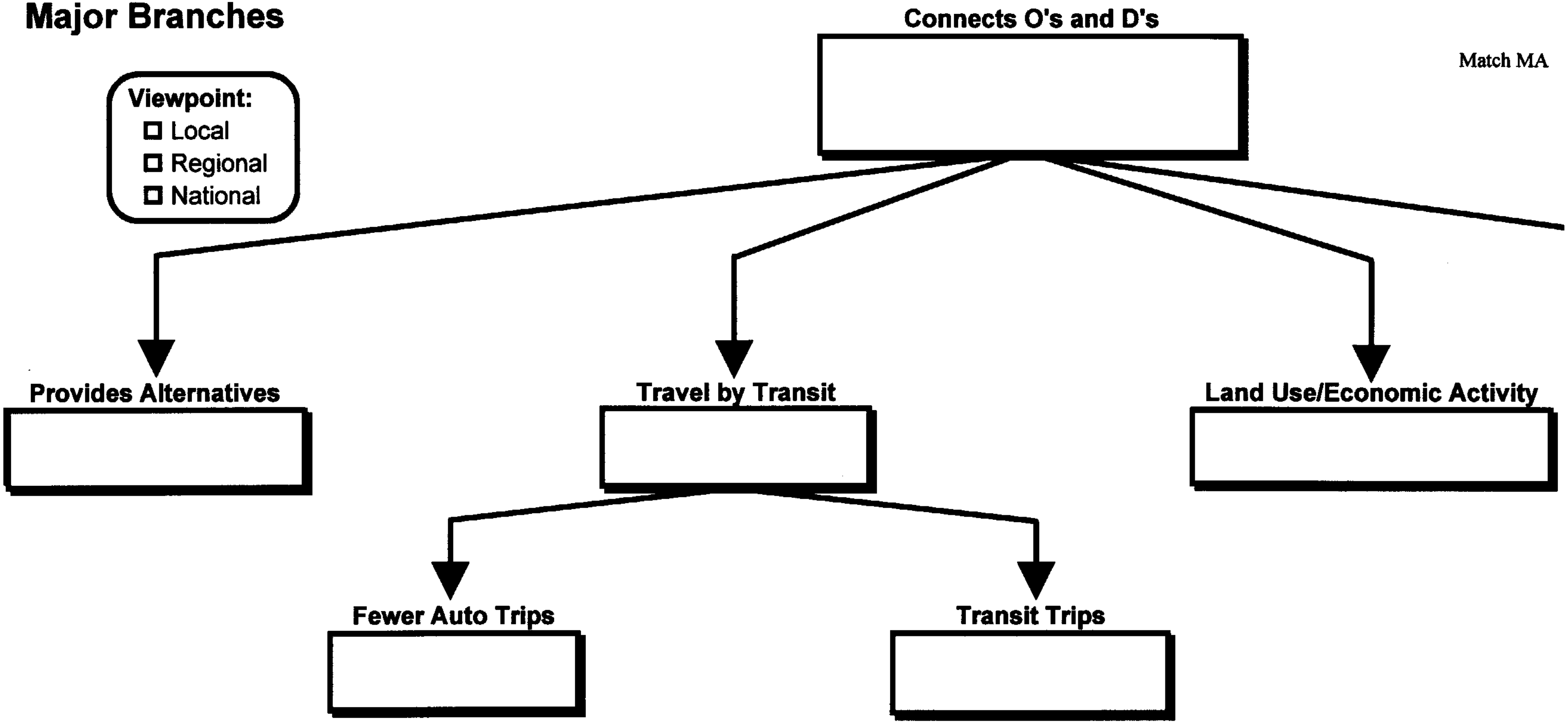
The benefit tree was originally drawn in Excel 3.0 (MS-DOS) format. The original Excel files are available. Contact the Center for Urban Transportation Studies to obtain a copy (414-229-5787). The spreadsheet allows considerable flexibility in how the benefit tree can be presented. For example,

a. boxes can be added and removed;
b. boxes, text, and arrows can be given different colors;
c. text can be modified; and
d. arrows can be rerouted.

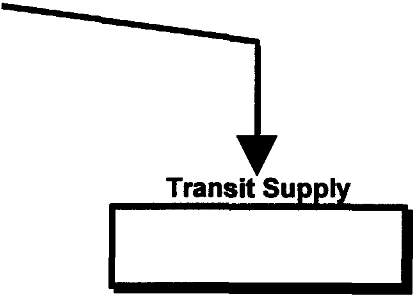
Having the ability to print the tree on a color printer would permit an even better visual display of the tree. The files contain the full text of the benefit tree, but the text can be easily blanked by coloring it white.

