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16. Abstract

This report describes the development of a transit accessibility index (TAI) and a transit dependence index (TDI). The TAI reflects the level of transit service supply, whereas the TDI indicates the potential level of transit needs. Together, the TAI and TDI provide a means for transit agencies to identify patterns of disparity in service provision to population groups with different levels of need. They can also help track and monitor changes in transit service delivery due to shifts in the population and/or land use distribution.

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# Measuring Access to Public Transportation Services: Development of Transit Accessibility and Transit Dependence Measures

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# Table of Contents


**1. INTRODUCTION .......... 1**

**2. CONSIDERATIONS FOR THE ACCESSIBILITY INDICES .......... 3**

2.1 Functional Form of the TAI .......... 3
2.1.1 Spatial Separation Measures .......... 3
2.1.2 Cumulative Opportunity Measures .......... 3
2.1.3 Gravity Measures .......... 3
2.1.4 Utility Measures .......... 4
2.2 Utility Approach to Measuring Transit Accessibility .......... 4
2.3 Elements of the Utility Measure for the TAI .......... 6
2.3.1 Local Accessibility .......... 8
2.3.2 Network Accessibility .......... 8

**3. DEVELOPMENT OF TRANSIT ACCESSIBILITY MEASURES .......... 11**

3.1 Notations and Overall Framework .......... 11
3.2 Elements of the Transit Path Choice Model .......... 12
3.2.1 Modeling the Probabilistic Choice Set .......... 12
3.2.2 Modeling the Conditional Choice Probability .......... 13
3.2.3 Model Estimation .......... 13
3.3 Formulation of Utility-Based TAI .......... 13
3.3.1 Choice Set Determination .......... 14
3.3.2 Computation of the Utility Measure .......... 14

**4. CONSIDERATIONS AND DEVELOPMENT OF A DEPENDENCE INDEX .......... 17**

4.1 Definition of Dependence .......... 17
4.2 Formulation of a TDI .......... 17

**5. CONCLUSIONS .......... 21**

**6. REFERENCES .......... 23**

# List of Tables

Table 4.1 Summary of past definitions of transit dependent users. ............................................ 18

# List of Figures

Figure 2.1 Relevance of a destination depends on transit service coverage .................................. 5
Figure 2.2 Elements of utility associated with transit service ........................................................ 7

# 1. Introduction

In view of transit service performance problems such as declining ridership and social inequity, public agencies and transit operators are looking for methodologies to accurately identify where the problems are and to quantify the severity of the problems so that appropriate actions can be taken. To date, many performance measures have been developed and used in a variety of ways, reflecting differing perspectives and responding to differing transit problems. For a variety of reasons—particularly federal reporting requirements and the relative ease of obtaining data—many transit agencies have focused on measures that reflect the *agencies'* point of view and concern with transit system *efficiency* (that is, how well a transit system utilizes available labor and capital resources). On the contrary, critical aspects of performance that are important to the transit customers, and the community at large, have often been insufficiently addressed. It is only recently that the social-welfare role of transit and the need to improve public transportation customer service as a means to increase transit ridership have begun to receive serious consideration. These considerations call for *customer-oriented* performance measures for evaluating transit service.

This report describes the development of customer-oriented measures of the transit level of service for fixed-route systems. The measures presented here will ultimately be packaged into a GIS-based software program for use by TxDOT and other transportation agencies to design transit systems that provide good access to transit and the equitable distribution of accessible transit services. Two measures are presented here: the transit accessibility index (TAI) and the transit dependence index (TDI). The objectives for developing the TAI are to:

1. identify areas with relatively low accessibility to provide a basis for developing improvement proposals;
2. evaluate estimates of impacts due to improvement projects;
3. evaluate estimates of impacts due to land use changes; and
4. provide information for designing policies to target specific aspects of transit service.

The objective for developing the TDI is to identify areas with relatively higher transit needs (i.e. more transit dependent users) than other areas. The TDI will help transit agencies to correlate the level of service supply with the demand level of the public so as to ensure that the system reaches the users who need the service the most.

The remainder of this report is organized as follows. Chapter 2 discusses the various considerations involved in the development of the TAI. Chapter 3 describes the development of the TAI. Chapter 4 presents the considerations and the development of the TDI. Chapter 5 concludes the project with a discussion on further development of the TAI and the TDI.

