Research Plan

1. Statement of the Problem

"An experienced Australian traveler once said that on business trips to Australian cities he could reckon to make four meetings in a day," writes Thomson (1977:48). "In Europe he could manage five; in the United States he could manage only three." The reason behind the variations in this traveler's itineraries was not an American propensity for long meetings, or the speed of travel in American cities, which is in any case faster than in Western Europe or Australia (Kenworthy and Laube 2002). Instead, his schedules were determined by the great distances—and hence long travel times—separating his business contacts in metropolitan areas of the United States. What the traveler wanted was interaction in the form of personal contact with the people with whom he did business. The speed with which he was able to travel was relatively unimportant to him; much more central was the amount of interaction he could accomplish in a given time.

This traveler was unwittingly expressing a view of transportation policy based in accessibility, in contrast to the mobility-centered view so dominantly reflected in current policy and in the physical form of the built environment in American metropolitan areas. Transportation planners and decision makers lack tools and data to evaluate the accessibility performance of metropolitan regions, and as a result rely instead on traditional measures of mobility. We contend that a shift from mobility to accessibility as the primary criterion by which transportation policy is evaluated is a necessary step towards sustainability in the transportation system, and by extension, in policy toward the built environment generally.

This project will support such a policy shift by developing and estimating—for the first time—measures of accessibility that will enable a meaningful comparison between multiple metropolitan areas of the United States. An outcome of the research will be a new method—in the form of indicators that can be analyzed both within and between regions—by which to gauge the progress of policy on infrastructure and the built environment toward sustainability.

Transportation and the Built Environment

That transportation systems and policy are central to environmental outcomes is hardly a matter of dispute. The domestic highway transportation system accounts for a significant share of criteria pollutants emitted, including 44% of carbon monoxide emissions, 33% of nitrogen oxides, and 25% of volatile organic compounds (Federal Highway Administration 2003). In addition, the transportation sector is responsible for 27% of U.S. greenhouse gas emissions (Environmental Protection Agency 2006). But the threat of the transportation system to sustainability is not limited to effects on the atmosphere. Low-density, auto-oriented metropolitan development patterns lead to high amounts of impervious surface per capita, which in turn increase non-point-source pollution of surface water. These development patterns consume land at a rapid clip, with a number of metropolitan regions growing in surface area at a rate many times their rate of population growth. The equity impact of these development forms is observable in the relative inaccessibility of the poor in regions that offer few reasonable transportation alternatives to auto ownership. And the human cost of a mobility-centered infrastructure is significant. Roadway fatalities per million population in the United States are the third highest of the 29 nations of the Organization for Economic Cooperation and Development and occur at nearly three times the rate of the Netherlands (Organization for Economic Cooperation and Development 2006).

Technological advances have dramatically reduced—and will continue to reduce—the impact of each mile traveled on the atmosphere. But these approaches, while central to mitigating transportation-based emissions, are insufficient in and of themselves as a policy for sustainable mobility. Continuing rapid growth in vehicle miles traveled (VMT) threatens to dampen or even swamp technological gains. The number of VMT has grown unremittingly in response to land-use patterns that demand ever-increasing mobility to reach the ordinary destinations of an ordinary day. Notwithstanding gains made from improvements in technology of fuels and vehicles, increasing VMT will inexorably tend toward higher levels of air pollution and other environmental impacts. This fact makes land-use patterns central to longer-term environmental policy making. Moreover, the implications of the transportation system for sustainability reach far beyond the realm that can be treated by improved vehicles, roads, or energy sources alone. The water-quality, social-equity, and land-consumption impacts of the status quo in metropolitan development would hardly be mitigated through a shift to energy-efficient and non-polluting vehicles (Sperling 1997).

A more inclusive view of transportation sustainability is hence needed. One candidate analytical approach seeks to link individuals' travel behavior to the characteristics of the built environment. Scholars working under this approach hypothesize that areas that are developed in a fashion that is compact, mixed use, and safe and amenable for pedestrians and cyclists will influence people's travel behavior toward less driving, and more transit use, cycling, and walking. Ancillary benefits in physical activity, health, and obesity mitigation have also been asserted. If this causal link can be established, these scholars reason, then policy makers will have the support they need for advancing different development directions for the built environment. Planning for "smart growth" would enjoy a legitimacy rooted in the proven mitigation of environmental and other harms.

In this vein, researchers have attempted since 1970 to determine the precise nature of the causal link between the built environment and people's travel behavior (e.g, Lansing et al. 1970, Cervero 1989, Boarnet and Crane 2001). But the connection has proven surprisingly elusive. Experimental designs—under which a randomly selected control group would live and travel in auto-oriented regions, and an experimental group might inhabit compact neighborhoods—are generally impossible in this arena. Without this experimental capacity, researchers have relied on quasi-experimental designs in which real-world variability is controlled statistically. As a consequence, conclusive evidence on the relationship has been hard to come by, and policy makers are, in effect, advised to await further study before taking action. An early study (Gilbert and Dajani 1974, 275) concluded that "the extent to which urban form influences transportation energy usage and the possibilities for using transportation policy as a land use control…are complicated and perhaps not subject to definitive answers, and thus we are led to the all-too-common conclusion that more research is needed." After nearly three decades of increasingly sophisticated research using ever improved datasets, statistical methods, and techniques for geographic analysis, Boarnet and Crane (2001, 14) reached nearly the same results: "Our conclusion is not that urban design and transportation behavior are not linked, or that urban design should never be used as transportation policy. Rather, we conclude that we know too little about the transportation aspects of the built environment…."

