EQUITY IN REGIONAL SERVICE PROVISION*

Alan T. Murray
Department of Geography, The Ohio State University, Columbus, Ohio 43210, U.S.A.
E-mail: murray.308@osu.edu

Rex Davis
Marketshare, Toowong, Queensland 4066, Australia.

ABSTRACT. Most transportation agencies stipulate that an important planning goal is to provide equitable and just public transport services. However, who is to be served and the type of service that should be provided has been ambiguous. This paper develops a methodology for examining equity in the provision of public transportation services. An approach for identifying areas in need of public transport is developed based upon the use of socio-demographic and economic information. Public transport need is then related to levels of access to service. This approach makes it possible to establish the degree to which public transport services may be considered equitable in relation to need and suitable access. A detailed analysis of the southeast Queensland region of Australia illustrates how this approach may be used to inform public transport decision making.

1. INTRODUCTION

Public transport continues to be an important social service in urban areas. In general, the public has been extremely supportive of public transport given its significance. This is undoubtedly why substantial subsidies are directed to the provision of public transport. There are two principal reasons given for subsidizing unprofitable urban public transportation services. The first reason is that ensuring the existence of public transport services reduces demands on road networks by providing an alternative to private vehicle travel, especially in peak traffic periods (Starrs and Perrins, 1989). The second justification is on the basis of achieving better social outcomes, either through a quasi redistribution of income or as a travel mode option for those who would otherwise have none (Hodge, 1995). The latter rationale reflects the dominant characterization of public transport in automobile dependent countries like the United States and Australia.

*We thank the editors and anonymous referees for their constructive comments on earlier versions of this manuscript. This research was supported in part by a seed grant from the Center for Urban and Regional Analysis at The Ohio State University and a grant from the Australian Research Council (while the first author was a research fellow at the University of Queensland in the Australian Housing and Urban Research Institute). We thank the editors and anonymous referees for their constructive comments on earlier versions of this paper.

Received February 2000; revised November 2000; accepted January 2001.

Blackwell Publishers, 350 Main Street, Malden, MA 02148, USA and 108 Cowley Road, Oxford, OX4 1JF, UK.
Government subsidies to public transport providers are substantial. The Industry Commission (1994) estimated that the urban public transport deficits in Australia (excluding depreciation and local government subsidies) for population centers containing over 50,000 people in 1992–1993 was 2.834 billion Australian dollars. The American Public Transportation Association (2000) estimated government subsidies (capital and operating) in the United States for public transport to be over 17 billion dollars for 1998. At a local level, the greater Columbus, Ohio region received approximately 75 percent of its public transport budget for 1998 (or $43 million) from local, state, or federal subsidies (Federal Transit Administration, 2000). Although expenditure on public transport services undergoes periodic budgetary review, analysis oriented at assessing the effectiveness of subsidies in achieving government objectives for equitable public transportation service provision is rarely required or produced. Patronage figures may provide an estimate of the potential stress on the road network if public transport services were to be abandoned. However, measuring governmental objectives associated with providing public transportation to the disadvantaged is not so straightforward. There is a need for strategic techniques that facilitate evaluating equity concerns related to current and proposed public transport services in order to inform and enhance regional policy and decision making.

This paper develops a means by which equity-oriented objectives for public transportation may be appraised. Using geographic information systems (GIS) and multi-criteria techniques, sociodemographic and economic factors are integrated in order to determine public transport need. This allows need to be compared to current levels of suitable access to public transport. The next section reviews the notion of equity as it relates to transportation planning. Methods for evaluating equity in public transport provision are then detailed. Results based upon analysis in the southeast Queensland region of Australia are then presented. Finally, a discussion ensues and conclusions are given that highlight the implications of this research in regional planning.

2. PUBLIC TRANSPORT EQUITY

The concepts of equity, justice, and fairness are subject to broad interpretation, which is perhaps why they have been central elements in philosophy and political economy for many centuries. In general, the notion of equity, justice, or fairness deals with principles that determine the distribution of income, goods, or services. Because the construction of these principles requires moral and subjective judgment, the study of equity-based concepts is fraught with definitional confusion and pluralism. This is most likely due to use-specific circumstances and contextual emphasis. Hay (1995) finds that the concepts of equity, justice, and fairness are so amalgamated in the literature that distinguishing between them is difficult at best. Harvey (1996) discusses that a definition of justice necessarily presumes some set of universally accepted norms, but the application and interpretation of the concept will be both relative and specific.
The terms equity, fairness, and justice are undoubtedly confusing and ambiguous in a comparative sense. In fact, Savas (1978) and Marsh and Schilling (1994) conclude that equity is typically defined in terms of both justice and fairness. Throughout this paper we will assume that equity, justice, and fairness are synonyms, so they will be used interchangeably.