# 2. Considerations for the Accessibility Indices

This chapter discusses the various considerations by which the proposed TAI is developed. These considerations have been drawn from the PI's experience with the development of the Urban Accessibility Index (Ref 1) and our earlier review of existing transit service delivery measures (Ref 2). The considerations include:

1. the mathematical structure of the measure;
2. the behavioral dimensions and service characteristics to be incorporated in the measure; and
3. the ability to aggregate the measure across various dimensions

These points are discussed in the following sections.

## 2.1 Functional Form of the TAI

Four types of accessibility indices have emerged from past research on the subject (Ref 3). These include spatial separation measures, cumulative opportunity measures, gravity measures, and utility measures. The nature of these measures and their applicability in the context of evaluating transit service are described below.

### 2.1.1 Spatial Separation Measures

This is the simplest form of an accessibility measure and it represents the spatial separation (in terms of distance or travel time) between the origin and the destination. This form of measure is undesirable for the purpose of this project because the measure does not account for the attraction level (for example, land use intensity) at the destination end, nor does it reflect the sensitivity and needs of users with different characteristics.

### 2.1.2 Cumulative Opportunity Measures

This measure calculates the accessibility for a given origin as the total number of attractions (for example, the number of grocery stores) within a pre-specified travel time or distance. The main criticism for this form of measure is its lack of behavioral foundation. Specifically, the uniform application of a travel time threshold would disregard the differential sensitivity to travel time across transit users.

### 2.1.3 Gravity Measures

Gravity measures incorporate a separation factor and an attraction factor. They usually take the form of the sum of attraction-to-separation ratios across destinations. The separation factor provides a dampening effect that devalues the attractions far from the origin. Similar to the spatial separation and cumulative-opportunity measures, the gravity measures also suffer from the limitation of assigning the same accessibility value to all individuals in the same origin zone.

### 2.1.4 Utility Measures

Utility measures represent the utility an individual perceives from travel alternatives. Specifically, the accessibility for an individual is generally calculated as the expected maximum (or the logsum) utility from a random utility model. Usually, such measures are derived from a multinomial model of destination choice or a nested logit model of destination and mode choice. Since utility is generally formulated as a function of the characteristics of the individual, as well as the characteristics of the choice alternatives, the utility measures have the capability of representing accessibility at an individual level according to individual preferences and taste differences. This is why the utility measures have been considered the most suitable form for the purpose of this project.

## 2.2 Utility Approach to Measuring Transit Accessibility

In the past, the utility approach to measuring accessibility has been criticized for its underlying assumption that all individuals consider the same choice set of alternative destinations. This is especially a problem in the context of measuring transit accessibility because any single bus, or a collection of buses, usually covers only a portion of a given study area. Thus, while an individual can potentially drive a car to reach any of the alternative destinations in the area, she can reach only a subset of destinations with transit. For instance, consider an individual residing at *o*, and let *a*, *b*, and *c* be activity centers (see Figure 2.1). All of these activity centers are accessible by car, but only *c* is serviced by transit. Thus, only when a destination is considered as reachable by transit can we calculate the associated utility based on the service available for reaching the destination. The utility can then in turn be incorporated into the final accessibility index.