While the search for greater knowledge in the land-use/travel-behavior connection will continue unabated, policy in the realm of transportation, sustainability, and the built environment will be made for the foreseeable future under conditions of distinct uncertainty. Policy makers and public officials do not have the option of waiting until behavioral science provides reasonable certainty on how the built environment affects travel, because policymaking in the realm of transportation and the built environment is continuous and unavoidable: transportation systems are planned and built, land is regulated and developed, and the built environment—with all its implications for sustainability—is produced. Moreover, the built environment is rapidly regenerating and expanding; of the buildings in existence in the year 2030, 50% will have been built after 2000 (Nelson 2004). Notwithstanding the uncertainty in the science of travel behavior, the relationships among transportation, the built environment, and sustainability are too vital and urgent to ignore. The predominant travel-behavior approach to linking this relationship to policy has proven inadequate, leading us to seek a new direction.

Accessibility and Sustainability: Reductions in Vehicle Miles Traveled is Not Enough

In this environment of scientific uncertainty, the concept of accessibility (Hansen 1959, Handy and Niemeier 1997) offers an alternative basis for sustainability policy regarding the built environment (Kwok and Yeh 2004). Accessibility can be defined as the "ease of reaching destinations," as opposed to mobility, which is the "ease of movement."[1] Where destinations are nearby, high accessibility can be provided even with low mobility (as the Australian business traveler found in the compact cities of Europe); conversely, where origins and destinations are spread broadly, even great mobility does not ensure high accessibility. The two concepts can be readily distinguished through an understanding of the meaning of a change in each: an improvement in mobility is a reduction in the time-plus-money cost of travel per mile, while an improvement in accessibility is a reduction in the time-plus-money cost per (value of) destination.

Where travel-behavior studies are subject to methodological uncertainty regarding the direction of causation, the determinants of accessibility are clear: an area is more accessible when a person can reach more destinations from it with a given time and money budget. Thus when one compares the change in accessibility of an area over time—or the accessibility of one area compared to another—the determinants can be definitively decomposed into the nature and number of the destinations reachable from that area and the characteristics of the transportation network connecting the area with others (Grengs 2004).

The power of the accessibility concept does not stem only from its capacity to rise above seemingly intractable debates over the relationship between the built environment and travel

[1] In other contexts, "accessibility" focuses on the needs of people with disability. The concept is used more broadly here.

behavior. Rather, the notion of accessibility—much more than the unidimensional idea of VMT reduction—is intimately and inherently bound up with the concept of sustainability. This is because accessibility serves the three dimensions of sustainability: environment, equity and economy. Reductions in auto trips mitigate the environmental impact of the automobile, and our national study of metropolitan accessibility will be oriented towards policy to realize these gains. Yet auto-use reductions in isolation fail to serve the tripartite goals of sustainability. For example, auto-use reductions that degrade the accessibility of lower-income people, or those that are the product of a depressed regional economy, or even those that are associated with reduced interaction within cities and regions could be considered "successes" under a simple "reduction-of-VMT" criterion.

By contrast, accessibility evaluation is inherently multidimensional. It focuses not on the austere value of travel reductions alone, but on the capacity of the built environment to offer a high quality of life while offering a range of options for travel—not just long distance auto trips. Because accessibility is always distributed differently between socioeconomic groups and geographic regions, it lends itself to equity-based analyses, and these will be central to this study. One can, for example compare the accessibility of low-income, carless residents of central cities between multiple metropolitan areas (Kawabata 2003), the relative accessibility of drivers and transit users between regions (Kawabata and Shen 2006) or the equity of the distribution of accessibility from one region to the next. The evaluation of accessibility also inherently incorporates dimensions of the urban economy, which thrives on interaction among locations within a metropolitan region. The capacity of accessibility to capture dimensions of environment, economy, and equity simultaneously makes it the crucial link between transportation and the built environment on the one hand, and sustainability policy on the other.

Accessibility and Sustainable Transportation Planning: The Inadequacy of "Congestion" as a Problem Definition

An axiom of modern transportation planning is the notion that transportation is a "derived demand" (Meyer and Miller 1984); that is, people rarely consume transportation for the pleasure of movement per se, but rather travel in order to reach opportunities available at destinations. This fundamental understanding is primarily an underpinning of travel demand analysis, which models transportation flows based on the arrangement of land use patterns across a region (Mitchell and Rapkin 1954). Despite some recent speculation that some market segments may view movement as an end in itself (Salomon and Mokhtarian 1998), the "derived demand" hypothesis remains the consensus of the field, a view supported by the preponderance of empirical evidence.