In transportation planning in Britain, Trinder et al. (1991) found equity to be related to need, so the provision of transportation was essentially viewed as a basic right. That is, a legitimate and necessary role of government is to ensure access to transportation for all people. This is not different from the perspective in the United States (Hodge, 1995; Garrett and Taylor, 1999). Thus, financial considerations are not necessarily the primary basis for making transportation planning and investment decisions. This is pervasive in transportation planning and policy arenas, where social justice, fairness, equality, and equity is implied (Sen et al., 1999) or explicitly stipulated (Metropolitan Transport Strategy Group, 1995; New South Wales Department of Transport, 1995; Queensland Government, 1997). However, there is a tendency to focus on issues of economic efficiency in which project priorities are determined on the basis of cost-benefit analysis. This fails to consider service need and equity as suggested by the use of terms such as social justice and fairness. Given this, there is a need to evaluate transportation services in terms of distribution equity.

Since we are interested in evaluating public transport services, it is important to discuss how persons that are needy, or more in need than others, may be identified. The main objective in evaluating equity in this paper is to examine the current provision of public transport in order to identify those people who do not have sufficient public transport service opportunities, but may need these services. These are the individuals that we refer to as the transport disadvantaged. There are a number of factors that contribute to the situation of having a transport disadvantage, as shown in Figure 1. The combination of all three elements in Figure 1 creates a transport disadvantage because of the unmet need that ensues as a result of particular circumstances.

Morris (1981) identifies several groups as having a need for public transport: those that are too young or old to drive, the disabled, homeworkers, low income earners, unemployed youths, and migrants. Starrs and Perrins (1989) state that those in need of transportation services are widely defined and can include the elderly, the young, those who cannot drive a vehicle, the disabled, low income earners, women, and those of an ethnic background. If we assume that all people with complete access to a private vehicle have all the transport mobility that they require, then any group with limited or no access to a private vehicle is reliant to some degree on the provision of alternative transportation services. A summary of the groups that potentially need public transport is given in Table 1.

3. ASSESSING PUBLIC TRANSPORT ACCESS

The previous section discussed the factors contributing to the existence of transport disadvantaged individuals. Of course, need is only one of two factors
TABLE 1: Groups Most Likely to Need Public Transport

<table>
<thead>
<tr>
<th>Group</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>Under 16 years of age</td>
<td>Unable by law to operate a motor vehicle.</td>
</tr>
<tr>
<td>Senior Citizens</td>
<td>Unwilling or unable to operate a motor vehicle.</td>
</tr>
<tr>
<td>Income</td>
<td></td>
</tr>
<tr>
<td>Low Income</td>
<td>Income constraints prevent car ownership.</td>
</tr>
<tr>
<td>Language difficulties</td>
<td></td>
</tr>
<tr>
<td>Migrants and Overseas Visitors</td>
<td>Unlicensed or unwilling to drive. Lack of language skills also is a barrier to using public transport.</td>
</tr>
<tr>
<td>Single or no car households</td>
<td></td>
</tr>
<tr>
<td>Multiple Adult Households</td>
<td>Demands on having at most one vehicle can be incompatible.</td>
</tr>
<tr>
<td>Couples With Families</td>
<td></td>
</tr>
<tr>
<td>Two Family Households</td>
<td></td>
</tr>
<tr>
<td>Disability</td>
<td></td>
</tr>
<tr>
<td>General Disability</td>
<td>Unable to drive.</td>
</tr>
<tr>
<td>Physically Ill</td>
<td>Unable to drive.</td>
</tr>
</tbody>
</table>

contributing to the status of transport disadvantaged. The other is inadequate transportation services in relation to need. Thus, both factors are important in the evaluation of equity in public transport services. Given this, the ability to assess current public transport service provision is essential. One aspect of the assessment process could focus on service quality, such as regularity of service, travel time from origin to destination, and employment or services that may be reached. This is typically referred to as accessibility and approaches for carrying out such analysis are discussed in Handy and Niemeier (1997), Kwan (1998), and O’Sullivan, Morrison, and Sheaver (2000). Evaluating accessibility is extremely data intensive as one must know precisely where individuals are, where they want to go, and how they can potentially get there. A less data intensive alternative is to focus on the proximity of public transport services to individuals or areas, which is referred to as access. Strategic transportation planning and policy making typically uses access as a performance measure (see Murray et al., 1998). In fact, regional transportation policies in Australia specifically refer to levels of access as a means for assessing public transport service provision. Although the access measure is relatively simple, its simplicity and ease of understanding is precisely the reason that it is relied upon in planning and policy processes. For these reasons, access, rather than accessibility, is used in our analysis of Queensland. However, provided that appropriate information exists, the approaches detailed in this paper can be extended to accommodate accessibility and service quality considerations without any loss of generality.

Most major urban regions recognize the need to ensure that there is suitable access to public transportation. The reasons for this are associated with maintaining reasonable ridership levels as well as monitoring how well the public is being served. Thus, it is certainly appropriate that questions regarding equity and fairness in the distribution of public transport services be raised. A thorough review of the issue of access to public transport may be found in Murray et al. (1998), which details that there are at least two forms of access: origin-based access and destination-based access. Origin-based access refers to potential use of public transport beginning at one’s residence, whereas destination-based access refers to potential use of public transport from an activity area such as work or shopping. Almost all studies of access to public transport tend to be origin-based due to behavioral uncertainty and data demands (Murray, 2001). This analysis will focus only on origin-based access to public transportation.

