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ACCESSIBILITY MEASURES: FORMULATION CONSIDERATIONS AND CURRENT APPLICATIONS

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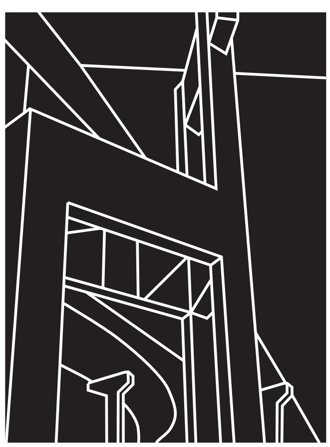

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16. Abstract

This report examines micro-scale and macro-scale factors for inclusion in an ideal accessibility measure. Their potential influence on the evaluation of mode choice and destination choice is discussed. Availability in Texas' major cities is presented, as well as the subjective nature of the factors. In addition, an evaluation of accessibility measures currently in use is presented.

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by

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CHAPTER 1 – INTRODUCTION

Insufficient transportation funds for desired projects, combined with increasing traffic-related concerns in many urban areas, has led to a need for a careful and systematic evaluation of the impacts of transportation projects. A measure that incorporates the attributes of the person using the transportation system, the intended activity at journey's end, and the transportation system can be useful in such a systematic evaluation of transportation projects.

The overall goal of this project is to develop an accessibility measure to characterize prevailing conditions in urban areas. This measure is intended to provide accessibility information specific to multiple levels of spatial interest, modes, activity purposes, and times of day. Both work and non-work activities, such as medical, recreational, educational, etc., are proposed to be included in the measure to be developed in the project.

A literature review, undertaken as the first task in this effort, revealed that no accessibility measure in use, or described in the literature, accommodates the multiple dimensions proposed above. Further, there is no consensus on the appropriate form of an accessibility measure, nor is there agreement on a definition of accessibility. Many measures proposed, or in use, only address accessibility issues related to employment.

In addition to accommodating different activity types, the accessibility measure proposed to be developed in the project should include alternative transportation modes. Typically, measures have relied on either coarse factors that provide a broad picture and are better suited to auto travel or fine factors that generally describe a subzonal level of spatial detail and therefore can better accommodate bike and walk modes. This distinction is referred to as macro-scale versus micro-scale in the literature.

In this second report of the project, macro-scale and micro-scale attributes of accessibility factors are identified for possible inclusion in an accessibility measure. The conceptual definition of accessibility generates these factors; it is defined as the ease with which one can reach a desired location by a given mode to pursue an activity of a desired type at a desired time. Some significant characteristics of potential factors are importance in an accessibility measure, the feasibility of inclusion in a measure, and the availability of data.

This report is structured as follows: Chapter 2 lists the attributes of the different factors considered, discusses their contribution to an "ideal" accessibility measure, and provides an indication of the availability of data at this time in Texas' larger cities (Houston, Dallas/Fort Worth, El Paso, Austin, San Antonio); Chapter 3 reviews accessibility measures currently in use in the United States and abroad; and Chapter 4 draws important conclusions from this stage of the research. Appendix A lists the personnel contacted for this phase of the project.

Section 1.1 - Definitions

This report examines the different elements of an accessibility measure. To maintain consistency throughout the document, the following definitions will be used.

Measure – an equation describing accessibility. This equation can take many forms such as a gravity accessibility measure or a utility accessibility measure.

Factor – the elements of an accessibility measure. Typically, an accessibility measure has a component related to the transportation system (referred to in this report as the impedance factor) and a component related to the trip destination (referred to in this report as the destination factor). This report will also discuss a third, traveler-related, component for an accessibility measure.

Attributes – characteristics of the factors of an accessibility measure. The factors of an accessibility measure may be described by several different attributes. For example, the impedance factor may have attributes related to different modes such as driving a car, taking transit, or riding a bicycle. Examples of attributes of the impedance factor are in-vehicle travel time, transit travel time, and bike lane width. Examples of attributes of the destination factor are number of employees, square-footage of retail space, and quality of shop goods.

CHAPTER 2 – ATTRIBUTES OF FACTORS FOR AN "IDEAL" ACCESSIBILITY MEASURE

It is important to accommodate characteristics of land use and the transportation system in developing an accessibility measure. The attributes compiled in Tables 2.1 and 2.2 have been extracted from many sources.

