



USDOT Region V Regional University Transportation Center Final Report

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**Information and Transportation Choices, Long- and Short-Term, that  
Link Sustainability and Livability**

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# Accessibility Analysis for Transportation Plans and Projects

## Introduction

Transportation plans and projects are typically evaluated, both prospectively and retrospectively, with metrics of mobility, notably highway level of service. This practice implicitly treats mobility improvements as desirable. Yet mobility improvements can induce land-use change in the form of either a spreading or a clustering of origins and destinations. Where spreading occurs, the induced land-use change can degrade, neutralize, or even reverse the accessibility impacts of the transportation investments. By contrast, where origin-destination clustering is induced, the land-use effects can enhance the accessibility impacts of the transportation investment.

For these reasons, an evaluation of transportation projects based in accessibility—which is the fundamental purpose of transportation—must first project land-use impacts of the transportation project before its impacts may be gauged. This implies a reformed transportation-planning practice that does not stop at mobility but evaluates transportation plans and projects through metrics of accessibility.

## Findings

This report demonstrates an approach to accessibility-based evaluation of transportation projects, using two plans in San Antonio, TX. Land-use impacts of the transportation plans are first modeled using TELUM, a freely available transportation/land-use model funded by the Federal Highway Administration and chosen because of its availability to transportation planners in local practice. After projecting land-use implications, auto-based accessibility to work is modeled for the two sets of transportation plans.

The first, the region's long-term transportation plan adopted in 2014, engenders significant spreading of origins and destinations compared to the no-build scenario—land-use implications that are forecasted to reverse any accessibility gains associated with the transportation investment.

By contrast, the land-use implications of the second plan, a series of expansions and improvements to a suburban ring road referred to as Loop 1604, are forecasted to magnify the accessibility improvements of the transportation investment by clustering land-uses compared to the no-build scenario.

## Recommendations

These analyses demonstrate that land-use implications are central to the capacity of transportation investments to improve accessibility. Evaluation of mobility in isolation threatens to assess as a transportation success an investment that failed to improve accessibility.

The analysis is presented here as a tool for planners in practice to employ. The tool takes standard mobility analyses as an input and produces an accessibility forecast. This approach can help ensure that transportation planning advance accessibility, transportation's fundamental purpose.

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# Accessibility Analysis for Transportation Plans and Projects

## Introduction

The concept of highway level-of-service (LOS) and associated mobility metrics including measures of congestion-related delays and prospective value of travel time saved (as incorporated in cost-benefit analyses) have for decades shaped the practice of transportation planning (Transportation Research Board 2010, Texas Transportation Institute, Laird et al. 2014, Weiner 2012). As recently as 2016, the Federal Highway Administration proposed a set of performance measures for the national highway system pursuant to MAP-21 legislation; seven out of the proposed eight are mobility measures, linked to vehicular speeds, whereas none are accessibility measures (Federal Highway Administration, 2016). Mobility thinking has become so ingrained within the transportation planning profession that many evaluations of transportation projects focus on mobility-related level of service without discussing the rationale or justification behind the widely accepted level-of-service measure.

The mobility-centered approach is operationalized in transportation planning's "predict-and-provide" formulation (Bannister and Button 1992) in which planners model travel flows over transportation networks, simulate the impact of future land-use and population change on those flows, and identify opportunities to improve flows through targeted expansion of capacity. In practice, this often has meant expanding highway links whose forecast volume-to-capacity ratios presage unacceptable degradation in LOS.

This planning approach has been criticized for overestimating the certainty of modeling results (Zhao and Kockelman 2002), imposing an overly narrow technical rationality on the transportation planning process (Willson 2001), and ignoring the futility of a strictly supply-based approach to transportation problems (Downs 2004, Institute of Transportation Engineers 1989). Less common is the critique of the standard transportation paradigm, with its focus on the goal of preserving and expanding mobility, rather than accessibility (Levine et al 2013). This critique argues that planning and evaluation frameworks that are not grounded in the fundamental purpose of transportation threaten to generate perverse transportation outcomes.

An accessibility-based view starts from the idea first articulated early in the 20<sup>th</sup> century (Bonavia 1936) that the demand for transportation is largely derived from people's demand to reach their destinations, rather than for the sake of movement per se. Though this view enjoys near-consensus status within the transportation professions, the fields have rarely confronted its implication: metrics of the quality or quantity of movement alone fail to gauge how well transportation is serving its purpose of accessibility. Moreover, since transportation infrastructure expansion can induce distance-increasing land-use change (Transportation Research Board 1995), mobility improvements can translate, in the longer term, into degraded accessibility when increased distances are not compensated for by improved travel speeds (Levine et al 2012).

While this outcome would be undesirable based on the accessibility perspective, it would be judged a mobility success so long as roadway delays were reduced in the process. Standard state-of-the-

practice mobility metrics can be insensitive to the accessibility outcomes of plans. The mobility framework, rather than presuming positive accessibility outcomes from mobility improvements, is quite indifferent to accessibility implications.

Aligning transportation planning with transportation's fundamental purpose thus demands a shift from mobility to accessibility as the core framework underpinning both broad plans and specific projects. In some ways, the shift is underway. Regional planning agencies have begun to evaluate alternative development scenarios on the basis of the accessibility each provides. Less common is the accessibility-based analysis of individual projects or plans; this is true of the review of specific development proposals as well as the evaluation of proposed transportation projects. Yet the shift from the regional-scenario level to the project or plan level is vital, since it is the aggregation of multiple incremental decisions that ultimately forms altered regional development patterns. In other words, operationalizing accessibility in practice depends in part on bringing accessibility-based analysis to applied transportation and land-use decisions, roles currently filled by mobility-based level-of-service or traffic-impact analyses.

This shift, in the context of land-development decisions, is the subject of a companion article (Levine et al 2017). For transportation decisions, the shift from the regional-scenario to the project level would allow planners to distinguish between transportation investments that are likely to increase accessibility over the longer term from those that may degrade it, and is the subject of this article. The distinction between these two conditions hinges on the land-use effects of the transportation investment: where a transportation investment induces greater proximity of origins and destinations (compared with a No Build alternative), the land-use impact can amplify the effect of the transportation investment in enabling accessibility. By contrast, when the transportation investment induces greater spread of origins and destinations, the land-use effect can diminish, negate, or even reverse the project's mobility-based accessibility gains. An accessibility-based evaluation of a transportation plan or project requires appropriate tools to distinguish between accessibility-enhancing and accessibility-degrading transportation investments.

This article defines and demonstrates such tools, testing them out for two transportation plans (sets of affiliated transportation projects) in metropolitan San Antonio, Texas, a rapidly growing sunbelt region in the United States. The first is the Long-Range Transportation Plan for the San Antonio metropolitan area for 2015, incorporating multiple projects throughout the region. The second is a series of expansions and improvements to a suburban ring road, referred to as Loop 1604. The analysis forecasts land-use impacts of each of these transportation plans using TELUM, a freely available transportation/land-use model funded by the Federal Highway Administration and housed at the New Jersey Institute of Technology. Impacts on future auto accessibility to employment are then gauged based on the projected land uses. The results show in both cases that taking an accessibility-based approach reveals outcomes that differ substantially from the standard mobility-based approach.