The dominant feature of access to public transport is the stipulation of a suitable performance standard. For example, most regional planning authorities in Australia have a very specific suitable access standard. In southeast Queensland this access standard is 400 meters (Queensland Government, 1997). That is, if areas are within 400 meters of a public transport stop (bus, rail, and ferry in southeast Queensland), then they are considered to be suitably served by public transport. Thus, governmental agencies are often concerned with how much of the regional population is suitably covered by public transportation. One approach for determining access coverage based upon the work of Murray et al. (1998) will now be discussed using the following notation.
$l = \text{index of areas or households};$

$k = \text{index of public transport stops};$

$d_{lk} = \text{shortest distance from area } l \text{ to stop } k;$

$\bar{d}_l = \min_k \{d_{lk}\}$

$S = \text{suitable access standard}.$

The distance measure $d_{lk}$ may represent actual road network distances or an appropriate proxy such as straight line (Euclidean) distances. It is worth noting that travel time measures could also be used. Once distances between areas and stops have been determined, then the distance to the closest stop for each area, $\bar{d}_l$, may be calculated. Given a suitable access standard $S$ we may classify areas as either having or not having suitable access to public transport. If an area $l$ is within $S$ of a public transport stop, then $\bar{d}_l \leq S$ and indicates that the area is suitably served by public transport. Such a comparison may be carried out using most commercial geographical information systems (GIS) for all areas in a region once an access standard and distance metric is decided upon (see Murray et al., 1998).

As mentioned previously, governmental agencies and planning bodies are often concerned with how much of the regional population is suitably covered by public transportation. Regional policies and project appraisal is typically carried out on the basis of contributing to further regional coverage by public transport. However, this alone does not address equity and social justice concerns.

4. **EQUITY ASSESSMENT**

Transportation project appraisal has evolved to include an amalgamation of rather traditional techniques such as impact assessment statements, cost-benefit analysis, and technical descriptions. A major problem with these project appraisal approaches is that there is limited scope for including equity issues in the established procedures. The cost-benefit analysis component in the evaluation of transportation infrastructure and services is now more or less mandatory in most Western countries. A representative example in public transport planning may be found in Perrin and Benz (1990). The popularity of cost-benefit analysis as a project evaluation tool can be attributed to the fact that it is a formal approach, provides the capability for ranking similar project schemes, and enables transportation variables, such as travel time savings, to be measured (Nash 1993). However, cost-benefit analysis is a measure of allocative efficiency and issues of equity are altogether separate (Savas, 1978; Battiato, 1993). Further, cost-benefit analysis lacks a spatial dimension and fails to incorporate distribution considerations (Austin, 1974). Although equity considerations may be raised in reports accompanying a cost-benefit analysis, or a description of the distribution of benefits included in the cost-benefit analysis, social justice is not an underlying variable that directly will affect the crucial
summary concepts, such as the benefit-cost ratio or the net present value of an investment. The exception is the “planning balance sheet” approach, which allows one to quantify the readily quantifiable as well as list intangible and unquantifiable effects (see Hensher, Kirby, and Beesley, 1983). In terms of planning and analysis in Australia, cost-benefit analysis remains the dominant approach recommended by the Commonwealth and State governments.

As mentioned previously, impact statements are also used to evaluate social and environmental consequences associated with proposed transportation projects. An impact assessment study will usually detail the potential effects of proposed projects, with particular emphasis on landscape change, air and noise pollution, cultural implications, and social disturbance (Glasson, Therivel, and Chadwick, 1994). There are established procedures in impact assessment development for quantifying environmental degradation, but this is not true for issues of equity (Ortolano, 1996). Although social considerations are included in impact statements, they mainly focus on the specific impacts experienced by particular groups. Social impact assessment appears to be a decent technique for the evaluation of equity issues through the consideration of the distribution of impacts and benefits from a new project. Although environmental and social impact statements seemingly address equity concerns, their purpose is not to evaluate social justice issues. Even if a well conducted social impact assessment accurately describes equity issues stemming from a transportation project, the capability for consistent and unbiased application in the evaluation of other transportation projects is still lacking, particularly with respect to budget prioritization.

The lack of methods for evaluating equity issues in the evaluation of transportation projects puts decision makers in a rather compromising position. Costs and benefits may be quantified through consistent and established evaluation techniques, whereas a subsidy to support unprofitable and underutilized bus services, as an example, is supported only with a narrative on the need to address equity principles as outlined in planning documents. In an environment of increasing scrutiny of publicly funded programs, it is understandable that governmental agencies in the United Kingdom, United States, and Australia are skeptical about investing in public transport. However, most urban planning authorities suggest that greater investment in public transport is required (Industry Commission, 1994; Hodge, 1995). What approaches may then be suitable and appropriate for supporting equity considerations in public transport planning?

In public sector analysis and planning the most advocated alternatives in the analysis of social justice concerns are coefficient oriented measures. These techniques offer a formal and consistent approach for evaluating equity in the distribution of public services. As the name suggests, one is left with a single quantitative measure, or coefficient, of equity for a region. A number of different coefficient measures, ranging in sophistication and spatial representation, may be identified (see Coulter, 1989; Mulligan, 1991; Marsh and Schilling, 1994). Specific examples include the Gini coefficient, Theil’s index of entropy, the
coefficient of variation, and the index of concentration. These measures typically provide a comparison of a service distribution to some mean value (representing equality of service) across a region. The advantage of a coefficient approach is its comparative capability.