Apart from its role in land-use based travel demand analysis, the derived-demand assumption has another important implication, which transportation policy has too rarely confronted. Traditionally, the transportation planning and engineering professions have assessed their success through their ability or inability to alleviate roadway congestion. This goal is embedded in the tools used to evaluate transportation outcomes, notably "level of service," or freedom of a particular roadway link from congestion (Transportation Research Board 1985). More broadly, the Texas Transportation Institute publishes its "Urban Mobility Report" annually, analyzing congestion conditions across multiple metropolitan areas in the United States. Congestion, and freedom from congestion, are attributes of transportation links, not of individuals. As such, mobility research most typically glosses over distributional issues, in contrast to current analyses of accessibility, and those proposed in this project. And, of course, highway congestion is of little relevance to households without cars.

Apart from their neglect of distributional outcomes, these mobility-based evaluations suffer from a distinct logical flaw. Pursuit of congestion relief through added transportation capacity can induce destinations to move farther and farther apart (Transportation Research Board, 1995). A paradox can thus arise: increased mobility can actually be associated, over the long run, with more time and money spent in travel, rather than less. Travel to more remote shopping or work locations might be accomplished at a high speed, but the spread of these destinations can demand more travel than in more compact and clustered urban arrangements in which travel is slower.

If travelers do not consume transportation for its own sake but in order to access destinations, then policies that lead to increased costs per destination would be counterproductive because they would leave the travelers with less time and fewer resources to spend at their destinations. Thus a full acknowledgement of the profession's "derived demand" framework for transportation necessarily implies a rejection of "mobility" or congestion relief per se as an independent goal for transportation policy. Instead, mobility is properly seen as one means to (sustainable) accessibility. Proximity would be another.[2] Importantly, this second means holds distinct advantages in that it can support accessibility with lower energy requirements and environmental impacts.

Ultimately, accessibility gauges the potential for interaction (Hansen 1959)—the fundamental reason for the existence of cities to begin with—rather than the quality or amount of movement per se. Throughout future energy-supply shifts and environmental transitions, it is this capacity—the capacity for interaction—that must be maintained as the source for adaptation to uncertain conditions. Where mobility is the yardstick by which metropolitan quality of life is measured, these vital interactions are maintained through a vulnerable land- and energy-intensive lifestyle. This project seeks to shift transportation policy evaluation from mobility towards accessibility, under which "success" is continued, robust, and more equitably distributed metropolitan interaction combined with the potential for mitigating environmental degradation caused by our transportation system.

2. Approach/Activities

In our conceptual framework, accessibility is the critical link between sustainability and the built environment as it is shaped by land-use and transportation decisions. Because this link is multidimensional, encompassing environment, economy and equity, it is best gauged by multiple indicators. A key methodological challenge for our study, therefore, is to develop a set of accessibility measures that, collectively, can effectively support land-use and transportation decision-making at the level of the metropolitan region. These measures should also be capable

[2] A third means to accessibility would be remote connectivity (Shen, 2000). This is not considered within the scope of this project.

of explaining differences in accessibility among regions, and should be meaningful tools to evaluate land-use and transportation policies as these shape the built environment.

Developing Accessibility Measures

Over the last half a century, geographers, urban planners, and transportation researchers have developed various types of accessibility measures that are suitable for different applications.[3] These existing measures constitute a strong foundation for developing and estimating appropriate measures for our study. To provide a balanced view of each metropolitan region and to facilitate inter-regional comparison, our accessibility measures will need satisfy the following criteria:

- In combination, they need to be able to capture the key dimensions of the relationship between sustainable development and the built environment.
- Using a particular accessibility measure, the numeric outcomes for different regions must be legitimately seen as values on a common scalar and, therefore able to be compared meaningfully.
- The measures need to be easily computed using available data, and results should be unambiguously interpretable.
- The measures need to be based on data from consistently defined areas. We are interested in entire metropolitan region, and will examine territorial definitions—e.g., the census' "urbanized area"—that will allow us to make intermetropolitan comparisons.

We propose multiple measures of accessibility, each of which has strengths and weakness in capturing the phenomena of interest. The concept of accessibility incorporates dimensions of environment, economy, and equity, and these dimensions are simultaneously present in the indicators proposed below. Individual indicators may offer particular strengths that correspond to one or more of the components of sustainability policy.

Minimum Required Travel: The potential that the built environment offers for reductions in travel is central to the environmental dimension of sustainability. A useful accessibility measure that can capture the ability of a metropolitan region to adapt in response to changes in environmental conditions is "minimum required travel" (MRT). In the context of work-related travel, MRT is the minimum commuting that is theoretically required to match all workers with suitable jobs. Leaving workers at their current place of residence, this measure estimates the total commute that would arise if job locations were traded in a fashion that would minimize the total travel distance, time, or costs. If one region offers a hypothetical minimized commute less than that of another, the first region would be the more accessible, since its potential for interaction—given locations of jobs and houses—would be greater. The approach for computing the minimum commuting is illustrated by Yang (2005):

[3] See Morris, et al. 1979, Handy and Niemeier 1997, and Harris 2001 for comprehensive reviews of accessibility measures.