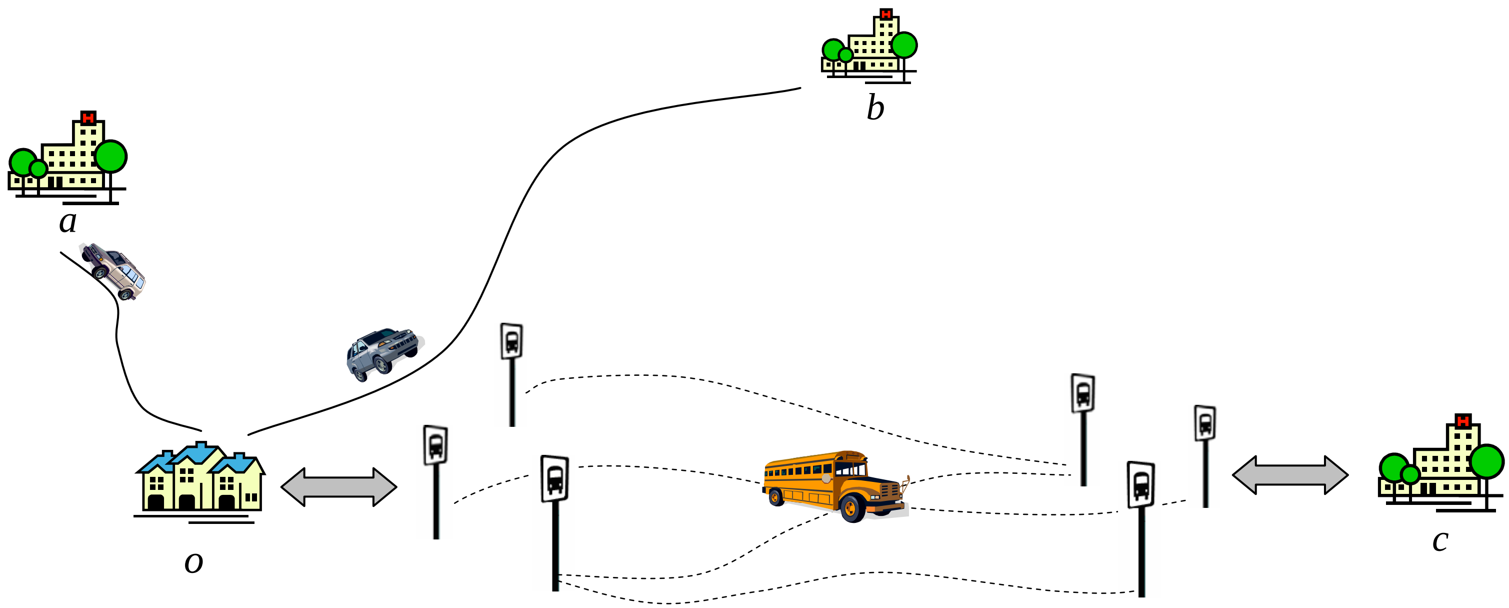


**Figure 2.1 Relevance of a destination depends on transit service coverage**

Our application of the utility approach to measuring transit accessibility therefore involves the following two stages:

1. For each potential destination, determine the feasibility of using transit to reach the location and, if the destination is a feasible choice alternative, determine the utility (level of transit service) presented to the individual with respect to the destination; and
2. Consolidate the utilities associated with all feasible destinations to form a measure of transit accessibility.

In the remainder of this chapter and the next chapter, we describe the framework proposed for achieving the first stage of the two-stage process. The second stage of consolidating the utilities across space as well as other dimensions will be the subject of the next report.

## 2.3 Elements of the Utility Measure for the TAI

In this section, we discuss the various elements considered as relevant to the perceived feasibility and utility associated with using transit to reach a given destination. As depicted in Figure 2.2, the perceived feasibility and utility depend on both the ease of reaching boarding and destination points, referred to as *local accessibility*, and the ease of travel between boarding and egress points, referred to as *network accessibility*. While local accessibility is related to the placement of transit stops, network accessibility is mainly concerned with the actual transit operation, particularly the alignment of routes and the scheduling of service. Travel to a destination by transit is feasible only if the local and network accessibilities meet an individual's desired level. Once a destination is regarded as feasible, the utility associated with using the transit service to reach the destination is the combined levels of local and network accessibilities.

Below we discuss the elements of transit service that constitute the local and network accessibilities.