However, in practical applications, the evaluation purpose may need to focus on individual performance of areas rather than an examination of regional variation as reflected in coefficient measures. In this instance, the crucial element is the structuring of an index that establishes the status of an area. Thus, the index approach, as contrasted with the coefficient measure, represents a multivariate integration of a number of indicators (or variables), such as income levels and ethnic composition for specific areas, like suburbs. Talen (1998) effectively develops an index of need based upon socioeconomic characteristics. Indices may be derived and justified using formal statistical techniques, such as correlation and principal components analysis, or negotiated preferences, such as ad hoc weighting and selection techniques. Further, indices may combine included variables using linear or nonlinear functions.

It is interesting to note that there is a close relationship between indices and coefficient measures. In fact, once specified, an index may then be used in a coefficient measure. However, in the analysis presented in this paper, we are more interested in the specification of the index and the relative information it provides.

5. EVALUATING PUBLIC TRANSPORT EQUITY

Need

An index-based approach for measuring need and evaluating equity issues in a consistent and unbiased manner is not particularly new or unique. In fact, little if any attention is typically given to the specific details of derived indices. Such an oversight may or may not be significant, but if an index is to be used in the justification or evaluation of public transport investment, especially for addressing issues of social justice, it is essential that the details be explicit. Specific issues include: (i) listing of variables included, (ii) detailing the use of processed or interpreted data, (iii) including the method used to combine variables—linear or nonlinear, and (iv) explaining any weightings used in combining variables.

The most straightforward way to begin the index derivation process is through the use of an example. If the impacts of a proposed light rail project for a particular region are being analyzed, it is likely that only suburb-level considerations need to be taken into account. That is, the interest is in identifying changes occurring in the various suburbs throughout the region associated with the proposed public transport service. As the focus in this case is on social justice concerns, we would like to determine the anticipated need for this public service in each suburb. In doing this, average household income, unemployment rates, and family structure may be useful and appropriate indicators of need for public transport in each suburb. In this example, the suburbs are the geographic areas.
and the indicators are average household income, unemployment rates, and average family size. The use of an index suggests that these three indicators can be combined in order to infer relative need for public transport in each suburb.

The important part of index creation is information addressing the above issues (i)–(iv). Notation for mathematically specifying an index of need is first necessary

\[ i = \text{index of geographic areas}; \]
\[ j = \text{index of indicators or variables}; \]
\[ w_j = \text{importance weight of indicator } j; \]
\[ R_{ij} = \text{derived value of indicator } j \text{ in area } i; \]
\[ \Phi_i = \text{measure of relative need}. \]

This notation allows us to formally define an index of potential need for public transport \( \Phi_i \) as a function

\[ \Phi_i = U(R_{i1}, R_{i2}, \ldots) \]

This function may be defined to be any utility function, as discussed in Austin (1974), and may represent a range of statistical and comparative quality measures, such as those detailed in Can (1992). The index concept is very much a part of the multiple attribute decision analysis methods detailed in Keeney and Raiffa (1976) and Rietveld (1980). The prevailing idea is that one wishes to take into account a number of attributes (or criteria) in order to make a comparative assessment in a region. Of course a major feature of this work is that we are not carrying out an evaluation of a small number of alternative projects, as is the general emphasis in the above work. Rather, we are interested in assessing the relative degree of potential need for public transport using a number of relevant indicators of need.

The indicators (variables) of need may be related to each other in a variety of ways, either linear or nonlinear, when combined in an index (Keeney and Raiffa, 1976). Our preliminary analysis suggested independence between the variables used. Further, for public policy interpretation and discussion, the relationships between the variables were required to be as simple and unaltered as possible. Thus, we structured the index of potential need for public transport as a linearly weighted function of indicators, which means that the index is multivariate in nature. Any of the weighting approaches discussed in Malczewski (1999) could be incorporated (however, usually complex nonlinear weightings are applied when combining alternative objective function measures, which themselves serve as a means for integrating attribute variables). The specific functional form of the utilized index of need is the following

\[ \Phi_i = \sum_j w_j R_{ij} \]
In order for $\Phi$ to be meaningful, then either the weights would need to be adjusted appropriately or the indicators would need to be transformed and standardized in some way (Massam, 1988). It may be particularly difficult to adjust weights in a sensible way using raw indicator values. A more reasonable alternative is to construct a valid and consistent interpretation of the indicators—this is what $R_{ij}$ represents. Suppose that an individual indicator can only take on values ranging from 1 to 6, as an example. If we interpret a value of 6 to mean most needy and a value of 1 to mean least needy, then the range of 1 to 6 reflects varying levels of need. As a general construct, $R_{ij}$ may have the following values and associated interpretation

$$R_{ij} = \begin{cases} 1 & \text{least needy} \\ \vdots & \\ p & \text{most needy} \end{cases}$$

where $p$ represents the number of classes. Note that in the above discussion $p$ is equal to 6. This standardization represents a value function approach to scaling information (Malczewski, 1999).