Minimize $C = \Sigma_i\Sigma_j C_{ij} X_{ij}$ (1)

Subject to $\Sigma_j X_{ij} = W_i$

$\Sigma_i X_{ij} = E_j$

$X_{ij} \geq 0$

where C is the total commute distance, time, or cost for the metropolitan region;
C_{ij} is the commute distance, time or cost for a trip from i to j;
X_{ij} is the number of workers living in zone i and working in zone j;
W_i is the total number of workers residing in zone i;
E_j is the total number of jobs in zone j.

To ensure that workers will be appropriately matched with jobs, both labor force and employment will be classified into occupations. Minimum required commuting will be computed for workers in every occupation, and a weighted average will be calculated for all workers.

This approach is not limited to the work trip. Rather, the minimization procedure described above can be similarly applied to estimate the minimum required travel for household retail and service activities. In addition to gauging the potential of the built environment to support reductions in travel and its associated environmental costs, this measure captures a dimension of economic activity. Transportation costs impede the economic transactions of employment and purchasing of goods and services, since they represent barriers that need to be overcome in order for the transaction to occur. Where the built environment offers potential for reductions in these costs, it facilitates economic activity by lowering the costs of transactions on which such activity is based.

Gravity-Based Accessibility: The second essential dimension of sustainable development is economic productivity. Higher economic efficiency, measured in terms of greater labor productivity, can be achieved for a metropolitan region when the effective labor market becomes larger and more diverse (Prud'homme and Lee 1999). The effective metropolitan labor market can be characterized using an appropriate measure of employment accessibility, which should be positively related to both the number of jobs located within any given travel time or cost from the workers' residence and the speed at which the transportation system enables the workers to reach these jobs. The classic accessibility measure proposed by Hansen (1959) is termed the "gravity" model because of its similarity in form to the formula for physical gravitation. The model provides a good basic approach for this purpose:

$$A_i = \Sigma_j O_j f(C_{ij}) \quad (2)$$

where A_i is accessibility for location i;
O_j is number of relevant opportunities in location j;
C_{ij} is travel time or monetary cost for a trip from i to j;
$f(C_{ij})$ is the impedance function measuring the spatial separation between i and j;
For a region with N locations (zones), i = 1, 2, ..., N, and j = 1, 2, ..., N.

The impedance function, $f(C_{ij})$, is an indicator of the difficulty of travel between location i and location j. A commonly used mathematical formula of the impedance function $f(C_{ij})$ is based on the theoretical work of Wilson (1971), and is expressed as $f(C_{ij}) = \exp(-\beta C_{ij})$, where β is an empirically calibrated parameter.

When using equation (2) to compute employment accessibility, job opportunities can be classified into occupations, and a weighted average accessibility score can be obtained for workers in all occupations. This ensures that employment accessibility indicators are based on a match between workers and potentially suitable jobs.

Greater economic efficiency can also be achieved for a metropolitan region when residents can enjoy more choices of goods and services at a given travel time or cost. Equation (2) provides a suitable basic model for measuring non-work accessibility as well, including access to retail and access to services. Given the importance of these functions, retail-service accessibility is an important indicator of quality of life in a metropolitan region. In addition, this indicator captures an important environmental dimension. Plentiful work and non-work destinations nearby would positively affect the accessibility indicators of a neighborhood, municipality, or metropolitan region. Proximity of these opportunities is the foundation that can support the pairing of reduced travel with maintenance of the interaction central to a high quality of life. Because it is an attribute of individuals and their neighborhoods (as opposed to transportation links), this indicator is also readily analyzed in equity terms as well.

Relative Accessibility: The third essential dimension of sustainability is social equity. Given the high costs of private-car ownership, the quality of the access afforded by alternatives to the automobile will be an important indicator of the fundamental fairness of the transportation system. For this reason, we will need accessibility measures that will focus on the viability of public transportation as a means for accessing jobs, goods and services. Because public transportation is less energy-intensive than the private automobile, these measures will provide yet another indication of the ability of a region to adapt under scenarios of major energy crises. To compute these measures, we will use equations (1) and (2) to calculate accessibility scores for public transportation and private auto separately. The results will enable us to identify the current accessibility gaps between these two travel modes. One specific indicator is the modal accessibility gap index proposed by Kwok and Yeh (2004):

$$MAG = (A^P - A^C) / (A^P + A^C) \tag{3}$$

where MAG is the modal accessibility gap for employment or retail-service; MAG has a value between –1 and +1, with 0 indicating no modal accessibility gap;
A^P is accessibility for public transportation;
A^C is accessibility for automobile.

Alternatively, we can measure the viability of public transportation as a travel mode by computing the percentages of workers and households that can rely on it to obtain certain levels of accessibility for employment and retail-service (Shen 1998). Possible benchmarks for these calculations include the metropolitan mean of accessibility scores and standard deviations from the mean.

To make all the results comparable across metropolitan regions, we will first use data from each region to estimate a β parameter for the impedance function in equation (2), then compute the average of these estimated β values, and finally uniformly apply the average β value to all regions. In addition, data on employment opportunities, retail-service opportunities, and location-to-location travel time will all be measured consistently in the timing of data collection and the scale of the geographic units used for data analysis.