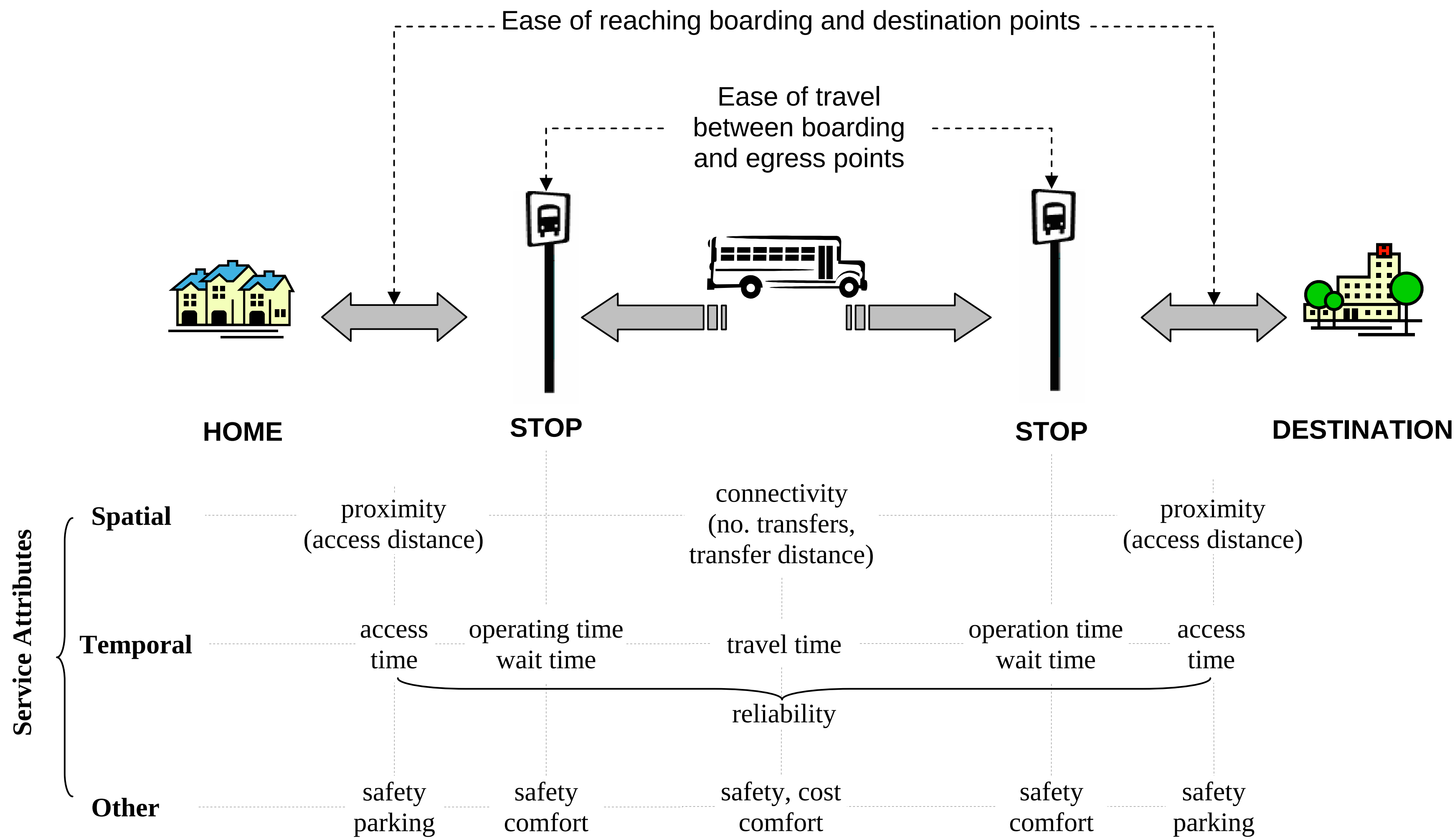


**Figure 2.2 Elements of utility associated with transit service**

### 2.3.1 Local Accessibility

The level of local accessibility can be characterized along the spatial, temporal and other dimensions as follows (see Figure 2.2).

*Spatial*

If transit service is not provided within the proximity of where an individual lives and where she wants to go, then, as far as she is concerned, transit service does not exist. Thus, spatial proximity is one of the elements, and probably the most important one, that determines local accessibility. The definition of proximity should be dependent on the individual. For example, a distance of a quarter-mile may be considered walkable, and thus accessible, by a young adult but not by a senior adult. Proximity should also be defined based on the available access mode, that is, whether the individual walks, bicycles, drives, or gets a ride from home to a given transit stop (or from the egress point to the destination). For example, if a senior citizen has the option of getting a ride to a transit stop, then she might consider a transit stop that is more than a quarter-mile away accessible by auto, even though she would consider it inaccessible by walking.

*Temporal*

Related to spatial proximity is access time, or the time it takes to travel from home to the boarding point (or from the egress point to the destination) by the available access mode. Clearly, the access time would depend on the characteristics of the access mode. It depends also on the traffic condition during the access trip as well as environmental characteristics such as the terrain.

*Other*

Local accessibility is also influenced by concerns other than spatial proximity or access time. However, like access time, these concerns are specific to the access mode. For example, safety may be an issue when walking access is concerned. If the walk to a transit stop is short in distance, but is not supported by pedestrian facilities and/or involves crossing a couple of busy roadways, then the transit stop may be considered inaccessible. For auto access, the availability and security of parking facilities near a transit stop could impact the perceived local accessibility of that stop.