Major Branches

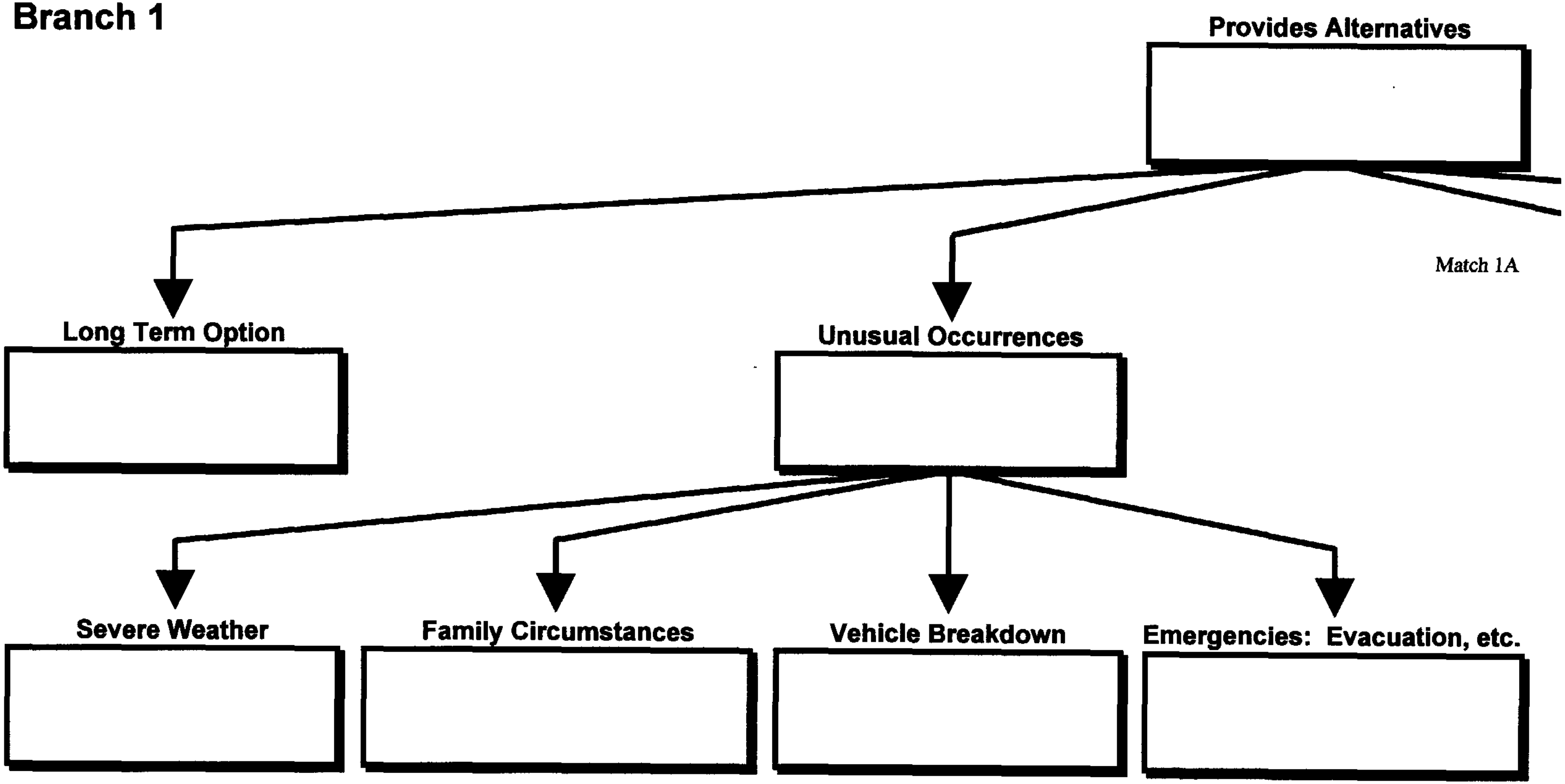
Match MA



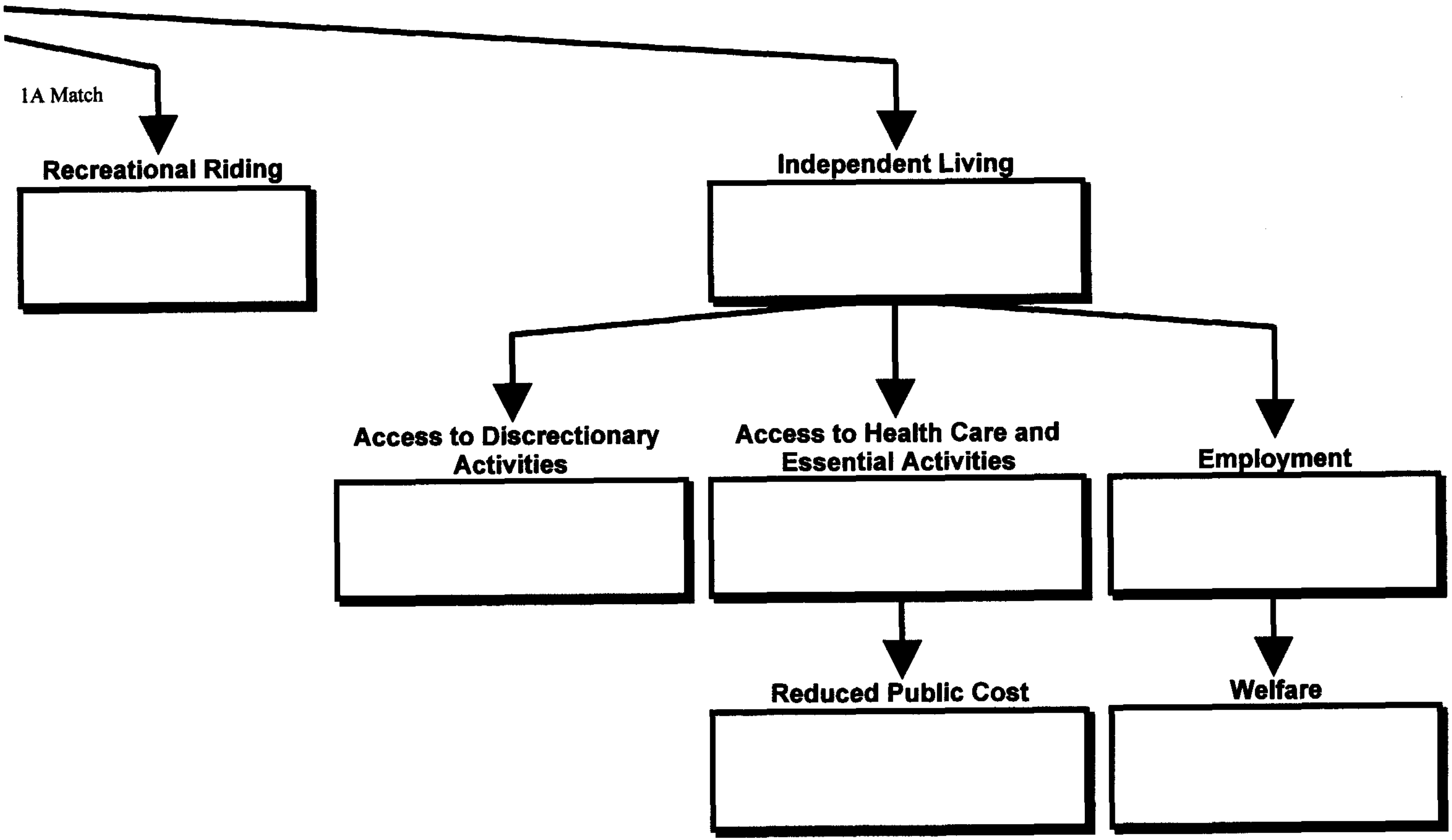
MA Match



Branch 1



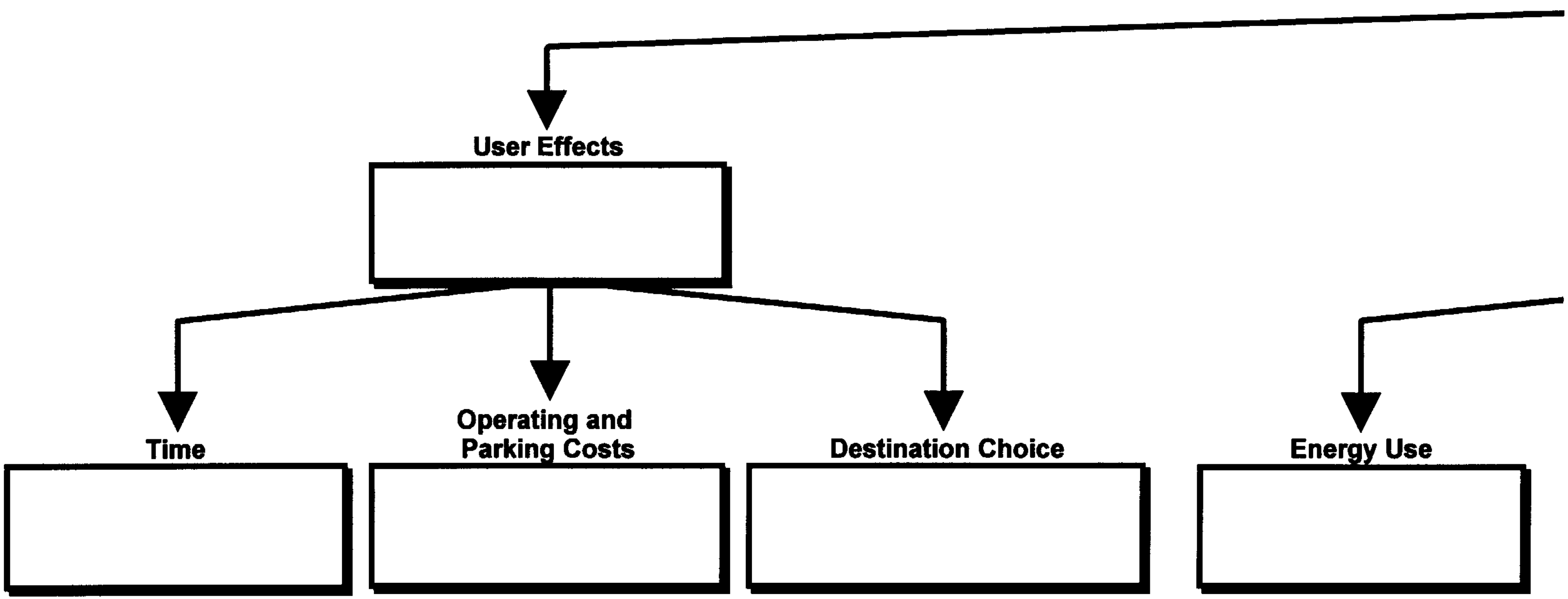
Viewpoint:
- ☐ Local
- ☐ Regional
- ☐ National


1A Match
Recreational Riding
Independent Living
Access to Discretionary Activities
Access to Health Care and Essential Activities
Employment
Reduced Public Cost
Welfare