To make the computation of these accessibility measures practical, we will select a sample of 12 to 20 large and mid-sized metropolitan regions for this study and use commonly available data. The basic geographic unit for data collection and analysis will be the traffic analysis zone (TAZ), which is typically an aggregation of census tracts or block groups. For computation of travel impedance, we will collect from local planning agencies zone-to-zone travel times by automobile and by public transit for each selected metropolitan region. For workers' residential locations, we will use census demographic data for 2000. And for employment locations, we will use either the Census Transportation Planning Package (CTPP) for 2000 or data from a private provider, such as Dun and Bradstreet.

As a product of this study, a set of accessibility scores will be computed for each of the selected regions using the measures discussed above. The regions will be compared and ranked in term of accessibility measures, which correspond to each of the key dimensions of sustainability.

Using Accessibility Measures to Inform Metropolitan Planning

To inform land-use and transportation planning at the level of metropolitan region, we must be able to explain factors underpinning the differences in the accessibility scores among the selected regions. Therefore, we will explore the connection between accessibility and characteristics of the built environment of the metropolitan regions. For this purpose, we will develop several measures of the urban form and transportation provision. Specific measures of urban form include population and employment densities, compactness and fragmentation of urban development, and land use mix. We will make use of published results for some of these measures (e.g. Ewing et al. 2002, Galster et al. 2001, Cutsinger et al. 2005), and compute the rest as part of our study.

Measures of the characteristics of transportation infrastructure and service include the availability and extensiveness of a rapid transit system (subway or light rail), the geographic coverage and frequency of bus service, and the amount of highway and road per capita. The specific forms of these measures will be determined based on available data. Efforts will be made to ensure that they are consistent across the metropolitan regions included in our study.

The connection between accessibility measures and characteristics of the built environment will be examined using simple methods of statistical analysis. We will explore the correlation between each measure of accessibility and each measure of urban form or transportation provision to identify the direction and significance of the connection. We will also use the t test and ANOVA to examine variations in accessibility among metropolitan regions grouped by urban form and transportation characteristics. In light of these statistical analyses, we will discuss the key determinants of a metropolitan region's performance in terms of various measures of accessibility.

Ideally, the relationships between accessibility and the measures of urban form and transportation provision should be quantified and statistically tested using multivariate analytical techniques, such as multivariate regression. Unfortunately, the number of metropolitan regions selected for our study is too small to allow effective application of these methods. We hope that more sophisticated analyses will be feasible in the future when our conceptual and analytical approaches become commonly adopted by metropolitan planning organizations to support their decision making. We view the current project as a step in that direction.

The comparative analyses of metropolitan regions will enable us to better understand which regions offer greater geographic equity, or modal equity, in accessibility, and what factors underpin these differences. This improved understanding will provide a solid basis for exploring desirable land-use and transportation policies for improving accessibility, which will in turn improve the prospects for sustainable development.

Data Processing and Computation

This study will involve an enormous amount of data collected in various formats from 12 to 20 metropolitan regions. To effectively facilitate the measurement of accessibility, data from different regions will be processed into consistent formats. Some utility programs will be written for data processing.

The computation of accessibility scores will require customized programs that translate our accessibility measures into executable computer codes. We will develop these application programs using the C programming language. Other data analyses will be performed using existing commercial software, including ArcGIS for mapping and SPSS for statistical analysis.

3. Expected Results, Benefits, Outputs and Outcomes

The research we propose will contribute directly to several of EPA's policy priorities: providing a quantifiable measure that informs the short- and long-term depletion of air, land, and energy resources. This work will contribute to a better understanding of economic and social dimensions of urban sustainability; explore important sources of environmental degradation by addressing policy at the regional scale; and offer an innovative tool for decision making in the face of uncertain information. We expect our research to provide insight for local public officials, nonprofit advocacy groups, scholars, and professional planners, with potential to improve EPA's policy priorities in two specific respects.

First, the results will inform current practice in metropolitan transportation planning by revealing conflicting goals between mobility-based and accessibility-based planning. Transportation planners and engineers have traditionally focused on the goal of mobility, and have only recently begun a halting adoption of accessibility as a goal. Mobility and accessibility are frequently paired as if they were co-equal goals without acknowledgment that mobility is properly seen as a means to accessibility, rather than an end in itself (e.g., CalTrans 2006; Handy 2002). Moreover, even where accessibility has been used for assessment of policy success, it has often replaced mobility measurements at the level of the individual project—for example, for a single highway link or transit line (Federal Highway Administration 2005). The problem is that at such a small scale, accessibility and mobility indicators tend to point in the same direction. By contrast, when viewed from the larger scale of the metropolitan region, mobility goals may actually conflict with accessibility goals. Steps to improve mobility may degrade accessibility by encouraging ever-increasing travel distances. Accounting for this potential effect demands measurement and comparison of accessibility at the metropolitan scale, rather than strictly at the project level. This analysis will support comparisons between metropolitan areas, and ultimately, comparisons between metropolitan areas over time.

