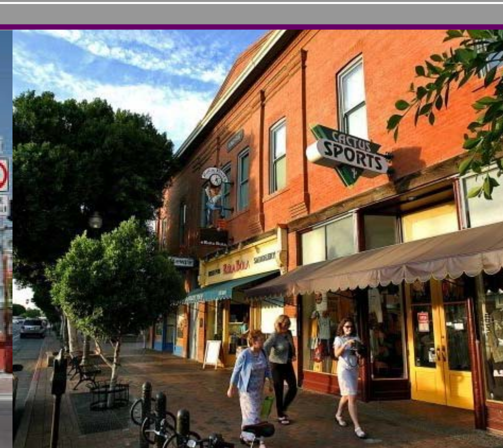
Land Use and Traffic Congestion

Final Report 618
March 2012



ADOT
Arizona Department of Transportation
Research Center

Land Use and Traffic Congestion

Final Report 618
March 2012

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16. Abstract
The study investigated the link between land use, travel behavior, and traffic congestion. Popular wisdom suggests that higher-density development patterns may be beneficial in reducing private vehicle dependency and use, which if true, could hold important implications for urban transportation planning and related goals such as congestion relief, air quality, and sustainability. However, an important consideration is whether more higher-density development also exacerbates traffic congestion on adjacent streets and roads simply because of its concentration of activity. Researchers performed a detailed analysis of the relationships between higher-density land use and traffic conditions in four Phoenix transportation corridors. The corridors included three older, high-density, mixed-used urban areas and a more contemporary suburban area with lower density but high traffic volumes. The analysis showed that the urban corridors had considerably less congestion despite densities that were many times higher than the suburban corridor. The reasons were traced to better mix of uses, particularly retail share, which led to shorter trips, more transit and nonmotorized travel, and fewer vehicle miles of travel (VMT). Also recognized was the importance of a secondary street grid in the three urban areas, which allows for better channeling of traffic and enables walking. Researchers developed a set of regression models to quantify the effects of key land use variables on household vehicle ownership and VMT, illustrating the mitigating effects of higher density, better mix, and better transit accessibility. Researchers also performed an extensive review of literature on transportation and land use interaction, and surveyed local officials to elicit information about familiarity with compact, mixed land use concepts; perceptions of impact on travel and traffic; and desirability of greater proliferation in Arizona's metropolitan areas.

17. Key Words
Land use; traffic congestion; smart growth; mixed-use development; integrated transportation and land use planning; the 4Ds; traffic mitigation; density; transit-oriented development; auto dependency

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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EXECUTIVE SUMMARY

The purpose of this project was to analyze and interpret the relationship between higher-density development and traffic congestion. Governments have expressed increased interest in the possible benefits of compact, mixed land use—referred to in many circles as smart growth—to reduce auto dependency and use. If true, this finding could be of significance in planning solutions to a host of transportation system investment, performance, and impact issues.

Before considering any type of formal policy position in relation to land use, the Arizona Department of Transportation (ADOT) is expanding its understanding of the relationships between land use development patterns and transportation. Among ADOT's key questions are:

- Does higher-density development reduce auto use, to what extent, and in response to what factors?
- Does higher-density development also generate higher levels of traffic congestion simply due to the higher concentration of activity?
- Do Arizonans know about smart growth, and what are their perceptions of its impacts and desirability?

The research study that is summarized in this report was commissioned to address these specific issues. It involved a national-scale review of research and evidence on transportation and land use relationships; detailed local analysis of these relationships using data from metropolitan Phoenix; and a survey of officials in Arizona's metropolitan areas about their perceptions of land use/transportation, how higher-density development is viewed, and whether there would be receptiveness for compact, mixed-use approaches regionally and in their own area.

The findings of this study confirm the benefits of better land use. In its assessment of a prodigious volume of research on this topic, the project's literature review was able to highlight the following findings:

- **Density and Vehicle Miles Traveled** Using residential density as a primary indicator of concentrated land use, a variety of studies have shown that households in higher-density (i.e., more urban) settings tend to own fewer vehicles, drive less, walk and take transit more often, and generate one-half to one-third of the daily vehicle miles traveled (VMT) of their suburban counterparts.
- **Beyond Density:** Research has found that the effects of land use on travel behavior are rooted in factors beyond simple density. Also important are related factors such as mix of uses, auto- vs. pedestrian-oriented design, and regional accessibility enhanced by multiple travel choices (especially transit). These characteristics of density, diversity, design, and destinations are commonly referred to as the 4Ds.
- **Travel Purpose:** Work travel, which is associated with peak period congestion, generally garners most of the attention in transportation planning and policy deliberations. Indeed, where compact land use is focused around high-quality

regional transit—at both the origin and destination of a journey—commuters will use transit in large numbers because of its convenience. However, the travel market that may be most influenced by compact mixed-land use is nonwork travel, which accounts for as much as 80 percent of routine household travel and has been the fastest-growing segment since the 1980s. This relationship/trend can be directly linked to land use, recognizing that in conventional suburban areas almost all household needs—shopping, transporting children, personal business, social, and recreation—require private vehicle travel. Areas where residents live in older, mixed-use communities with nearby services and restaurants show a much greater concentration of travel to local destinations—including walking, biking, or short car trips—despite a daily commute that may well be a long distance solo-driver trip.

- **Market Forces:** Critics of smart growth approaches to land use maintain that it is a planner's notion that does not reflect market realities. However, real estate industry experts assert that the reason more compact, mixed-use development has not occurred has to do with restrictive local zoning codes or traffic level of service standards, and not because of market demand, which is gauged as twice as high as current build rates. This is borne out by visual preference surveys that show a general preference for older (pre-World War II) suburban development patterns, which are more compact and walkable, and foster more social interaction between residents.

To ascertain the validity of these research findings in the Arizona environment, researchers performed a number of detailed studies using local data and both existing planning tools as well as some new ones developed specially for analysis of the role of land use. These analyses were focused on the Phoenix metropolitan area and were performed using data, modeling tools, and staff support of the Maricopa Association of Governments (MAG).

Conventional four-step transportation planning models are unable to account for important differences in land use as represented by the 4Ds. The influence of land use is most relevant at the level of the individual traveler and what they can walk to within ¼ to ½ mile at either origin or destination. Four-step models operate at a traffic analysis zone (TAZ) level of aggregation, which is generally much too coarse for discerning land use differences. For this reason, this genre of models also does not deal directly with nonmotorized trips such as biking or walking, which are a critical element in compact mixed use designs.

Using data from MAG's 2001 regional household travel survey supplemented with information from its travel model and geographic information systems (GIS) databases, researchers developed a set of regression models to quantify the relationships between travel behavior, traveler demographic characteristics, and measures of the 4Ds. These models show the effect of the 4Ds of land use on both household vehicle ownership and on household VMT. Residential density, land use mix, walk opportunities, and regional transit accessibility to jobs were the variables used to represent the 4Ds. Negative signs on the coefficients for these variables indicate that as each of the land use variables increases, vehicle ownership and VMT rates decline proportionately. Vehicle ownership is an important determinant of travel in the VMT models, so when it is reduced in relation to better land use, its effect is compounded by also acting to reduce VMT.

The MAG region was divided into 17 jurisdictional areas and the household travel survey database used to explore differences in travel in relation to these key land use factors. Higher-density and more mixed-use areas such as South Scottsdale, Tempe, and East Phoenix were found to behave significantly differently from lower- density/less mixed-use areas like Glendale, Gilbert, and North Scottsdale. Residential density for the more compact areas ranged from 6.14 to 6.94 households per acre vs. 2.86 to 3.61 households for the lower-density group. These higher-density areas also had better mix (0.53 vs. 0.30 value on a 0 to 1.0 entropy index scale); more retail and service opportunities within walking distance (42.4 vs. 15.4); and considerably more jobs accessible by transit (59,000 vs. 27,000). The implications of these differences may be seen in various travel measures, including:

- **Vehicle Ownership**: 1.55 vs. 1.92.
- **Average Trip Lengths**: 7.4 vs. 10.7 miles for home-based work trips; 2.7 vs. 4.3 for home-based shopping trips; 4.4 vs. 5.2 for home-based other trips; and 4.6 vs. 5.3 for nonhome-based trips.
- **Per Capita VMT**: 10.5 miles per day vs. 15.4 miles per day.

The 4Ds models were subsequently used to investigate the potential impact of improved land use characteristics in each of the 17 areas. To do this, average residential densities were raised to 10 households per acre (vs. on the order of two to four in most places), land use mix was brought to the ideal entropy index value of 1.0, the number of walk opportunities was increased to 100 in all places, and regional transit accessibility was raised to somewhere between the current minimum and maximum for the respective area. This resulted in estimates of VMT reduction of 20 percent to 45 percent, with an average overall of 25 percent.

Having reasonably demonstrated that areas in Phoenix with higher density generated less vehicle travel per capita than lower-density areas, the second hypothesis investigated was whether a higher concentration of activity would also lead to localized traffic congestion. A sample of four urban corridors was selected for detailed study—also in the Phoenix area—based on information from local and regional officials that these areas were perceived to have major traffic congestion issues: Scottsdale Road between Thomas Road and Chaparral Road in the older, southern part of Scottsdale; Central Avenue north of downtown Phoenix, between McDowell Road and Camelback Road; the Mill Avenue and Apache Boulevard corridor through Tempe; and West Bell Road in the northwest part of the region, connecting the central valley with the newer communities of Peoria, Glendale, and Surprise.

The objective was to examine the interplay between the intense development patterns in these areas and the condition of traffic on the street and road network. Researchers performed the following assessments:

- **Density:** Three of the areas—south Scottsdale, Central Avenue, and Tempe—exhibited some of the highest development densities in the region while Bell Road served an area of intense activity spread over a large area of moderate to low density.
- **Composition:** The Scottsdale, Central Avenue, and Tempe areas also had a high level of mix in their land uses, while Bell Road was heavily residential. The overall jobs-to-housing ratio in the Bell Road area was only 0.49 compared to 1.42 in Scottsdale, 2.30 in Tempe, and 5.60 in the Central Avenue corridor. Retail jobs per household (a measure of access to local services) was not quite as skewed, but Bell Road's ratio of 0.31 was still only about half of the 0.56 to 0.65 level found in the other three areas.
- **Road Network:** Each area is served by the one mile arterial "super grid," with no area having a freeway closer than two miles from its center. However, a major distinction occurs in the secondary road system, with Central Avenue and Scottsdale having a rich network of secondary streets on one-eighth mile spacing. Tempe's secondary grid is not quite as fine but is still much better than the Bell Road corridor, which has little secondary road system beyond subdivision networks.
- **Transit:** Central Avenue and Tempe are well-served by the regional bus system and are also connected by the region's inaugural light rail line (not operational at the time of the analysis). Scottsdale is moderately served by transit, while Bell Road has only park-and-ride bus service. Transit accounts for about 6 percent of all internal trips in Scottsdale, and between 3 percent and 6 percent of external trips. In the Central Avenue corridor, about 8 percent of internal trips and about 7 percent of external trips are made by transit, while in Tempe about 3 percent of internal trips and 5 percent to 10 percent of external trips are by transit. In contrast, less than 1 percent of all trips in the Bell Road corridor involve transit.
- **Traffic Congestion:** Interestingly, traffic congestion levels were much lower in the Scottsdale Road and Central Avenue corridors than in the Bell Road corridor. Volume-to-capacity (V/C) ratios in both Scottsdale and Central Avenue were in the 0.8 to 0.9 range in the PM peak period compared to 1.6 to almost 2.0 along Bell Road. Tempe fell predictably in between given its less-articulated secondary road network, with V/C ratios in the neighborhood of 1.0. Tempe also employs traffic-calming strategies on its secondary road network to discourage cut-through traffic, which pushes traffic onto major arterials.
- **Through Traffic:** Traffic volumes in each of the four areas are affected by through travel (no trip end within the defined area). Central Avenue, Bell Road, and Apache Boulevard in Tempe all had rates of through travel that accounted for about half of peak period traffic volumes. Without this through traffic movement, Central Avenue and Tempe would be relatively uncongested, though Bell Road would still be congested from its internal volume. Scottsdale's rate of through traffic on the measured links was much less—about 22 percent to 28 percent—probably due to the design of the local grid, which encourages through travelers to use peripheral streets.

These findings tended to corroborate responses elicited from participants in the project's survey of officials. For this survey, which was conducted early in the project, researchers distributed 423 questionnaires and received 134 responses from a diverse list of elected officials, planning and zoning officials, transportation planners, and members of other relevant disciplines in the Phoenix, Tucson, and Flagstaff metropolitan areas. Some of the key discoveries in this investigation are given below:

- **Traffic Congestion Concerns:** While important, traffic congestion was rated as less a factor in project review than were issues of compatibility with adopted plans and impact on surrounding neighborhoods and businesses.
- **Familiarity:** Most officials were familiar with mixed-use concepts, had been involved in the review of these concepts, and had even encouraged submission of such projects.
- **Transportation Impacts:** The overwhelming majority of officials responding believed that compact, mixed-use development would increase transit use and nonmotorized travel, though only about one-third felt unequivocally that it would lead to less traffic congestion. (Most were unsure.)
- **Desirability:** The great majority believed that the region would benefit from more mixed-use centers and corridors, focusing employment in centers and corridors, and building more mixed-use communities. About 80 percent believed that their own community would support compact, mixed-use development. Residential/retail and office/retail mixed use were the most highly rated combinations.

These findings suggest an opportunity to advance the dialogue on and support for compact, mixed-use development in Arizona's metropolitan areas. Among the initiatives that might be considered are the following:

- **Education:** There is a need to better inform the public, the business community, and officials about the nature and benefits of compact, mixed use. Themes developed in this project can serve as educational messages.
- **Better Analysis Tools:** Local planners and planning commissions are still using traditional traffic engineering approaches to assess the impact of development projects. By looking only at traffic congestion levels on adjacent links, ignoring through travel, and failing to account for the efficiencies of mixed-use development on lower vehicle trip rates and VMT, progressive projects are likely to be rejected or unreasonably downsized. The metropolitan planning organizations should take steps to add 4D enhancements to their existing tools.
- **Visioning and Plan Overhauls:** Existing long-range or comprehensive plans may be silent or devoid of a position on compact, mixed-use development. Regional or local targeted visioning exercises can raise visibility and understanding of the issues, leading to greater acceptance and support in updated plans.
- **Incentives:** Adoption of compact, mixed-use development approaches can be encouraged in various ways. Grant monies and/or technical assistance can be offered to support studies or demonstration projects. Several states prioritize state program or grant funding based on demonstrated steps by a jurisdiction to embrace and incorporate key elements in their plans, codes, or procedures.

- **Supportive Infrastructure:** A key incentive in its own right, local land use choices can be influenced by the manner in which transportation resources are distributed. Priorities can be placed on investments that will most contribute to concentrated land use policies such as transit investments, local street and sidewalk infrastructure, or rehab/upgrade of facilities in older developed areas.

CHAPTER 1. INTRODUCTION

PURPOSE OF THE STUDY

The purpose of this research project was to examine the relationship between land use and traffic congestion, recognizing that the way land is used affects the volume and character of traffic on the street and highway network. Similarly, adding new roads or expanding existing roads has an impact on the way abutting land is used.

There is considerable controversy over whether increasing the density of development (i.e., a higher number of persons or employees per square mile of land) would reduce or increase traffic congestion. Some researchers argue that compact, mixed-use development is inherently more efficient and sustainable, using less land and reducing private vehicle use rates by bringing people and activities closer together, and also providing densities that are capable of supporting walking and effective transit services. Other researchers say that conventional patterns of low-density development with different land uses (residential, commercial, industrial, institutional), separated from each other and reachable only by car, are much more in character with Americans' preference. Further, they argue, increasing density will only lead to more traffic congestion and loss of personal mobility.

Better data on the relationship between land uses and traffic congestion could help lead to better decisions—decisions that could help reduce traffic congestion, improve air quality, enable safer travel, and lower roadway infrastructure costs.

Given the abundant supply of available land in the Southwest and that most growth has occurred during the era of the automobile, it is no surprise that development patterns in Arizona have been expansive rather than concentrated. In such an environment, the consideration of higher density, more urban growth concepts may seem out of place. However, growing evidence from research on the nature of compact, mixed-use development—particularly if it is also focused around efficient regional transit service—suggests that it generates considerably less vehicle use and VMT than contemporary low-density development. The question is whether these benefits are sufficiently high that higher-density development should be seriously considered in sustaining travel mobility over the long term or whether any such concentration of development would also generate proportionately higher levels of congestion in the adjacent area that would be unacceptable and negate any positive results.

In terms of public acceptance, the nature of this issue is sufficiently volatile that any attempt to promote compact land use policies could raise questions and possible resistance. To better understand these relationships and define an appropriate policy or position on land use, the Arizona Transportation Research Center (ATRC) commissioned this study to perform the following investigations:

- Review the key literature on the relationship between land use density and intensity (i.e., land uses like sports arenas or shopping malls that tend to draw large volumes of traffic) and traffic congestion.
- Survey/interview a sample of officials from metropolitan Tucson and Phoenix regarding their land use decision-making and the level of attention paid to traffic congestion.
- Evaluate a set of urban corridors (i.e., major roadway thoroughfares, including connecting roadways traversing an urban region) by using samples from metropolitan Phoenix and Tucson. Upon selection, use appropriate data to examine the nature of the relationship between land use and traffic congestion in the corridors.
- Identify methods by which future land use decisions could be made to better contribute to mitigating traffic congestion.

RESEARCH APPROACH AND REPORT ORGANIZATION

These objectives became the basis of the research plan, each through a major task activity resulting in a task report summarizing the approach and key findings. The task reports were reviewed by members of the Technical Advisory Committee (TAC), with comments and suggestions reflected in the final documents. These earlier products have now been integrated into a complete report, with each major activity report representing a chapter in the final report document. The following describes the program of research, which corresponds to the organization of this report.

Chapter 2. Literature Review

Early in the project, investigators conducted an extensive review of the literature about land use related research studies to provide a solid basis for shaping the research hypotheses to be tested and providing empirical evidence of the effects of land use on transportation. A synthesis study on this subject performed for the Transit Cooperative Research Program (TCRP) of the Transportation Research Board (TRB) served as a starting point (Kuzmyak et al. 2003). Chapter 15, “Land Use and Site Design,” is one of 19 individually published volumes that make up TCRP Report 95, *Traveler Response to Transportation System Changes Handbook.* The literature reviewed in this earlier project dated back to the 1970s, and was then updated for the current study through a series of computer-assisted searches of reports, monographs, and journal and newspaper articles. Researchers identified and catalogued more than 100 sources, and incorporated findings from about 70 sources into the new review. These findings were organized according to the following topics:

- **Trends:** Examines trends in population growth, demographic changes, development patterns, and transportation investment as they relate to rates of growth in vehicle ownership, use, and VMT.
- **Key Factors:** Evaluates land use attributes such as density, mix of uses, connectivity, and accessibility that appear to affect travel behavior.
- **Travel Markets:** Explores how land use impacts different purposes of travel, particularly work vs. nonwork travel.

- **Transit:** Explores the role and importance of transit investments in guiding development patterns and impacting travel choices.
- **Self-Selection:** Addresses the issue of whether the differences in travel observed in compact, mixed-use areas are due to design or to the characteristics of people who choose to live there.
- **Density vs. Congestion:** Explores contemporary arguments and evidence about the link between higher density development and traffic congestion.
- **Market Forces and Equity:** Explores concerns about whether compact mixed land use is affordable and whether planning for it defies market forces, and social trends in location preferences that may be challenged.
- **Planning Capabilities:** Addresses the extent to which planning for compact, mixed-use development is limited by the structure and capabilities of planning tools (models) and supporting data.