Accessibility measures typically have two main components. One is related to the journey to a destination. This component is often called an "impedance factor," and typically exerts a dampening effect on accessibility. Attributes that contribute to this component of accessibility are presented in Table 2.1. The other component is the destination factor and it is related to the characteristics of the destination location for activity participation. Attributes of this factor are presented in Table 2.2. Characteristics of the traveler also influence the degree of accessibility enjoyed by this individual, and are included separately in Table 2.3. The attributes of these factors capture the main aspects of the conceptual definition of accessibility described above and are listed in the rows of the tables.

Tables 2.1 through 2.3 classify the attributes of the factors as either fine or coarse. Fine attributes are commonly associated with non-motorized trips, while coarse attributes tend to be associated with motorized trips. Fine attributes are sometimes referred to as micro-scale design features and describe subzonal characteristics. Coarse attributes are sometimes referred to as macro-scale design features and describe zone-level characteristics.

Most accessibility measures in the literature contain impedance factor attributes relating only to auto and transit modes. This is primarily because of the emphasis in transportation and air quality modeling on motorized trips [*1*]. Since motorized trips are typically from zone to zone in an area, they are characterized by zonal level, or macro-scale, data. However, the need to consider non-motorized trips in urban areas is increasingly being recognized today. This trend has led to increased attention on micro-scale factors, since non-motorized trips are typically intrazonal. Many transportation modelers acknowledge the limitations of the traditional four-step modeling method that relies solely on macro-scale data related to the transportation system, and are working toward a more inclusive system that incorporates micro-scale elements related to land use and transportation. The symbiosis between land use and the transportation system is considered so important that the Environmental Protection Agency plans to release a report detailing the potential air quality credits non-attainment areas can receive based on improved land use/transportation system relationships.

Sidewalk continuity, parking availability, and pedestrian and transit amenities are examples of fine attributes of the impedance factor. Although these attributes describe a fine level of spatial detail, it is possible to aggregate the data to characterize a zone. The percentage of bus stops with shade or the percentage of sidewalks meeting the standards of the American Disabilities Act (ADA) are examples of fine attributes aggregated to the zonal level. The fine attributes listed in Tables 2.1 through 2.3 were extracted from the literature. Those in Tables 2.1 and 2.2 generally relate to three qualities that influence the evaluation of travel options and are grouped accordingly. These are safety, convenience, and aesthetics. In addition, several impedance-related attributes describe the comfort quality of travelling.

The columns of the tables indicate three other aspects of the attributes compiled. One aspect is the mode that the attribute influences. Some attributes, such as connection to other modes and area crime, affect all modes. Others, such as bike racks on the bus and sidewalk continuity, affect a subset of modes. Another aspect of the attributes indicated in the columns of the tables is the degree of subjectivity. Although bike lane width is easily measured, the adequacy of lighting is not. Also, what is adequate for one person may not be for another. Some data can be measured objectively but may have a subjective interpretation by an individual. To indicate this aspect, attributes are rated on the degree of subjectivity: low, medium, and high. The third aspect of the attributes described is the availability of the information listed in the rows. This is classified into easy, medium, and hard to acquire. Data rated easy have already been collected and are readily available. Data rated medium may have already been collected; however, it may be dispersed among different departments or agencies in an area. Finally, data rated hard are not collected at this time. Due to attention on the air quality benefits of certain land use/transportation system relationships, larger Texas urban non-attainment areas are likely to start collecting relevant data in the near future.

The availability of data was determined by contacting appropriate personnel in the major cities of Texas – Houston, Dallas/Fort Worth, El Paso, San Antonio and Austin. Data availability is typically confined to the limits of the relevant agency, e.g. city or transit authority. Contact information for the local authorities interviewed is provided in Appendix A.

The next three sections describe the attributes identified in more detail. The next section explains the attributes related to impedance. This is followed by a section on destination attributes and finally a section on the traveler attributes.

Section 2.1 – Impedance Attributes

This section discusses the attributes of the impedance factor that a traveler may take into consideration when evaluating travel choices. Attributes of the impedance factor listed in Table 2.1 are broadly classified into fine and coarse attributes. As discussed above, the factors characterized as fine represent spatial characteristics at the subzonal level. These fine attributes are further divided into four categories: safety, convenience, comfort, and aesthetics. Potential safety concerns for travelers include crashes and crime. Personal safety is most closely related to walk and transit modes. Convenience attributes relate directly to the conceptual definition of accessibility in that it is a measure of ease to pursue an activity. Comfort and aesthetics are two areas that may enhance or detract from the characteristics of the other categories. For example, the lack of shade at a bus stop may detract from the convenience of it being a short distance from a traveler's origin and destination. A scenic path may make walking attractive despite the greater travel time.