### 2.3.2 Network Accessibility

Similar to local accessibility, network accessibility can also be characterized along the spatial, temporal and other dimensions as follows (see Figure 2.2).

*Spatial*

Network accessibility refers to the provision of service between a given pair of (accessible) boarding and egress stops. The spatial aspect of the service that contributes to network accessibility is network connectivity—that is, whether there is a route, or a combination of routes, that forms a path connecting the boarding and the egress stops. For any path that involves transfers between different routes, the concept of connectivity would depend on an individual's sensitivity to the number of transfers required and the walk distance between transfer stops.

*Temporal*

Once a connecting path is identified, an individual would need to consider the temporal provision of the service along that path. The considerations include the time span over which service is provided, the service frequency, and the service reliability at the trip ends (note that service frequency and service reliability together determine the wait time experienced at a transit stop). The temporal considerations also include the various elements that impact the total travel time, including the total in-vehicle travel time, the total transfer time (which is usually the walk time), the service frequencies for intermediate routes, and the travel time reliability. It should be noted that the sensitivity to these various temporal service characteristics is likely to vary from individual to individual, and also from one travel occasion to another. For instance, if transit is being considered for a commute trip, then the individual would probably be more sensitive to service reliability, and be more inflexible about service hours, than if it was for maintenance shopping.

*Other*

Concerns about safety at transit stops (including the trip ends and the transfer locations) may also influence individuals' perceptions of network accessibility. Such concerns include appropriate lighting and/or coverage at the waiting area. Other non-spatial, non-temporal service attributes that impact network accessibility include the cost of travel and the comfort level in terms of the occupancy levels vis-à-vis the transit vehicle capacity.

# 3. Development of Transit Accessibility Measures

The discussion presented in the preceding chapter points to the need for an analytical framework that supports:

1. the identification of the criteria based on which an individual decides whether a transit service is considered as available for reaching a destination; and
2. the identification of the perceived utility associated with using a transit service to reach a feasible destination.

A modeling framework with the above capability is the probabilistic choice set (PCS) model (Ref 4) that considers an individual's choice behavior as a two-stage process:

1. choice generation process; and
2. choice from a given choice set.

In this chapter, we discuss the application of the PCS model in developing the TAI. Section 3.1 introduces the mathematical notations and presents the overall modeling framework. Section 3.2 describes the modeling of the choice generation process, the modeling of an individual's choice from a given choice set, and the estimation procedure for identifying model parameters. Section 3.3 discusses how the estimation results can be used to formulate the utility-based TAI.

## 3.1 Notations and Overall Framework

We consider the problem where an individual, $n$, makes a choice of transit path (corresponding to a bus or other transit service) for reaching a given destination. We denote the universal choice set (all transit paths in the study area) by $M$ and the deterministically identified feasible choice set for the individual by $M_n$ ($M_n \subseteq M$). $M_n$ can be defined by set of transit paths between pairs of transit stops within a maximum access distance (e.g., 5 miles) around the individual's origin and destination. Let the size of $M_n$ be $m_n$. Denote all the ($2^{m_n} - 1$) non-empty subsets of $M_n$ by $G_n$. Each element $C \in G_n$ is a possible choice set that an individual actually considers in her decision-making process.

The probabilistic choice set modeling approach gives the probability of individual $n$ choosing alternative transit path $i \in C$ as:

$$P_n(i) = \sum_{C \in G_n} P_n(i \mid C) P_n(C) \quad , \text{..........} \quad \text{Eq. (3.1)}$$

where $P_n(i \mid C)$ denotes the probability of individual $n$ choosing an alternative transit path $i$ given that the choice set is $C$; and $P_n(C)$ denotes the probability of the individual's choice set being $C$.

## 3.2 Elements of the Transit Path Choice Model

### 3.2.1 Modeling the Probabilistic Choice Set

We adopt the random constraints approach to model choice set generation (Refs 5, 6, 7). Based on this approach, a transit path $i$ is considered available, and hence included in the individual's choice set, if a set of constraints are met. For example, the access and egress distances are within an individual-specific distance threshold; the number of on-route transfers is under an individual-specific value; and the total travel time and cost are also under individual-specific threshold values. If any one of the constraints is violated, the path would not be considered available. The individual-specific threshold values are unobservable and are thus modeled as functions of observable attributes and unobservable random variables.