## Accessibility Evaluation of Transportation Projects

Accessibility-based analysis has made some inroads in the analysis of regional planning scenarios. Seattle, Chicago, and San Francisco metropolitan regions are among those that have employed accessibility performance measures to evaluate potential regional futures (Chicago Metropolitan Agency for Planning, 2010; Metropolitan Planning Commission, 2009; Puget Sound Regional Council, 2008). Accessibility metrics have been employed to understand the economic, equity, and multimodal performance of future regional scenarios. In particular accessibility measures have been used to understand how transportation and land-use systems facilitate or impede access to opportunities spread across metropolitan areas for particular population segments.

Regional scenario-based accessibility analysis is made easier by the fact that these future scenarios are typically “what if” possibilities rather than predicted futures. Planners are able to characterize how the future might look in terms of both land-use patterns and transportation infrastructure, and from these data, the relative accessibility performance of various scenarios can be compared.

Nevertheless, accessibility-based analysis has rarely been used for the analysis of transportation plans or projects. Technically, forecasting the accessibility impacts of transportation plans involves forecasting how a particular plan will shape both future transportation patterns and future land uses. Transportation projects can be thought to have two effects on accessibility, one short term and direct and the other longer term and indirect. Traditionally only the short-term, mobility-based impacts have been considered in transportation plan and project evaluations. The short-term impact is the reduction in travel times which increases accessibility by reducing generalized travel costs. The long term impact is from the induced land use effects, which may counteract or further enhance the short term mobility benefits (Boarnet & Haughwout, 2000).

Analysts commonly take the future spatial pattern of employment and households as fixed and exogenous, and then predict trip patterns based upon that spatial pattern. This was the case for the study area of this article. The Alamo Area Metropolitan Planning Organization has a single land use forecast for the years 2020-2040 which is not contingent on the adopted transportation plan (Alamo Area Metropolitan Planning Organization, 2015). The transportation infrastructure is then planned in response to the predicted trip patterns that result from the exogenously provided land use pattern.

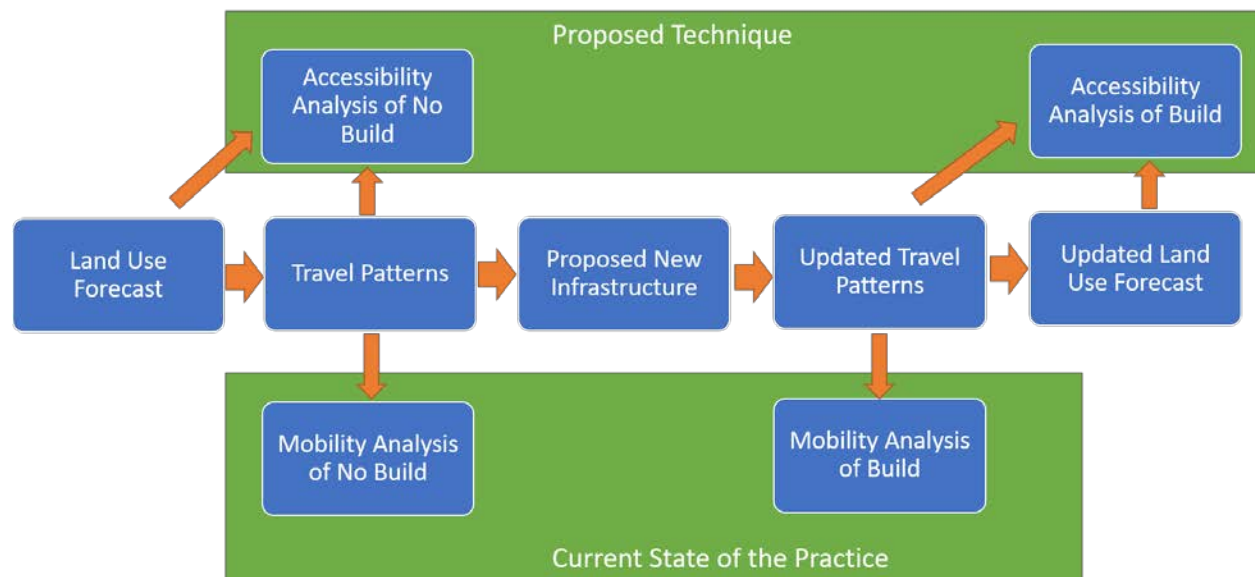
However, this common practice of assuming fixed future land uses is problematic, since the pattern of future land uses is influenced by the provision of transportation infrastructure. If new development significantly decentralizes due to new transportation infrastructure, the speed benefits may be partially or completely counteracted in accessibility terms by increasing travel distances (Grens, et al. 2010; Levine et al. 2012). An accessibility analysis of a transportation plan that does not allow for induced land-use change implicitly assumes none; analysis in this mold amounts to a mobility analysis in another form, since all mobility improvements analyzed in this fashion will translate into accessibility improvements, because land use is assumed to be unaltered by the new transportation infrastructure.

In order to ascertain the full accessibility impacts of a transportation project, a land-use forecast sensitive to the impacts of the proposed transportation plan on future land use patterns is required. The

accessibility impacts of the proposed plan or project must account for both the short term mobility impacts and the longer term land use changes.

Figure 1: Accessibility-Based Transportation Project Evaluation illustrates the method used here to address these requirements. On the bottom the current state of the practice is diagrammed, where a future land use forecast serves only as an input into describing future travel patterns. This assumes that proposed infrastructure has no role in shaping future land use patterns. The new proposed method is on the top. It assumes that the proposed transportation infrastructure will reshape land-use patterns. It builds on existing procedures of mobility-based analysis, but incorporates both changes to travel patterns and changes to land use patterns within the broader framework of an accessibility analysis.

Figure 1: Accessibility-Based Transportation Project Evaluation





## Project-Level Analysis: The Differences Between Transportation and Land Use Project Evaluation

A companion article (Levine et al., 2017) argues that project-by-project decision-making influences the majority of transportation and land-use planning decisions. It proposes a method for carrying out accessibility-based evaluation of individual projects – for the case of land-development projects – and that project-level analysis differs from the more standard regional-scenario analysis in essential ways, thus requiring specialized tools.

The key difference between regional-scenario analysis and project-level analysis is that for individual projects the interaction between transportation and land use must be *projected* into the future. The impact of transportation on land use or vice versa is accounted for in a prospective manner. The article also suggests several desirable characteristics for project-level analysis, including a capacity to assess the marginal impact of a project on regional accessibility and not just to the project's immediate area, and a technical ease of use so that transportation or land-use planners in local practice can carry out the analysis without sophisticated models or tools (Levine et al., 2017). The article presented here shares these characteristics. However, while the companion article proposed a new practical approach to accessibility-based analysis for *land-use projects*, this article focuses on the prospective accessibility-based analysis of *transportation projects*.