Chapter 3. Survey of Officials

Report findings from a detailed survey targeted four types of officials in relation to their role in land use decision-making: local elected officials (mayors, commissioners, councils); planning and zoning officials; professional land use and transportation planners; and other state and regional officials. The survey elicited information about:

- Methods of becoming involved in the land use planning and development process.
- Key factors influencing development decisions.
- Methods for assessing transportation impacts.
- Experience with and attitudes toward compact, mixed-use development.
- Expected transportation effects of compact, mixed-use development.
- Adequacy of information for assessing mixed-use development proposals.
- Most appropriate development options for a specific region and in the official's own jurisdiction.

Researchers also used the survey to identify the most congested highway corridors for consideration in the detailed analysis of land use impacts on transportation and traffic congestion.

Chapter 4. Analysis of Corridors

This chapter describes the results of the core activity in this study, namely investigation of the nature and degree of the relationship between development patterns and adjacent traffic congestion. After considerable review of potential examples, investigators selected four corridor areas from the Phoenix area: Scottsdale Road, North Central Avenue, West Bell Road, and the Mill Avenue/Apache Boulevard portion of Tempe. Next, they assembled detailed information to examine the relationship between land development characteristics and travel patterns and traffic congestion on adjacent facilities. Key steps or elements of this analysis that are detailed in the chapter are:

- Detailed profiling of land use characteristics in the study areas, including density, sociodemographic characteristics, jobs-housing balance, and general land use mix.
- Transportation (street/highway) network characteristics, capacity, and traffic conditions.
- Traffic composition, in particular the proportion of volume on selected links that have an origin or destination within the study area vs. the share that is “through” traffic.
- Transit network, coverage, service level, and use.
- Internal capture (retention) of resident travel within study area, by travel purpose.
- Average trip lengths across study areas in relation to development characteristics.
- Walkability and nonmotorized travel.

Chapter 5. Land Use Impacts on Design

Having demonstrated in Chapter 4 that high density was not clearly correlated with higher congestion, the subsequent investigation was to explore options for the types of policies that could be more conducive to reducing traffic congestion. Researchers developed a methodology for identifying the effectiveness of key land use design and transportation system measures in reducing VMT production. This work was performed using data obtained from the MAG travel model database, land use database, and 2001 regional household travel survey. Using these data, researchers created a set of regression models that predict the effects of different land use and transportation system options on household auto ownership and VMT production rates. They used these modeling tools to estimate the effects of higher density, better mix, better design, and greater regional transit accessibility on VMT production for 17 distinct jurisdictions in the Phoenix region.

Chapter 6. Summary, Conclusions, and Recommendations

The final chapter offers an overall summary of the project’s objectives, analytic approach toward addressing those objectives, key findings, and recommendations for advancing the concepts of compact, mixed-use development toward greater acceptance in planning and implementation.

Appendices

Information in the appendices includes:

- A summary of open-ended responses to key questions in the survey of officials.
- A description of the candidate corridors recommended for study and the process used to select the final sample for this analysis.
- Compilation of the MAG traffic counts used to validate the link congestion analysis conclusions in Chapter 4.

CHAPTER 2. LITERATURE REVIEW

INTRODUCTION

To begin this investigation, researchers conducted a comprehensive search and review of the relevant literature dealing with the transportation/land use connection. This review encompassed a full range of research, empirical, and policy studies, tracking developments in this topic since the late 1980s. Researchers used the findings from Chapter 15, "Land Use and Site Design," of the *Traveler Response to Transportation System Changes Handbook* (Kuzmyak et al. 2003) as a starting point for this study. As a result of this existing work, which dates back to the early 1970s, researchers could focus the current review more heavily on work that has been done since 2002.

During this recent six-year period, the research and discussion has, if anything, intensified. Many of the early debates—dealing mainly with whether land use does in fact matter—have been substantially resolved, while new and more complex questions have emerged, such as what land use factors actually contribute to travel behavior, and whether residential self-selection plays a central role in the observed differences in travel. The positive aspect is that the increased attention to the topic has brought more and better data and methods, which have permitted more incisive analysis.

More than 100 sources were identified for this study, and almost 70 of those reviewed were regarded as sufficiently relevant to be formally documented and included in this synthesis. (See the bibliography of this report for a summary of the key points or findings of these sources.)

Following a brief review of the history and trends in land use and transportation, the remainder of this chapter summarizes the findings from this review, organized in relation to the key research or policy questions that spawned the particular study or article. Those questions are as follows:

- Does land use impact travel, to what extent, and through what mechanisms?
- What types of travel are most affected?
- How important is the role of transit?
- Is there a self-selection bias that confounds the travel effect attributed to land use?
- What is the market for acceptance of alternative land use approaches, and what factors impede its propagation? Are there equity implications attached to planning approaches that manage land use?
- Does density cause more congestion, and what are its effects on mobility and accessibility?
- How well do current travel models account for key land use relationships?

BRIEF HISTORICAL PERSPECTIVE AND TRENDS

In the late 1980s, important trends were converging to draw high-level attention to the issues of urban sprawl, traffic congestion, and associated fiscal and environmental concerns. Whereas the predominant growth pattern following World War II was suburban, the mid-1980s marked an important tipping point in this trend when the majority of employment—not just households—came to be located outside the central cities of metropolitan areas. A variety of factors fueled this growth, primarily the excess capacity in suburban portions of the interstate highway system and an era of "cheap money" from the savings and loan industry. The former made huge portions of undeveloped land accessible to the metropolitan region, while the latter encouraged large-scale real estate speculation. Seemingly overnight, major office parks and massive regional shopping malls sprouted up around highway interchanges, seizing upon the high accessibility, lower space cost, and the instant advertising associated with those locations. In Arizona this trend was further encouraged by the attraction of sales tax revenues from these new projects.

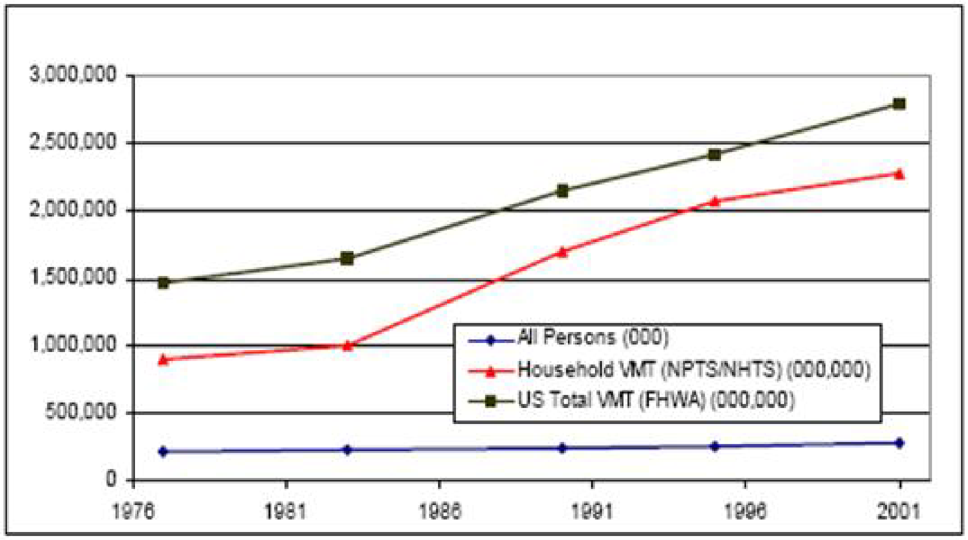
The readily available capital led to massive overbuilding in many areas, empty structures, land flips, and the subsequent demise of the savings and loan industry. However, the exodus of employment from the central business district was accelerated, along with well-established residential trends, most of it without the construction of new noninterstate transportation capacity—particularly for cross-suburban movements. As a result, suburban-to-suburban traffic flows rapidly grew to consume available road capacity, suddenly transforming many previously tranquil, quasi-rural areas to traffic levels previously seen only in core urban areas. The problem was of sufficient gravity that the U.S. Department of Transportation (USDOT) labeled it the "suburban mobility crisis" and directed considerable resources to the development of initiatives aimed at stimulating local solutions to these problems through demand management and public-private partnerships. Effective solutions were not found, since the land patterns and densities were described as dense enough to cause major traffic congestion, but not to support transit or other transportation alternatives. Because new road capacity was limited by available space and funding, most of these areas continue to experience pronounced levels of traffic congestion, limiting additional growth that has been forced to move further outward because of growth caps or traffic ordinances.

Superimposed on these critical trends of the late 1980s, the nation's transportation infrastructure faced a fiscal crisis. Years of deferred maintenance were suddenly made evident in broken pavements, the collapse of several major bridges, and a determination that many others were structurally or functionally "deficient" in their ability to carry the traffic volumes and vehicle weights that were being increasingly imposed on them (because of an increase in large trucks, including tandem semitrailers). Critical maintenance, repair, and replacement had been ignored because of insufficient planning and a failure to allocate resources at the federal and state level. The critical nature of this discovery led to the passage of the revolutionary Intermodal Surface Transportation Efficiency Act of 1991, or ISTEA, which engineered changes to the federal gas tax and transportation trust fund to avail billions of additional dollars to state transportation programs to avert a collapse of the nation's transportation system. With these new funds, however, came strict new conditions, forcing states and metropolitan areas to make preservation their top priority, followed by safety, management (measures to improve efficiency), and capacity expansions. Consequently, 85 percent of federal road dollars have been consumed by preservation, with generally less than 5 percent available for new capacity. As a result, relatively little money has been available to address congestion problems through new roads—a problem that not only hasn't gone away, but has become more compelling as deteriorating conditions are again making news and the yield from both federal and state gas taxes (fixed cents per gallon) has declined in the face of rapidly rising fuel prices.

Key Trends

A recent study for USDOT explores some of the key trends in travel that have been occurring in the United States over the past several decades (Polzin 2006). In his assessment, Polzin concludes that changes in the trends that have been driving the growth in VMT may in fact be slowing down, though the nonlinear relationship between VMT and congestion is such that slower VMT growth may not portend lower rates of congestion growth. This is because of the non-linear relationship between volume, capacity, and speeds, where additional increments of volume beyond a given V/C ratio result in rapid declines in speed, and even reductions in speed and throughput beyond a critical V/C level.

Using aggregate data from the Federal Highway Administration (FHWA) Highway Statistics database and household travel data taken from the National Household Travel Survey (NHTS), researchers plotted total population, total VMT, and total household VMT from 1977 through 2001 to coincide for comparison purposes with the dates when the NHTS was conducted (Figure 1). While the population has only grown by 30 percent during this period, total VMT has grown by more than 90 percent, and the VMT generated by households (i.e., travel for personal as opposed to commercial purposes) has grown by 151 percent. The fact that household VMT has grown five times faster than the rate of population provides strong corroboration with people's perception that traffic congestion has gotten rapidly worse. Statistics on highway lane mileage from Highway Statistics further shows that road capacity has grown no faster than the rate of population during the same period.



Source: VMT from Table VM-1, FHWA Highway Statistics Series, http://www.fhwa.dot.gov/policy/ohpi/hss/hssoubs.htm. NHTS/NPTS data from *Summary of Travel Trends 2001 National Household Travel Survey*, December 2004, Table 1, Page 9.

Figure 1. Population and VMT Trends.

Demographers such as Alan Pisarski have attempted to explain the factors underlying this growth. Key factors cited include increases in household income, workforce participation and driver's license acquisition by women, increased auto ownership, and other changes in household composition (such as size and life cycle). Discussion about these trends in forums on traffic congestion staged throughout the 1990s generally maintained that they would soon reach saturation levels, leading to a subsequent tailing off in the rate of growth in VMT and congestion. Pisarski later acknowledged that in his 1996 Commuting in America II, he was wrong about single-occupant vehicle (SOV) use having peaked, and that it has continued to rise. However, he attributed this error in projection to growing affluence and travelers' association of driving with maximizing their ever-increasing value of time (Pisarski 2005).

Conspicuously missing from these assessments, however, is any accounting for the role of land use. Throughout this period, American society was rapidly suburbanizing, resulting in greater reliance on the automobile for household travel, fewer opportunities to walk or take transit, fewer occupants per auto trip, and longer trip lengths for trips of all purposes. Among the key demographic changes that were occurring in households during this period was a decline in average household size of 18.2 percent as baby boom children began to leave home. These trends, shown in Figure 2, as well as those in Figures 3 and 4, are taken from the *2001 NHTS Summary of Travel Trends* (Hu and Reuscher 2004).

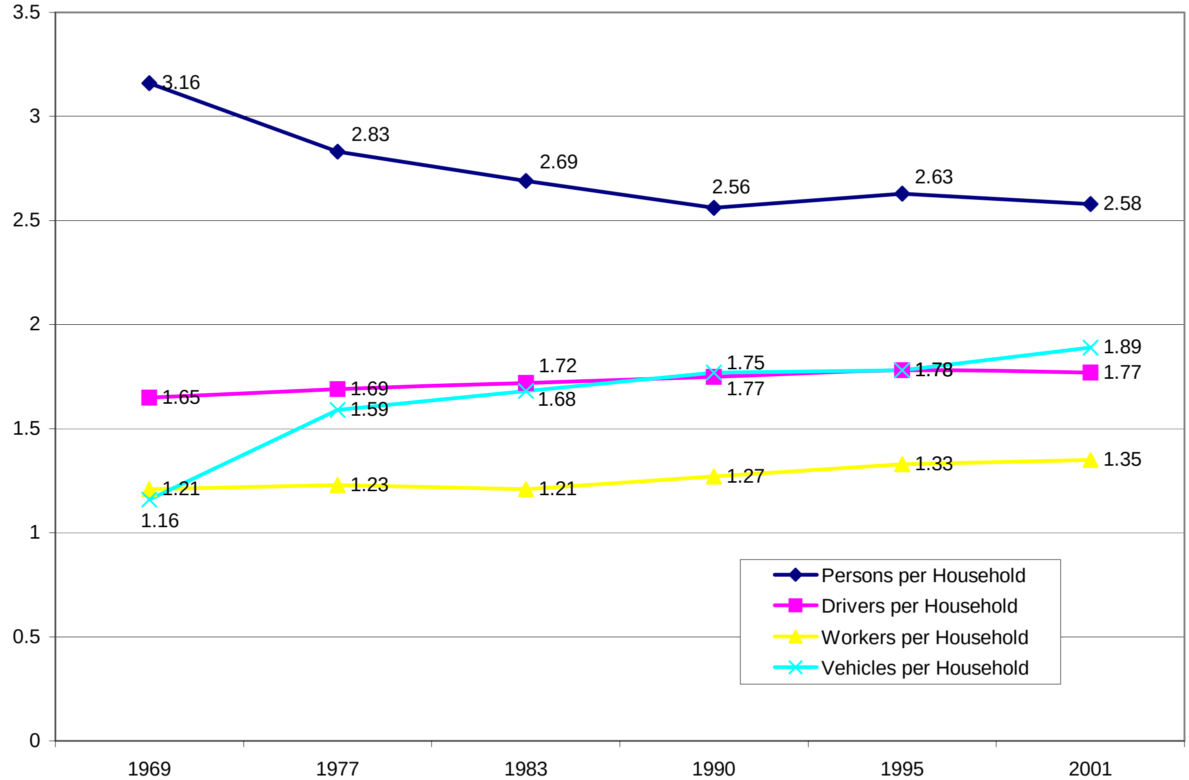


Figure 2. Household Characteristics: 1969 through 2001.

During this period, more women entered the workforce as workers per household increased by 11.6 percent, and more acquired drivers' licenses, increasing drivers per household by 7.3 percent. However, the most graphic change beyond the decline in household size was auto ownership, which increased 62.9 percent, from 1.16 per household to 1.89. This means that the number of vehicles actually surpassed the number of licensed drivers in the average household. With those additional vehicles, increasingly necessitated by suburban residential and work locations, household vehicle travel accelerated after 1983. As illustrated in Figure 3, despite the decline in household size, the number of daily vehicle trips almost doubled—from 3.83 per day in 1969 to 5.95 in 2001, and daily household VMT accordingly increased from 34.01 to 58.05 miles—an increase of more than 70 percent. On a per-person basis, given the simultaneous reduction in household size, per capita household VMT more than doubled, from less

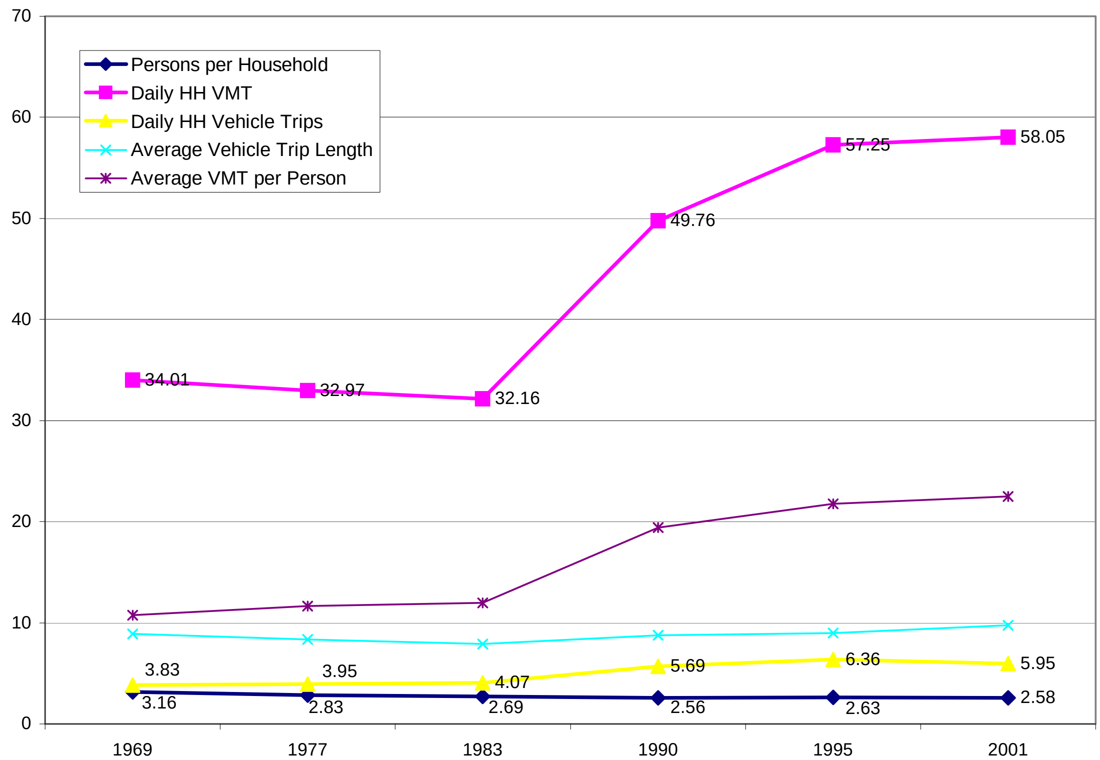


Figure 3. Change in Household Travel Characteristics: 1969 through 2001.

than 11 miles per person per day to more than 22. This increase occurred not because of longer vehicle trips lengths per se—which increased moderately from 8.5 to about 10 miles—but mainly because more vehicle trips were made.