Second, the results will fill a major gap in the current state of transportation planning scholarship. There is a view prevalent in the urban planning and transportation literature that a low-density, auto-oriented metropolitan form is also a low-accessibility form (Ewing, 1994). That is, while it may support rapid travel, it demands large investments of time and money in transportation in order to offer its residents access to their ordinary daily needs. The implications of this view would be far-reaching. A mobility-based transportation-planning logic frequently militates towards development of low-density areas that support rapid automotive travel. If these forms of development turn out to degrade metropolitan accessibility overall, there would be a transportation basis for policy reform towards sustainability in the built environment. The problem is that the assertion that low-density, auto-oriented development is a low-accessibility form has little basis in empirical analysis.

This project seeks to remedy that deficiency. Broadly speaking, compactly developed areas differ from low-density zones in two principal respects: travel distances within them are shorter (because origins and destinations tend to be more clustered), but travel speeds are lower (because greater vehicle density slows traffic). The net effect on accessibility hinges on the balance of the two: where the speed effect dominates, compact areas would be less accessible, but where the distance effect dominates, compactness in the built environment would be associated with increasing accessibility. Some preliminary work of ours (Levine et al. 2002, Shen 2004) suggests that the distance effect may in fact dominate in many circumstances, but we expect that this will vary from region to region. Under which land-use circumstances does the assertion hold that low-density urban sprawl leads to poor accessibility, and under which circumstances does it not hold?

We believe that probing this untested question is best posed within a framework of intermetropolitan comparisons of accessibility. Ultimately, we seek to accomplish for accessibility that which the Texas Transportation Institute's well-known Urban Mobility Study does for mobility: affect the terms of the debate and establish a measurable basis for policymaking at the metropolitan and intermetropolitan scale. The keen interest of the EPA in communities and the built environment represents a significant opportunity to inject accessibility—and hence sustainability—principles into transportation decision-making. The move within transportation circles toward accessibility-based transportation planning can be encouraged and accelerated with input from the EPA.

4. General Project Information

Facilities

The research will take place on the campuses of the University of Michigan, Ann Arbor, and the University of Maryland, College Park. Both campuses offer access to computer hardware and software (including campus-wide site licenses for statistical and geographic information system software); research libraries; and extensive on-line collections of journals and databases. The two institutions will offer dedicated space for the project.

Personnel Expertise/Experience

The core investigative team is comprised of established scholars and professionals in accessibility research and practice. Their descriptions and respective roles follow:

Jonathan Levine, Principal Investigator. Jonathan Levine is Professor and Chair of the Urban and Regional Planning Program at the University of Michigan. His principal research and teaching interests are at the intersection of transportation policy and land-use policy. His work seeks bases for transportation policy reform that differ from traditional concerns in congestion mitigation or proven VMT reduction. The first basis—expanded choice in transportation and land use—was developed extensively in his recent book, *Zoned Out: Regulation, Markets, and Choices in Transportation and Metropolitan Land Use* (Resources for the Future 2006). He has explored the issue of accessibility—the second basis for policy reform—in projects sponsored by the Mineta Transportation Institute (MTI) and the Floersheimer Institute of Policy Studies; these have been published by MTI and the *Journal of Transport Policy*. He will serve as the lead investigator for this project, and will be responsible for overall project direction.

Joe Grengs, Co-Principal Investigator. Joe Grengs is Assistant Professor of Urban and Regional Planning at the University of Michigan. His work examines the relationships between transportation policy and urban development patterns, with particular focus on how the suburbanization of people and jobs influences poverty concentration and social inequality. He has developed innovative techniques for measuring accessibility with geographic information systems, and has studied the social consequences of accessibility with support from the U.S. Department of Transportation, the U.S. Department of Housing and Urban Development, the Lincoln Institute of Land Policy, and the National Poverty Center. He will direct the selection of metropolitan areas for analysis, and will oversee the acquisition and processing of spatial and tabular data, and will serve as manager of quality assurance. Together with Qing Shen, he will develop and apply the measures of land-use patterns to be analyzed jointly with accessibility measures.

Qing Shen, Co-Principal Investigator. Qing Shen is Professor of Urban Studies and Planning at the University of Maryland, College Park. His research interests include urban transportation policy and metropolitan planning. Author of numerous publications in refereed journals, he has received research funding from the National Science Foundation, the New England University Transportation Center, and the Lincoln Institute of Land Policy. He has developed and applied innovative approaches to examining employment accessibility for workers who reside in different parts of a metropolitan area and travel by different modes. These approaches have been widely adopted by researchers in urban planning, geography, and other fields. He will develop the accessibility measures to be applied, and will oversee the calculation of these measures for the metropolitan areas selected. Together with Joe Grengs, he will develop and apply the measures of land-use patterns to be analyzed jointly with accessibility measures.