Accessibility analysis for transportation projects differ from land-use projects in three fundamental ways: 1) Basis of comparison 2) Scale of effect and 3) Technical requirements. The first and most central difference between project-level accessibility analysis of transportation and land-use projects stems from the nature of the decisionmaking underpinning the two. Transportation projects are generally the product of public planning and investment, an attribute that facilitates analysis because alternatives are readily identified that would form a basis for comparison. For example, the accessibility impacts of transportation project “X” may be judged in comparison with a No Build Scenario, or possibly in comparison with transportation project “Y.” By contrast, land-development investment, while regulated through public planning, is a private affair. This impedes the delineation of clear basis for comparison. In the companion paper the ambiguity of the alternative to proposed land-development projects led to the development of the accessibility-elasticity metric to establish an implicit basis of comparison. This metric is not needed in the analysis of transportation projects described here because of the readily identifiable alternative (“No Build”) against which they can be compared.

The second difference between accessibility analysis of transportation projects and land-development projects is one of scale. The companion paper demonstrated the accessibility analysis of land-development projects as small as around 200 residential units or 100,000 square feet of retail. Any land-use change whose mobility impacts can be analyzed through traffic-impact analysis can be similarly evaluated in accessibility terms. By contrast, small transportation projects (such as an intersection improvement) are not as readily evaluated for their land-use impacts; transportation projects must have a measurable impact on regional impedance in order to influence future land use patterns; as a practical matter, this means that such projects must have a discernable influence on a region’s travel demand model to have meaningful land use impacts. For this reason, this paper analyzes large groupings of

transportation projects, which here we refer to as “plans”: the 2015 Long-Range Transportation Plan for the San Antonio region, and a series of projects associated with Loop 1604, a suburban ring road.

Such regionally significant bundles of transportation projects have a discernable impact on regional measures of average household accessibility. This contrasts with land-development projects, whose accessibility impacts are likely to be a “drop in the ocean” relative to total regional accessibility. Where the accessibility-elasticity metric assisted with the problem of small size relative to the region in the land-development case, its necessity in the analysis of transportation projects is much less, and it is not used in the current study. It is in theory possible that a small transportation project with discernable land use impacts could be evaluated through an accessibility elasticity metric similar to the one used in the companion paper.

The third difference that makes the evaluation of transportation projects more challenging than land-use projects is that projecting future land-use impacts is technically more difficult than projecting future transportation impacts. For the case of land-use projects, planners and engineers can fairly readily project transportation impacts by turning to the widely available and accepted method of traffic impact analysis (Institute of Transportation Engineers, 2010). By contrast, for the case of transportation projects, practitioners have no standard or convenient method for projecting land-use impacts. Projecting land-use impacts typically requires complex software tools and a range of data – often including parcel-level land categories and small-scale employment – that are not easily within reach of most local and even many regional transportation or land-use planning agencies.

### Examples of Accessibility-Based Transportation Project Analysis

We evaluated the peer-reviewed literature for similar project-level analysis by examining it along three dimensions. First, does it analyze a specified bundle of transportation projects? This is the criteria by which we distinguish project-level analysis from scenario analysis. Second, is it a prospective analysis? That is, is the analysis of accessibility impacts a forward-looking evaluation of the impacts of the proposed set of project? Retrospective analysis is of interest for researchers but is not useful for the evaluation of proposed transportation projects in practice. And third, are induced land use impacts forecast? In order for a method to be useful for the prospective accessibility-based evaluation of transportation projects, it must meet all three of the above criteria.

We found a small body of work that examines the impacts of large transportation infrastructure projects on accessibility (Gulhuan 2014; Geurs 2012; Gjestland 2012; Fan 2010). However almost all of these papers examine only the mobility effects of the transportation projects they analyze (see Table 1 below). In other words, these analyses assume there is no induced land use change, only improvements or changes to travel times. This is a very limiting analysis, because if only mobility effects are accounted for any transportation project that improves speeds will be by definition accessibility enhancing.

Geurs (2012) is a rare example of a prospective analysis for the accessibility impacts of a transportation project that includes anticipated impacts to land use change. This study employs a land-use model to forecast variation in employment locations as a result of the proposed transportation projects and thus exemplifies an approach to accessibility-based transportation project analysis proposed in the present

article. The goals of the present article are similar but include the demonstration of the general applicability of accessibility-based analysis to transportation projects and the illustration of the consequences of this approach by directly contrasting how accessibility and mobility analyses can lead to divergent results.

Table 1: Literature on the Prospective Accessibility Analysis of Transportation Projects

Author Year	Project Level	Prospective	Land Use Forecast
Gulhan 2014	X	X	
Bocajero 2014	X		
Hensher 2014	X	X	
Stepniak 2013	X		
Bocajero 2012	X		
Kilby 2012		X	
Geurs 2012	X	X	X
Gjestland 2012	X		
Tiwari 2011	X		
Curtis 2011		X	
Fan 2010	X		
Bertolini 2005		X	
UK 2005	X		
Gutierrez 2001		X	
NHCRP 398	X	X	

## Data and Methods

We selected the San Antonio, Texas metropolitan area, also known as the Alamo Area, for analysis because it is a fast-growing metropolitan region with significant investment planned in new roadways. According the Alamo Area's long range transportation plan, the Alamo Metropolitan Area expects growth from a population of 2.0 million in 2010 to 3.4 million by 2040 (Alamo Area Metropolitan

Planning Organization, 2015). Employment is likewise expected to grow rapidly from 0.9 million jobs in 2010 to 1.7 million by 2040. Figure 2 illustrates the current employment density in the 5-county metropolitan region, with employment centers located in historic downtown San Antonio as well as in a band along the northern suburbs. The metropolitan San Antonio region embodies a strong decentralization trend, with the highest population and employment growth in recent years occurring in suburban locations and along major highway corridors.

We analyze two sets of transportation projects for their accessibility impacts. The first set of projects is the region's long-term transportation plan adopted in 2014, known as "Mobility 2040" (Alamo Area Metropolitan Planning Organization, 2015). Note that we only consider effects of the plan for the period from 2010 to 2020. The goals of the plan are typical for a metropolitan long range transportation plan, and include decreasing traffic congestion, improving public transit, mitigating environmental impacts, supporting economic growth, improving safety, and coordinating with local land use plans. The 25-year plan includes a total of \$17.2 billion in transportation funding for operations, maintenance, safety improvements, and roadway expansions. Approximately \$2.1 of this total is applied to roadway expansions. A map of the proposed roadway expansions is included below in Figure 3.

The second set of transportation projects is a series of transportation improvements along San Antonio's outer loop known as "Loop 1604." Loop 1604 is in most locations a 4-lane expressway with frontage roads running parallel. The Loop 1604 projects primary consist of expansions from 2-lane to 4-lane expressway in select locations, with occasional expansion to 6 lanes. The Loop 1604 projects are displayed below in Figure 4.