Table 2.1 - Some Attributes to Include in an "Ideal" Accessibility Measure – Impedance

Spatial Level	Dimension of Accessibility	Attribute	Mode Effect				Degree of Subjectivity	Availability
			Ped.	Bike	Transit	Auto		
Fine	Safety	**Lighting**	√	√	√	√	High	**Hard**
		Area crime	√	√	√	√	High	**Medium**
		Number of stop signs	√	√		√	Low	Easy
		Speed limit	√	√		√	Low	**Easy**
		Street width	√	√		√	Medium	Medium
		Pavement condition		√		√	Medium	**Hard**
		Debris and trash on road	√	√	√		Medium	Hard
		Bike lane continuity		√	√	√	Low	Easy
		Bike lane width	√	√		√	Low	Medium
		Sensitivity of lights to bikes		√			Low	Easy
		Sidewalk continuity	√	√	√		Low	Hard
		Length of "Walk" signal	√				Low	Medium
	Convenience	Connections to other modes	√	√	√	√	Medium	Medium
		Parking availability			√		Medium	Easy
		Service frequency			√		Medium	Easy
		Transfers required			√		Low	Easy
		Bike racks on the bus		√	√		Low	**Easy**
	Comfort	Shade on walkways	√				Medium	Hard
		Shade at bus stop			√		Medium	Hard
		Bench at bus stop			√		Medium	Easy
		Topography	√	√			High	Easy
	Aesthetics	Scenery	√	√			High	Hard
		Signage	√	√	√	√	Medium	Hard
Coarse		IVTT Peak			√	√	Low	Easy
		IVTT Off-peak			√	√	Low	Easy
		OVTT Peak			√	√	Low	Easy
		OVTT Off-peak			√	√	Low	Easy
		Cost	√	√	√	√	Low	Easy

Section 2.1.1 – Safety-Related Attributes

The first broad category of attributes in Table 2.1 describes safety-related qualities affecting impedance. The two main attributes affecting all modes are lighting and area crime. Trips beginning or ending before dawn or after twilight are influenced by these conditions. The influence distinguishes between the relative quality of modes. For example, poor lighting conditions make walking and biking difficult and potentially harmful; therefore, auto-use may be positively influenced. The adequacy of lighting is a subjective attribute that is difficult to quantify, while area crime can be objectively assessed from local crime statistics. However, the ability to characterize an attribute objectively does not account for perceptions about how safe a traveler feels.

The next few safety attributes represent elements of the general transportation system. The presence of stop signs acts to slow traffic and provide safe crossings for pedestrians and bicyclists. Similarly, speed limit on a street may create safety or harm for non-motorized travel. Pavement condition and the amount of debris in the roadway are other attributes that can be measured objectively, but may have subjective interpretations by travelers. The presence of potholes and debris in the road may negatively influence biking in the traveler's evaluation of it as a travel option. One attribute related to all the modes is street width. Narrow streets and large cars may contribute to higher travel impedance for travelers. Wide curb lanes may make traveling by bicycle more comfortable. If there is no sidewalk the curb lane may have to accommodate all travel – motorized and non-motorized.

Finally, under fine safety attributes are those related strictly to the non-motorized modes. These attributes characterize the extent and quality of bicycle and pedestrian elements of the transportation system. When a traveler is evaluating mode options, safety attributes may affect the attractiveness of the bike and pedestrian modes. These modes are safer when there is separation of facilities, such as bike lanes and continuous sidewalks, and appropriate interfaces with roads, such as lights sensitive to bikes and "walk" signals long enough for pedestrians to cross a facility. This information can all be objectively measured; however, it is not readily available with the metropolitan planning organizations of Texas cities.

Section 2.1.2 – Convenience-Related Attributes

The next large category of fine attributes of the impedance factor is convenience. Connection to other modes is the primary factor in this category that affects all modes. The ease of parking at a "Park and Ride" lot or the proximity of a transit stop to a bicycle lane may influence the attractiveness of a multi-modal trip. One attribute related to the ease of driving alone is parking availability. Parking availability may influence how people evaluate mode as well as destination choices. These are all attributes that can be measured objectively but may be perceived differently by different people.