Carl Simon, Co-Principal Investigator. Carl Simon is Professor of Mathematics, Economics and Public Policy at The University of Michigan and Director of UM's Center for the Study of Complex Systems. His research focuses on the construction and analysis of dynamic mathematical models of phenomena in the social and health sciences, especially in the construction and estimation of critical indices such as the basic reproduction number of disease spread, measures of vaccine efficacy, the Groves-Ledyard Free Rider Mechanism in economics, and optimal presidential term lengths in political science. His research group was awarded the 1994 Howard Teman Prize for their work on estimating the contagiousness of HIV and the 2005 Kenneth Rothman Prize in epidemiology for their work on optimal disease intervention strategies. Simon is co-founder and co-leader of UM's Sustainable Mobility and Accessibility Project (SMART), an initiative to bring complex systems approaches to the study of mobility issues. He has been named The LS&A Distinguished Senior Lecturer for 2007. He will consult on the adaptation of accessibility measures to the intermetropolitan scale of the current project.

Susan Zielinski, Co-Principal Investigator. Susan Zielinski is Managing Director of SMART (Sustainable Mobility and Accessibility Research and Transformation), an interdisciplinary transportation and accessibility project of CARSS, the Centre for Advancing Research and Solutions for Society, at the University of Michigan. As founder and former Director of Moving the Economy, her practice as an urban planner has focused on collaborative development of innovative, sustainable, and integrated transportation solutions that will address the emerging challenges and opportunities of mobility (and accessibility) in growing city regions of the world. This development work includes identifying and catalyzing emerging markets for New Mobility innovations world-wide. Within the accessibility context, in1995 she wrote a chapter on accessibility entitled "Access Over Excess" in a book called "Change of Plans". In 1996, she delivered a presentation based on this original work to the OECD Environmentally Sustainable Transport conference in Vancouver. Susan will be responsible for project management, and will oversee relationships with project partners.

Ph.D. Students, University of Michigan and University of Maryland. This project will involve one Ph.D. student from each of the participating institutions. Depending on the timing of an award, students may be recruited to doctoral study at the University of Michigan or the University of Maryland.

Project Schedule

A project time line follows:

Task	Start Month	End Month	Lead Investi-

			gator
Develop Initial Workplan	1	2	Levine
Coordinate Partner Feedback on Initial Plan (see next section)	2	3	Zielinski
Selection of Metro Areas	3	4	Levine
Data Acquisition	4	16	Grengs
Processing of Travel Data	5	21	Grengs
Processing of Employment Data	12	18	Grengs
Development of Standard Data Formats	8	12	Grengs
Development of Accessibility Measures	5	12	Shen/ Simon
Programming of Routines	15	21	Shen
Develop Initial Data Summary	21	21	Levine
Coordinate Partner Feedback on Initial Data Summary	22	23	Zielinski
Calculation of Accessibility Scores	21	24	Shen
Analysis of Accessibility with Respect to Metropolitan Form	24	28	Levine
Analysis of Accessibility with Respect to Equity	24	28	Grengs
Analysis of Accessibility with Respect to Mode	24	28	Shen
Analysis of Accessibility with Respect to Location	24	28	Shen
Draft Final Report	28	32	Levine
Develop Metadata	28	32	Grengs
Develop Website for Data Dissemination	28	32	Levine
Coordinate Partner Input on Draft Final Report	33	34	Zielinski
Dissemination in journal, web, and other formats	34	36	Levine

Proposed Management/ Communicating and Sharing Data

Jonathan Levine will serve as director for the project as a whole. Susan Zielinski will be project manager. In this role, she will track adherence to project schedules and products, ensure regular communication among other investigators, and coordinate communication with the external advisory committee.

A secure website will be set up with read/write access for all investigators. In this way, data will be kept accessible throughout the research process. Monthly meetings will be held among all investigators, with off-site team members connected remotely.

Interactions with Other institutions and Organizations

To inform, enrich, and promote the work of the core investigative team, and to set directions for future work to develop the “Metropolitan Accessibility and Transportation Sustainability” project, a diverse advisory group will participate at four key junctures over the course of the project:

Initial workplan— review and recommendations
Initial data summary (mid-project)—review and recommendations
Final draft—review and recommendations
Dissemination of the concept and the report through relevant contacts and channels

Advisory Group Members

The advisory group is comprised of a wide range of local, regional, national, and international groups and agencies representing business, government, academia, and community. Several members of the group are international; we hope to build on the current project to support international comparisons of accessibility, with Canada being a likely first step.

- Eric Britton, Founder and Director, EcoPlan International and The Commons
- Mary Crass – Senior Policy Analyst, Urban, Environment, and Accessibility Issues, European Conference of Ministers of Transport (ECMT of the OECD)
- Charlotte Kahn, Executive Director, Boston Indicators Project
- William Klein, Director of Research, American Planning Association
- Xuan Liu, Data Center Coordinator, Southeast Michigan Council of Governments
- Alex Marshall, Senior Fellow, Regional Plan Association, New York
- Eric Miller – Bahen/Tanenbaum Professor, Department of Civil Engineering, University of Toronto
- SMART (Sustainable Mobility & Accessibility Research & Transformation, project of CARSS – Center for Advancing Research and Solutions for Society at the University of Michigan)
    i. David Berdish – Ford Motor Company
    ii. David Featherman, Director, Center for Advancing Research and Solutions for Society (CARSS)
    iii. Elisabeth Gerber, Director, Center for Local, State, & Urban Policy, Gerald Ford School of Public Policy
    iv. Tom Gladwin, Director, Erb Insitute, Ross School of Business Max McGraw Professor of Sustainable Enterprise; Co-Director, Erb Institute for Global Sustainable Enterprise; and Co-Director, (SMART) Project of CARSS
    v. Malcolm McCullough, Associate Professor, Alfred Taubman School of Architecture and Urban Planning
    vi. Walter McManus, Automotive Analysis, UMTRI (University of Michigan Transportation Research Institute)
    vii. Irv Salmeen, Ford Motor Company
    viii. Amy Sheon, Associate Director, CARSS
    ix. John Sullivan, Ford Motor
    x. Peter Sweatman, Director, UMTRI (University of Michigan Transportation Research Institute)
    xi. Moira Zellner, Associate Professor UIC Chicago
- Harriett Tregoning, Executive Director, Smart Growth Leadership Institute