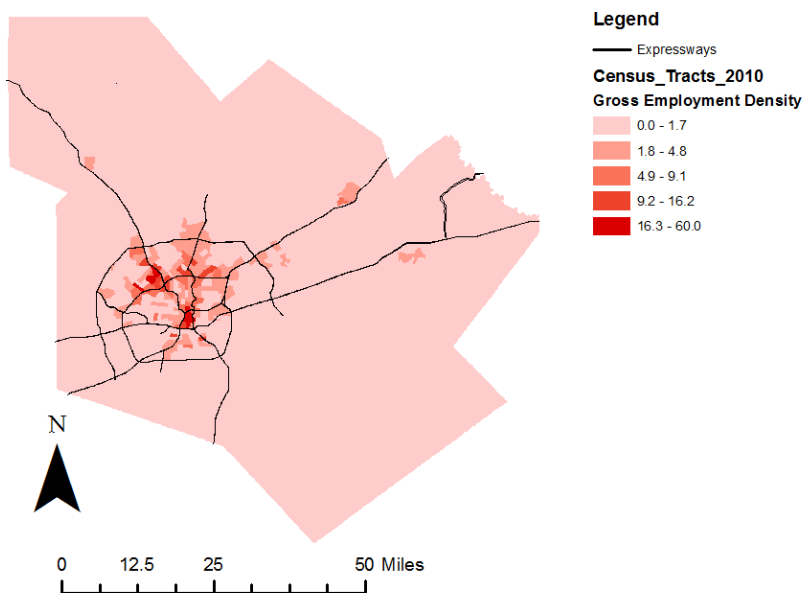


Figure 2: Employment Density for Alamo Region, 2010

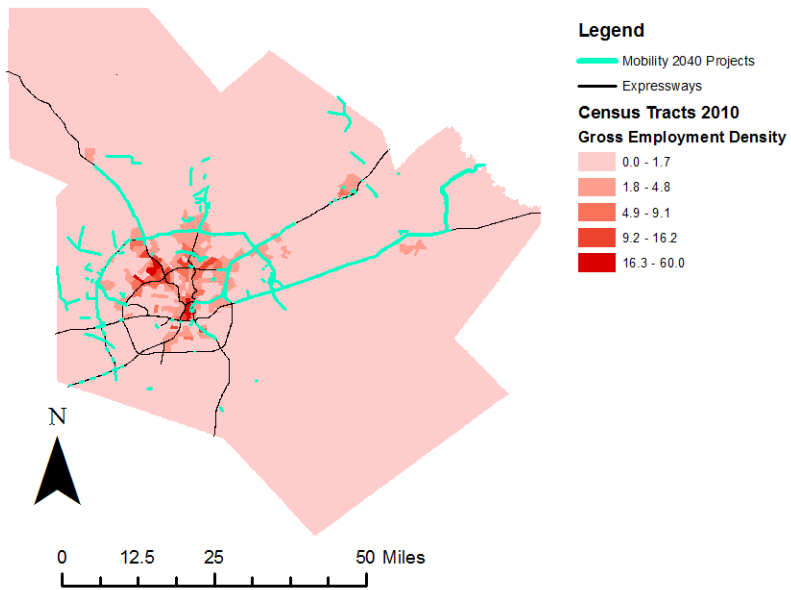


Figure 3: Mobility 2040 Roadway Projects

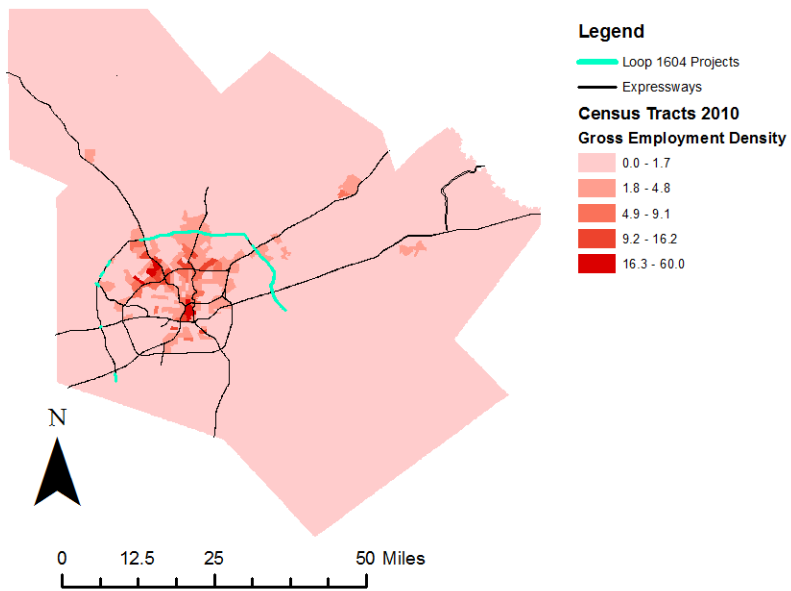


Figure 4: Loop 1604 Projects

## The TELUM Land Use Model

An objective of this study is to develop a methodology that could be widely used with minimum demand for technical capacity or data-intensive input requirements, and this goal guided the selection of a land-use model.

The freely available land use model TELUM is used here for land-use modeling. TELUM was developed under the guidance of the Federal Highway Administration in order to allow middle-range MPOs the capability to conduct their own land-use modeling in house (New Jersey Institute of Technology, 2005) . TELUM is a software program that incorporates data fed into it via Microsoft Excel and Microsoft Access, and produces land use forecast data that can be visualized in ArcGIS. A disadvantage of TELUM is that it is not integrated with any travel demand model, so land use forecasting and travel demand forecasts must be fed iteratively back and forth, limiting the level of synchronization between the transportation forecast and the land use forecast.

TELUM is an aggregate, zonal-based model rather than a microsimulation model. Provided zonal data on households and employment from two time periods and land use consumption data for one time period, the TELUM land use model calibrates a parameter explaining land use change based upon recent trends. Then based upon these calibrated parameters, future land use can be forecast via the same zonal structure up to 6 time increments into the future. TELUM allows for a distinction of up to 6 household types and 8 employment types in its zonal forecasts.

As an aggregate, zonal land use model, TELUM can be calibrated with commonly available US Census data. Land use data must be analyzed via a GIS system to associate different household and employment activity types with their land consumption requirements. The underlying causal framework of the TELUM model assumes that newly located household are attracted by accessibility to employment, other similar type households, available land, and zonal specific factors. New employment is attracted to the workforce, other employment locations, land availability, and zonal specific factors.

For this case study, the launch year for the land use models was 2010 while the base year was 2005. For each of these two years, we gathered information on households by income category and employment by industrial grouping for the 436 Census Tracts in the region. Household data by Census Tract for 2005 and 2010 are from the American Community Survey. Employment data by industry and by Census Tract are from the LEHD Origin-Destination Employment Statistics (LODES) Dataset. These data are used to calibrate different attractiveness features for future growth, including land supply and the influence of employment accessibility.

Land consumption is determined by a different model within TELUM. This model is calibrated based upon launch-year land-use patterns in relation to launch-year employment and population patterns. Land use parcel data were provided by the Alamo Area Metropolitan Planning Organization (AAMPO) with the following land use categories: Residential, Commercial, Industrial, Undevelopable, Right of Way, and Vacant Developable.