Mathematically, we define the random constraint approach as follows. Let $H_{nik}$ be the $k$ th criterion associated with path $i$ as assessed by individual $n$. Express the criterion as

$$H_{nik} = \alpha_k + \eta_k Y_{nk} S_{nik} - \upsilon_{nik} \geq 0 \, , \quad \text{Eq. (3.2)}$$

where $Y_{nk}$ are observable individual characteristics; $S_{nik}$ are observable path attributes; $\upsilon_{nik}$ is a random variable capturing any unobservable effects; and $\alpha_k$ and $\eta_k$ are parameters to be estimated in order to identify the constraints. Rearranging the expression yields:

$$S_{nik} \leq \frac{\upsilon_{nik} - \alpha_k}{\eta_k Y_{nk}} \, . \quad \text{Eq. (3.3)}$$

This inequality gives us the individual-dependent thresholds based on which individual $n$ decides whether the desired level of local or network accessibility is attained. For instance, if $S_{nik}$ denotes the access distance between the individual's origin and the boarding stop and $Y_{nk}$ denotes the age of the individual, then the right-hand side of the above expression gives the distance threshold as a function of age.

Let $A^*_{ni}$ be a latent binary variable that takes the value of 1 if path $i$ is perceived as available by individual $n$, otherwise it takes the value of 0. Assuming that $\upsilon_{nik}$ 's are independently and identically distributed with a logistic distribution, the probability that individual $n$ will perceive that path $i$ is available is given by:

$$\begin{aligned} P(A^*_{ni} = 1) &= P(H_{nik} \geq 0, \forall k) \\ &= \prod_k P(\upsilon_{nik} \leq \alpha_k + \eta_k Y_{nk} S_{nik}) \\ &= \prod_k \frac{1}{1 + e^{-(\alpha_k + \eta_k Y_{nk} S_{nik})}} \, . \quad \text{Eq. (3.4)} \end{aligned}$$

The probability that $C$, where $C \in G_n$, is the individual's choice set is calculated as follows:

$$P_n(C) = \frac{P(A^*_{ni} = 1, \forall i \in C) \cap P(A^*_{nj} = 0, \forall j \in M_n \setminus C)}{1 - P(A^*_{nl} = 0, \forall l \in M_n)}$$

$$= \frac{\prod_{i \in C} P\left(A_{ni}^* = 1\right) \prod_{j \in M_n \setminus C} P\left(A_{nj}^* = 0\right)}{1 - \prod_{l \in M_n} P\left(A_{nl}^* = 0\right)}$$

$$= \frac{\prod_{i \in C} P\left(A_{ni}^* = 1\right) \prod_{j \in M_n \setminus C} \left(1 - P\left(A_{nj}^* = 1\right)\right)}{1 - \prod_{l \in M_n} \left(1 - P\left(A_{nl}^* = 1\right)\right)} . \quad \text{Eq. (3.5)}$$

### 3.2.2 Modeling the Conditional Choice Probability

We model the conditional choice probability $P_n(i \mid C)$ based on the usual multinomial logit structure. That is, assuming the validity of the IIA (independent from irrelevant alternatives) property and a linear-in-parameter utility structure, we model the probability that individual $n$ choosing transit path $i$ from a given choice set $C$ as :

$$P_n(i \mid C) = \frac{e^{\beta' X_{ni}}}{\sum_{j \in C} e^{\beta' X_{nj}}} , \quad \text{Eq. (3.6)}$$

where $X_{ni}$ is a vector of observed attributes associated with path $i$ as perceived by the individual $n$ (including a constant and interaction terms), and $\beta$ is a vector of parameters to be estimated.

### 3.2.3 Model Estimation

The unknown model parameters $\beta$, $\alpha$ and $\eta$ can be estimated by using the maximum likelihood function. The log-likelihood function to be maximized is given by:

$$LL = \sum_n \sum_{i \in M_n} I_{ni} \cdot \ln \sum_{C \in G_n} \left(P_n(i \mid C) P_n(C)\right)$$