Within the convenience dimension of the impedance factor are several attributes related to the transit mode. The frequency of service, necessity of a transfer and availability of bike racks may all contribute to a person's evaluation of transit.

Section 2.1.3 Comfort-Related Attributes

The third main category of fine impedance attributes is comfort. The only easily measured attribute here is the presence of a bench at a bus stop. Shade is an important factor in Texas, but difficult to assess especially over the course of a day.

Section 2.1.4 Coarse Attributes

The coarse attributes corresponding to impedance characteristics refer to level-of-service characteristics such as zone-to-zone travel times and costs. These zone-to-zone travel times and costs are estimated routinely for the auto mode by metropolitan planning organizations, and are usually available for the peak and off-peak periods. Some areas have also estimated these attributes for transit.

Section 2.2 – Destination Attributes

Attributes that describe a destination fall into three main categories: safety, convenience and aesthetics. Each of these attributes is discussed the following three sections.

Section 2.2.1 – Safety-Related Attributes

The attributes listed in Table 2.2 under safety actually affect all the elements of a trip to a destination. These attributes are lighting and area crime. Perceived safety can enhance or detract from other elements in the conceptual definition of accessibility – what activity to pursue, when to pursue it and by what mode.

Section 2.2.2 – Convenience-Related Attributes

Many of the attributes that contribute to the convenience of an activity constitute the core of the attractiveness of a destination in an accessibility measure. The Americans with Disabilities Act (ADA) access attribute reflects a level of convenience that affects a larger population than the physically challenged. Ramped entrances are also convenient for elderly people and parents with strollers. Hours of operation as an attribute of accessibility was first proposed by Hagerstrand [*2*] in the construction of time-space prisms.

A traveler wishing to pursue a variety of activities may evaluate available choices based on store size, the variety of shops in a shopping center, or the land use mix of a potential destination. These attributes can be measured objectively, but their importance in evaluating destination options may vary among travelers.

Table 2.2 - Some Attributes to Include in an "Ideal" Accessibility Measure – Destination

Spatial Level	Dimension of Accessibility	Attribute	Mode Effect: Ped.	Bike	Transit	Auto	Degree of Subjectivity	Availability
Fine	Safety	Area crime	√	√	√	√	High	Medium
		Lighting	√	√	√	√	High	Hard
	Convenience	ADA access	√	√	√	√	High	Hard
		Variety of shop goods	√	√	√	√	High	Hard
		Hours of operation	√	√	√	√	Low	Hard
		Variety of shops	√	√	√	√	High	Medium
		Land use mix	√	√	√	√	High	Medium
		Store size	√	√	√	√	High	Medium
		Setback from sidewalk	√	√			High	Medium
		Parking cost	√	√	√	√	Medium	Medium
		Parking availability	√	√	√	√	Medium	Medium
		Access to different modes	√	√	√	√	Medium	**Medium**
	Aesthetic	Atmosphere	√	√	√	√	High	Hard
		Customer recognition	√	√	√	√	High	Hard
		Locally owned	√	√	√	√	High	Medium
		Interior design	√	√	√	√	High	Hard
		Quality of shop goods	√	√	√	√	High	Hard
		Site design	√	√	√	√	High	Hard
Coarse		# employees/SIC code			√	√	Low	Easy
		Square footage/SIC code			√	√	Low	Easy

Table 2.2 cont.

Whether a patron can easily enter a destination from the sidewalk, or if s/he must cross a large parking lot, may also affect its attractiveness as an option. From the point of view of a driver, the availability and cost of parking may be part of the decision matrix when evaluating destination options.

The last attribute of convenience of a destination is related to access to different modes. The choice of modes available at a destination may make that destination a more attractive option.

Section 2.2.3 – Aesthetics-Related Attributes

While the safety and convenience dimensions in Table 2.2 are related to destination attractiveness in obvious ways, aesthetics are the elusive core of how a destination may be evaluated. Previous research has found atmosphere of a store to influence attractiveness, but this is highly subjective and consequently difficult to characterize [*3*]. The availability of a particular good may be a deciding factor for a destination. Familiarity between employees and customers may breed a loyalty that is beyond the description of safety and convenience. These attributes are highly subjective and hard to measure.