The TELUM model uses a single zone-to-zone impedance matrix to define how employment accessibility influences future residential growth and how accessibility to workers influences future employment growth. We used peak-hour auto travel times provided from the AAMPO travel demand model as the source of these impedance matrices. The travel demand model was run with different transportation plan configurations for future years by the AAMPO at our request.

The TELUM land use model was used to forecast 2020 land-use patterns for both the Build and No Build scenarios for each sets of transportation projects evaluated. The model was calibrated based upon population and employment data from 2005 and 2010, land-use consumption data from 2010, and travel impedance data from 2010. Then two different 2020 travel impedances were fed into the model to produce two distinct land use forecasts, one for the Build Scenario and one for the No Build Scenario.

We calculated accessibility to employment by automobile for each of the two scenarios with a gravity potential measure (See equations 1.1 and 1.2). Because TELUM produces population forecasts by household type and employment forecasts by industry type, a variety of accessibility measures are possible; for example, it is possible to calculate the accessibility impacts on low-income households separately from high-income households. However, we report only aggregate accessibility impacts here for purposes of brevity. The travel cost for the accessibility calculations in this case only accounts for peak-hour auto travel times. If the data were available, other types of accessibility such as transit accessibility could be calculated. Impedance values are taken from AAMPO's travel demand model impedance curves (San Antonio-Bexar County Metropolitan Planning Organization, 2011).

Equations 1.1 and 1.2:

$$1.1 \quad A_i = \sum_j D_j f(c_{ij}) = \sum_j D_j e^{-0.14 * t_{ij}}$$

$$1.2 \quad A_{Region} = \sum_i A_i H_i$$

For equations 1.1 and 1.2,  $A_i$  is accessibility for zone  $i$ ,  $H_i$  is the number of households residing in zone  $i$ ,  $D_j$  is the total number of jobs located in zone  $j$ ,  $t_{ij}$  is the auto-based travel time between zone  $i$  and  $j$  during the peak hour, and  $-0.14$  is the impedance coefficient with units in inverse minutes.

We also examined the changes to mobility for each of the two scenarios by examining aggregate travel time for 2020 vehicle flows across the metropolitan region. This was done by summing up all projected zone-to-zone vehicle flows by the peak-hour vehicular travel time for each scenario.

$$2 \quad T = \sum_{i,j} F_{ij} * t_{ij}$$

In equation 2,  $T$  is the aggregate travel time in minutes,  $F_{ij}$  is the flow of vehicles from zone  $i$  to zone  $j$  over the peak hour and  $t_{ij}$  is the peak-hour travel time from zone  $i$  to zone  $j$ .

## Results

The results section details the implications of the 2015 Transportation Plan and the 1604 Loop projects. For each set of projects, the spatial implications in terms of household locations, employment locations, and accessibility shifts is mapped. Then accessibility and mobility impacts of these projects is also summarized in tabular format. The accessibility impacts take into account both changes to travel speeds and land-use patterns, whereas the mobility impacts only take into account changes to travel speeds.

### Analysis 1: Mobility 2040 Transportation Plan vs. No Build

Our first analysis examined the accessibility implications of the Mobility 2040 long range plan versus a No Build Scenario. We examined how mobility and accessibility change between the Build and No Build scenarios for the year 2020, which involved a 10-year land-use forecast from launch year 2010 data. Although 2040 data were available for land use forecasting, we found that extrapolating the land-use forecast over 30 years produced exaggerated results; on the other hand, a land-use forecast over less than 10 years might not show enough land-use change for a meaningful accessibility analysis.

### Land Use Forecast and Accessibility Shifts

Forecast land-use shifts due to the Alamo Area transportation plan are illustrated in Figure 5 and Figure 6. These shifts illustrate how the Build Scenario differs from the No Build Scenario by taking the difference between the two for each zone. Household and employment shifts are shown with absolute values. Household gains for the Mobility 2040 projects are concentrated along the northern metropolitan fringe, in particular the northeast. Household losses are concentrated on the northern, inner ring suburbs, but also encompass much of the central city. Employment gains due to the transportation plan cluster in the northwest and northeast, while employment losses are scattered throughout the central city and the northern inner ring.

The resultant geography of accessibility changes is illustrated in Figure 7. Accessibility losses are greatest for the central city, but also there are some accessibility losses along the metropolitan fringe. The accessibility gains occur along the inner-ring suburbs. However, this map shows the geography of accessibility change without taking into account population weights. aggregate accessibility impacts based on resident population are presented in Table 2.