The next step then is to determine an appropriate assignment of interval values for each indicator using the original data. If we define $\gamma_{ij}$ to be the raw indicator data values, then we can begin by examining the distribution of an individual indicator (index $j$). Figure 2 shows the indicator distribution of average income in southeast Queensland. Thus, there are suburbs on one end of the distribution with an average income of 22,576.85 Australian dollars (AUD) per year and suburbs on the other end with an average income of AUD 44,827.23. The mean for this distribution is AUD 28,939.57. The use of the distribution facilitates the delineation process for assigning interval values to $R_{ij}$. In effect, the raw indicator values $\gamma_{ij}$ are being used to determine appropriate values for $R_{ij}$. In Figure 2 the assignment of values to the various interval classes is shown above the frequency distribution. In this example, we have elected to use $p = 6$, so each interval has an associated integer value ranging from 6 down to 1. The selection of interval classes may be based upon the use of a number of potential techniques, such as equal size, standard deviations, quantiles, natural breaks, optimal, or percentile rankings. (see Murray and Shyy, 2000). The interpretation of the assignment of value to the indicator variables is that they correspond to a likelihood of need for public transport. The particular income levels shown in Figure 2 may be interpreted in this way, where a value of 6 is associated with the best potential need for public transport and a value of 1 indicates the least likely to need public transport. It is worth mentioning that interval class selection may be structured to include spatial characteristics as well (Murray and Shyy, 2000).

The use of $R_{ij}$ defined in this way makes the selection of weights $w_j$ more straightforward. For example, intuitively derived weights may be most appropriate or there may be a need to rely on multicriteria ranking techniques (e.g., Gomes, 1989; Saaty, 1990). Once a decision has been made concerning interval
selection and appropriate weights, then the index $\Phi_i$ provides a measure of relative need. In this case, higher index values correspond to a greater potential need for public transport in a suburb, whereas lower index values correspond to a lesser need for public transport. It is worth noting that the maximum and minimum possible values of $\Phi_i$, given weights $w_j$, may be formally specified

$$\Phi_{\text{Max}} = p \sum w_j$$
$$\Phi_{\text{Min}} = \sum_j w_j$$

Thus, it is possible to relate any value of $\Phi_i$ to the maximum and minimum possible values in order to assess relative need for public transport in an area.

Access

The next step in establishing whether there exists a transport disadvantage in given areas is to make a comparison of the index of potential need for public transport to a measure of suitable public transport access. As detailed previously, suitable public transport access may be calculated, even down to the household...
level if desired. However, the actual unit of analysis is likely to be much larger in spatial scale due to planning intent, manageability, and privacy concerns. This is certainly the case in the analysis presented later because the interest is in characteristics of suburbs, so it is necessary to interpret access to public transport at the suburb level based upon the use of more spatially defined measures of coverage. The following notation will facilitate this explanation

\[
\lambda_{il} = \text{proportion of population in area } i \text{ found in unit } l; \\
N_l = \text{set of units } l \text{ in area } i; \\
\tau_i = \text{percentage of area } i \text{ suitably covered by public transport.}
\]

Using this notation we may define suitable coverage of an area as follows

\[
\tau_i = \sum_{l \in N_i} \lambda_{il} f(\bar{d}_l, S)
\]

where

\[
f(\bar{d}_l, S) = \begin{cases} 
1 & \text{if } \bar{d}_l \leq S \\
0 & \text{otherwise}
\end{cases}
\]

The variable \(\tau_i\) gives the proportion of the population in area \(i\) having suitable access to public transport. This indicator of public transport access must then be interpreted using the interval scale approach discussed in the previous section. Thus, an index of suitable access coverage would be

\[
\Psi_i = \begin{cases} 
1 & \text{best served by public transport} \\
p & \text{worst served by public transport}
\end{cases}
\]

Again, the distribution of the \(\tau_i\) values would be evaluated in order to appropriately classify the corresponding \(\Psi_i\) ratings. Given \(\Phi_i\), the index of potential need for public transport, and \(\Psi_i\), the index of suitable access to public transport, there is now a basis for evaluating equity issues in public transport planning.

**Transport Disadvantaged**

The previous sections have detailed how need for public transport service may be structured as well as how suitable access to public transport may be measured. Relating need and access in a meaningful way is necessary for determining whether or not transport disadvantaged areas exist in a region. The following notation will facilitate this discussion

\[
\alpha = \text{threshold indicating inadequate access to public transport}; \\
\beta = \text{threshold indicating public transport need}.
\]

Regional inequities in service distribution may be recognized when the need for public transport, as measured by the index \(\Phi_i\), exceeds some acceptable...
threshold \( \beta \) and when suitable public transport access, as measured by the index \( \Psi_i \), exceeds some acceptable threshold \( \alpha \). In this particular instance, the acceptable threshold \( \beta \) for potential need for public transport would likely be based upon some deviation from \( \Phi_{\text{Max}} \). Therefore, in cases where \( \Phi_i \leq \beta \), this would imply a significant potential need for public transport in area \( i \). Similarly, the acceptable threshold \( \alpha \) for suitable access to public transport would be based upon some deviation from \( p \) (the maximum possible value of \( \Psi_i \)). So, in cases where \( \Psi_i \leq \alpha \), this would imply that suitable access to public transport in area \( i \) is not provided. The use of these threshold parameters allows us to integrate and formally relate need and access in order to determine whether areas are transport disadvantaged. It may be worth noting that this represents an alternative to the equity mapping approach discussed in Talen (1998).