Moreover, the primary increase in VMT has come not from more commute travel, which has been mitigated somewhat by employment moving toward the suburban population, but from the increased reliance on the automobile for nonwork travel. Figure 4 illustrates this trend clearly. While annual household VMT for travel to and from work has increased moderately—from about 4200 to about 5700 miles per year (even with more workers per household)—VMT associated with travel for nonwork purposes has jumped from 8240 per year to 15,463, an increase of 87.7 percent. The biggest increases were in conjunction with travel for shopping, which increased by 130 percent, and personal and family business, which increased by 112 percent. The reasons for this comparative increase in discretionary travel may have something to do with increases in real income, but (as will be shown later) is much more directly tied to the broad scale shifts in location that have occurred, to places where it has become necessary to drive for virtually all family-related business, from shopping to transporting children. Nonwork travel now makes up 73 percent of daily household VMT, up from 66 percent in 1969, composing the great majority of vehicle travel activity. Contrary to intuition, this nonwork auto travel also comprises more than half of the travel on the roads during peak travel hours.

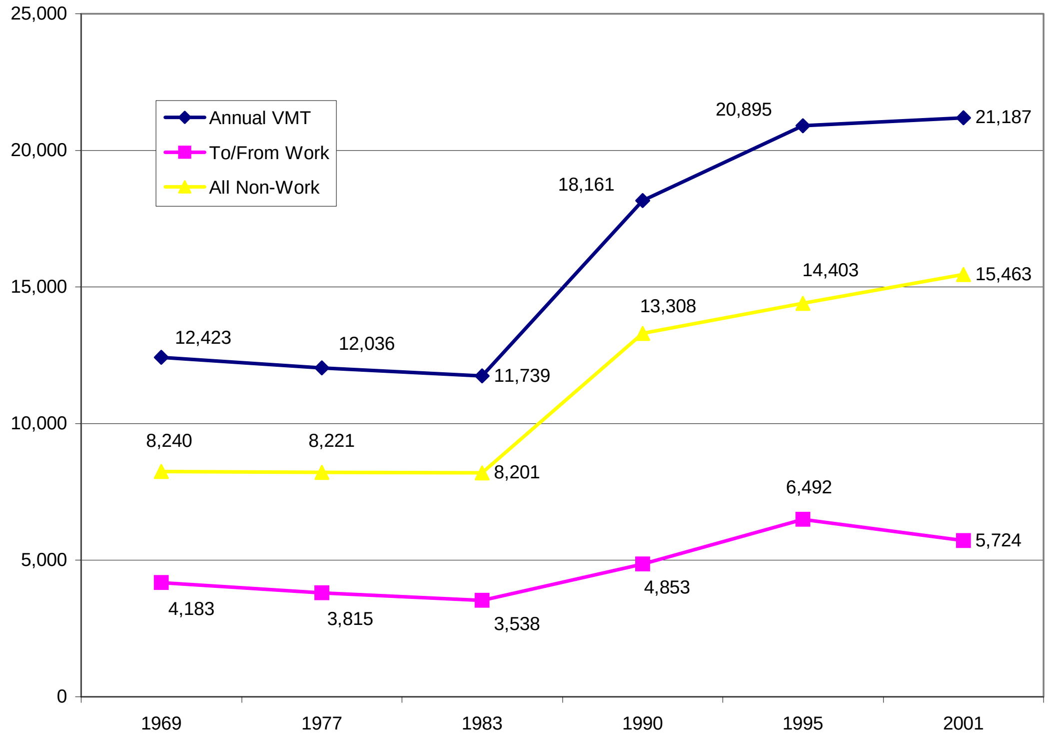


Figure 4. Source of Growth in Annual Household VMT.

These are the primary trends that help explain the changes in travel patterns and the growth in traffic congestion and delay being experienced in most of America's metropolitan areas.

HOW DOES LAND USE IMPACT TRAVEL?

Intuition suggests that traffic volumes on a busy arterial roadway are associated with the type and density of activity built along that roadway. For example, the entrance to a shopping mall is frequently teeming with cars, and suburban commercial strips also give visual evidence of customers maneuvering in and out of parking lots, or disrupting flow by trying to cross several lanes of traffic to make a turn at a busy intersection. These are inescapable facts of urban life. But what about bumper-to-bumper traffic on freeways? Ten mile backups on a regional beltway? Or agonizing signal-to-signal delay moving along a major or minor arterial, even where there is no obvious nearby commercial or higher density residential development?

The fact is that travel patterns are complex, with travel being a "derived demand" necessitated by the needs of households and customers to reach daily activities. In the transportation planner's parlance, the nature of the subsequent travel demand is best seen as a regional "trip table" of productions and attractions, or demands for travel matched against multiple locations where those demands can be fulfilled. Many factors are considered when deciding where to go to satisfy a particular trip purpose, although travel time and cost are frequently prominent in these decisions. The transportation network is the mechanism by which this diverse pattern of origin demand and destination supply is connected. Trips of many purposes and geographic orientation are superimposed upon the network at any given time such that at any given location, the travel stream may be composed of trips with many different purposes from many different locations throughout the region. Typically, trips being made on the highest functional class of highways (freeways and interstates) are the longer trips on the system, while those on arterial and connector roadways have proportionately higher shares of local travel. However, these relationships quickly dissolve if congestion clogs one group of facilities more than another or the road system lacks sufficient connectivity between particular points. As a result, travelers in suburban areas frequently use the freeways to make local trips, traveling only between one or two exits, or longer distance travelers use local roads to avoid congestion on higher class highways or as a shortcut. Hence, traffic volumes and congestion on a given roadway segment are seldom well explained by immediately adjacent development, but have multiple contributing causes.

Preferences with regard to housing type location and affordability, employment, schools, and other factors cause households to make varied decisions about where to live, where to work, where to shop or recreate, and how to travel. Subsequently, often-unforeseen changes in household structure, employment status or location, or economic conditions may call into question location choices that made great sense at an earlier time. Growth and new development have a way of changing the conditions that were once prized and expected, such as when a trouble-free, 30 minute commute gradually becomes a frustrating 60 to 90 minute ordeal, or a favored shopping district is suddenly impossible to access at particular times.

While no policy can guarantee a consistent level of access or travel speed to a given location, an important hedge against losing the amenity associated with a particular location is to ensure that it has travel options. If a long commute becomes too unbearable to drive, the commuter with options lives within easy access of an efficient transit service or can take advantage of a priority high occupancy vehicle (HOV) lane. For residents fearing difficult access to traffic-choked shopping centers, location in a community that offers a variety of services and amenities locally—either within walking distance or a short car trip on local streets—can be a periodic or regular substitute to longer trips in heavy traffic. Unfortunately, because of the uniqueness and scarcity of these communities near transit with good local land use, the cost of living in these areas is frequently too high for persons of limited economic means.

Few residential communities offer the option of good transit or HOV connectivity to the surrounding region, or local access to key domestic needs and amenities. And too few destination areas offer freedom from driving once there by virtue of compatible activities and pedestrian access. Suburban development patterns stress uniformity (believing that it is essential to keep different land uses separated), create housing developments that ensure socioeconomic homogeneity, and shape street patterns to keep out through traffic and make it easy to drive to. However, these designs also reduce travel options and place residents under the influence of broader external development trends.

So, does land use have an association with travel behavior, and if so, what is the manner of that association? At the most primary level of whether land use matters, a number of academics took an early position that any link between land use and travel behavior was inconclusive. Included in this group are such noteworthy spokespersons as Genevieve Giuliano, Peter Gordon, Harry Richardson, Randy Crane, Marlon Boarnet, Pat Mokhtarian, Xinyu Cao, and Susan Handy. Most if not all of these researchers are based in California, and data from which their early conclusions were drawn (also principally from Southern California) showed no clear association between characteristics of land use as they measured them and travel behavior. Giuliano and Crane (Shay and Khattak 2005) maintained that the relationship between urban design and travel behavior was complex and not completely understood. Giuliano argued that because urban areas in the United States are already so accessible (by automobile, mainly), settlement patterns so well-established, and maintenance of privacy so important, transportation plays an ever-decreasing role in the locational decisions of households and businesses. Crane and Boarnet, in series of studies, determined that "the relationship between neotraditional design and travel behavior is made more complex by the difficulty of isolating the various design elements that may have a causal relationship to travel behavior – moreover, some traits, such as visual appeal, sense of safety or community, are hard to define and the synergy of design is hard to measure" (Shay and Khattak 2005). To the extent that any differences in behavior were observed, most of these researchers suggested that the predominant effect being observed was one of "self-selection"—namely, that persons who were inclined to walk, take transit, or be comfortable living in closer contact with others were more likely to choose to reside in places that offered those opportunities. As discussed earlier, a key issue is also that these areas are currently only affordable to people of means. The issue of self-selection is explored in a later section of this report.

Such a uniform dismissal of a relationship between land use patterns and travel behavior contradicts a large and growing body of empirical evidence from other studies. A much larger contingent of researchers has taken the position and conducted the research to affirm that in fact, land use does have an impact on travel behavior. Key among this group are Robert Cervero, Kara Kockelman, Kevin Krizek, Reid Ewing, and Larry Frank (Kuzmyak et al. 2003). A variety of empirical studies performed in the mid- to late-1990s revealed that households residing in more traditional urban neighborhoods with a mixture of uses, walkable streets, and good access to transit tended to own fewer vehicles, make fewer vehicle trips, and generate less VMT than their counterparts living in suburban subdivisions.

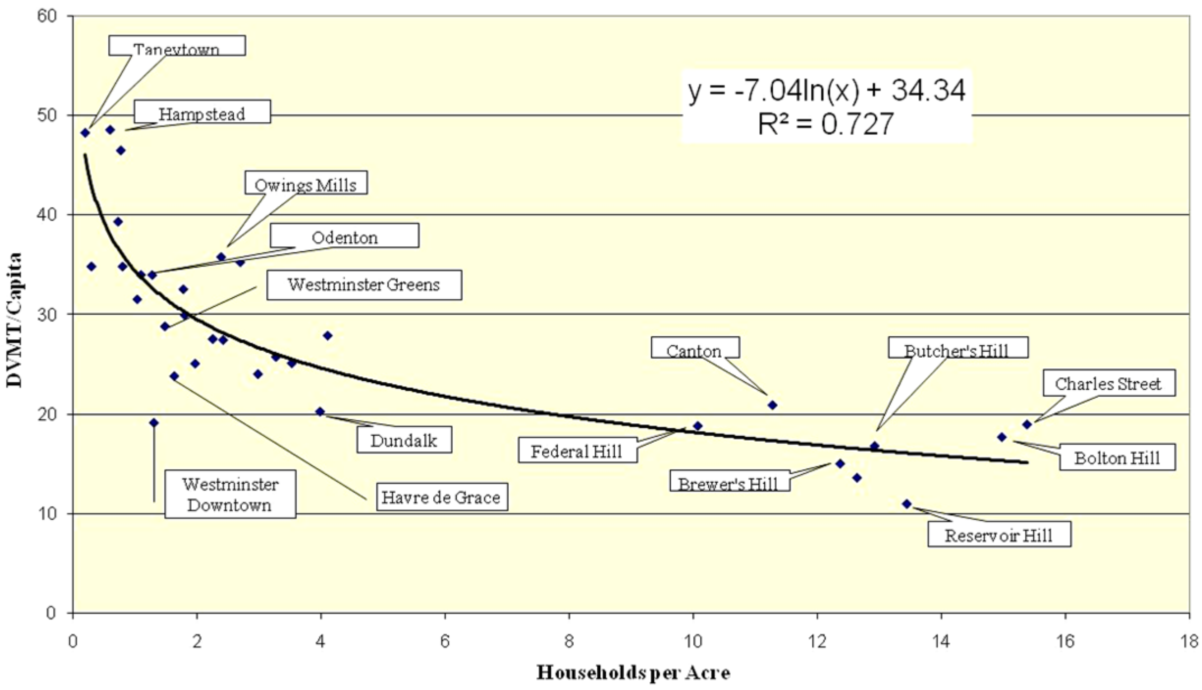
A 1995 study by Cervero and Radisch (1996) of two demographically similar neighborhoods in the East Bay area of San Francisco found significantly lower rates of auto use in the traditionally designed neighborhood for commuting (63 percent vs. 79 percent) and for nonwork travel (85 percent vs. 96 percent). A significant difference was found in the degree to which residents in the traditional community walked or used bicycles, amounting to 52 percent of all trips under two miles in the traditional community vs. 17 percent in the comparison community. In a 1997 study of trip rates and

VMT in Seattle neighborhoods, Rutherford, McCormack, and Wilkinson (2001) found that average daily travel mileage by all modes was considerably less (17 to 22 miles per person per day) in three traditional neighborhoods than in demographically matched inner and outer suburban neighborhoods (30 and 39 miles, respectively). Walk shares were also much higher (18 percent vs. about 2 percent to 3 percent) in the traditional neighborhoods (Kuzmyak et al. 2003).

Working with data from Baltimore's 2001 regional household travel survey, Kuzmyak developed measures of household and per capita VMT for 32 different neighborhood clusters in the survey sample, and compared their performance with residential density as a measure of urban vs. suburban land use. As seen in Figure 5, a remarkably strong relationship was found between per capita VMT generation in these neighborhood clusters and residential density, with households in the more urban locations generating between 10 and 20 VMT per person per day compared with rates of 30 to 50 miles per day in the more typical suburban areas. What is interesting about this relationship is not only the tendency for VMT rates to increase with lower densities, but to do so at a nonlinear rate, reflected in the logarithmic curve fitted to the data with an R^2 value of 0.727. This relationship was surprisingly independent of traveler affluence; as a regression of household VMT vs. household income failed to show a statistically meaningful relationship. Very similar relationships were discovered in data from the Washington, D.C. region (Kuzmyak, Baber, and Savory 2006).

Figure 5. Daily Per Capita VMT vs. Residential Density in Baltimore Region.

Source: Baltimore Metropolitan Council, 2001 Travel Survey



Early studies such as these simply compared communities on a simple measure like residential density, or on a binary basis, as to whether they did or did not resemble traditional vs. conventional settings. Subsequent research has become much more focused on identifying the specific characteristics of land use that impact travel, while more directly controlling for socioeconomic and other key differences.

What these later studies have revealed is that land use is about much more than simply density. By reducing distances between households and activities, compact development improves accessibility by all modes of travel. Walking becomes more feasible, but also vehicle trip lengths are shortened by the existence of more local opportunities. While density is a strong surrogate for proximity, the kinds of land uses that are mixed and the character of the mix also matter. Also, the ease with which travelers can part with their cars and walk to and among these various activities as well as to reach transit service is an important determinant. This set of relationships has been dubbed the "3Ds" of local land use—density, diversity, and design—with density reflecting intensity of development (people or jobs), diversity representing both the degree and balance of mix, and design representing the layout of the area in relation to ease of pedestrian access. While it is difficult to attribute the coining of the 3Ds concept to any given researcher, Cervero and Ewing are widely associated with its use and quantification. In a paper titled "Travel and the Built Environment—A Synthesis," , the authors presented elasticities of demand for vehicle trips and VMT related to each of the 3Ds, which they abstracted from 14 different studies (Ewing and Cervero 2001). These elasticities were subsequently adopted into the U.S. Environmental Protection Agency's (EPA's) Smart Growth Index Model for use in local planning activities and for areas seeking emissions credit for land use actions (Kuzmyak et al. 2003).

Most land use researchers, including Cervero and Ewing, also recognized that the effects of land use on travel behavior were not just occurring at the neighborhood level, but at the regional level as well. In essence, the link between land use and travel behavior is tied to the concept of accessibility—the nearness of activities and the breadth of choices represented in those opportunities. The 3Ds do a good job of reflecting local accessibility differences, but also important is the degree of access to opportunities available outside the neighborhood, or regional accessibility. Picturing two communities that are otherwise similar with regard to local mix and design, clearly the community that offered more activities and opportunities to its residents outside its boundaries within a given travel time window would have a much different profile in terms of travel opportunities and subsequent travel choices. This greater regional accessibility is a function of both the physical proximity of external opportunities and the ability of the transportation system to reach them. Hence, areas with good highway access and connectivity would be expected to have good regional accessibility, but the same area served by good regional transit service would be expected to have even greater regional accessibility when viewed from a multimodal perspective. Regional accessibility is now often referred to as the fourth D of land use, representing destinations. Ewing and Cervero also derived an elasticity for regional accessibility to employ in the Smart Growth Index Model. They found that if regional accessibility were doubled for a given household, VMT would decline by about

20 percent. And if density, diversity, design, and regional accessibility were all doubled, the combined impact would be a 35 percent reduction in household VMT (Ewing 2005).

MOST IMPORTANT VARIABLES AND TYPES OF TRAVEL MOST AFFECTED

A number of studies have focused on measuring the ways in which land use characteristics influence travel (Bose and Fricker 2003; Boarnet and Sarmiento 2003; Barnes 2003; Khattak and Rodriguez 2005; Krizek 2003a, b; Krizek and Johnson 2006; Paez 2006; Soltani and Allan 2006; Hess et al. 1999; Hess, Vernez-Moudon, and Logsdon 2001; Shay and Khattak 2005; Ewing 2005; Frank, Kavage, and Litman, 2006; Zhang 2006; Lam and Niemeier 2005; Urban Land Institute 2005; Cervero 2006; Targa and Clifton 2004; Marshall and Grady 2005; Rodriguez, Khattak, and Evenson 2006; and Yi 2006).

Perhaps the landmark study in measuring the relationships between transportation and land use was performed by Kara Kockelman. Using data from the San Francisco Bay Area, she attempted to explain differences in travel as a function of three key factors: socioeconomic characteristics, regional accessibility, and local accessibility. Kockelman used data from the regional household travel survey as the source for trip rates by mode, VMT, and auto ownership. She measured regional accessibility as the cumulative number of jobs reachable in all other TAZs, discounted by the travel time to reach them. And she tested a variety of 3Ds measures for local accessibility, including population and employment densities, and measures of diversity for land use mix and entropy for mix balance derived using GIS tools and fine-scale land use data. Regression analysis was used to determine the degree of statistical relationship between these factors and household VMT, trips by auto and walking, and auto ownership. Her analysis showed that household VMT increased with household size, income, and auto ownership, but declined with improvements in regional accessibility (elasticity of -0.31) and in the 3D variables of mix (dissimilarity, elasticity of -0.10) and balance (entropy, elasticity of -0.10). Density did not prove to be an important explanatory factor. Another important finding was the role of land use on auto ownership, with increases in regional accessibility, and local dissimilarity and entropy all acting to reduce household auto ownership (Kockelman 1996).

Using a similar approach, Kuzmyak developed a set of household VMT and auto ownership models from Baltimore data. This research found the same direction of influence from the regional accessibility and local 3Ds variables, but was strengthened by the addition of a new variable to measure walkability (design). Kockelman did not use such a measure in her models, fearing problems of subjectivity with a pedestrian environment friendliness (PEF) type index of walkability. Using GIS tools as well as a database locating employment by size, type, and specific geography, Kuzmyak created a walk opportunities index that summarizes the opportunities lying within a one-quarter mile buffer of a household. Each opportunity is identified, given a value based on the Standard Industrial Code (SIC) identity and size, and its value is discounted by the walk time required to reach it on the respective street grid. The index is quite similar in behavior to the measure of regional accessibility, only for walking. The Baltimore models proved to be statistically more robust (much higher R^2 values), while the elasticities for the land use variables were of similar magnitude. The Baltimore research also demonstrated the specialized role played by local land use. The local 3Ds variables were very important in the models predicting auto ownership and nonwork VMT (and total VMT), but were not significant in the home-based work models. What this implies is that households apparently make decisions about how many vehicles to own and how to travel for nonwork trip purposes based on the 3Ds characteristics of their neighborhoods (as well as regional accessibility, of course), but these characteristics do not seem to be important in work-related travel. The influence of local land use is felt indirectly, through auto ownership, and again through multimodal regional accessibility for work-related travel (Kuzmyak, Baber, and Savory. 2006).