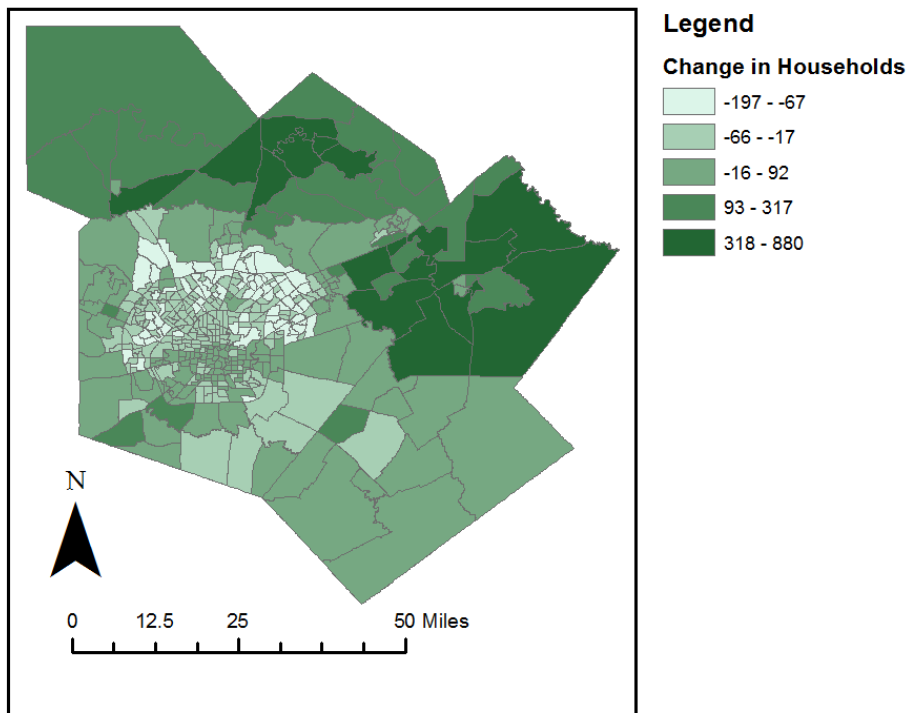


Figure 5: Forecast Household Shift due to Alamo Transportation Plan to 2020

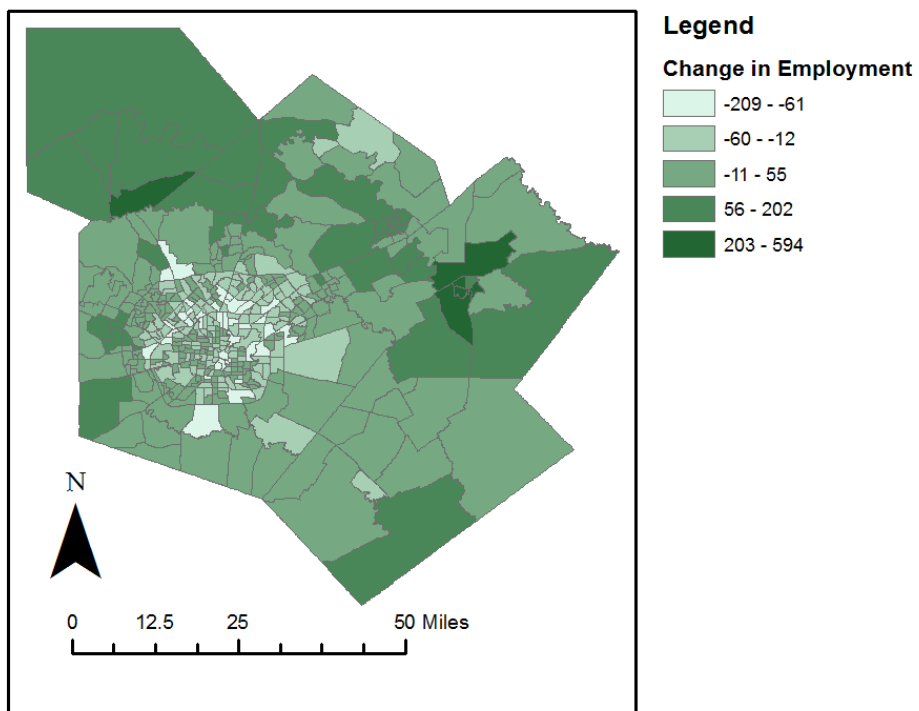


Figure 6: Forecast Employment Shift due to Alamo Transportation Plan to 2020

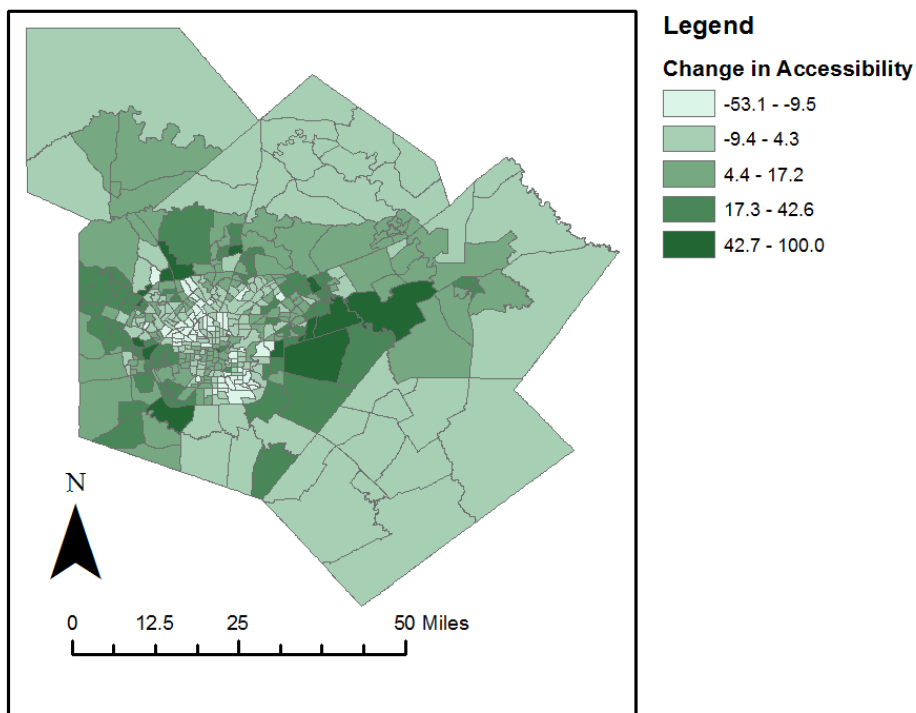


Figure 7: Accessibility Shift due to Alamo Transportation Plan to 2020

### Accessibility and Mobility Effects

Table 2 examines mobility and accessibility performance across four scenarios: Build, No Build, Speed-Only Effects and Year 2010. Speed-Only Effects show what the impact would be on accessibility if the proposed transportation projects had no land-use impacts but only speed impacts. Year 2010 mobility and accessibility are included as a baseline for comparison. The primary mobility effects are reported via aggregate peak-hour travel time and average peak-hour trip time. The primary accessibility effects are reported via population-weighted accessibility. Percent differences are reported for the Build Scenario in comparison with the No Build Scenario and the Year 2010 baseline.

The mobility impacts of the Alamo's Mobility 2040 Plan through 2020 are significant, however despite this, its accessibility impacts are negligible. The Build Scenario reduces aggregate travel time by 5.5%, so travel times are improved. In addition, if the associated transportation projects had no land-use effect--if they only changed interzonal speeds--they would increase accessibility by 3.1%. The reason the accessibility improvement is less than the mobility improvement is that accessibility creates greater weights where current households reside, and presumably the speed improvements are predominantly weighted towards less-populated areas of the region.

However, after taking into account the land-use effects of the Mobility 2040 Plan through the year 2020, the net accessibility benefits are -0.2%. There is no discernable benefit to average household accessibility as a result of the Mobility 2040 Plan.

Table 2: Mobility 2040 Plan Mobility and Accessibility Impacts through 2020

	Build Scenario	No Build Scenario	Speed-Only Effects	Year 2010
Mobility Impacts	Aggregate Travel Time			
Vehicular Travel Time, Minutes	82,098,736	86,908,769	NA	73,189,146
Average Trip Time, Minutes	24.59	26.03	NA	21.92
Percent Diff. No Build	-5.5%	NA	NA	NA
Percent Diff. with 2010	12.2%	18.7%	NA	NA
Accessibility Impacts	Gravity-Weighted Accessibility to All Employment			
Minimum Zone	22	21	21	66
Maximum Zone	96,340	96,069	97,071	107,978
Mean Zone	28,105	27,790	28,298	29,330
Standard Deviation	23,335	23,635	23,553	25,382
Population Weighted	24,406	24,446	25,194	27,988
Percent Diff. No Build	-0.2%	NA	3.1%	NA
Percent Diff. with 2010	-12.8%	-12.7%	-10.0%	NA

### Analysis 2: Loop 1604 vs. No Loop

The second analysis focuses on the accessibility effects of a series of related transportation projects, a bundle of expansions and improvements to a suburban ring road known as Loop 1604. The existing transportation plan is examined with all Loop 1604 projects included versus the same transportation plan but with all Loop 1604 projects excluded.