Branch 2

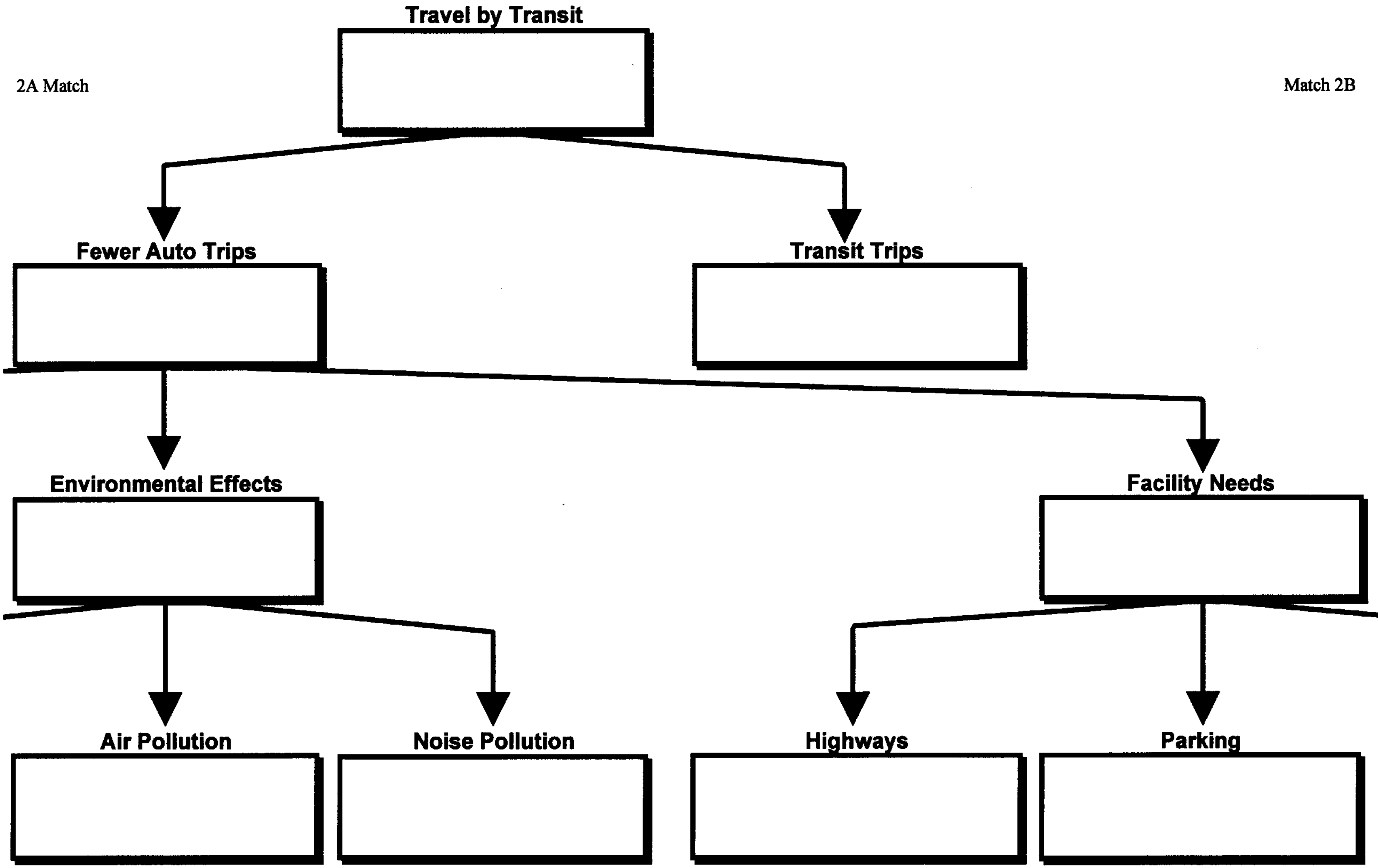
Viewpoint:
- ☐ Local
- ☐ Regional
- ☐ National