Supporting this important finding is research performed by Solimar Research for the South Bay Cities area of Los Angeles. Researchers used travel surveys to study travel behavior in four mixed-use neighborhoods in the southwestern portion of Los Angeles County: the older portions of Redondo Beach, Torrance, Ingleside, and El Segundo. These areas included a mix of socioeconomic levels, but also a reasonable offering of shopping and services within walking distance of residents. The survey found that residents of these areas made about three-fourths of their grocery and other shopping trips and about half of their restaurant trips to the local center. The percentage of these trips made by walking as opposed to driving ranged from 31 percent to 72 percent, depending on the trip type, the particular area, and the distance of the household from the center of town. Residents also made many walk trips to the centers simply for pleasure and exercise. This travel behavior stood in stark contrast to almost exclusive reliance on driving for work trips, given that most workers were employed at noncentral locations which were not served by transit and where free employer parking was almost universal (Solimar 2005).

Similar results were found in a 1998 study by R. L. Steiner of six traditional shopping districts in the Oakland-Berkeley area of San Francisco. The districts, which had a variety of mix and scale of business activity, were all in middle class neighborhoods of moderately high density (13 to 21 persons per acre), and had Main Street type characteristics with good pedestrian access. Surveys found that a significant percentage of customers at each site got there by walking. Weekday shares were 20 percent to 38 percent walk and 41 percent to 79 percent auto, with much higher walking rates (24 percent to 65 percent) among residents living within one mile of the district (Kuzmyak et al. 2003, p. 15-52). So, while the primary benefits of mixed, compact land use may be on nonwork travel, with a secondary effect on work travel through the influence of auto ownership and regional accessibility, should we lessen expectations for land use to influence work travel? Not necessarily.

While the suburban exodus of jobs has moved work closer to employees in many instances, many other factors influence commuters' travel choices. First, commuting to a suburban job almost guarantees use of an auto. Not only are most of these areas too scattered to be reached in any other way, but once there, the commuter is likely to be dependent on a private vehicle for any other need. Trips for food and personal business like banking, filling a prescription, or attending a meeting generally require use of car. So the 3Ds of land use that are so important in lessening car dependency at the residence also come into play at the destination. The degree to which employment destinations have walkable densities, mix of uses, pedestrian facilities, managed parking, and ideally transit access has a major impact on commuting mode choice decisions. In his paper "Built Environments and Mode Choice: Toward a Normative Framework," Cervero found that accounting for density, mix, sidewalk coverage, and regional accessibility in home-based work mode choice models added major explanatory power in predicting the likelihood that commuters would opt for alternatives modes (Cervero 2002).

Another important land use factor in work travel behavior is jobs-housing balance. Demographers and trends specialists like Pisarski point out that with multiworker households, it becomes very difficult to optimize residential location to ensure an efficient commute. Seldom would it be expected that both wage earners would work in the same general location and, hence, share the benefits of a planned commute advantage. Moreover, given the frequency with which either job or residence locations change, an "ideal" location often abruptly shifts on one or both ends, rendering the original location planning moot. While not a complete solution to this practical dilemma, an important planning consideration is the balance in the location of jobs and housing.

In many areas, local jurisdictions have tried to direct their employment growth to particular areas, often distinct from current or proposed housing. The result is long commutes over imperfect road networks, often involving long, circuitous paths that add miles to the actual distance. Added to this is a frequent imbalance in functional jobs/housing balance, where the jobs are not particularly well-matched to the characteristics of the resident workers. Conversely, appropriately skilled workers for the given jobs cannot find housing nearby that they can afford. Each of these imbalances exacerbates the efficient connection of worker to job and contributes to trip length and traffic volumes.

Table 15-14 in Kuzmyak et al. presents findings from a number of studies of the effect of jobs/housing balance and commute travel behavior. Review of this information concluded that even with good matching of resident and workplace job skills, jobs-housing balance is at best an indicator of the potential for matchups that would internalize commute travel in small areas. However, as area size grows, jobs-housing balance becomes more of a force in enabling productive matchups. Results of studies by Frank and Pivo, Ewing, Cervero, and others suggest shorter commute trip lengths by 7 percent to 30 percent in balanced areas. The strength of this relationship must be tempered, however, by the context in which the measurement is made, since characteristics like density, centrality in the urban region, and transit access have an important bearing on the ultimate benefit of balanced jobs and housing (Kuzmyak et al. 2003).

A fairly recent study by Cervero and Duncan attempted to determine whether jobs-housing balance or retail-housing mixing produced the greater impact on vehicle travel. Using data from the San Francisco Bay Area, they examined the degree to which job accessibility is associated with reduced work travel and how closely retail and service accessibility to residences is correlated with miles and hours traveling to shopping destinations. They found that higher accessibility to occupationally matched jobs reduced VMT and vehicle hours traveled (VHT) for work trips, particularly when such job matches were plentiful within four miles of home. They found elasticities for work tours to be considerably higher than those for shopping tours (0.329 vs. 0.137) such that even while the share of daily VMT devoted to shopping and services was higher than for commuting (42.8 percent vs. 36.7 percent), the higher elasticity meant that access to jobs reduced VMT 72.5 percent more than access to shops and services (Cervero and Duncan 2006).

THE ROLE OF TRANSIT

Intensified, compact, mixed land use schemes are often associated with proposals for major investments in rail transit systems. The resultant development, termed transit oriented development (TOD) serves the dual objective of providing a logical location for intensified development while also encouraging greater ridership levels on the transit system. Advocates argue that the transit focus is essential to concentrating development patterns in a way that is impossible with auto-shaped, low-density sprawl. Critics argue that the massive resources diverted to a rail transit system are misspent, given the few people likely to use the systems and the opportunity missed in diverting those resources from highway projects that would benefit the most people.

Given the described importance of multimodal regional accessibility in shaping auto ownership and longer-distance travel decisions, the strategic role that can be played by high-quality regional transit is evident. If that transit service is independent of the surface roadway network, as with rail or even bus rapid transit, its ability to provide a consistently high level of accessibility to regional destinations over time amidst growing road congestion has great value in preserving mobility. Perhaps the most strategic value of such a system, however, is the excuse it provides to create development nodes around station areas. These nodes then contain the characteristics of higher density, mixed use, and walkability that breeds lower auto ownership, more internal trips, less VMT, and more walking. While compact, mixed-use developments can be located virtually anywhere, they are given additional stimulus when located near a transit node because of the additional dimension of regional accessibility they provide the respective community. Linked in a system, they also provide an ensemble of varied destinations that residents can easily access if they can’t find what they want in their own neighborhood. TOD specialists like G.B. Arrington suggest that rates of household vehicle trip generation in TODs may be as much as 50 percent less than those in comparable conventional developments (Arrington 2007).

At the same time, there is no denying the expense and skepticism associated with new transit systems, whose primary purpose is to shape future land use. In mature metropolitan areas like Washington, D.C., San Francisco, and Philadelphia, the basic transit system already exists, its use patterns are well-established, and time has allowed the importance of the transit stations to be translated into higher land values and demand for higher intensity development. At that point, the major challenge is to guide that development so it occurs in the most productive and sustainable fashion. In newer areas that haven't grown up in the presence of regional transit, like Los Angeles or Portland, Oregon, the formula for success may not seem as easily replicated.

An article in the *Los Angeles Times* levied strong criticism at the logic of investing billions of public dollars on transit and TOD projects in Los Angeles between 2001 and 2005, and yet residents are still driving. Reporters examined driving habits at four housing complexes built at or near transit stations along both the Red and Gold lines and found that only a fraction of the residents shunned cars and used transit, particularly during the morning rush hour. They discovered that many of the drove to workplaces because either their place of employment was not near a station, it was not easy to get about without a vehicle at the destination, they had free parking, or it simply took longer or cost more to take transit. However, the reporters also concluded that the transit system's failure was due to the false assumptions that most traffic was generated by commuting and that most people worked downtown, neither of which is true. In fact, most of the construction in the TODs to date has been for housing rather than employment or mixed use, meaning that thousands of people are now clustered near transit stations that they only occasionally use and still have few local travel options (Bernstein and Vara-Orta 2007).

Many critics of TOD point to Portland, Oregon, as an expensive, failed experiment. One such prominent critic is Randal O'Toole, founder of the American Dream Coalition. Despite Portland's unusual commitment to planning around transit, at the expense of improving roads and allowing more freedom for development at the periphery of the region (beyond the Urban Growth Boundary), O'Toole argues that the plan has not been a success. While Portland's planners claim that its residents love transit and use it frequently, O'Toole points out that the region lost many transit riders in the 1980s when the high cost of construction forced cuts in bus service, dropping transit share from 2.6 percent in 1980 to 1.8 percent in 1990. Over the next 12 years, while ridership slowly climbed back to 2.3 percent of travel, he projects that the situation will again deteriorate as additional service cuts are made (O'Toole 2007).

While O'Toole's arguments draw attention, extent of transit ridership in Portland relative to its size is an interesting consideration. As seen in Table 1, with a regional population in 2005 of about 2.175 million people, Portland ranked 23rd in size among major U.S. metropolitan areas. However, its residents logged more than 104 million annual transit trips, which qualified for 10th highest among U.S. metro areas (which is 100 million annual riders more than it had in 1979). Considered in relation to its population size, this meant that Portlanders averaged 48.1 transit trips per person per year in 2005, which was 7th highest in the country, placing them behind only New York (146.8); Chicago (51.6); Philadelphia (57.4); Washington, D.C. (78); and Boston (80.1), and only slightly behind San Francisco (51.9). Its transit use rates are multiples above places like San Diego (9.9), Dallas (11.9), Houston (16.7), Miami (19.3), and Tampa/St. Petersburg (4.3), while on a par with older Eastern transit cities like Baltimore (38.7), and Pittsburgh (29.2. Similarly, its VMT per capita rate—a measure of its auto dependency and the demand its residents place on the highway system—is 23.6, which is quite favorable in comparison to places like Dallas (31.1), Houston (36.9), and Atlanta (33.8). This efficiency in VMT generation shows up in congestion delay, as residents of Dallas, Houston, and Atlanta experience considerably more hours of congestion delay than residents of Portland (figures are presented in a later section).

When Portland first decided to develop its future growth patterns around its light rail transit (LRT) system, it had more than its share of critics. One such critic was the town of Gresham, located between downtown Portland and the airport. While Gresham chose to distance itself from the transit system during its construction and early operating period, by the late 1990s it annexed land to incorporate the MAX line within its jurisdictional borders.

THE PARADOX OF SELF-SELECTION

An important set of arguments challenging the rationale for advocating compact, traditional land use policies suggests that while persons living in such areas may in fact drive less and walk more, the reason for this difference in behavior lies more with individuals and their attitudes toward these opportunities than the areas themselves. They argue that such individuals may be predisposed to such behavior and seek out communities in which they can indulge these priorities. Forcing persons without these predispositions into neighborhoods that favor walking and transit use may not yield the desired result that these individuals will drive less. This point of view may be largely attributed to a 1994 study by Kitamura et al., which analyzed travel behavior differences among five diverse neighborhoods in the San Francisco Bay Area. Attitude surveys, combined with travel diaries, were used to conclude that residents' attitudes toward their neighborhoods and their travel patterns were highly correlated and, in fact, that the attitudes showed greater statistical significance than the neighborhood characteristics (Kuzmyak et al. 2003).

A number of researchers have since taken interest in this perspective, including Susan Handy, Patricia Mokhtarian (part of the 1994 Kitamura team), Xinyu Cao, and Kevin Krizek—all academic professionals with extensive research backgrounds (Handy 2006; Handy, Cao, and Mokhtarian 2005; Schwanen and Mokhtarian 2005; and Krizek 2003a). In addition to the findings of the Kitamura study, an early study by Newman and Kenworthy (1989) on the correlation between density and gasoline consumption (i.e., VMT per capita) for a sample of international cities came under criticism for failure to account for major underlying factors such as transit availability and income in ascribing major benefits to higher density. This set of events has made the land use research field, and academic researchers in particular, extremely zealous about following acceptable

Table 1. Population and Transportation Statistics of 23 Largest Metropolitan Areas.

Size Rank	Urban Area	Population[1] (thousands)	Annual Transit Ridership[2] (rank, in millions)	Annual Transit Trips per Capita	Daily VMT per Capita[3]	Delay per Peak Traveler[4] (hr/yr)
1	New York, NY	18,815	2,759.8 (1)	146.8	15.5	46
2	Los Angeles, CA	12,875	451.5 (3)	35.1	22.7	72
3	Chicago, IL	9,525	492.3 (2)	51.7	20.5	46
4	Dallas/Ft Worth, TX	6,145	73.3 (15)	11.9	31.1	58
5	Philadelphia, PA	5,827	334.5 (6)	57.4	18.9	38
6	Houston, TX	5,628	94.6 (13)	16.7	36.9	56
7	Miami, FL	5,413	104.7 (9)	19.3	19.2	50
8	Washington, D.C.	5,306	414.1 (4)	78.0	22.9	60
9	Atlanta, GA	5,278	142.4 (8)	26.9	33.8	60
10	Boston, MA	4,482	394.9 (5)	80.1	20.3	46
11	Detroit, MI	4,467	35.6 (25)	8.0	24.1	54
12	San Francisco, CA	4,203	218.2 (7)	51.9	22.4	60
13	**Phoenix, AZ**	**4,179**	**45.7 (22)**	**10.9**	**27.3**	**48**
14	Riverside/S. Bern, CA	4,081	NA	NA	24.5	49
15	Seattle, WA	3,309	98.6 (12)	29.8	25.8	45
16	Minneapolis -St. Paul, MN	3,208	69.7 (16)	21.7	24.5	43
17	San Diego, CA	2,974	29.3 (27)	9.9	23.7	57
18	St. Louis, MO	2,803	46.4 (21)	16.6	28.7	33
19	Tampa/St. Pete, FL	2,723	11.7 (36)	4.3	22.8	45
20	Baltimore, MD	2,668	103.4 (11)	38.7	21.4	44
21	Denver, CO	2,464	86.3 (14)	35.0	22.1	50
22	Pittsburgh, PA	2,355	70.0 (17)	29.2	22.7	16
23	**Portland, OR**	**2,175**	**104.5 (10)**	**48.1**	**23.6**	**38**

[1] Table of U.S. Metropolitan Statistical Areas, U.S. Census Bureau, July 2007.

[2] 2005 Annual Transit Ridership by Metropolitan Urban Area, Federal Transit Administration, U.S. Department of Transportation.

[3] *Our Nation's Highways*, Federal Highway Administration, U.S. Department of Transportation, 2005.

[4] Annual Mobility Report, Texas Transportation Institute, 2005.

scientific principles regarding causality. Four criteria are cited by Handy as necessary to prove causality in a relationship:

- Association: The cause and effect are statistically connected.
- Time order: The cause precedes the effect in time.
- Nonspuriousness: No third factor creates an accidental or spurious relationship between the variables.
- Causal mechanism: The mechanism by which the cause influences the effect is known.

It has been argued by the self-selection proponents that the first criterion has been essentially demonstrated, namely that residents of neighborhoods with higher levels of density, land use mix, transit accessibility and pedestrian friendliness walk more and drive less than residents of places with lower levels of these characteristics. However, they point out, most of these studies have reached their conclusions from cross-sectional data, and while they have controlled for sociodemographic differences among communities and travelers, they have not accounted for the effects of attitudes toward travel. Hence, the time order and nonspuriousness criteria have not been addressed, leaving open the possibility of self-selection in which individuals who would rather not drive choose to live in neighborhoods that are conducive to driving less (Handy, Cao, and Mokhtarian 2005). Schwanen and Mokhtarian (2005) used such a cross-sectional approach, but with a different methodology that incorporated attitudes and found that neighborhood type did impact travel behavior, even after attitudes were accounted for, and Cao and Mokhtarian (2005) found that characteristics of the built environment influenced walking behavior even after accounting for a preference toward walkable neighborhoods.

In a 2003 *APA Journal* article, Krizek reported on research to try to address this issue by taking two important steps: improving the measures of urban form themselves to better reflect the characteristics of neighborhood accessibility, and opting for a longitudinal as opposed to cross-sectional approach to studying travel behavior changes in relation to land use. He employed data from the multiyear Puget Sound regional panel survey in which he examined changes in the structure, neighborhood, and travel behavior of 430 households that had changed residential location within the region during consecutive two-year survey intervals. He found that households do, in fact, change their travel behavior when they are exposed to different urban forms following a move. Models revealed that in the presence of improved neighborhood accessibility, households increased their number of daily trip tours (journeys to and from home), but the number of trips per tour decreased as did both total personal miles of travel and VMT. In other words, they made more trips, but the trips were shorter, single-purposed, and less likely to involve auto use (Krizek 2003a).

Handy, Cao, and Mokhtarian obtained similar corroboration of a causal effect from land use by also applying a quasi-longitudinal approach to data from eight northern California communities. Four pairs of traditional vs. conventional suburban, demographically matched neighborhoods were selected from the Sacramento, Modesto, Santa Rosa, and

San Jose areas. Roughly 500 residents from each neighborhood were surveyed on their travel behavior, vehicle ownership, neighborhood characteristics and preferences, and travel attitudes. Vehicle miles per respondent were found to be 18 percent higher among residents of the suburban neighborhoods. To sort out the effects of neighborhood characteristics from attitudes and preferences, a set of multivariate models was estimated using vehicle miles driven as the dependent variable. In these simple models, when attitudes were accounted for, no significant effect of built environment was determined.[1] However, as a stronger test of causality, a longitudinal methodology was applied to measure changes among residents who had recently moved. These models revealed significant associations between changes in travel behavior in response to changes in the built environment even when attitudes had been accounted for, providing support for a causal relationship (Handy, Cao, and Mokhtarian 2005).

While no one is prepared to yet proclaim complete satisfaction with the premise that changing land use will lead to a fully corresponding change in travel behavior (i.e., toward more walking and less driving), increasing statistical evidence is being furnished. An interesting parallel question is whether travelers have enough experience with higher-density, mixed-use, transit and pedestrian-serviceable land forms to be able to form an experience-based set of preferences that withstand the test of time and alternative land use offerings, which are currently in short supply.

DENSITY, CONGESTION, ACCESS, AND MOBILITY

A legitimate concern among critics of compact, mixed-use development patterns is the effect of higher density on traffic levels and congestion. In a 2003 article, Wendell Cox argued that one of the principal reasons that smart growth or compact city strategies cannot reach its objective of reducing traffic congestion (or its rate of growth) is because of the strong positive relationship between higher population density and higher traffic volumes. He claimed that as population densities rise, vehicle use also rises and cited research sponsored by the FHWA (Ross and Dunning 1997) that shows traffic volumes rising at least 80 percent of the rate of the corresponding increase in population density. Moreover, he suggested, as more vehicle miles occur in a confined geographical location, traffic slows down and is subject to more stop-and-go operation, leading to increased time spent in traffic and higher air pollution emissions since most vehicle tailpipe pollutants are emitted at higher rates at lower speeds. To illustrate his hypothesis, Cox fitted data from the Texas Transportation Institute’s (TTI’s) 2000 database to a linear regression, resulting in a formula that predicts vehicle miles per square mile in relation to population density, as displayed in Table 2 (Cox 2003).

[1]It should also be noted, however, that the measures used to capture local and regional land use and accessibility are extremely important, and have generally not been rigorously applied in studies such as these.