6. APPLICATION

Southeast Queensland is a rapidly growing region containing approximately 2.2 million people. The population in this region is expected to grow to nearly 4 million in the next 40 years. Turning around the declining modal share of public transport is considered essential in regional policy and planning (Queensland Government, 1997). There is also considerable importance given to the achievement of socially just and environmentally sustainable outcomes through an increase in public transport service provision. This includes infrastructure expenditure, enhancing public transport quality, and improving access to public transport services. One of the major planning goals is the provision of suitable public transport access to 90 percent of the population in the region (Queensland Government, 1997). Suitable access is defined in specific terms as residing within 400 meters of a public transport stop (bus, rail, and ferry services in this region). On the other hand, the socially equitable distribution of public transportation service is not so specifically detailed, but is no less regarded. The reason for this may be due to the ambiguous and contentious nature of equity in contrast to the more obvious, and less politically sensitive, issue of access to service.

The suburb (or statistical local area in the Australian census hierarchy) was deemed to be the most appropriate level of analysis. The reasons for this include evaluation intent and data availability, particularly with respect to determining need for public transport. There are 290 statistical local areas in the southeast Queensland region. For examining access to public transport, greater spatial detail is desirable for ensuring accuracy in service provision estimates. The most disaggregate information on where individuals reside is the collection district level (225 dwellings per unit on average) in the Australian census hierarchy. In this analysis collection district level population information was used to evaluate access to public transport service. There are 10,911 public transport stops distributed throughout southeast Queensland and 3,793 collection districts. The proximity of stops to collection districts was evaluated using the 400 meter distance standard stipulated in regional planning documents. Details on this
component of the analysis may be found in Murray et al. (1998). This information is then translated to the suburb level in order to make consistent comparisons to derived measures of need for public transport.

The achievement of 90 percent coverage of the regional population based upon the 400 meter standard is a policy goal that may ultimately influence greater use of public transportation. However, there is nothing in this policy goal to ensure that those that are potentially in need of public transport receive access within 400 meters. Further, there is nothing inherent in this policy approach that gives priority to those areas characterized as being in need of public transport. In this analysis, we construct the index of need $\Phi_i$ using five indicators (socioeconomic variables) in order to identify suburbs that are potentially in need of public transport. The five indicators (with data sources) are:

- **Young**—individuals between 0–16 years (1996 census)
- **Aged**—individuals 65 years and over (1996 census)
- **Low income earners**—those with an income below 300 dollars per week\(^1\) (1996 census)
- **Households without automobiles** (1996 census)
- **Disabled persons** (Centrelink data 1996—Commonwealth Government)

The number of individuals associated with each of these variables was scaled by the total population of the suburb. The relative distribution of each of these variables is shown in Figure 3. Regionally the correlation between variables is fairly stable. As a result there is a significant degree of local variation, making it a challenge to find important equity trends.

The particulars associated with the creation of the index of need for public transport in southeast Queensland may now be detailed. In this analysis, unity weighting was applied to each of the indicator variables. This was done in order to reflect equal importance of each factor (variable) and avoid value judgments on the social significance of the indicators with respect to transport disadvantage. Further, such a weighting reflects the degree to which these factors have been found to be characteristic of disadvantaged individuals (see Transportation Research Board, 1999). Interval classification of the indicators was based upon a value of $p$ equal to 10 using equal intervals (variable range divided into $p$ classes, similar to Figure 2). The maximum and minimum values of the index of need would be $\Phi^{\text{Max}} = 50$ and $\Phi^{\text{Min}} = 5$, given that there are five indicator variables, weights equal to 1.0 for each indicator, and an interval range of $p = 10$.

The potential need for public transport in southeast Queensland using $\Phi_i$ is depicted in Figure 4. Values of $\Phi_i$ in the region actually reach a maximum of 30 rather than the theoretical maximum of 50. This is a result of the variable independence. The areas with the greatest potential need for public transport

\[^1\]The “living wage” in Australia has been identified by the Australian Industrial Relations Commission in minimum wage judgements as 339.40 dollars per week for 1996. Given the way earnings are reported in the census, 300 dollars per week is the best approximation possible.

FIGURE 3: Individual Distributions of Variables Associated with Public Transport Need, (a)–(e) and access (f).
FIGURE 4: Potential Need for Public Transport in South East Queensland.

are distributed throughout the region. There is a cluster of suburbs around the Brisbane city center with likely need for public transport. Also, Figure 4 shows that there is a corridor of suburbs with high need index values extending southwest from the Brisbane city center towards Ipswich. South of Brisbane there are suburbs around Beenleigh with significant potential need for public transport. To the north of Brisbane there are areas around Redcliffe with high potential need. The Gold Coast and Sunshine Coast both contain pockets of likely public transport need scattered along the coastline. It is interesting that most of the rural areas (reflected by the size of the individual statistical local areas) shown in Figure 4 contain significant proportions of people with potential need for public transport.