### Land-Use Forecast and Accessibility Shifts

The net effect of the Loop 1604 projects results in more centralized locations for households as illustrated in Figure 8. Household increases are found throughout the central city and along the northern inner ring suburbs. Household losses are found throughout the metropolitan fringe, both to the north and to the east. Employment changes are more centralized, with employment gains occurring in a crescent from the central city to the northern edge. The largest employment losses are in the far northwest, the far north, and the far east of the metro area.

The geographic area that benefits from these shifts in terms of accessibility is the central city, as shown in Figure 10. Although the geographic area with accessibility losses is much larger, from the perspective of population the area with accessibility gains is actually larger in magnitude.

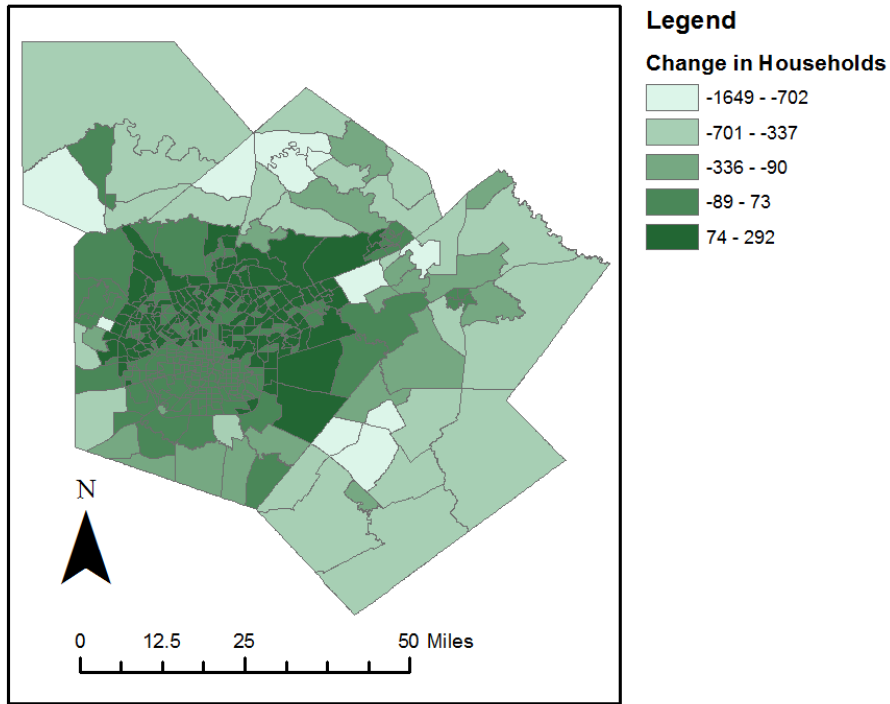


Figure 8: Household Changes due to Loop 1604 to 2020

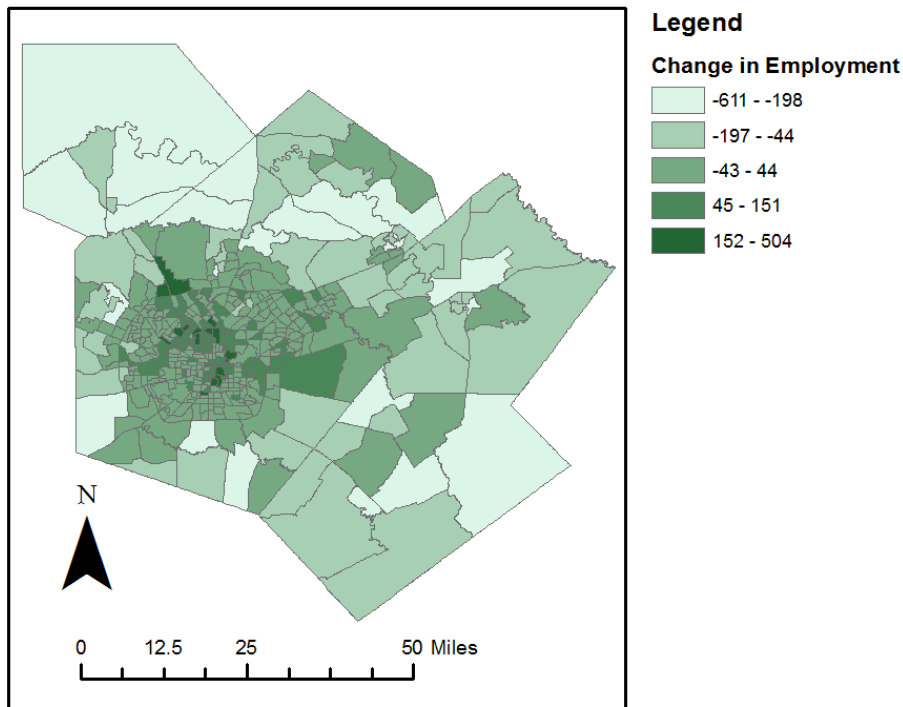


Figure 9: Employment Changes due to Loop 1604 to 2020

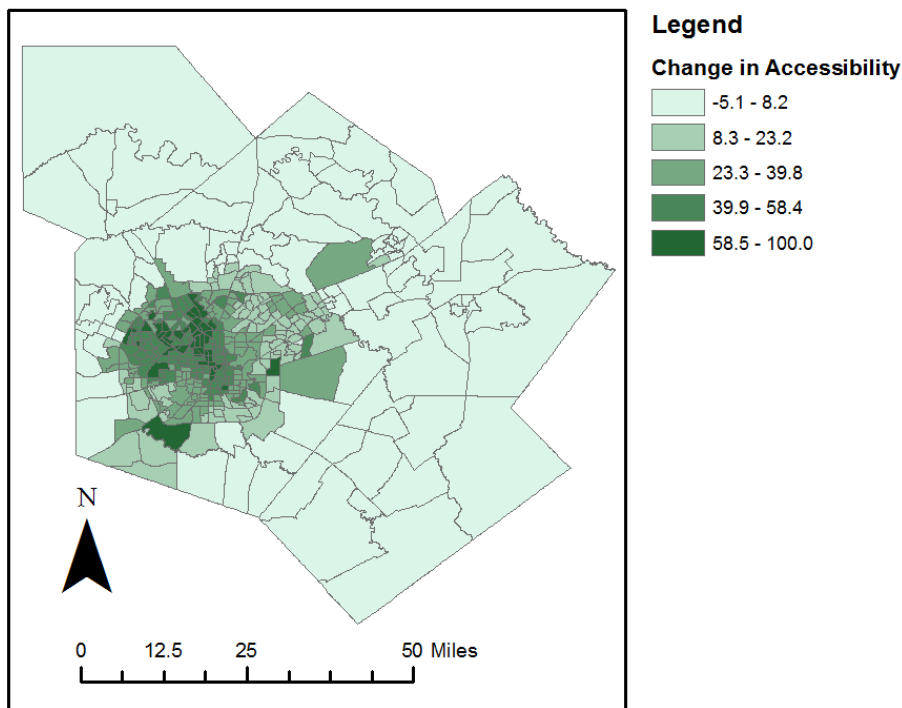


Figure 10: Accessibility Changes due to Loop 1604 to 2020

### Comparison of Accessibility and Mobility Effects

Loop 1604 is the opposite kind of case from the Mobility 2040 Plan; it has fairly strong mobility benefits, but its accessibility benefits are much higher than these mobility benefits alone. The centralizing (and proximity-increasing) effect that building the Loop 1604 projects have relative to the No Build Scenario compounds its positive mobility effects.