Table 2. Effect of Higher Density on Vehicle Travel.

Population/ Square Mile	Vehicle Miles/ Square Mile	Compared to Density of 1,000 per Square Mile	Vehicle Miles per Person	Compared to Density of 1,000 per Square Mile
5000	93,069	2.90	18.6	0.58
4000	77,835	2.42	19.5	0.61
3000	62,601	1.95	20.8	0.65
2000	47,367	1.47	28.7	0.89
1000	32,133	1.00	32.1	1.00

Source: Cox, W., “How Higher Density Makes Traffic Worse,” 2003.

Cox’s model predicts that as population density per square mile increases, so does vehicle travel intensity in terms of vehicle miles per square mile. Indeed, at a density of 5000 persons per square mile, the number of vehicle miles per square mile would be 93,069, which is a multiple of 2.9 times the rate of 32,133 vehicle miles per square mile at a population density of 1000. However, increasing population density by a factor of five only increases VMT density by 2.9, implying an inherent efficiency in the higher population density. The two columns on the right have been calculated from the first two columns to highlight how the average person in the higher-density environment (5000 persons/mi^2) generates only 18.6 VMT, vs. 32.1 in the low-density environment, a VMT per capita savings of about 43 percent. This represents a considerable savings in highway construction and maintenance requirements to taxpayers, but also translates into less travel delay for users.

To be sure, if 2.9 times the number of vehicle trips were squeezed onto the same highway network, congestion levels would probably rise rapidly, given the nonlinear nature of traffic flow as volumes approach design capacity. However, there is no accounting in Cox’s analysis as to what the actual traffic congestion levels would be since he did not account for the corresponding highway capacity. Nor did he account for the presence of transit in diverting some of these trips or for higher rates of walking that would allow people to reach desired activities independent of the number of cars on the roads. The relationship between metropolitan population density and annual hours of delay per peak hour traveler for several metropolitan areas—New York, NY (4313 persons/mi^2 and 46 hours delay); Portland, OR (2853 persons /mi^2, 38 hours); Dallas (2188 persons /mi^2, 58 hours); Atlanta (1694 persons /mi^2, 60 hours); Houston (1618 persons /mi^2, 56 hours); and Phoenix (2028 persons /mi^2, 48 hours)—suggest that numerous mitigating factors beyond simply density contribute to predictions of traffic congestion, delay, and the quality of the travel experience.

Density itself, without attention to mix, balance, and connectivity, could very well create nightmarish traffic. Hence, construction of high-density employment in one location, high-density commercial activity along an arterial highway, and multifamily housing development with no services nearby is probably a recipe for traffic disaster. However, if the uses are mixed, if distances are compact, and if connections are pedestrian-friendly, the literature shows such developments will internalize a higher proportion of their trips, relieving the road network of large amounts of VMT. Still, these areas with purposely designed compact, higher-intensity development may well be locations of higher traffic. If they are nodes on a system of arterial highways, the higher rates of activity in these places most likely will slow down traffic. The question, however, is whether that is uniformly a bad thing. If the transportation objective is to move as many cars as fast as possible, regardless of trip length or orientation, then the slowdown is judged a bad thing. However, if the objective is to allow as many people as possible to access as many activities as meet their needs in as little time as possible, then the occasional loss of free-flow traffic conditions may be a productive compromise. For those travelers making longer-distance trips that would be inconvenienced by higher congestion in the activity nodes, provision of good regional transit service can begin to offset this inconvenience by providing choices. This vision is rooted in the concept of accessibility, which is increasingly viewed as a more desirable and more achievable goal than mobility as defined by private auto travel. From the standpoint of economics, a much higher level of social welfare is achieved when more people are able to maximize their activity needs at lower cost (time and monetary).

For example, in Figure 6, Household A resides in an area that is more compact and pedestrian-oriented with various nearby services, while Household B resides in a more typical residential subdivision where there are no nearby services. Household B has access to two large supermarkets within 10 to 15 minutes drive from home. Household A has access to one of these major supermarkets (a slightly longer drive), but also has access to a smaller supermarket within three-quarters of a mile of home to which residents can walk in 15 minutes or drive within five minutes. In addition, a small neighborhood grocery store, a bakery, and a 16-hour convenience store are within easy walking distance of home (one-eighth to one-quarter mile). Household A has greater accessibility as well as more choices and amenity, than Household B. Moreover, Household A has indemnity against traffic congestion delay. Household A may wish to do its major shopping at the large supermarket, but at busy travel times (or over time as traffic levels rise) that destination may be much less attractive than the smaller or more specialized options within the neighborhood.

In 2007, researchers at the University of Minnesota's Center for Transportation Studies demonstrated why accessibility may be the most appropriate lens for viewing the performance of the transportation system. The report begins by suggesting a different way of looking at the annual congestion indices published by TTI, arguing that while congestion is a serious issue, counting cars and clocking speeds fails to tell the whole truth about land use and transportation relationships. Using data from the Twin Cities, they note that while the Twin Cities is not at the top of the national list for traffic congestion, traffic is getting worse and delays doubled during the 1990s. However, during this same time, the number of workers and the number of jobs reachable within 30, 45, and 60 minutes increased in almost all of the TAZs studied. This increase was attributed to jobs moving closer to workers and vice versa such that commuting times went up by no more than 5 minutes. In accord with this finding, researchers observed that

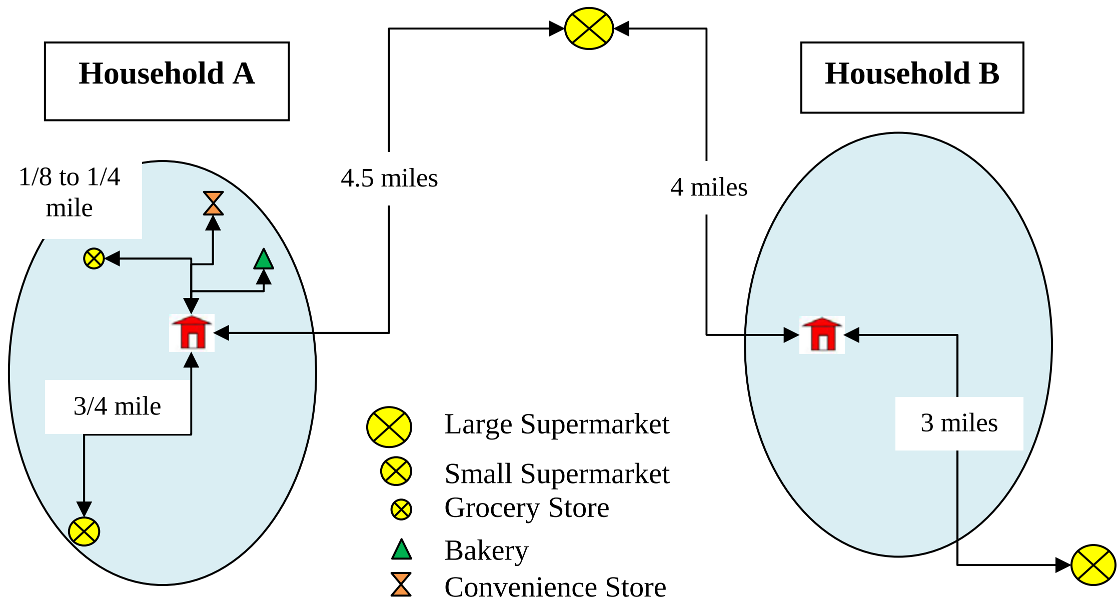


Figure 6. Accessibility Benefits from Compact, Mixed Land Use.

an explosion of townhouses and condos in urban centers over the past decade has brought many new residents into activity-rich TAZs and dramatically increased the number of destinations that are easily accessible. This occurs, they point out, despite the fact that the density of people and activities ensures that no one moves around these places very fast but, by contrast, in less dense areas cars can run at 50 mph but pass a much smaller number of desirable destinations. The study also found a link between accessibility and home values, with prices increasing by $1,000 for every 4000 jobs available within 20 minutes. The report recommends increasing access to destinations as the best approach to combating congestion (Levinson and Krizek 2007).

G. D. Morrow elaborated on this point by suggesting that when more compact, mixed-use development is allowed, traffic initially gets worse because it takes time for all those conveniences to infill to the point where it is more convenient to walk to a corner store than drive to the mall. But as neighborhood land use becomes more diversified, convenience trips by auto decrease, allowing the conversation to shift away from congestion to more important matters like good schools, safe streets, and better communities (Morrow 2007).

MARKET FORCES AND EQUITY ISSUES

While neighborhoods and activity centers exhibiting the characteristics of compact, mixed-use, pedestrian-friendly design were once widely available, since World War II and particularly since the 1970s, they have become much less common. In some new metropolitan areas like Phoenix, Tucson, and other areas of the Southeast and Southwest that grew primarily after the emergence of the automobile, few such areas may have ever existed. Although different trends may now be emerging, older downtown areas and inner suburbs across the country were bypassed by the suburban and urban exodus that transformed most metropolitan areas. Their housing stock and residents are older, and deterioration is evident in the physical infrastructure, given the directing of resources toward burgeoning new areas in the name of economic development (Lee and Leigh 2005). On viewing these trends, the State of Maryland enacted the country's first Smart Growth and Livable Communities Act in 1997 when it realized that the high incremental costs required to provide water, sewer, transportation, schools, and other services at the urban fringe were costing more and coming at cross purposes to maintaining its existing communities. It found that these older communities still had considerable holding capacity for new growth plus existing infrastructure to support more than one mode of travel, while financing outward expansion was resulting in more traffic congestion and loss of forest and agricultural lands—the latter a major issue in the decline of the Chesapeake Bay.

The question might logically be asked does the public even want a different kind of development option, given what appears to be a clearly substantiated preference for suburban living that has manifested over the past several decades? Various economists and think tanks with strong free-market leanings argue that there is minimal support for smart growth policies, and many will suffer loss of opportunity and freedom from so-called "planned" environments. In a 2005 article, Cox argued that efforts to combat urban sprawl were reducing housing affordability, and with it the opportunity for home ownership and economic security for both middle income and disadvantaged groups such as blacks and Hispanics. He claimed that where housing markets are artificially constrained by planning policy, such as in Portland with its urban growth boundary, housing prices are driven up as inexpensive housing at the urban fringe disappears. He maintained that the United States is not running out of land; that there is no shortage of agricultural land; and that in areas like Atlanta, Dallas, and Houston where there are no such restrictions, home ownership rates are increasing among, for example, African American households (Cox 2005). In a 2008 report published by *Demographia*, Cox cited results from a fourth annual survey of affordability in 227 international housing markets. The report cites prescriptive planning and urban consolidation as the principal causes of housing affordability loss, and that places like Ottawa, Atlanta, and Dallas have remained affordable (smaller percentage of household income for mortgage) thanks to fewer restrictions on building. Further, he argued that if the infill and densification objectives of smart growth planners were valid, the market would respond because customers and developers would move sharply toward such alternatives (Cox and Pavletich 2008).

Randal O'Toole, author of the American Dream Coalition newsletter and numerous articles for the conservative think tank Cato Institute, makes similar arguments about how smart growth policies are reducing housing affordability and quashing the American dream. After examining measures of housing affordability in more than 300 metropolitan areas, O'Toole concluded that high housing prices are almost always due to government planning rules that prevent home builders from meeting the demand for new homes. Such rules cause housing prices to increase much faster than incomes, and he estimated that planning-induced housing shortages have added almost $100,000 to the cost of a median value home in more than 50 metropolitan areas (O'Toole 2006)[2]. In his article "Debunking Portland," O'Toole takes particular issue with Portland, which he claims planners laud as a model of sound land use and transportation planning, but which has resulted in unaffordable housing, severe traffic congestion, and numerous social problems. He says that Portland saw the greatest decline in housing affordability of any U.S. urban area in the 1990s, and that affordable housing today means either subsidized housing or tiny homes that make no sense in the West's "wide open spaces" (O'Toole 2007).

In responding to O'Toole and Cox's arguments, several additional—and highly relevant—factors must be brought into the equation. Perhaps the most contentious question is in whether development at the fringe pays its own way. If, in fact, all the costs associated with creating a new subdivision of homes at the urban periphery were capitalized into the selling price of the product, and the product was still considered affordable, then it would be difficult to argue against the rationale that planning policy was restricting opportunity and, in fact, acting in a manner that raises equity concerns. Typically, however, this is not the case. The incremental costs of extending water and sewerage systems, utilities, schools, and roads are seldom absorbed by the developer or reflected in the selling price of the dwelling unit. Moreover, the jurisdictions themselves are able to deflect these costs to a higher level of government—county or state —while enjoying the freedom to make critical local decisions regarding zoning and building permits. Instead, taxpayers or existing service users are obliged to cover these costs through higher tax or utility bills, often at the expense of making needed upgrades in their own communities.

Developers in Frederick County, Maryland-– a rapidly growing outer county in metropolitan Washington, D.C.—have been steadily converting farmland into single-family residential subdivisions. The product would appear to be the embodiment of O'Toole and Cox's American dream: new, luxury homes on ¼-acre lots located 40 miles by interstate highway from the nearest job centers, with no retail or service offerings within five miles and at a price that would be far less than a comparable home in one of the region's inner counties (although smaller, existing homes may be available for similar cost). The author was retained to examine the likely impact on the transportation system of a proposed 15,000-unit subdivision, where the developers and the land owners had engineered a favorable majority on the county's board of supervisors. This majority was sufficient to gain a revision to the land use plan and the zoning necessary for their project, but without scrutiny regarding resulting traffic impacts or the costs of new infrastructure. As is often typical in development reviews, the developer was being held accountable only for those traffic impacts where the development intersected with the

[2] It should be noted that a major driver of housing costs has been speculation. This was demonstrated by the recent collapse of housing values in the Phoenix metro area with the economic downturn. Housing in this region that experienced less of a loss of value resided in areas with good transit access and a proximity to jobs and services. Bedroom communities without this proximity to employment and services have fared poorly in the current recession.

existing road system. The county consented to perform a traffic impact study on the road system in that subarea, which projected probable traffic levels at five-, 10-, and 15-year intervals into construction of the project. The county's adequate public facilities ordinance caps traffic congestion levels at a V/C ratio of 0.75, beyond which mitigation is required. Using the findings from the county's traffic study, it was determined that virtually the entire existing road network would need to be transformed from winding two-lane country roads to four-lane arterials at a cost of more than $300 million—evenly split between state and county systems. The State Highway Administration corroborated these cost estimates, neither of which had been accounted for in the developers' costs, and which neither the state nor the county was prepared to cover. The costs of schools also were not included in the developers' budgets. In this rare instance, the development was stopped until these major hidden costs could be addressed, which would have added thousands of dollars to the selling price of these "affordable" homes.

Another way to look at affordability is in terms of the full cost of home ownership, including not just the mortgage cost but the cost of transportation. In its report *A Heavy Load: The Combined Housing and Transportation Burden of Working Families*, the Center for Housing Policy presents statistics on the combined housing and transportation cost burdens of working families in 28 metropolitan areas (Lipman 2006). It found that, on average, working families spend about 57 percent of their incomes on the combined cost of housing and transportation, with roughly a 50/50 split. In search of lower-cost housing, working families often dramatically increase their commute distance and cost, resulting in moderate-income households having the longest commute distances, the fewest transportation alternatives, and the highest transportation cost burdens. In places like Dallas–Fort Worth, proclaimed as bastions of affordable housing, households living in suburban fringe communities in 2006 were devoting 41 percent of their incomes to transportation expenses (Lipman 2006). Moreover, the trends in the home mortgage market have been equally problematic: Home purchases made on cheap credit through adjustable rate mortgages are now resulting in either much higher monthly payments for households that can afford them or foreclosures for many who cannot.

From an equity point of view, this version of the American dream may be questionable. Spacious luxury homes in outlying areas are being mass-marketed in much the same way as were the giant domestic cars of the 1950s and '60s (or large, luxury sport utility vehicles today) as something people "should" have and that provides a visible marker of accomplishment and status. Such dwellings, at 3500 to 4000 square feet, are arguably larger than most households have been shown to need (or afford), but feel compelled to acquire to gain the tax advantages that have made home ownership the best-earning (if artificially induced) economic asset, at least until fairly recently.

Part of the reason for higher home prices in places like Portland is that the value of greater transportation accessibility is capitalized into the housing-transportation equation. Table 1 showed how Portland's success in encouraging more transit travel has been exceeded by only nine other much larger and more mature U.S. metropolitan areas. The other clue to the economic value of transportation accessibility is in the time lost to congestion delay. In the TTI's Annual Mobility Report, statistics show that the annual delay in 2005 per peak hour traveler in Atlanta was 60 hours (tied for second worst nationally), 58 hours in Dallas (ranked fifth), 56 hours in Houston (ranked seventh) which is much more like Los Angeles (72 hours, ranked first) or Washington, D.C. (tied for second), than Portland (which averages 38 hours per traveler, qualifying for a ranking of 33rd). Working class families in these American dream cities may be buying homes at attractive prices at the urban fringe, but many are also enduring great penalties in travel time and congestion each day despite low densities and few planning restrictions. In a study of the Washington, D.C., region, researchers found that the cost of one-way commutes of as little as 12 to 15 miles would cancel any savings on a lower priced outer suburban home (Weiss 2007). A spokesman for the AAA noted that a savings of $40,000 to $50,000 on a house bought at the urban fringe would not allow the owner to break even if it meant expanding commute distance by 30 miles a day, particularly with gas at $3 per gallon (Weiss 2007).

Why hasn’t the market responded with the kinds of smart growth solutions that the planners advocate? There are number of interesting responses from the development industry itself.

Gregg Logan, a senior development analyst for the Atlanta-based R. C. Lesser & Company, was one of several private sector experts asked to share perspective on market trends at the TRB’s 2002 Conference on Smart Growth and Transportation. Logan detailed how surveys conducted nationally by his firm over a wide range of household types had identified a market demand for more compact, mixed-use living options that was about twice that which was being offered. His research showed that at least 35 percent of surveyed households would prefer something other than the conventional single-family detached suburban home, a trend that they attribute in part to a reshaping of the U.S. housing market that in 10 years will find about 70 percent of households with no children living at home. He noted similar research and conclusions by the National Association of Home Builders that, in a survey of 2,000 home buyers, found that 35 percent said their most preferred option was to build a new home on vacant land in the central city or inner suburbs compared to 29 percent whose most preferred option was a new home in outlying areas. So while a majority of buyers are not necessarily looking for something different, he noted that at least one-third may make different kinds of product and location decisions in the near future. Logan believes that a tipping point has been reached in many U.S. housing markets where people stop “driving for value” to outlying areas because the trade-off has become too great. He contrasts Atlanta with areas like Los Angeles or San Francisco that have gone through that life cycle and where people are making different choices, perhaps accepting a housing alternative that is not completely what they wanted, but where the drive-for-value trade-off for the “ideal” house was simply too demanding (Logan 2005).