Potential need for public transport provides only one component of the analysis of social equity in service provision. The other component is the actual suitable access to public transport afforded to these areas. The public transport access index $\Psi_i$ used a value of $p = 10$ and equal intervals, as was done for need. A value of 10 equates to suburbs with the greatest proportion of persons without suitable public transport access in relation to the 400 meter goal, whereas a value of unity corresponds to the lowest proportion of people with suitable public transport access. A general regional finding associated with suitable access in the region is that only 55 percent of the regional population has suitable access to public transport. This is far below the regional goal of 90 percent. The index of public transport access $\Psi_i$ is displayed in Figure 5. As can be seen, the greatest levels of public transport access are provided to residents of Brisbane city, the city contains approximately half of the total regional population (1.5 million people). This is largely due to the extensive bus network provided by Brisbane Transport, the public transport company owned by Brisbane City Council. Beyond the administrative boundaries of Brisbane City Council, public transport access declines concentrically from the city center, with suitable public transport access almost nonexistent 30 kilometers from the city. However, public transportation access on the Gold Coast is also relatively good, whereas north to the Sunshine Coast suitable public transport access is sporadic. Rural areas in the region, where the population is the most dispersed, clearly have the lowest levels of suitable public transport access in Figure 5.

Integrating the results presented in Figures 4 and 5 is accomplished using appropriately defined thresholds of need and acceptable service. Standard query-based functionality found in commercial GIS packages may be used for this operation. Threshold values of $\beta = 20$ and $\alpha = 5$ are imposed to identify transport disadvantaged suburbs in the southeast Queensland region. These areas are highlighted in Figure 6, where all suburbs with $\Phi_i \geq 20$ (most transport needy areas shown in Figure 4) and $\Psi_i \geq 5$ (areas with poorest access to public transport shown in Figure 5) are darkly shaded. Figure 6 indicates that many of the suburbs identified as having high potential need for public transport are already being provided adequate access. However, there are numerous suburbs that may be classified as being transport disadvantaged, which should be a
FIGURE 5: Levels of Suitable Public Transport Access in South East Queensland.
concern to policymakers. The 58 areas identified in Figure 6 can be broken into four categories. The first category is suburbs on the outskirts of greater Brisbane—north towards Caboolture, south towards Beenleigh, and south-west towards Ipswich. These areas should be the greatest concern to policymakers because they contain affordable housing and, in many cases, are growing in population due to new low-density suburban development. The second category consists of industrial areas east of Brisbane city center (the airport and seaport). While having relatively low populations, these areas are also a concern given the need to provide public transport services to areas of substantial employment (destination access to public transport). The third category is the northern coastal region—the Sunshine Coast. Although there are suburbs in the northern area of the Gold Coast that are transport disadvantaged, almost all of the Sunshine Coast has both a low level of public transport access and a considerable potential need. The population of the Sunshine Coast has increased rapidly over the past ten years, a trend that is expected to continue. The low level of public transport and the consistently high potential need for public transport on the Sunshine Coast suggests that significant expenditure on public transport services and infrastructure should be prioritized for this region. The final category is rural areas, which includes Esk, Boonah, Beaudesert, and Gatton and the relatively unpopulated Moreton and Stradbroke Islands. These areas, while having high public transport need, have relatively dispersed populations, so increasing the provision of public transport services would be challenging.

7. DISCUSSION

Substantial subsidies for public transport are requested and received on the basis of fulfilling a social responsibility. Although widely held as important and funded accordingly, public transportation services are rarely monitored for effectiveness in serving the transport disadvantaged. Equity or justice for this social service is only achieved when appropriate transportation is provided to those that need the service. Again, this is an implicit obligation that transit agencies refer to when requesting subsidies. The results depicted in Figure 6 have some significant policy implications in this regard. If equity issues are in fact worthy of the attention they receive in Queensland strategic planning processes (i.e., Queensland Government, 1997), then public transport projects that improve access to the transport disadvantaged areas shown in Figure 6 should be high priorities. In fact, in some cases it may even be possible to justify system reconfiguration in order to serve transport disadvantaged areas. As an example, Murray (2001) demonstrated that based upon the stated access standard of 400 meters, only 20 percent of the current public transport stops are necessary for maintaining the current level of regional access. Public transport in southeast Queensland is predominately bus oriented (approximately 10,700

---

2 Such potential changes would certainly involve assessing system integration, cost, utilization, etc. as reviewed in Gendreau, Laporte, and Mesa (1995).

FIGURE 6: Transport Disadvantaged Areas in South East Queensland.
bus stops compared to only 211 train and ferry stops), so this would provide some opportunity to realign current services (bus stops, routes, and buses) at a relatively low cost in order to serve at least some transport disadvantaged areas. Nevertheless, several of the transport disadvantaged areas in this region are rural in nature, have low population, and are not expected to have population growth in the near term. This would make the provision of public transport services in these areas somewhat expensive and considerably underutilized. This is certainly the case for the Esk, Gatton, and Boonah shires on the region boundaries in Figure 6. Although still important in these areas, public transportation provision does need to be sensitive to other considerations, particularly economic efficiency. Innovative approaches to providing transportation alternatives, such as subsidized taxis or call-and-ride minibus services, may represent a more cost effective solution over traditional methods like extending or modifying current public transportation services.