$$= \sum_n \sum_{i \in M_n} I_{ni} \cdot \ln \sum_{C \in G_n} \left[ \frac{e^{\beta' X_{ni}}}{\sum_{j \in C} e^{\beta' X_{nj}}} \cdot \frac{\prod_{i \in C} \prod_k \frac{1}{1 + e^{-(\alpha_k + \eta_k Y_{nk} S_{nik})}} \cdot \prod_{j \in M_n \setminus C} \left(1 - \prod_k \frac{1}{1 + e^{-(\alpha_k + \eta_k Y_{nk} S_{nik})}}\right)}{1 - \prod_{l \in M_n} \left(1 - \prod_k \frac{1}{1 + e^{-(\alpha_k + \eta_k Y_{nk} S_{nik})}}\right)} \right]$$

$$\quad \text{Eq. (3.7)}$$

## 3.3 Formulation of Utility-Based TAI

Once the parameter estimates from the transit path choice model are obtained, the TAI with respect to individual $n$ and an origin-destination pair can be constructed as follows:

1. Determine the choice set $C_n$; and
2. Compute the utility measure.

We explain the two steps in more detail below.

### 3.3.1 Choice Set Determination

The microsimulation method is used to determine the choice set for each individual. The microsimulation method determines the outcome of a discrete choice through a random draw from the choice alternatives in proportion to their predicted probabilities. In the context of determining choice sets, the method entails the following major steps:

1. Determine the feasible choice set, $M_n$, for each individual *n*;
2. Compute, according to Eq. (3.4), the probability for each feasible path $i$, $i \in M_n$, being perceived as available by each individual;
3. Using Eq. (3.5), compute for each individual the probability ($P_1$, $P_2$, …, $P_J$; $J = 2^{m_n} - 1$) of each possible choice set ($C_1$, $C_2$…$C_J$) being the choice set that the individual actually considers;
4. For each individual, generate a uniformly distributed random number ($U_n$) between 0 and 1; and
5. Select the choice set for each individual using the computed choice probabilities and the uniform random number drawn as follows:

   if $0 \leq U_n < P_1$, the choice set is $C_1$;
   if $P_1 \leq U_n < P_1+P_2$, the choice set is $C_2$;
   if $P_1+\ldots+P_{j-1} \leq U_n < P_1+\ldots+P_j$, the choice set is $C_j$;
   if $P_1+\ldots+P_{J-1} \leq U_n \leq 1$, the choice set is $C_J$.

### 3.3.2 Computation of the Utility Measure

The conventional form of the utility measure is given by:

$$\mathrm{E}\left[\max_{i \in C_n} U_{ni}\right] = \ln \sum_{i \in C_n} \exp(V_{ni}) \quad \text{Eq. (3.8)}$$

In the context of the path choice model, the logsum of the utilities represent the expected “worth” of the set of accessible transit services for the purpose of traveling between the given origin and destination. The proposed TAI is derived from the logsum measure as follows:

1. Compute, based on Eq. (3.5), (3.6), and (3.1), the utility $V_{ni}$ associated with each path $i$, $i \in C_n$, for each individual *n*;
2. Let $V_{\min}$ be the lowest utility value found for all transit paths across all individuals. Add $V_{\min}$ to all $V_{ni}$ computed in the previous step so that the lowest utility value is shifted to 0. Note that this shift in utility values does not change the choice probability associated with each path.
3. For each individual, compute the logsum value according to Eq. (3.8). Due to the shifting performed in the previous step, the term $\sum_{i \in C_n} \exp(V_{ni})$ in Eq. (3.8) is never less than 1 and the logsum value is never negative for any individual.

4. For the ease of interpretation, normalize the logsum values obtained from the previous step to a range of 0 to 1 (based on the corresponding percentile ranking) to give the final TAI values.

We can then aggregate the TAI values computed using the above procedure across a set of alternative destinations for an individual, and further aggregate the TAI values across the individuals to arrive at a generalized TAI value for the region. If data are available for estimating the parameters corresponding to different trip purposes and/or time of day, aggregation would also be possible across these two dimensions. We are developing the methods to accomplish aggregation across the various dimensions, and we will describe them in the final report.

# 4. Considerations and Development of A Dependence Index

As stated in Chapter 1, the purpose of a dependence index is to identify the potential level of transit needs, or potential patronage, in an area to aid the evaluation or justification of transit investments. The development of the TDI is based on the knowledge synthesis presented in the previous project report (5178-1). In this chapter, we present a brief summary of the knowledge synthesis in Section 4.1 and describe the proposed TDI formulation in Section 4.2.