Number of employees or square footage by type has typically been used as the only attribute for this factor in accessibility measures. This information is typically gathered at the zonal level.

Section 2.3 – Traveler Attributes

Socio-demographic characteristics that describe travelers are generally included in transportation modeling, but are rarely included in accessibility measures. Yet these characteristics influence what opportunities are available and what importance is placed on them. Perception of ease or difficulty influences both modes and destinations. Attributes such as age and car availability are important elements in determining accessibility to activities. The attributes listed in Table 2.3 may potentially influence demand for activities at destinations and accessibility to activities. Current transportation data collection methods request many of the attributes listed in Table 2.3. Attributes that may influence accessibility that are not collected, or hard to collect, include lifestyle preferences and activity needs.

Table 2.3 - Some Attributes to Include in an 'Ideal' Accessibility Measure – Traveler Attributes

Spatial Level	Dimension of Accessibility	Attribute	Mode Effect				Degree of Subjectivity	Availability
			Ped.	Bike	Transit	Auto		
Fine		Car availability	√	√		√	Low	Hard
		Ethnicity					Medium	Hard
		Household income	√	√	√	√	Low	Hard
		Gender	√	√	√	√	Low	Hard
		Time availability	√	√	√	√	Low	Hard
		Work status	√	√	√	√	Low	Hard
		Children	√	√	√	√	Low	Hard
		Age	√	√	√	√	Low	Hard
		Handicap	√	√	√	√	Low	Hard
		Lifestyle preferences	√	√	√	√	High	Hard
		Activity needs	√	√	√	√	Low	Hard
Coarse		Average income	√	√	√	√	Low	Easy
		Average household size	√	√	√	√	Low	Easy

A wide variety of attributes of factors may be involved in the evaluation of mode and destination options. This evaluation process is also influenced by individual characteristics. Therefore, the perception of accessibility can vary among individuals at the same place desiring to undertake the same activity by the same mode.

CHAPTER 3 – CURRENT APPLICATIONS OF ACCESSIBILITY MEASURES

Due to the difficulty in obtaining data on fine attributes and due to different purposes for which an accessibility measure has been developed, most accessibility measures found to be currently in use rely on coarse factors. In the next few sections, we briefly discuss the objective for the development of accessibility measures and the type of measures being employed in different parts of the world.

Section 3.1 – Use of Accessibility Measures in Europe

In the Netherlands, concern regarding increased automobile use has motivated the national transportation department to develop a method to increase coordination between transportation and land use planning. The initial target is work trips, and the first step is evaluation of employment sites. Specifically, the transportation needs of employees and clients of large employment centers are evaluated. For example, a business that relies on a large amount of truck traffic is more conveniently located near a major roadway, while a business with a large number of commuting workers may find a location near several public transportation nodes a better match. At this time the results of a pilot study are being evaluated [*4*].

Specific policy guidance in the United Kingdom has motivated the development of accessibility measures. As part of its sustainability policy, the United Kingdom requires all areas to create "accessibility profiles" [*5*]. These profiles should indicate the accessibility offered by public transportation to housing and employment. There is no further guidance regarding the development of a measure and different areas are pursuing different methods. Available literature on a computer model that is available does not specify the type of accessibility measure used, but gravity- and cumulative opportunities-type accessibility measures appear to be the ones in use [*6*].

Section 3.2 – Use of Accessibility Measures in the United States

In the United States, the main motivation for calculating an accessibility measure is to evaluate transportation systems [*7*]. Only two areas in the United States, that we are aware of, currently have an accessibility measure that is used regularly to assess the condition of the transportation system. In Oregon, accessibility is one of seven criteria used to evaluate projects [*8*]. The type of measure used is based on utility theory with accessibility defined as the mode choice model's logsum, divided by the in-vehicle travel time coefficient [*9*]. Decision weights then permit ranking of various projects. In Albany, New York, accessibility is used as a performance measure. Travel time between representative locations, such as major intermodal facilities, during peak and off-peak hours is used as the accessibility measure [*9*].

Other areas in the United States have investigated accessibility measures, and even have conducted case studies; but they have not included them as regular performance measures or as project evaluation tools. One example is the Southern California Association of Governments (SCAG), which is considering a cumulative opportunities measure based on employment. The accessibility of an area would be determined by the percentage of jobs available within a certain travel time. Some of the shortfalls of this measure include the following: the treatment of all jobs as equal, possibly skewed results from zero-time work trips, and the generic limitations of only assessing accessibility to employment.