A number of technically oriented questions may be raised regarding the sensitivity of the findings. In particular, how do changes to the following items alter which areas are identified as being transport disadvantaged

(a) spatial scale,
(b) standardized data,
(c) interval range (value of $p$),
(d) interval classification method,
(e) indicator variables included.

In theory it is possible to address each of these application issues. However, in practice some are more difficult to analyze than others. As an example, sensitivity to spatial scale is not particularly easy to vary due to the questions of need and access being examined. It would be helpful to have spatially disaggregate information at the household level, but this is not available from the census or other sources. Thus, it is not practical to examine sensitivity to spatial scale in this analysis. What is feasible to evaluate in this analysis is sensitivity in interval classification and included attribute variables.

Interval range variations of $p = 6, 10, \text{ and } 15$ were examined in our analysis. In addition, we have used a number of interval classification methods (equal, quantile, percentile ranking, and optimal). The results were not particularly sensitive to interval range. The lowest range ($p = 6$) did appear to give a different ordering of $\Phi_i$ values across the region, but still highlighted the same transport disadvantaged areas as higher interval range values. On the other hand, alternative classification methods resulted in significantly different $\Phi_i$ values than those produced using equal intervals above. Over each of the interval ranges, the quantile, percentile ranking, and optimal method indicated higher values of $\Phi_i$ than those closer to $\Phi^{\text{Max}}$. As an example, for $p = 10$, Bilinga (near Coolangatta on the Gold Coast) receives the highest $\Phi_i$ value of 30 using equal intervals, but receives a value of 41 using the optimal method. The highest $\Phi_i$ value using the optimal method is 44 for Caloundra on the Sunshine Coast, which receives a value of 27 using equal intervals. There is clear evidence that the classification method chosen will have
an effect on which suburbs are identified as transport disadvantaged or otherwise, so attention and justification must be given for the use of a particular method. An explanation for this may be found by evaluating the individual distributions of the associated variables and considering the intent of the various classification methods. The quantile, percentile ranking, and optimal approaches each vary the length of individual classes (unlike the classes shown in Figure 2), which more or less ensures that each class has members. However, the index of need $\Phi$ is being used so that it implies order and magnitude (an interval scale measure). Thus, only the equal interval classification method preserves the representation of magnitude. As an example, the variable distribution of households without a motor vehicle shown in Figure 3d has suburbs that are outliers, which increases the range along the x-axis. The use of equal intervals may result in some classes with no suburbs in this case (depending on the value of $p$), but this is desirable given the use of the index of need as a measure of order and magnitude.

The sensitivity of indicator variables incorporated in the need index $\Phi$ was also explored. The choice and combination of variables used will undoubtedly have an effect on the identification of transport disadvantaged areas. The variables included in the above analysis reflected, to the greatest extent possible, those groups with potential need for public transport as detailed in Table 1. This is perhaps the most significant issue. The removal of individual variables was explored, which necessitated the lowering of the need threshold $\beta$ in order to evaluate analysis sensitivity. The result of this sensitivity analysis was that identified transport disadvantaged areas remained unchanged from Figure 6, with the exception of the young and low income variables. In these two cases, only a subset of those areas shown in Figure 6 were characterized as transport disadvantaged. Removing the young from the index was the most significant, leaving only 19 areas out of the 58 identified in Figure 6, whereas removing low income left 41 areas. When variables associated with low income and the young are eliminated from the transport disadvantaged index, only 8 of the original 58 areas are identified as transport disadvantaged. However, even in these cases the findings suggest that there is some consistency across the associated variables of need. The nature of this relationship is not straightforward. The reason for this is that one could be more or less restrictive in establishing the need threshold. If this is done, then we begin to see additional areas being classified as transport disadvantaged. The above sensitivity analysis was focused on stability in the original findings and the indicator variables included. When variables are omitted and the need threshold relaxed, we do see the subset of the original 58 transport disadvantaged areas as being the most significant, but other areas could be classified as disadvantaged as well.

8. CONCLUSIONS

This paper has developed an approach for the evaluation of equity in public transport service provision. The method for evaluating transport need presented in this paper can be easily adapted to other issues where the location of public
services is compared to a multivariate demographic profile. The advantage of this approach is that it is flexible and may readily generate summary information for the purpose of decision support. It is envisaged that any public authority would be able to conduct an equity based analysis similar to that presented for public transport services in southeast Queensland in order to evaluate the effectiveness of particular government sponsored projects. More importantly, this method establishes a basis for comparison between alternative project proposals based on the achievement of equity outcomes. For example, two public transport service lines could be evaluated in terms of their relative success in serving transport disadvantaged areas. Finally, this analysis approach provides evidence to support alternatives that may be less financially appealing (i.e., using cost-benefit analysis), but demonstrate benefits to social equity in a region. This is a particularly important feature given that public transport services are highly subsidized.

REFERENCES