Even if a location closer to the central city makes economic sense, it may not be matched by the availability of housing in these areas. Logan foresees that as future metropolitan areas compete for skilled workers, the challenge will be to provide attractive, affordable places to live and work. In many cases, he suggests, it will be a more convenient environment—existing suburban business districts that are undergoing change or existing towns and in-town areas that already have urban amenities, such as not having to rely on a car at the workplace. According to Logan, a key market factor is investment and profit, and he noted that capital markets have come to increasingly favor real estate investments in unique, 24-hour locations with mixed-use environments and higher-value places (Logan 2005). Logan's airing of the unique development opportunities of older, inner-suburban areas is echoed by Lee and Leigh, who make the case that inner-suburban areas are well-suited to address affordable housing needs through higher density since they already incorporate mixed use and provide a broader array of transportation options. They point out that minorities and immigrant groups feel comfortable in these settings (Lee and Leigh 2005). This perspective is also backed by the Natural Resources Defense Council, citing statistics from a national survey that suggest that 87 percent of people planning to buy a home in the near future list a shorter commute as their top priority; that 57 percent of Hispanics and 78 percent of African Americans say they prefer walkable neighborhoods with shorter commutes; and that nine out of 10 Americans want their state to fund improvements in existing communities over incentives for sprawling new development (Natural Resources Defense Council 2007). Morrow writes that it is time to throw away the failed theory that land uses must be separated. He points out that most traffic is generated by convenience trips, not work trips, so that the first thing decision-makers should do is encourage mixed-use in all development. He boldly suggests that racism and classism are still major factors in planning and land use decisions—that by prohibiting multifamily housing or promoting restrictive zoning, middle income people are denied a right to housing in areas where they would be willing to trade density for improved accessibility (Morrow 2007).

Levine and Inam surveyed developers who are members of the Urban Land Institute about their perceptions of the market for smart growth land use. The most common response was that the market is high but the biggest reason why developers aren't building these types of projects at a higher rate is local government regulation. Difficulties in getting plans approved, zoning changed, or key building codes revised add risk and expense to such projects, assuming they can move forward at all. A number of respondents noted that it often was not the rigidity of the regulations per se, but the willingness of local decision-makers to use them to exclude alternatives. If these rules and attitudes were relaxed, the developers indicated they would build denser, mixed-use projects in greater numbers, particularly in inner suburban locations (Levine and Inam 2004). Anthony Downs of the Brookings Institution supported this claim by stating that "the belief that sprawl is caused primarily by market failures is based on the false assumption that there is a free land use market operating in U.S. metropolitan areas" and that no area has anything approaching this because of "local regulations adopted for political, social, and fiscal purposes." Downs also argued that because so many trips cross jurisdictional boundaries, only the coordination of transportation improvements with land use planning on the regional or metropolitan level can result in rational policies toward alleviating the effects of congestion (Downs 2004).

An expected benefit of compact, mixed-use communities would be lower rates of vehicle ownership and vehicle trip generation, more walking, and more internal capture of trips. Yet, a major problem linked to the institutional impediments described above is the application of traffic engineering guidelines and principles that make no allowance for these greater efficiencies. Many traffic engineers continue to use the standard vehicle trip generation rates contained in the Institute of Transportation Engineers (ITE) *Trip Generation Handbook* despite the fact that these rates were developed based on a sample of conventional single-use, low-density, auto-oriented projects in Florida (U.S.EPA 2006, Millard-Ball and Siegman 2006). The result is that either the projects are simply not approved for fear of traffic impacts or are overdesigned in terms of parking requirements and road capacity. This both raises the cost of the project but also lowers its effectiveness by reducing its compactness and encouraging additional vehicle traffic. Appendices to the ITE handbook have examples of mixed-use development with trip rates that are 28 percent to 41 percent less than for conventional development, but many planning officials refuse to accept them. Pointing to evidence that employment in downtown San Francisco doubled between 1968 and 1984 but auto trips on downtown streets stayed about the same (due to good transit and limited parking) Millard-Ball and Siegman argue that thoroughfares in compact, mixed-use areas should never be more than four lanes and should be part of a highly connected network of streets. Streets in such networks, they claim, can handle up to 34,000 vehicles per day in an urban context, which is a lot of capacity (Millard-Ball and Siegman 2006).

TRAVEL MODEL CAPABILITIES

The current generation of travel models greatly limits our ability to consider the full impacts of land use decisions when developing transportation plans or policies, or to consider the impacts and trade-offs of alternative transportation and land use plans. A number of factors contribute to this limitation.

One of the most basic factors is the level of spatial resolution. Conventional four-step travel forecasting models, used by virtually all metropolitan- or county-level planning organizations, are based on a system of TAZs superimposed upon a computerized link-and-node rendition of the transportation network. TAZs range in size, roughly in proportion to the population or employment density they contain; in compact central cities, TAZs may span only several city blocks while in suburban areas, they can cover large land areas. The problem in terms of land use sensitivity is that the geography of the TAZ is much too coarse. Measures of land use like the 3Ds show their most important variations at the level of the neighborhood. Thus, it is difficult to either interpret the role of land use on existing travel behavior within a zonal aggregation or to forecast what the effects of changes to land use at the level of the 3Ds on travel behavior might be. These characteristics have been shown to have an important effect on vehicle ownership, rates of vehicle use, walking and transit use, and VMT (Kockelman 1996, Kuzmyak et al. 2003, Greenwald 2006, Shay and Khattak 2005, Khattak and Rodriguez 2005, Cervero 2006 and 2002, Urban Land Institute 2005, and Marshall and Grady 2005).

Walking is not a serious travel choice in most four-step transportation models. The models were designed to analyze and forecast vehicle travel, which derives from estimating trip generation and attraction at the TAZ level and then matching trip ends across TAZs resulting in trip tables. These trips are then assigned to a motorized mode.

Since walk trips are fairly short, their beginning and ending is likely to occur entirely inside of a given TAZ. These intrazonal trips, which include vehicle trips, are lost to the subsequent analysis in the four-step model since only TAZ-to-TAZ movements are processed. Hence, walk trips are either not dealt with at all or are considered as a fraction at the initial trip generation stage and then set aside. Few models show sensitivity to land use in auto ownership or trip generation, and virtually no conventional model accounts for the possibility of a mode choice between a motorized and nonmotorized mode, or between a local destination that can be reached by walking vs. a destination that can only be reached by vehicle. Hence, analyses show no sensitivity to differences in trip generation rates, destination choice, or shifts to walking in response to land use design changes. As a result, there is no legitimate basis for considering the probable effects of alternative land use designs on travel behavior and, subsequently, congestion.

Two approaches are under way within the planning profession to address these deficiencies. The first, which is longer term, is the adoption of a new modeling paradigm that focuses more on the minute decisions of individual households (microsimulation) and the way in which they satisfy their activity needs. An increasing number of metropolitan planning organizations (MPOs) are exploring activity-based or tour-based models, but the experience with these tools is still emerging. The other approach consists of ad hoc approaches to enhance the forecasts from the conventional model to begin to account for the effects of compact mixed land use. Cervero describes the development and application of two interesting approaches: a post-processor methodology to relate the effects of the 4Ds to the four-step model, and development of a direct demand modeling approach to better account for transit ridership impacts in response to supportive land use in Charlotte, North Carolina (Cervero 2006). He also developed procedures to improve accounting for land use at origin and destination in work trips as part of mode choice modeling in Montgomery County, Maryland (Cervero 2002). Marshall and Grady effectively introduced a series of enhancements to increase model sensitivity to land use policies in regional scenario and visioning analyses. They used these techniques as part of scenario analyses in Baltimore, Chicago, and Austin (Marshall and Grady 2005).

Johnston performed a recent review of 40 long-range scenario exercises in the United States and Europe and found that 20-year VMT reductions in the range of 10 percent to 20 percent compared to future trend scenarios were achievable while supporting the same level of job and housing growth. The most effective policy sets combined land use policies of compact growth with strong transit provision and limited expansion of highway capacity, although in most studies highway level of service was the same or better than in the trend scenario. Johnston found also that the addition of pricing policies like fuel taxes, work trip parking charges, or all-day tolls increased the effectiveness of the land use and transit policies (Johnston 2006).

In 2007, Kuzmyak and Caliper Corporation developed procedures to quantify the VMT effects of the Southern California Association of Governments Compass Blueprint transportation-land use scenario. This scenario, which is the basis for the recently adopted regional transportation plan, emphasizes new regional transit investment and adoption of compact, mixed-use growth in centers and corridors with the goal of accommodating

6.3 million new residents by 2030 while averting transportation gridlock and meeting air quality goals. By shifting a relatively conservative portion of future household growth into areas with improved regional transit accessibility, intracounty jobs/housing balance[3], and local land use vis-à-vis the 3Ds, regional VMT was reduced by 5.1 percent over the trend scenario. This impact was estimated using post-processor techniques applied to the output of the regional forecasting model. The research team is now embarking upon development of a localized version of this methodology that can be applied within a sketch-planning derivative of the regional TransCAD model to support key local planning and decision-making.

Research is also advancing in other important areas related to better land use modeling capabilities. Key among these is the proliferation of GIS techniques and databases. Most MPOs and major jurisdictions now maintain a GIS capability for mapping and visualization of planning data where imagery is critical to understanding patterns and trends. However, when data are stored in the format of layers, researchers can superimpose and meld the data from one layer onto others and perform important mathematical calculations fairly simply. In recent years, transportation planning models like TransCAD, which is being used by MAG and Pima Association of Governments (PAG), are actively taking advantage of these expanded capabilities in their structures, with important implications for capturing the nuances of land use. Kockelman's breakthrough modeling methods in 1996 were possible through use of the MPO's GIS tools, which were used to create hectare-level raster files of land use that were then used to develop the composition indices of entropy and dissimilarity. Several papers reviewed in this study give evidence to ongoing work toward improving the science of measuring land use elements in ways that are relevant to travel behavior (Bose and Fricker 2003; Krizek and Johnson 2006; Paez 2006; Hess et al. 1999; Ewing 2005; and Frank, Kavage, and Litman 2006). In developing the improved models of household auto ownership and VMT in Baltimore, Kuzmyak and Savory used GIS data to create a walk opportunities index. A layer showing the location of individual households from the regional travel survey was combined with a layer showing the location and composition of regional employers based on Dunn & Bradstreet records, and further overlaid onto a layer with the respective street grid. A GIS programmer was then able to write a simple program to build walk paths to each of the opportunities, compute the walk time from the household to the opportunity, "value" the opportunity based on survey data, and sum the results into a measure of combined walk friendliness and the richness of local opportunities (Kuzmyak, Baber, and Savory. 2006).

Another technology-related improvement in modeling capability to assist with land use planning is network traffic simulation. Planners know that traffic flow is nonlinear—that as volumes approach design capacity, level of service declines precipitously and with it, throughput. Travelers respond in a variety of ways, including making corrections in route choice to try to minimize delay and travel time. Incidents such as collisions and

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[3]A more aggressive scenario that would have shifted jobs and housing among the region's jurisdictions was not considered in the modeling because it required additional deliberations among regional decision-makers.

breakdowns further perturb the network and flow patterns, particularly when the network is operating near capacity. A number of transportation model developers have created revolutionary software programs (such as TransModeler and VISSIM) that not only detail the traffic flows at the facility and local network level, but permit analyses of scenarios or mitigation actions in a surprisingly visual context—essentially cars running on actual streets. With such tools, it is possible to not only analyze flows in activity centers where there is higher-density development and traffic but to experiment with different types of grid networks, traffic management policies, turn lanes, parking policies, and signalization. In short, if compact, mixed-use centers are planned and traffic problems are feared/anticipated, these tools make it possible to examine a wide range of strategies to manage that traffic in ways that can reduce the impacts of congestion and also provide for safe pedestrian travel. Moreover, due to the visual faculty, a broader range of elected and staff-level decision-makers can be involved in the planning process.

CONCLUSIONS

Many issues are raised when considering the implications of higher-intensity land use as a policy strategy for addressing transportation needs and traffic congestion. Reverting to pre-World War II development concepts seems counterintuitive to a society that has grown up around the private automobile and the freedoms it has conveyed. Vehicle ownership, the interstate highway system, and favorable tax treatment for home mortgages have all combined to pull American households out of rental housing in dense industrial cities and into green, spacious suburbs. Jobs and commercial activity have followed suit, capping a metamorphosis that has been under way for more than 50 years. So why contest these established trends, judged to reflect the tastes and preferences of consumers (and voters), with a seeming “back to the future” regression?

A number of reasons have been explored and substantiated by research findings in this literature review:

- Studies are providing mounting evidence that households in compact, mixed-use neighborhoods—where distances are of walkable scale, residential and commercial activities are co-mingled, and transit exists as an alternative for regional travel—own fewer vehicles and generate far fewer vehicle miles (two to three times less) than comparable households in conventional suburban subdivisions.
- While commuting is associated with peak travel periods and highest rates of congestion, in fact the biggest contributor to VMT is nonwork travel. More than 70 percent of the average household’s vehicle travel is for nonwork travel—shopping, personal business, school, children’s activities, and social/recreational activities. Virtually none of these activities can be performed in suburban areas without a personal vehicle because of lower densities, separated uses, indirect travel paths, long distances, and designs that anticipate vehicle access. Nonwork travel has also been the fastest-growing segment of household travel over the past 40 years, and it makes up more than half of all travel on the roads during peak travel periods.
- Market studies by the development industry have indicated that the rate at which mixed-use communities are being built may be considerably less than market demand, a demand that is only expected to grow as the demographic profile of the population reshapes to include more retirees and single-person or childless couple households. The reasons given for the failure of the building industry to keep up with demand are largely local planning rules and guidelines that make building traditional mixed-use developments more difficult and, hence, more expensive.

- Mixing of land use at destinations and building at walkable densities also are shown to have travel benefits in making it more likely that workers or visitors will come to these areas by means other than private vehicle, or once there, be able to accomplish more than one purpose without requiring a vehicle for the other trips.

While an ever-growing body of studies indicates that persons in compact, mixed-use environments will drive less and walk more, a number of important questions remain before accepting higher-density development as a planning priority:

How long time before the effects of land use changes will be seen and felt?

Even if a substantial policy shift were to occur that prioritized compact, mixed-use development, many planning officials conclude that the overall percentage of the region's total population or employment that would be affected might be too small to make much of a difference. Such changes in landscape are not likely to occur overnight, of course, particularly in the more modern metropolitan areas, such as Phoenix, Los Angeles, Dallas, Houston, or Atlanta, which have very little existing structure that is compact or mixed use. Hence, the net effect on regional VMT and congestion would also probably be insubstantial and a long time coming.

While there is validity to such an argument, what is often overlooked is the potential impact of infill and redevelopment. This new growth—or even relocated existing activity—is likely to have a major transformative effect on the area in which it occurs or upon which it is superimposed. For example, Tysons Corner in Fairfax County, Virginia, outside Washington, D.C., is beginning a metamorphosis from a giant, loose suburban agglomeration of office and retail activity (10th largest employment center in the United States) with isolated residential condo enclaves, into a city with gridded streets, intermixed residential development, higher overall densities, and a new walk-friendly design that is being stimulated by the extension of the region's Metrorail system to Dulles Airport. As a result of this transformation, to occur rapidly over the next 20 years, the existing 100,000 employees and 20,000 residents of Tysons Corner will be facing significantly different conditions than today's exclusively auto-oriented environment. In a similar manner but at a more modest scale, the potential effects of infill and redevelopment are likely to challenge planning assumptions that current development and zoning will not change much over the next 20 to 30 years.

Does higher density mean more congestion?

There are two answers to that question: it depends, and if there is, it may not be an entirely negative outcome. First, it is essential to speak of compact, mixed land use in terms other than simply density. Obviously, higher density is to be expected when more uses are placed closer together. However, research is showing that density must be considered along with the type and balance of land uses that are combined and the overall design of the area (such as parking, traffic volumes, speeds, and pedestrian circulation and crossings) that enables internal circulation. Clearly, building only one land use type (say, multifamily residential) at high intensity and not supporting it with shopping or services, and not providing convenient pedestrian access probably will result in high vehicle trip generation and major traffic impacts.

On the other hand, if the right conditions are in place, residents of these areas are likely to make many more trips by walking and direct their car trips to special destinations outside the center. Similarly, employees or visitors to the area both have the opportunity to travel there by transit or carpool, and/or to dispense with their car while visiting other destinations in the center. The major concern about traffic congestion in such a higher-density place, therefore, is in relation to through traffic—people who live in one location and who choose to drive through the more urbanized place to get to their desired destination. Obviously, the pedestrians in the center are not particularly concerned about the congestion as long as they have adequate safe crossings. For the through travelers, the delay is unfortunate, but they conceivably have other choices in terms of where they live, work, or shop; the route they take; the time of day they travel; or the mode they use. The correct metric in determining the net efficiency and equity of such a policy is to examine total accessibility for all travelers. In other words, it is much more relevant to examine the impact on travel time for all travelers in the system considering all modes of travel rather than looking at simply vehicle speeds or delay over particular stretches of arterial.

To manage the traffic flow in such an area, traffic engineering strategies such as grids, one-way systems, bypasses, signal timing, and parking management can do a lot to make travel in and through the area more tolerable. Downtown San Francisco is an excellent example of how employment was able to increase by 100 percent and yet traffic levels on downtown streets did not increase due to good land use mix, transit, parking management, and effective pedestrian environments.

Does building compact, mixed-used communities or centers require a commitment to a regional rail transit system?

This question results from the debate in Phoenix about the merits of investing in rail transit in the wake of the new light rail starter line. Research on the 4Ds reveals a strong relationship between the local characteristics of density, diversity, and design and rates of vehicle ownership, vehicle trips, and VMT. However, the same research also indicates the importance of good regional access via transit. Both auto ownership and VMT rates are lowered not only by proximity to transit but to the degree of access it offers to regional activities (such as work, shopping, and education). In virtually all cases, the level of service—and corresponding accessibility—is much higher when the service is provided by a fixed guideway transit service that is unimpaired by highway congestion. The nodal nature of such systems provides an excellent opportunity to focus development around stations. Not only does the transit system provide rationale and definition for locating development in compact, mixed-use nodes, but the transit investment itself reaps the benefit of increased ridership and greater cost coverage from system revenues and higher productivity. However, for areas without rail transit, mixed-use development can still offer attractive transportation benefits. A number of older mixed-use communities in Los Angeles' South Coast are not on regional rail transit lines but still have measurable differences in travel behavior, primarily because residents make active use of local nonwork opportunities, which they access by walking or driving short car trips. This is in spite of the fact that most worker residents of these areas drive to job sites that are scattered across the region. Indeed, a pattern of these higher-density, mixed-use nodes would be an excellent precursor to designing a future transit service and that service would not have to start as rail-based. (Bus rapid transit might be sufficient or superior.) When considering a transit investment, the existence of higher-density nodes would likely make it easier to secure federal funding assistance and to develop a local funding base from beneficiaries owning property in the service area.

Is nature or nurture more important in determining whether traditional land use patterns will yield relevant changes in travel behavior?

Considerable debate has focused on the possibility that the tendency of residents of compact, mixed-use communities to walk more and drive less is more about their predisposition to live in a place where they can exercise those preferences, whereas residents of conventional auto-oriented developments choose their communities because they prefer to drive. Extensive research based on following households that have changed locations over time is now showing that these effects are perhaps not as pronounced as had been feared (i.e., people do tend to change behavior in relation to new environments).

In summary, it would appear that compact, mixed land use may be an effective tool in reducing vehicle dependency and, hence, demand for extensive new road capacity and corresponding traffic congestion. Consumers and the development industry appear ready and willing to provide it in greater numbers, allowing that local jurisdictions are prepared to amend their rules to enable it. Concerns about local traffic hot spots are understandable, but these are issues that can be analyzed with new modeling tools and either mitigated through better design and management or reconciled with improved measures of performance (beyond highway or intersection level of service).