As in Southern California, the accessibility measure used in an Albuquerque, New Mexico, case study concentrates on employment accessibility. In this case, two employment centers are considered and the percentage of people that can travel to these is used as the measure. Contours indicate these percentages. In addition, the State of Florida is considering the use of an accessibility measure for its highways. Corridors have been highlighted for consideration.

Several areas have indicated an interest in using accessibility as an evaluation tool for their transportation systems. However, due to data constraints and varying purposes, measures that use macro-scale factors and a narrow definition of attractiveness are currently in use.

A summary of the performance goal, form of measure and data requirements are presented in Table 3.1.

Table 3.1. - Summary of Applied Accessibility Measures – 7/2000

Where	Performance Goal	Form of Measure	Data Required	Comments
Netherlands (pilot completed)	• Mode choice • Facilitate participation in non-work activities • Characterize conditions for economic growth	Network distance Subzonal	• Distance to public transportation node • Headway • Distance to arterial road • Distance to ramp exit	Transportation needs of businesses and clients are matched to accessibility profiles of places
United Kingdom	Increase sustainability – via accessibility to public transportation	Subzonal	• Walk time to public transportation stop • Average wait time for service • Travel time by public transportation, zone-to-zone • Walk time to destination	• Local accessibility measures access to public transportation • Network accessibility measures access to specific destinations (e.g. hospital, sports arena)
Oregon	Measure performance of the transportation system	Logsum (expected maximum utility)	• In-vehicle travel time • Out-of-vehicle travel time • Fare • Parking cost • Operating cost • Distance	Logsum is divided by β_{IVTT} to estimate equivalent minutes of in-vehicle travel time
Albany, NY	Assess congestion management system	Network distances	Travel time between representative locations; peak vs. non-peak by quickest mode	Measure is travel time between representative locations
Albuquerque, NM (case study)	Track congestion to major employment centers	Travel-time contours	Peak travel time	
Florida (recc.)	Mobility measure for corridors	Network distance	Household distance to state highway system	
Southern California Assoc. of Governments (recc.)	Track access to employment	Cumulative opportunities	• Number of jobs • Travel time	

CHAPTER 4 – CONCLUSIONS

Metropolitan areas around the world are investigating alternative ways to evaluate the effectiveness of their transportation systems. In many cases they are using or considering accessibility measures. However, the desire to use such measures is tempered by the availability of information. No area is regularly collecting the detailed information needed for the development of a comprehensive accessibility measure. As the relationship between transportation and land use becomes a part of air quality improvement plans, some areas may begin collecting detailed accessibility-related data.

Several sources have acknowledged the impact, or potential impact, of the measures listed in Tables 2.1 – 2.3. However, the reality today is that only data for the coarse measures are usually available.

Graphic presentation of data via a geographic information system program may provide an opportunity to demonstrate the influences of some micro-scale features. For example, steep grades could be represented as more highly impeded routes for pedestrians and bicyclists than flat routes. For areas that may have data regarding shade availability, this amenity may be displayed graphically. Features such as rivers and highways that cannot accommodate pedestrian or bicycle crossing could be represented as barriers on a mode-specific map.

There are several reasons that micro-scale design features should be included in a measure that attempts to characterize the relationship between land use and the transportation system. First, these fine features influence the evaluation of destination and mode options [*3*]. Transportation models that use only coarse features are unable to accommodate such effects. Second, soon certain land use-transportation system combinations may allow areas to claim air quality credits. Third, micro-scale design factors describe and define elements of the transportation system specifically related to non-motorized travel. As the amount of non-motorized travel increases in urban areas, it will become increasingly important to accommodate micro-scale design factors.

While other demands for increased information about land use and transportation systems may make more detailed data available some time in the future, primarily coarse level data is available at this time. Since this research is intended to provide a measure that allows comparison between different cities, any measure developed will have to accommodate the area with the least amount of detailed information available. Although an accessibility measure that includes micro-scale design features may be the most descriptive of an area, the ultimate goal of this research necessitates reliance on macro-scale data. Therefore, the goal of this research is to develop an accessibility measure that uses data that are currently available, but may incorporate micro-scale data as they become available.

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