Match 2A

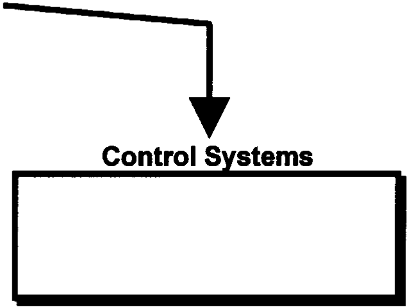


2A Match

Match 2B

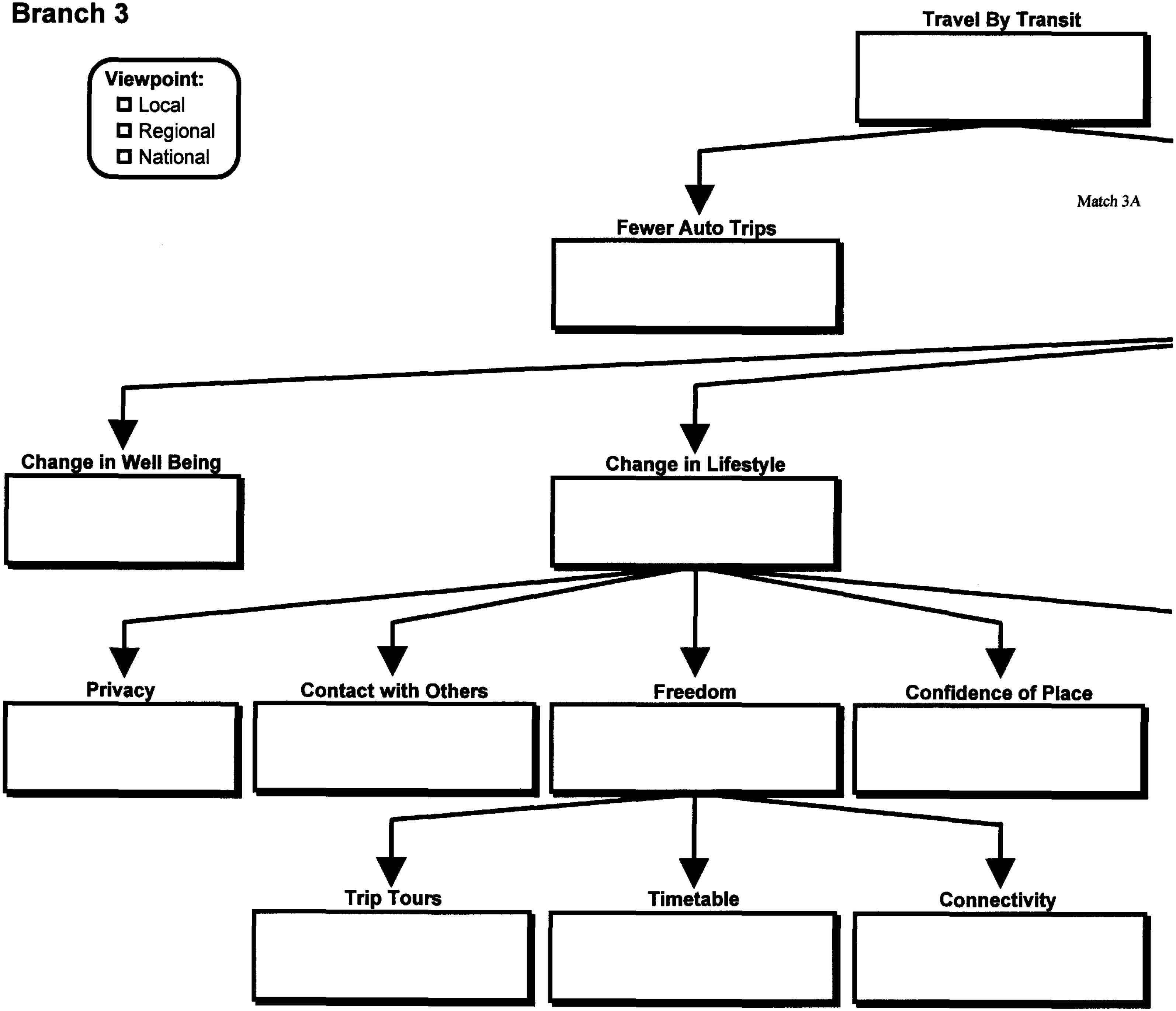


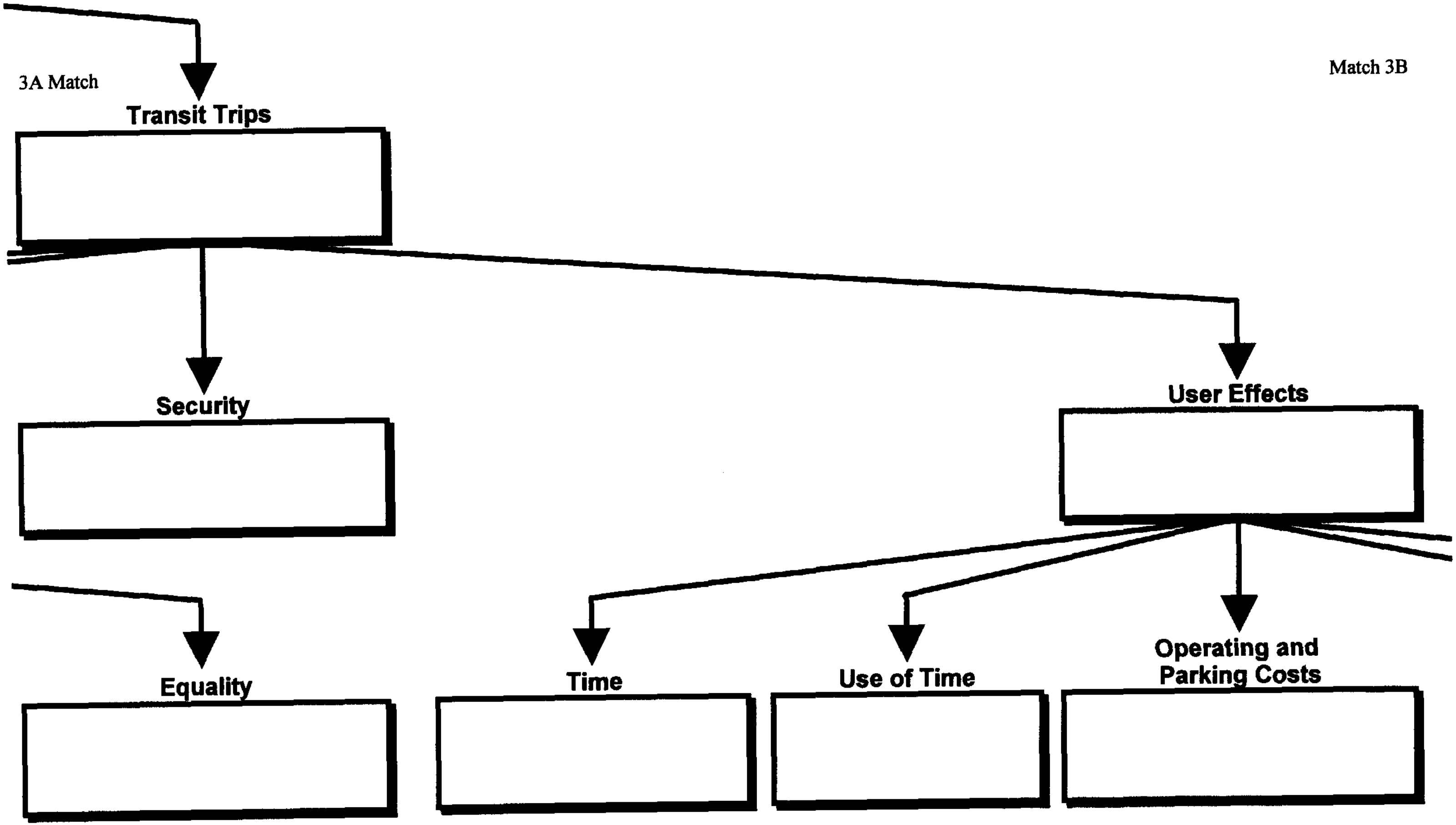
2B Match



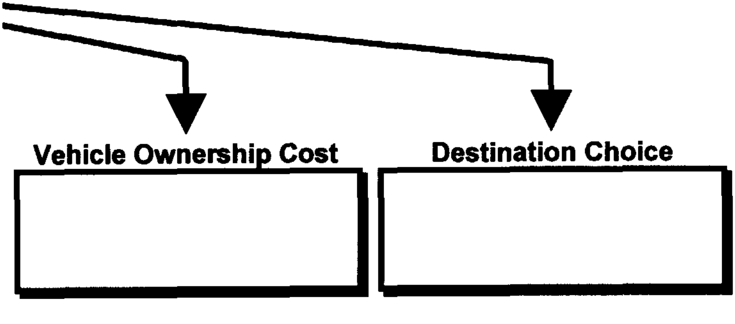
Branch 3

Viewpoint:
- ☐ Local
- ☐ Regional
- ☐ National

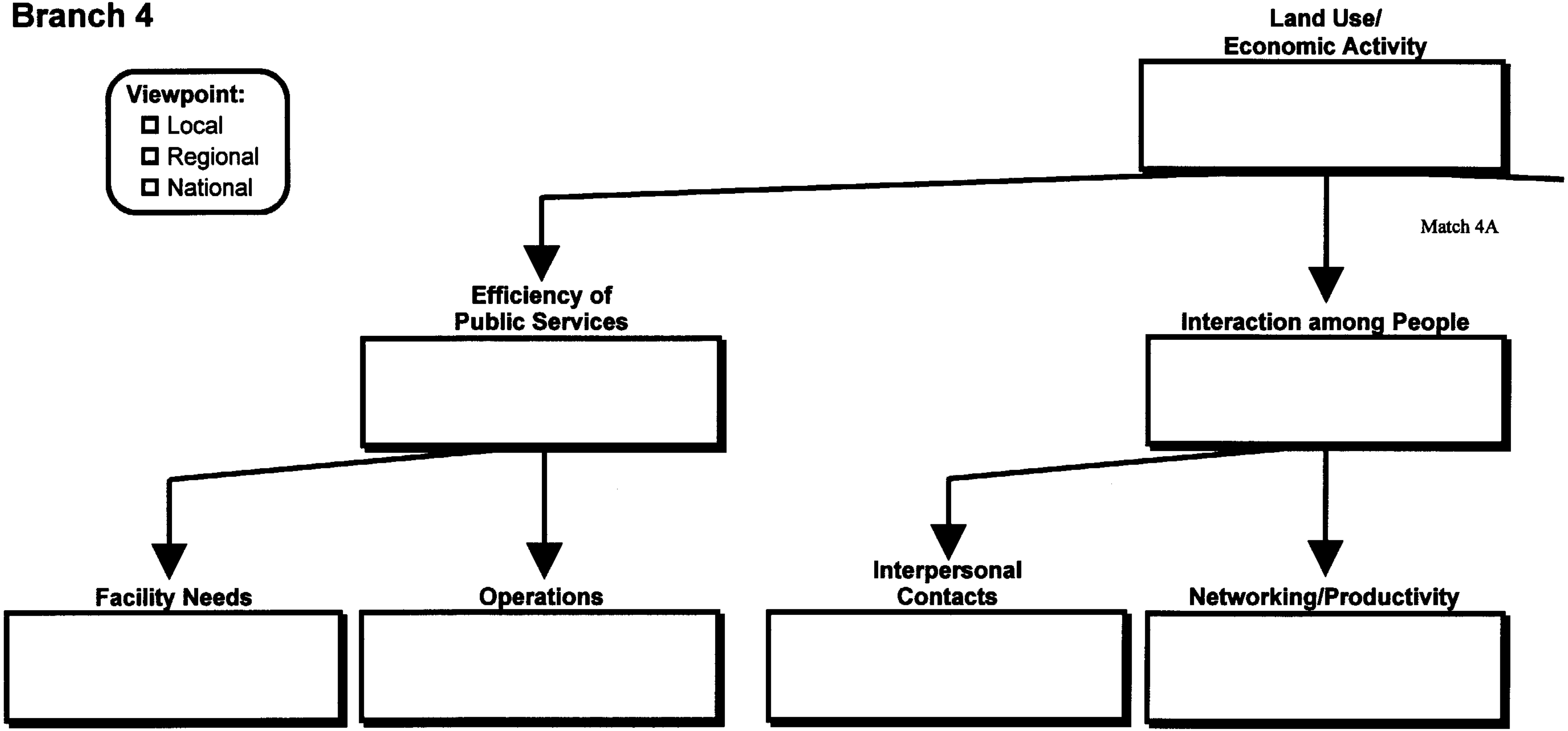


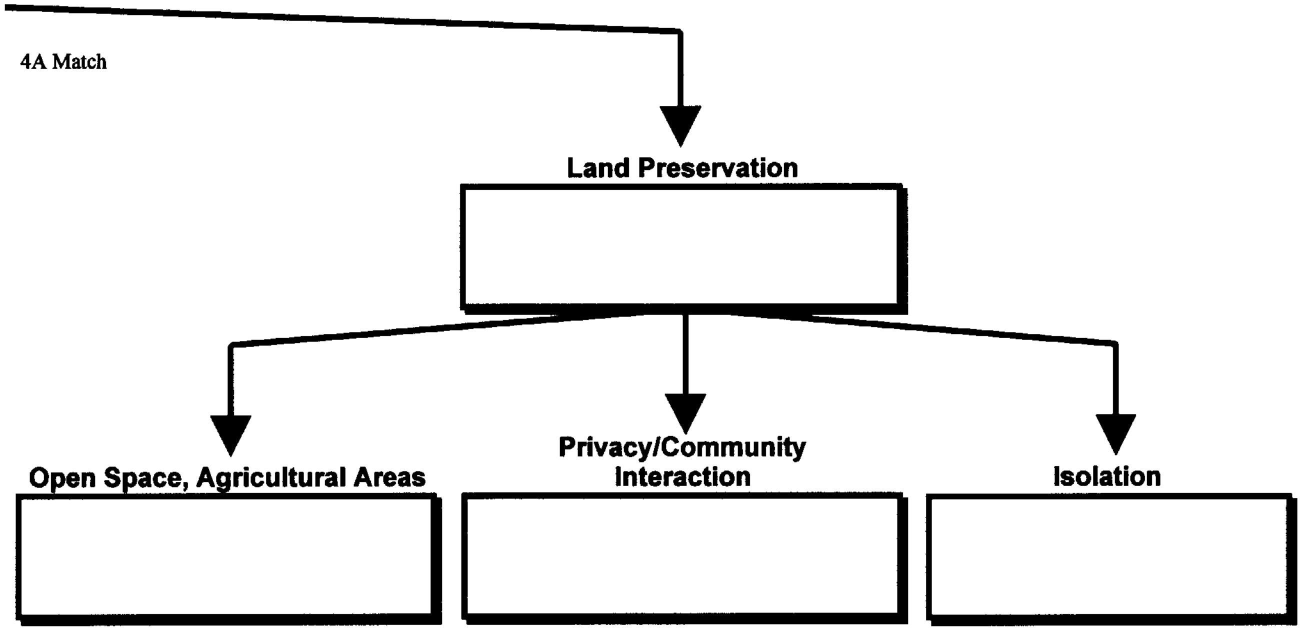

3A Match
Match 3B
Transit Trips
Security
User Effects
Equality
Time
Use of Time
Operating and Parking Costs