CHAPTER 3. SURVEY OF OFFICIALS

OVERVIEW

Between June and September of 2007, researchers surveyed local officials in the Phoenix and Tucson areas to examine their knowledge and attitudes toward compact, mixed-use development. The survey was intended to ascertain how various officials and their organizations were involved in the land use planning and development approval process, factors including transportation that were important in decision-making, patterns of coordination and support with other agencies, and the availability of data and planning tools for examining traffic impacts. A specific line of questions was directed at individual knowledge of and experience with compact, mixed-used development and perceptions of its potential benefits or liabilities in relation to traffic congestion, transit use, and walking activity. Participants then were asked to rank the most appropriate types of development for both their respective jurisdiction as well as the region as a whole. Finally, participants were asked to identify specific transportation corridors with traffic congestion problems that might be tied to development patterns. These suggestions were used to select sample corridors for detailed analysis later in the project.

Four groups of officials were surveyed: local elected officials, planning and zoning officials, local planning professionals, and state and regional transportation officials. A similar but distinctly worded questionnaire was mailed to 423 individuals representing the four groups, and 134 completed returns were received. Each group responded at or above the 33 percent target response rate except for the elected officials, where only 20 percent of mailed questionnaires were returned. Researchers used several strategies to maximize response rate, including making the survey available online for respondents with Internet access.

SURVEY DESIGN AND ADMINISTRATION

Based on the desired coverage and implied sample size of the survey, researchers decided to perform the survey using mail-out questionnaires rather than in-person or telephone interviews. The types of judgments and ratings asked for in the survey also argued for a printed version to be placed in front of the respondent.

Researchers used several methods to identify the potential survey sample. They asked the project review panel for recommendations, and the project’s locally based team member amplified these suggestions. While researchers wanted a broad sampling of areas by size and type, a major objective was to include locations where growth and traffic congestion issues were most pressing.

With the goal of increasing the reach of the survey and seemingly making it easier for both respondents to provide their input and the team to process, monitor, and analyze the results, researchers also developed a web-based electronic version of the survey. Being cautious about the degree to which respondents would be willing to participate in an electronic online survey and possible technical difficulties that might ensue, researchers mailed a hard copy version of the survey to respondents with a letter of invitation and stamped, preaddressed return envelope to facilitate its return. They also encouraged respondents to complete the survey on the project website. Ultimately, about one-third of all responses were submitted online and the remaining responses were mailed back. A small percentage (five respondents) completed forms in both media. A number of respondents reported that they had experienced difficulty in either accessing or using the online version of the survey, and subsequently opted for the mail-back alternative.

When initial response to the survey was not as robust as researchers had anticipated, they adopted three methods to increase response rate and sample size. First, in mid- to late-July, they conducted an extensive follow-up campaign. Researchers sent email reminders to 74 survey recipients for whom email addresses were available, followed by letter reminders from the ATRC to another 80 individuals. Second, they reviewed the original sample list and determined that the survey's coverage could reasonably be broadened to include a number of additional jurisdictions or organizations, resulting in survey packages being sent to 119 additional officials in early August. Third, ATRC initiated a personal telephone call-up campaign in early September, primarily directed at elected officials.

Table 3 provides a summary of the number of surveys sent out by jurisdiction and/or organization, the professional classification of the recipient, and the number of usable returns for each jurisdiction. Areas with the highest overall response rates included Gilbert, Glendale, Goodyear, Peoria, Surprise, and Oro Valley. In contrast, those areas with particularly poor response rates included Chandler, Mesa, Phoenix, Tucson, and Marana. Response rates from Maricopa and Pima County were about average.

The only group whose response rate was below 30 percent was elected officials, for whom only 16 of 81 surveys were returned (19.8 percent), despite the fact that the majority of the follow-up/reminder efforts were directed at this group. Researchers speculated that the reason for this subaverage response rate may have been because elected officials were uncomfortable about possibly going on public records with opinions or perspectives that might later be judged politically incorrect. No responses were received from elected officials in Mesa, Peoria, Phoenix, Tucson, Scottsdale, or Marana, and only one official responded from Tempe and Oro Valley.

Among the state and regional transportation officials, the best response rates were from the State Transportation Board, MAG's Executive Committee, and PAG's Board. Among the worst rates of response were the Arizona Senate Transportation Committee, for which none of five surveys were returned; MAG's member agencies (only four of 21 returned); MAG's Transportation Advisory Board (only one of five); and the Pima County Regional Transportation Board (only one of five).

Table 3. Description of Survey Sample.

	Elected Officials		Planners		Plan & Zoning		Jurisdiction Total	
	Sent	Returned	Sent	Returned	Sent	Returned	Sent	Returned
Phoenix Area								
Avondale	1	1	1	0	0	0	2	1
Chandler	6	2	2	0	7	1	15	3
Fountain Hills	2	1	2	1	0	0	4	2
Gilbert	3	3	3	1	2	1	8	5
Glendale	3	3	5	1	1	1	9	5
Goodyear	1	1	6	2	0	0	7	3
Maricopa County	4	2	1	1	9	1	14	4
Mesa	7	0	8	2	11	3	26	5
Paradise Valley	0	0	1	1	0	0	1	1
Payson	0	0	1	1	0	0	1	1
Peoria	6	0	26	11	8	3	40	14
Phoenix City	8	0	5	2	12	3	25	5
Scottsdale	7	0	39	10	14	7	60	17
Surprise	1	1	5	3	0	0	6	4
Tempe	7	1	28	7	10	3	45	11
	56	15	133	43	74	23	263	81
Tucson Area								
Tucson City	7	0	9	4	12	5	28	9
Oro Valley	7	1	4	3	1	1	12	5
Marana	7	0	4	2	14	2	25	4
Pima County	4	0	5	1	8	5	17	6
	25	1	22	10	35	13	82	24
Other Locations								
Coconino County			1	1			1	1
Yuma			1	1			1	1
	0	0	2	2	0	0	2	2

Misc Groups (all categorized as "Planners")

	Sent	Returned
AZ Dept of Commerce	1	1
AZ Planning Association	2	0
Arizona State Univ	2	0
DMB Assoc.	1	1
Maricopa Co Flood Distr.		
Leadstar Engineering	1	0
N. Ariz University	1	0
RBF Consulting	1	1
Show Low Main Street	1	0
Univ of Arizona	2	2
	12	5

State & Regional Officials

	Sent	Returned
AZ Senate Transp Com.	5	0
AZ State Transp Board	7	4
MAG Board	21	4
MAG Exec Committee	4	2
MAG Transp Adv Board	5	1
PAG Board	4	2
PAG Staff	6	3
Phoenix Transit	1	1
Pima Co RTA Board	5	1
SunTran (Tucson)	2	1
Valley Metro Board	9	3
	69	22

Summary by Category	Sent	Returned	Pct.
Elected Officials	81	16	19.8%
Local Planners	169	60	35.5%
Planning & Zoning	109	36	33.0%
State & Regional	64	22	34.4%
Grand Total:	423	134	**31.7%**

The specific professions represented in the four broad categories were:

- Elected officials: mayors (nine), council members (six), county supervisors (two).
- Planning and zoning officials: chair, vice chair or directors of planning; board/Commission (nine); planning board/commission members (13); town center development specialist (one).
- Local planning professionals: planners (20), traffic engineers (11), engineers or public works officials (10), economic development specialists (nine), transportation commissioners (eight), academics (two).
- State and regional transportation officials: State Transportation Board members (four), MAG board members (four), MAG Executive Committee members (two), MAG Advisory Board member (one), transit officials (six), PAG staff members (three), PAG board members (two).

While this distribution demonstrates a respectable diversity in the professions represented, unfortunately the various subgroups are too small to permit valid comparisons within the given category. Hence, all comparative analysis has been confined to the differences among the four primary groups.

ANALYSIS OF SURVEY RESPONSES

In the sections to follow, the responses to each question in the survey are tabulated and assessed. While researchers made a conscious effort to pose similar questions and concepts to each of the four respondent groups, differences in the function of each group made identical wording of questions impractical in many cases. However, where the topic and response set are similar enough to compare, the analysis attempts to do so.

Inspection of the four questionnaires will reveal the sometimes subtle differences in wording among groups, which sometimes also results in a different type of question being asked. Unfortunately, because of the length of the questionnaires, copies are not provided within this report. However, a summary of the questions asked and their manner of difference by respondent group is provided below.

Background Information:

- Same for each respondent; includes name, jurisdiction, title, and number of years in that position.

Role Played in the Planning Process or Methods of Influencing Land Use and Development Decisions:

- Elected officials and local planners: What role do you play in the planning process as it relates to land use and development decisions?

- Planning and zoning officials and state and regional transportation officials: In what ways is your organization able to influence local decisions on land use and development practices?

Key Factors Influencing Development Decisions:

- Elected officials and local planners: If you are ever asked to take a position on a development project, what level of importance would you attach to the provided list of 17 factors?
- Planning and zoning officials: What level of importance would you attach to the provided list of 17 factors when you are reviewing a development proposal?
- State and regional transportation officials: Based on your experience, how important *do you think* the following factors are to local jurisdictions when they develop land use plans or review development proposals?

Procedures and Requirements for Assessing the Transportation Impacts of Land Use Plans or Development Projects:

- Elected officials (Questions 4 through 8):

  4. To what extent do you personally review or consider transportation impacts or needs in conjunction with a particular development proposal?

  5. To what extent do you require your jurisdiction's planning specialists to review or consider transportation impacts or needs?

  6. To what extent do you coordinate with any of the following organizations in relation to transportation impacts or needs (internal, county, region, state, transit operators)?

  7. What is best description of your role in ensuring that there will be adequate transportation capacity?

  8. Are you aware of any policies, requirements, or studies that address the issue of transportation implications of land use decisions?

- Planning and zoning officials (Questions 4 through 8):

  4. To what extent and in what manner do you consider transportation impacts or needs when reviewing a development application (six areas including coordination with other agencies)?

  5. If you consider transportation impacts or needs for a major development project, at what level do you perform your assessment (ranges from near-site to regional facilities)?

  6. Do your jurisdiction's planners employ computer-based transportation models to evaluate transportation impacts or needs?

  7. Does your agency have any reports, studies, policies, or guidelines that are used to quantify transportation impacts or needs?

  8. Does your agency or jurisdiction monitor or collect data on the traffic effects of development projects?

- Local planners (Questions 4 through 7):
  4. In what ways are you asked by elected officials or planning boards to participate in the land use decision-making process?

  5. If you are asked to evaluate the transportation impacts or needs for a development project, at what level do you perform your assessment (ranges from near-site to regional facilities)?

  6. What tools or procedures are used to evaluate transportation impacts or needs, and are these applied internally or through coordination with other agencies or use of consultants?

  7. Does your agency or jurisdiction monitor or collect data on the traffic effects of development projects?

- State and regional transportation officials (Questions 4 through 6):
  4. In what ways is your organization asked by local jurisdictions to provide input or assistance to their land use decision-making process?

  5. Does your agency or jurisdiction monitor or collect data on the traffic effects of development projects?

  6. To what extent does your organization coordinate with any of the following organizations in relation to transportation impacts or needs?

Experience with Mixed-Use Development Projects

Each group was asked the following questions:
- Do you have direct experience with these types of projects?
- Have you received applications for these types of projects (all groups except state and regional officials)?
- Have developers been encouraged to submit applications for these types of projects? (State and regional officials were asked whether local planning agencies have been encouraged to consider these projects.)
- What effect would you expect they have on traffic congestion?
- What effect would you expect they have on transit use?
- What effect would you expect they have on bike/pedestrian travel?
- Would your community support these types of projects? (State and regional officials were asked more generally where the greatest support would likely be found.)
- Do you feel that sufficient information exists to evaluate the effects of these projects on traffic and congestion?
- If additional information were available, would you find it useful and how would you use it?
- Have you compiled information on the transportation impacts of mixed-use projects (state and regional officials only)?

Opinions on Appropriate Mix of Development Types

Each group was asked the following questions:

- What are the most appropriate types of future development for your jurisdiction (17 alternatives listed)? (This question was not asked of state and regional officials.)
- What are the most appropriate types of future development for the region (11 alternatives listed)?
- What types of development do you feel are <u>most likely</u> to occur in the region (state and regional officials only)?

Identification of Corridors with Traffic Congestion Problems

Each group was asked the following questions:

- What are the two most congested corridors in your region?
- What activity center(s) do they serve?
- In what time period(s) is the congestion most intense?
- What proportion of the congestion do you feel is due to development in the adjacent area vs. elsewhere in the region?

SUMMARY OF SURVEY FINDINGS

The following sections describe the results of the survey using the above outline.

Method of Involvement or Type of Influence Over Land Use and Development Decisions

The first investigation in the survey was to learn about the various ways in which each of the four types of officials took part in the process of planning for and making decisions about land use and development projects. Obviously, each group would be expected to have a different involvement based on their position and authority, so the question and categories were shaped to be most relevant to the respective group. Figure 7A illustrates the potential involvement mechanisms that were considered by elected officials. The most frequently cited methods of influencing development decisions were to appoint qualified persons to the planning and zoning board and to participate in policy debate with fellow elected officials. A majority (70.6 percent) indicated that they were in the position of receiving proposals from developers or business interests, reacting to petitions related to growth from the community (70.6 percent), or serving as an advocate for particular projects (64.7 percent).

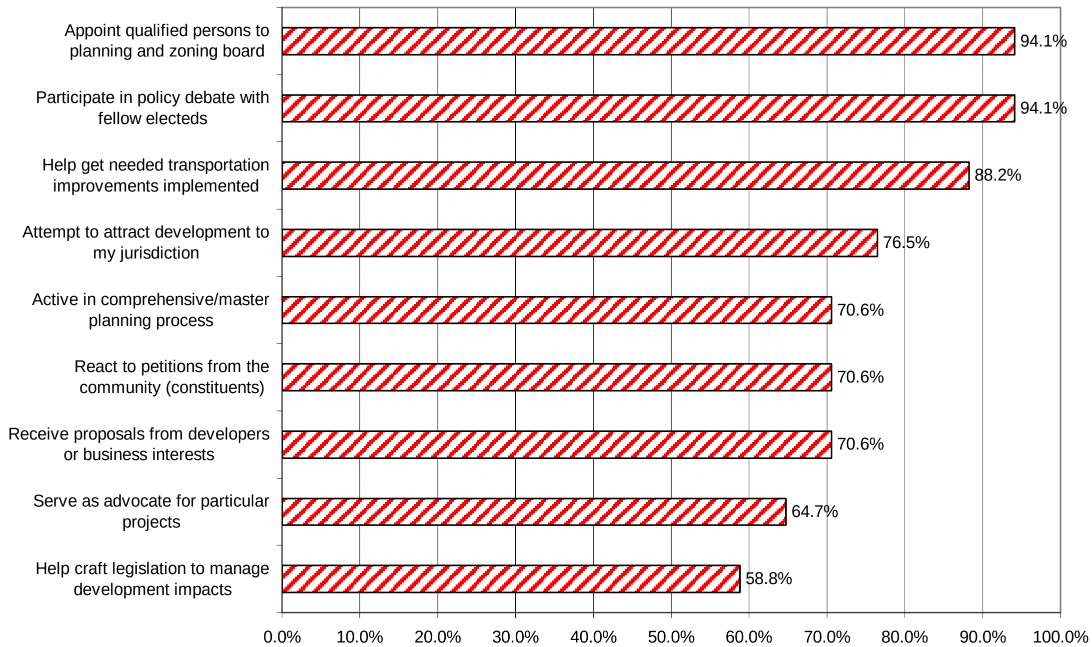

Figure 7A. Ways in Which Elected Officials Become Involved in Land Use Decisions.

The next group investigated was planning and zoning officials, who are persons generally appointed to boards or commissions whose sole job is to lead the planning, develop guidelines, and enforce regulations for development projects. Responses from this group are summarized in Figure 7B. Virtually all (94.4 percent) of these officials felt that their primary leverage over development plans and projects was through zoning, while a share almost as large (88.9 percent) indicated that a substantial tool was the comprehensive or master planning process. Following in order of frequency from there were parking requirements (77.8 percent), project review and the permitting process (75 percent), setting or applying architectural or building design codes or standards (63.9 percent), and ensuring protection of public safety or the environment (58.3 percent). Relatively few indicated impacting development via public facilities ordinances (33.3 percent), impact fees (33.3 percent), or traffic mitigation ordinances (22.2 percent) as these are probably highly site-specific measures and not in broad application in the surveyed regions. Other mechanisms mentioned included biological conservation plans, neighborhood protection zones, hillside protection ordinances, and the public involvement process. Several officials said that their function was advisory to the elected officials, and that they themselves did not possess wide authority to make development decisions.

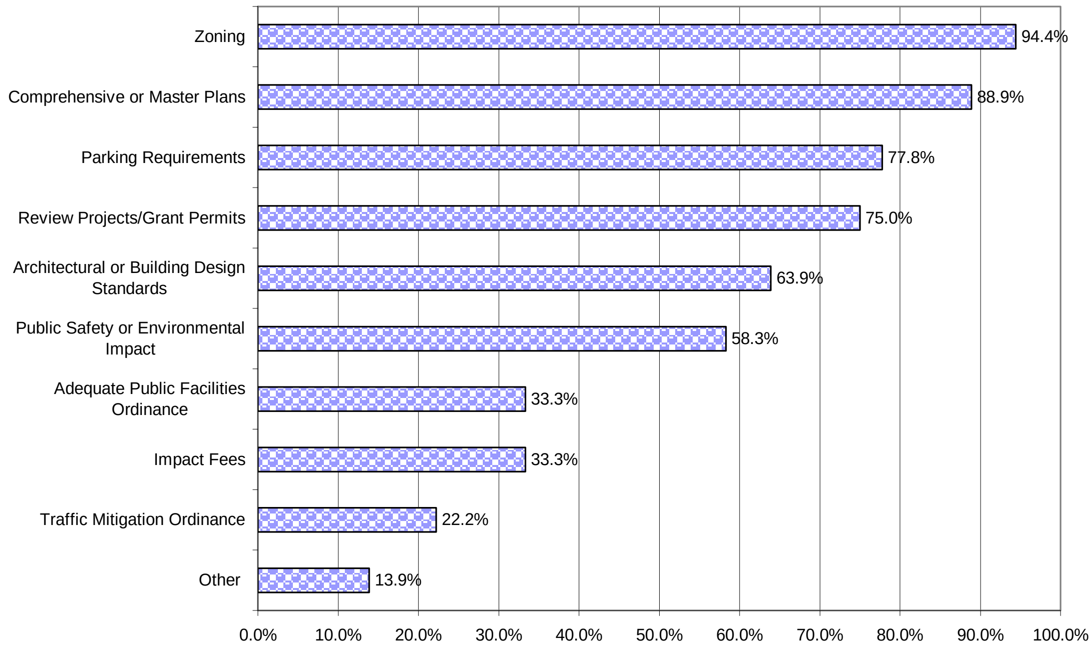

Figure 7B. Tools Available to Planning and Zoning Officials to Influence Type, Scale, Timing, or Impact of Development Projects.

Figure 7C illustrates the options that local planning officials and staff feel that they have for influencing land use and development decisions. Overall, a smaller percentage of professionals in this category felt that they had a significant role in land use and development decisions. The most commonly cited measures were participating in public involvement/stakeholder visioning efforts (61 percent) and preparing or updating comprehensive or master plans (52.5 percent). The explanation for this is probably that the sample of planning professionals along with the state and regional transportation officials, represents a much more diverse group of professional specialties than the elected officials or planning and zoning officials. An expected role of local planners would be in the quantification of impacts associated with either individual projects or for overall land use plans (e.g., comprehensive, general, or master plans). In this capacity, the most common participation was in conducting traffic impact studies, cited by 42.4 percent of respondents. However, more proactive technical planning roles such as participating in the development of growth projections (18.6 percent), preparing estimates of development holding capacity (13.6 percent), or running transportation models (13.6 percent) were cited by only a small share of all respondents. Another 42.4 percent indicated that they participated in the update of the long-range regional transportation plan, and 30.5 percent said that they assisted in the identification, evaluation, and prioritization of transportation projects in the regional Transportation Improvement Program (TIP).