Table 3, like Table 2, examines mobility and accessibility impacts across four scenarios: Build, No Build, Speed-Only Effects and Year 2010, and compares the Build Scenario's performance as a percent change relative to No Build and Year 2010. The mobility effect, as measured via average trip times, is an improvement of 2.5% in comparison with the No Build Scenario. Shifting to the accessibility impacts of Loop 1604 with respect to the Speed-Only Effects, the improvement to the average household's accessibility is 5.0%. Accessibility benefits exceed mobility benefits because these accessibility weights such benefits in locations where households and jobs are clustered.

Total accessibility impacts, including the effects of land-use changes in addition to speed effects, raise the accessibility impact of Loop 1604 projects to 9.5% for Build in comparison to No Build.

Table 3: Loop 1604 Mobility and Accessibility Impacts through 2020

	Build	No Build	Speed-Only Effects	Year 2010
Mobility Impacts				
Aggregate Trip Time, Minutes	81,890,310	83,949,731		73,189,146
Average Trip Time, Minutes	24.5	25.1	-	21.9
Percent Diff Baseline	-2.5%	NA		
Percent Diff with 2010	11.9%	14.7%		NA
Accessibility Impacts				
Minimum	19	26	26	66
Maximum	88,860	85,630	87,130	107,978
Mean	28,380	26,770	27,980	29,330
Standard Deviation	22,949	21,982	22,478	25,382
Population Weighted	25,108	22,939	24,094	27,988
Percent Diff No Build	9.5%	NA	5.0%	NA
Percent Diff with 2010	-10.3%	-18.0%	-13.9%	NA

## Discussion

The Mobility 2040 Plan shows mobility benefits through decreased average travel times, however despite this it offers no net accessibility benefits. A major reason for this is that the proposed transportation plan decentralizes both households and employment; after factoring in these land-use shifts, the average household has no greater accessibility in 2020 than if no transportation projects were completed at all (i.e. the No Build Scenario). The advantage of faster speeds, which are documented in the mobility analysis above, are completely counterbalanced by the land use decentralization induced by the transportation plan.

The Loop 1604 projects, on the other hand, illustrate accessibility benefits in excess of their purported mobility benefits. Nearly half of its accessibility benefits are due to induced land-use changes – i.e. a 4.3% increase in accessibility is attributable to land use changes, while a 5.0% increase is due to mobility changes.

The reason that the Loop 1604 projects are particularly effective for improving auto-based accessibility is because they offer a triply compounded benefit. First, average travel speeds are increased. Second, these travel speed improvements are focused on areas of existing population and employment concentration. And third, the Loop 1604 projects spur centralization of population and employment relative to the No Build Scenario. Accessibility benefits of this suite of projects are therefore created by changes to speeds and induced land use shifts as well.

As evidenced here, the mobility-based benefits of major transportation projects do not necessarily correspond with their accessibility benefits. While we verified that a major transportation plan does produce mobility benefits as expected, after taking into account induced land-use change the net effect on average household accessibility to employment was virtually zero. On the other hand, we found that a mobility-based analysis of the Loop 1604 suite of projects would significantly *underestimated* its accessibility benefits in comparison with a No Build Scenario. In sum this paper demonstrates that mobility-based analysis alone cannot provide a meaningful indicator of whether or not a particular project provides transportation benefits to households (as measured by accessibility changes), nor can it indicate the relative size of those benefits.

## Limitations

The analyses here are based on one round each of forecast transportation impacts and land-use impacts. That is, a new zone-to-zone travel time matrix is estimated for the Build and No Build scenarios, and a different regional land-use outcome is forecast for each scenario. More iterations are possible: the new land-use forecast would alter the zone-to-zone travel time matrix, and so on. The decision to iterate travel time and land use just once each was largely a function of the core purpose of this project: demonstrating manageable tools by which transportation planners in local practice could evaluate the accessibility impacts of contemplated transportation projects. Given lowered barriers to the use of integrated transportation-land use models, they could be used to forecast accessibility impacts, and presumably they would capture more comprehensively this interplay between the transportation and land use systems.

A second limitation is inherent to the forecasting enterprise. The No Build Scenario generated a rapidly decentralizing land-use pattern, which is largely a function of the extrapolation of past trends extant in the Alamo region. Previous years had seen rapid metropolitan expansion, and the model reasonably imputes a continuation of this trend into the future. But if the decentralization of previous years was in part a function of the region's historic transportation-investment policies, then its continuation is surely tied to the expectation that highways will continue to be expanded on the metropolitan periphery. If both the reality and the expectation of such investment were to change, the decentralization trends may well be altered – but that possibility is not incorporated into the land-use change forecast, even for the No Build Scenario.

Although we only present household average accessibility impacts in this paper, the method presented here readily supports different types of disaggregate accessibility impacts, including a differentiation of accessibility impacts by household type, accessibility to work as well as non-work destinations (i.e. shopping, health care), and accessibility by transit as well as by auto modes.

## Conclusion

When transportation planners evaluate the transportation-related benefits of a proposed project based upon mobility alone, they miss an essential part of the dynamic relationship between transportation infrastructure and land use patterns. Improved transportation infrastructure influences the pattern of new land uses, yet these impacts are rarely accounted for in transportation plan or project analysis.

Even though the need for accessibility-based transportation analysis has been well established, consideration of the land-use impacts of major transportation projects is routinely ignored.

In order to understand the transportation benefits of a major transportation project, an accessibility-based evaluation framework is required. And in order to evaluate the accessibility benefits of such a project, induced land-use changes must be taken into account, in addition to the better-understood travel-time impacts. It is possible – as demonstrated here – that the decentralizing effects of a transportation project might outweigh or counterbalance its speed-enhancing benefits. The practical method we present here illustrates how a land-use model can be integrated into the analysis of a transportation project in order to ascertain its net accessibility impacts.

Land-use impacts are by no means marginal in either of the cases we analyzed. In the Mobility 2040 case, the land-use impacts completely neutralize the purported mobility benefits. In the second case, the Loop 1604 Projects, the land-use impacts augment the mobility benefits, constituting 45% of the accessibility impacts. The land-use impacts of a major transportation project or plan are too large to be ignored, and accessibility analysis cannot be replaced by a simple mobility analysis which does not account for these land use shifts.

Since the tools, we leverage in the paper are widely accessible in planning practice, there is no technical reason that practicing transportation professionals cannot evaluate transportation plans or projects based upon their accessibility impacts. This approach can bring accessibility evaluation out of the somewhat abstract world of regional scenario planning by linking it to everyday decision making on nuts-and-bolts transportation projects and plans.

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