## 4.1 Definition of Dependence

Our earlier review of literature revealed that the definition of transit dependent users varied significantly across past studies. We have summarized the definitions used in earlier studies below in Table 4.1. As shown in the table, one indicator for transit dependence that is common to most studies is the absence of vehicles in the household. Low-income households, the elderly, and the young are also popular indicators of dependence. Some studies also consider disabled individuals, minorities or recent immigrants, the unemployed or low-skilled individuals, and families whose needs cannot be met by one car as transit-dependent users.

## 4.2 Formulation of a TDI

A number of qualities are desired of the TDI formulation:

1. the index should take a value between 0 and 1, with 0 being least needy and 1 being most needy;
2. the index should be able to reflect the effect of a single indicator or the combined effects of multiple indicators of transit dependence; and
3. the index should be applicable to the disaggregate level (individual household) as well as an aggregate level (zone).

Let $o$ be the index of geographic locations, $k$ be the index of indicators or variables, and $I_{ko}$ be the derived value of indicator $k$ at location $o$ such that $0 \leq I_{ko} \leq 1$. We formally define a measure of potential need at location $o$ for transit as

$$TDI_o = \prod_k I_{ko}$$

| Study | 0-vehicles | Low income | Elderly | Young | Disabled | Minority | Employment Status | Families whose needs cannot be met by one car |
|---|---|---|---|---|---|---|---|---|
| Falocchio | √ | | | | | | | |
| Beimburn | √ | | | | | | | |
| Kendall | √ | √ | | | | | | |
| Grengs | √ | √ | √ | √ | | | | |
| McLaughlin & Boyle | √ | √ | √ | √ | | | | |
| Doxsey & Spear | √ | √ | √ | √ | | | | |
| APTA | √ | √ | √ | √ | √ | √ | | √ |
| Crepeau | √ | √ | √ | | | Recent immigrants | Unemployed | |
| Kawabata | √ | | | | | | Low-skilled workers | |
| Garrett & Taylor | | √ | | | | √ | | √ |
| Perrin | | √ | √ | | √ | | | |

**Table 4.1 Summary of past definitions of transit dependent users.**

The formulation represents the product of values derived from multiple dependence indicators. The derivation of $I_{ko}$ from the raw data depends on the nature of the indicator and the scale of the analysis. For example, if we define *o* as the residential location of a household, then $I_{ko}$ can be a binary variable, with a value of 1 indicating the absence of vehicles in the household. Alternatively, $I_{ko}$ can be a decimal value representing the percentile ranking of the household's income status relative to all households in the study area. In the aggregate case where *o* represents a zone, $I_{ko}$ can be a ratio of the number of car-less households in zone *o* to the highest zonal total of car-less households observed in the study area. Or, $I_{ko}$ can be a decimal value representing the percentile ranking of the zonal average household income status relative to all zones in the study area.

## 5. Conclusions

The policy goals of increasing transit ridership and ensuring equitable service raise the need for service delivery measures that reflect the ease with which people are able to participate in the desired activities using transit as the means of transportation. This calls for accessibility measures that are capable of reflecting both the distribution of activity centers in a region, as determined by land use patterns, and the ease of reaching activities, as determined by the transit system. The measure should also recognize the moderating effect of demographic characteristics of current and potential transit users within the notion of the "ease of activity participation."

This report has presented an individual level, utility-based TAI that can potentially incorporate the many elements constituting the local- and network-level accessibility. The TAI takes the form of a logsum measure derived from a transit path choice model with probabilistic choice set generation. The probabilistic choice set modeling approach allows for the determination of an individual's sensitivity and tolerance level to transit service quality such as access distance, wait time, and number of transfers. The TAI reflects the expected worth of transit service available for an individual to participate in an activity at a given destination. It takes a value between 0 and 1, with 0 indicating a low transit accessibility. Values of the TAI can then be consolidated across destinations, population groups, trip purposes, and times of the day.

The report has also described an index for measuring the level of need for transit service. The TDI is a function of socio-demographic characteristics of potential transit users. It takes a value between 0 and 1, with 1 being most needy. The TDI can be coupled with the TAI for assessing the supply of transit service vis-à-vis the level of demand. The combination of the TAI and TDI will allow transit agencies to identify patterns of disparity in service provision to population groups with different levels of need. It will also help track and monitor changes in transit service delivery due to shifts in the population and/or land use distribution.

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