Quality Assurance Statement

This statement describes the quality assurance and quality control practices that will guide the research project to assure that the results obtained satisfy our objectives. We address in turn each of the seven items requested.

1. *Identify Individual Responsible for Quality Assurance:* Co-Principal Investigator Joe Grengs will serve as the manager of quality assurance. He will be responsible for developing quality assurance procedures, for training staff in the procedures, and for periodically reviewing progress. He will work closely with all co-principal investigators and will report directly to the Principal Investigator.

2. *Activities to be Performed and Criteria of Data Quality*: Refer to p. 5 for the methods and techniques to be performed. The techniques will combine several sources of secondary data, including: (a) journey-to-work travel flows between Transportation Analysis Zones (TAZ) from the Census Transportation Planning Package; (b) employment data at the TAZ level from the Census Transportation Planning Package or a third party vendor; and (c) travel times between TAZs from local planning agencies.

We will assess the quality of all secondary data sources and the results of our own computations with the following criteria:

- Attribute accuracy (the closeness of nonspatial attribute values to their true values). Attribute accuracy will be determined by randomly checking against other known values in other data sets. For example, the attribute of residents in the journey-to-work flows in a TAZ will be verified against values from the 100% count of the Census of Population and Housing aggregated at a common spatial extent.
- Spatial accuracy (the closeness of the locations of the geospatial features to their true position). Secondary data will be compared to the positions of other known boundary files. Accuracy targets will conform to the Federal Geographic Data Committee's (FGDC) National Standard for Spatial Data Accuracy Test Guidelines and EPA's Locational Reporting Standard.
- Completeness (the degree to which the entity objects and their attributes in a data set represent all entity instances of the abstract universe). The population and employment data we use will be compared to other known universes from the Census of Population and Housing and County Business Patterns. Missing data will be logged and treated separately in analysis.
- Lineage (description of the origin and processing history of a data set). Metadata will be reviewed for name of the organization that produced the data so that its policies, procedures, and methods can be evaluated to see if they were biased in representing the features.

Assessments of these criteria will be conducted on a predetermined frequency and a written record maintained that documents the results of the data review. Any deviations from the data quality objectives that are discovered during the assessments will be reported to the manager of quality assurance for corrective action.

3. *Study Design*: Refer to p. 5 for the study design. The study includes no sample collections, survey questions, interviews, or new technologies. Statistical analyses will be performed on datasets developed, but no power analyses to determine sample sizes will be required.

4. *Procedures in the Methods of Analysis*: Refer to p. 5 for the procedures to be used in the methods of analysis. The study involves no new technologies or calibration of analytical instrumentation.

5. *Verifying the Accuracy of Test Measurements*: We will produce two sets of test measurements, both reported at the level of the metropolitan area. The first is a set of accessibility indicators. The accessibility indicators will be entirely new constructs and no other data at the level of the metropolitan area provide a basis for verification of their accuracy. We can, however, verify the accuracy of the accessibility indicators at the level of the TAZ by making comparisons to previous studies of individual metropolitan areas (several of the studies were authored by the principal investigators of this proposal). At least nine metropolitan areas have been studied at the TAZ level, and the spatial patterning of accessibility in these previous studies will be compared to the patterning in the measures we compute. The second set of test measurements are land use indicators. No data provide direct comparison to these measures, but several previous studies (Cutsinger et al. 2005, Ewing et al. 2003, and Galster et al. 2001) provide sufficient detail to form a basis of comparison.

6. *Procedures for Data Reduction and Reporting*: The study involves no inferential statistical methods, since the data will be based on a census, rather than sample, of their metropolitan areas. Accessibility indicators will be computed from several sources of secondary data, as noted in item 2 above, using computer programming techniques with a software package such as Microsoft Visual C++. Land-use indicators will be computed using geographic information systems (GIS) software, including Environmental Systems Research Institute's (ESRI) ArcGIS package and Geoda.

7. *Procedures for Evaluating the Success of the Project*: We have assembled an extensive set of partners representing a broad range of technical and policy-related expertise. Among their tasks are three steps to help us evaluate the success of the project: a) review and comment on the initial workplan, b) review and comment on a summary of the data computations, and c) review and comment on the draft of the final report.