3B Match

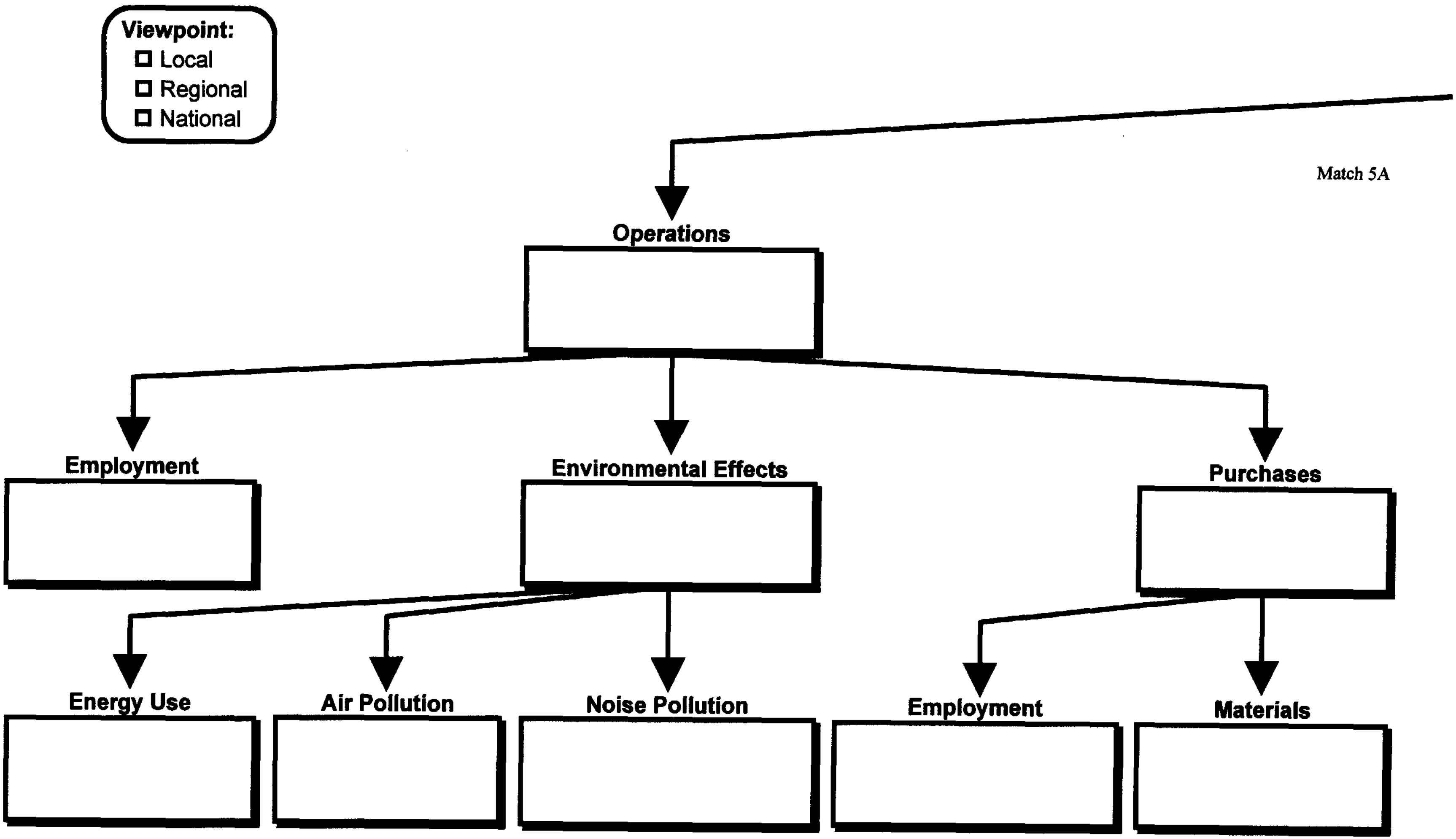


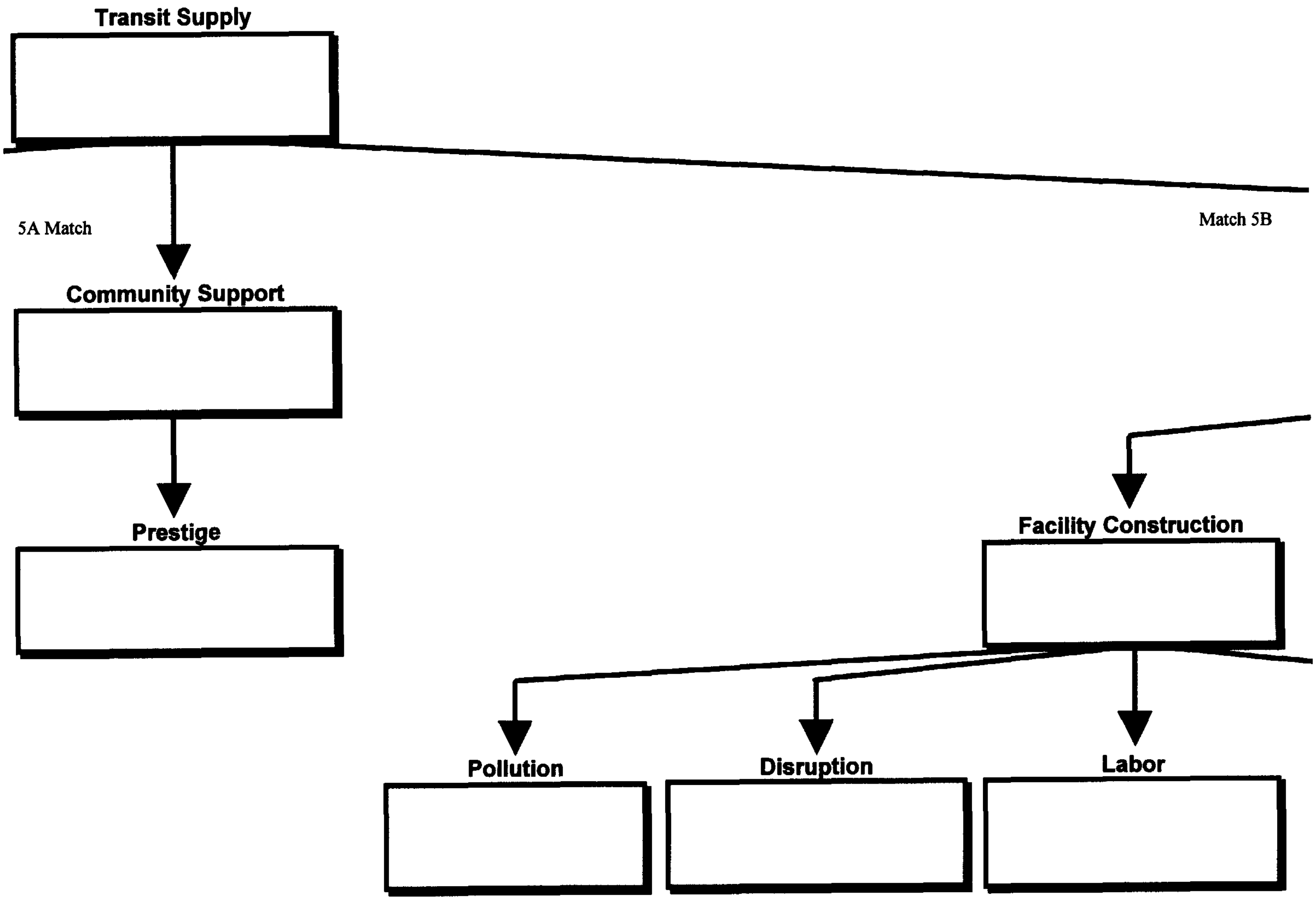
Branch 4


Viewpoint:
Local
Regional
National
Land Use/
Economic Activity
Match 4A
Efficiency of
Public Services
Interaction among People
Facility Needs
Operations
Interpersonal
Contacts
Networking/Productivity

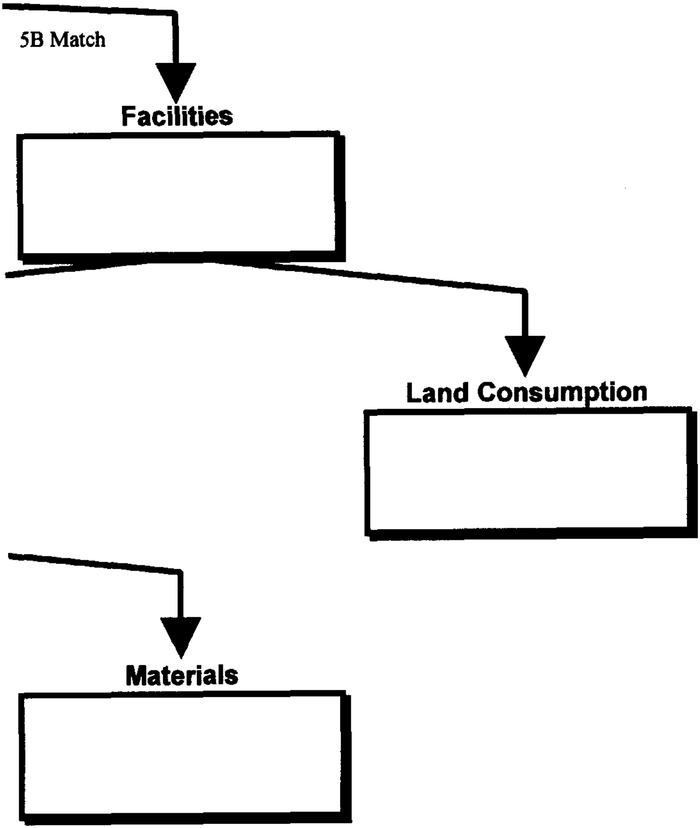

4A Match
Land Preservation
Open Space, Agricultural Areas
Privacy/Community Interaction
Isolation

Branch 5


Viewpoint:
Local
Regional
National
Match 5A
Operations
Employment
Environmental Effects
Purchases
Energy Use
Air Pollution
Noise Pollution
Employment
Materials



Transit Supply
5A Match
Match 5B
Community Support
Prestige
Facility Construction
Pollution
Disruption
Labor


5B Match
Facilities
Land Consumption
Materials