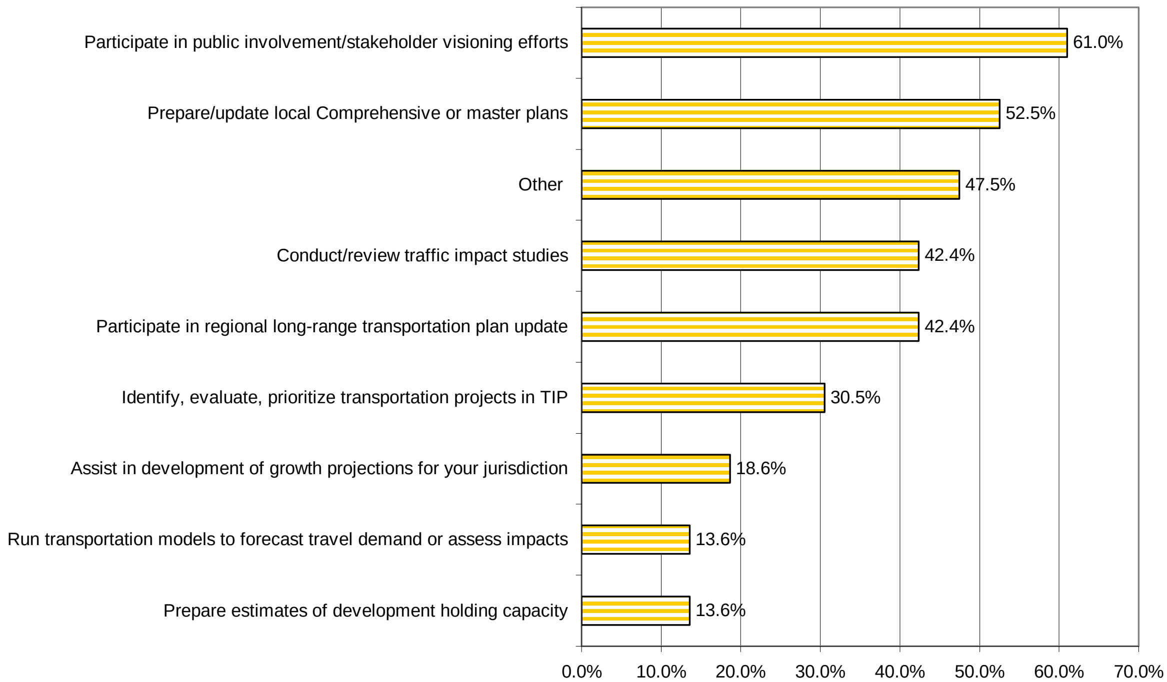

Figure 7C. Role of Local Planners in Land Use and Development Decisions.

An unusually high percentage of respondents (47.5 percent) cited other roles and activities that they felt were related to land use or development project decisions. A full list of these responses is contained in Appendix A and is summarized below (roughly in the order of frequency with which they were mentioned):

- Reviewing and evaluating development plans, plats, and requests for rezoning.
- Reviewing building, site, and civil construction plans for compliance, and issuing permits and certificates of completion and occupancy.
- Integrating land use and community development; participating in discussions related to growth, transit corridors, and housing development.
- Designing and constructing roads, managing street projects, implementing transit improvements, and updating circulation plans.
- Review of improvement plans at both preliminary and final design stages, looking at short term (10-year) vs. 20 year and build-out for both large developers and for capital improvement program.
- Serving as a transportation commissioner, which involves reviewing transportation planning issues and making recommendations to City Council.
- Negotiating development agreements.
- Annexations and historic preservation.

Responses from the final group investigated—state and regional transportation officials—are summarized in Figure 7D. The most common ways that these professionals are involved in the development process as may pertain to local land use decisions are working with the local jurisdictions through the regional planning process (87 percent) followed by reviewing local comprehensive or general plans (78.3 percent), leading public involvement/stakeholder visioning efforts (47.8 percent), and reviewing growth projections for member jurisdictions (47.8 percent). Next most common were functions related to assessing transportation needs and prioritizing capital improvements: 65.2 percent indicated a role in prioritizing and

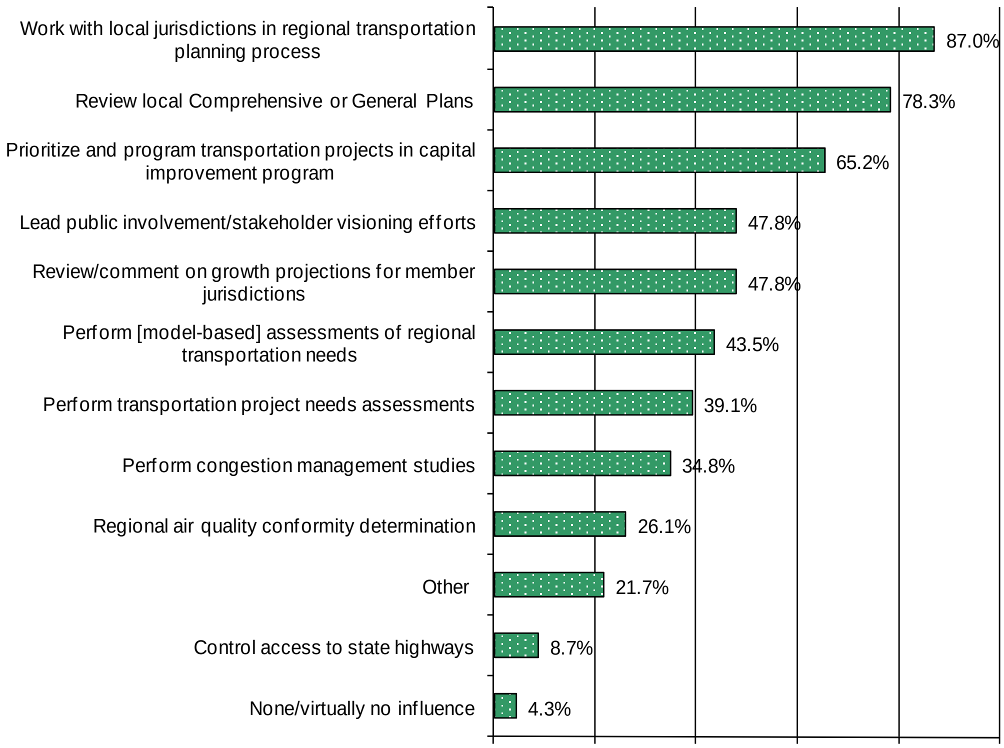

Figure 7D. Role of State and Regional Officials in Land Use and Development Decisions.

programming transportation projects into the capital program, 43.5 percent performed model-based assessments of regional transportation needs, and 39.1 percent performed transportation project needs assessments. Regulatory requirements are another way that state and regional agencies can somewhat influence development decisions, though only 34.8 percent indicated that they performed congestion management studies, 26.1 percent felt that air quality conformity analysis was available as an instrument, and only 8.7 percent cited controlling access to state highways.

A number of state and regional officials (21.7 percent) cited other ways in which they or their organization could influence development decisions. However, these additional methods were essentially included in the other responses.

Importance of Key Factors When Making Development Decisions

Question 3 in each of the surveys seeks to understand the respective group's ranking of key factors likely to have a bearing on the decision-making process when development proposals are being considered. The questions were worded identically for the four groups but the perspective was expected to be different based on each group's role. In particular, the question as posed to state and regional transportation officials was framed as "How important do you think these factors are to local jurisdictions when they make development decisions?"

Table 4 lists the 17 factors investigated and the average importance rating for each by survey respondent group. The average rating is computed from the scaled individual responses on a 1 to 5 scale, where 1 is not important and 5 is very important. A rank is also provided to facilitate examination of the relative importance of each factor with the given survey group and across the four groups.

Table 4. Importance of Key Factors When Making Development Decisions.

Planning Factor	Elected Officials	Rank	Planning & Zoning Officials	Rank	Local Planners	Rank	State & Regional Transp. Officials	Rank	Average Groups 1 - 3
Consistent with Comprehensive or General Plan	4.59	1	4.69	4	4.51	3	4.04	10	4.60
Conforms with zoning and adopted codes	4.47	3	4.81	2	4.51	2	4.52	2	4.60
Suitable/desirable land use for the given area	4.53	2	4.83	1	4.27	6	4.83	1	4.55
Impact on surrounding neighborhoods/businesses	4.25	8	4.77	3	4.61	1	3.78	14	4.54
Impact on transportation capacity	**4.38**	**6**	**4.32**	**5**	**4.46**	**4**	**4.04**	**11**	4.39
Traffic congestion potential	**4.20**	**9**	**4.21**	**7**	**4.34**	**5**	**3.91**	**13**	4.25
Impact on water/sewer capacity	4.38	5	4.20	8	4.13	8	4.13	9	4.24
Compatible with transit use or pedestrian circulation	3.94	14	4.23	6	4.18	7	4.43	3	4.11
Strategic to our economic development plan/goals	4.35	7	3.72	11	3.87	9	4.26	5	3.98
Acceptable to public, consistent with community "norms"	3.94	15	4.03	9	3.83	10	3.78	15	3.93
Improves jobs/housing balance	4.41	4	3.69	12	3.53	13	4.23	7	3.88
Project is particularly unique or attractive	3.82	16	3.94	10	3.65	12	3.70	17	3.81
Impact on school capacity	4.00	13	3.62	13	3.66	11	4.26	6	3.76
Quality/Reputation of the developer	4.12	11	3.32	14	3.19	17	4.22	8	3.54
Improves tax base	4.00	12	3.09	15	3.42	14	4.41	4	3.50
Number of new jobs that will be created	4.18	10	2.94	16	3.32	15	3.78	16	3.48
Level of political support or advocacy	3.06	17	2.69	17	3.27	16	4.00	12	3.01

The final column in the table represents the average rating for the first three groups—elected officials, planning and zoning officials, and local planners—since they are all making decisions related to their own jurisdiction. This average is then used as the basis for ranking the decision factors for all groups, which is why no group is shown as having an unbroken ranking from 1 to 17. The rating of the state and regional officials group was not included in the ranking since these ratings reflect how the officials perceive the other three groups are behaving.

The results show reasonable commonality in what the first three groups see as the five most important factors in evaluating a development proposal:

- Consistency with the comprehensive or general plan.
- Conforming with zoning and adopted codes.
- Suitable/desirable land use for the given area (not a top-five consideration for planners).

- Impact on transportation capacity and traffic congestion potential. (Neither is a top-five consideration for elected officials.)

Seen from the perspective of state and regional officials, these respondents only considered conforming with zoning and codes and suitable/desirable land use factors to be top-five priorities at the local jurisdiction level. State and regional officials thought that improved tax base and strategic to economic development goals were more likely to be among the top priorities.

Ranking at the bottom of the priority list for the local jurisdiction officials (groups 1 through 3) were:

- Level of political advocacy or support for the project.
- Number of new jobs created.
- Improved tax base.
- Quality/reputation of the developer.
- Impact on school capacity.

State and regional officials concurred with the lower rankings for number of jobs created and level of political support factors, but felt that improvements to the tax base would actually be a high priority, and impact on school capacity and quality of the developer would be at least moderately important factors.

Another way of viewing the value assessment using the same data is to look at the percentage of respondents designating the particular factor as important or very important. Table 5 shows that an analysis based on these criteria yields somewhat different conclusions than those in Table 4. For example, consistency with comprehensive or general plans and suitable/desirable land use are still among the top five or six considerations, but suddenly factors like impact on school capacity and impact on water/sewer capacity as well as improves tax base move into the top tier, as does level of political advocacy or support. Lower on the list are conforms with zoning and adopted codes and impact on surrounding neighborhoods/businesses. Using this method of comparison, there is a much closer correspondence between what jurisdictional agents and state and regional officials project is important.

Table 5. Factors that Respondents Ranked Important or Very Important.

Planning Factor	Elected Officials	Rank	Planning & Zoning Officials	Rank	Local Planners	Rank	State & Regional Transp. Officials	Rank	Average Groups 1 - 3
Impact on school capacity	88%	5	97%	3	95%	1	86%	4	93%
Impact on water/sewer capacity	94%	1	100%	1	84%	3	87%	3	93%
Consistent with Comprehensive or General Plan	94%	1	100%	1	83%	6	100%	1	92%
Suitable/desirable land use for the given area	94%	1	97%	3	84%	3	96%	2	92%
Improves tax base	82%	7	86%	5	86%	2	74%	12	85%
Level of political support or advocacy	81%	9	83%	7	84%	3	78%	9	83%
Acceptable to public, consistent with community “norms”	82%	7	81%	8	69%	8	86%	4	77%
Project is particularly unique or attractive	65%	15	86%	5	78%	7	74%	12	76%
Impact on surrounding neighborhoods/businesses	75%	11	81%	8	64%	9	74%	12	73%
Quality/Reputation of the developer	88%	5	58%	12	64%	9	83%	6	70%
Impact on transportation capacity	**94%**	**1**	**58%**	**12**	**56%**	**12**	**78%**	**9**	70%
Traffic congestion potential	**65%**	**15**	**75%**	**10**	**59%**	**11**	**61%**	**16**	66%
Compatible with transit use or pedestrian circulation	69%	13	64%	11	53%	13	83%	6	62%
Conforms with zoning and adopted codes	76%	10	31%	15	46%	15	65%	15	51%
Improves jobs/housing balance	69%	13	29%	16	47%	14	83%	6	48%
Number of new jobs that will be created	71%	12	36%	14	36%	17	61%	16	48%
Strategic to our economic development plan/goals	44%	17	17%	17	39%	16	78%	9	33%

In summary, the key findings of Question 3 are:

- Most respondents with local planning or decision-making authority for their jurisdiction suggest by their average responses that the most important factors they consider when making land use decisions are perfunctory: That the proposed project is consistent with adopted plans, that it conforms with existing zoning and adopted codes, and that it is a suitable and desirable land use for the given area. These responses would seem to dispel the notion that development decisions are primarily economically or politically motivated as factors like level of political advocacy or support, number of new jobs that would be created, or improvements to the tax base allegedly fall at the bottom of the list of considerations.
- This picture changes somewhat when the factors that receive a high percentage of important or very important ratings are considered instead of looking at average responses. From this perspective, school capacity, water, and sewer capacity move to the top of the importance list among the respondents from local jurisdictions.
- Concerns about adequate transportation capacity and the potential for traffic congestion or whether the project is compatible with pedestrian circulation or transit use are not high on the importance list for elected officials, although a strange dichotomy appears in the second test, which gauges percent ranking as important or very important. In this assessment, 94 percent of elected officials rank impact on transportation capacity as one of their top considerations, but traffic congestion potential ranks 15th. Planners and planning and zoning officials tend to rate both factors among their top five in the average ratings comparison, but again, both factors fall well down the list of priorities when the comparison basis of important or very important is used. Interestingly, state and regional officials perceive that the local areas would not rate transportation capacity or traffic congestion potential as factors of high importance on either scale.

Involvement in Transportation Impacts of Development Proposals or Land Use Plans

The next series of questions attempts to learn how intensively each group of respondents becomes involved in the examination of the transportation impacts or needs associated with development proposals.

Elected officials were asked to indicate (Question 4) how often they personally got involved in reviewing or considering the transportation impacts or potential transportation system capacity needs in conjunction with a particular development proposal. As shown in Figure 8, the majority of these officials said that they were always involved in these assessments, while the remaining 35.3 percent said that they were sometimes involved.

None of the officials claimed to be exempt from this review process. Of those who said they participated on an occasional basis, the circumstances of their participation included:

- When/if asked.
- When/if the issue comes before the town council.
- When/if traffic studies are provided as part of development proposals.
- Depending on personal knowledge of the development or area.

As a follow-up, the elected officials were asked to indicate the extent to which they requested or ensured that their jurisdiction’s planning officials or planning staff considered the impacts of a particular development proposal (Question 5). Their answers, summarized in Figure 9, suggest that in the great majority of cases (82 percent), the professional planning staff is asked to become involved in the analysis. In only 12 percent of the cases were planners not directed to get involved.

When a development *is* approved in the given jurisdiction, elected officials were asked to describe their role in ensuring that there would be adequate transportation capacity to serve the development. The largest percentage of officials, 82.4 percent, indicated that they trusted their planning or public works officials to provide this assurance. Another 47.1 percent claimed that they worked to ensure that the specific transportation needs were known and that facilities would be provided for in the respective capital program. Only a fairly small percentage, 17.6 percent, indicated that they did not overly concern themselves about this issue given the number of other intervening factors that would come to bear on transportation conditions.

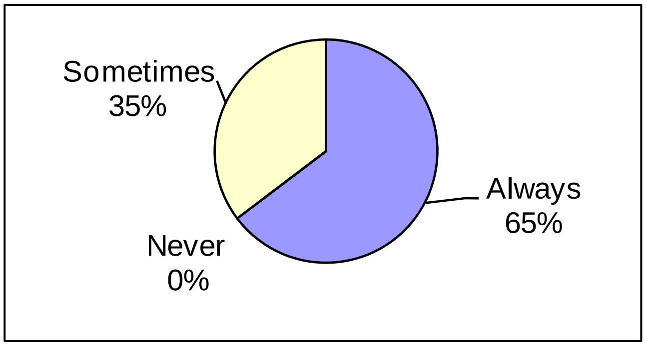

Figure 8. Frequency of Elected Officials Personally Reviewing Transportation Impacts/Needs of a Development Proposal (Question 4).

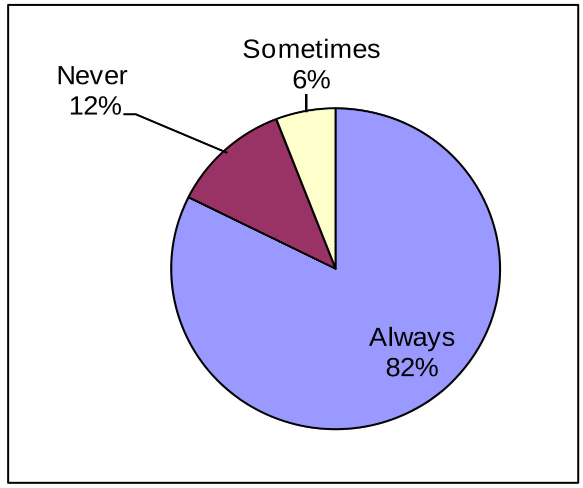

Figure 9. Elected Officials Asked Planning Staff to Consider Transportation Impacts (Question 5).

An important objective of the survey was to determine the degree to which entities making critical land use or development-related decisions—in this case, elected officials—coordinate with other entities that might be able to provide relevant tools, information, or expertise (Question 6). Responses to this question are shown in Figure 10. The most common coordination is with the jurisdiction's planning staff or public works officials, with 71 percent of officials indicating that they always coordinated with this group. Coordination with entities outside the jurisdiction was less frequent, with the largest percentage of respondents indicating that they sometimes coordinated with county planning or public works officials (44 percent), the regional MPO (53 percent), local or regional transit operators (56 percent), and Arizona DOT or other state agencies (41 percent). A surprisingly high percentage—about one-third—indicated that they always coordinated with these outside entities while only a small percentage (12 percent to13 percent) said that they never coordinated with either county or state entities.

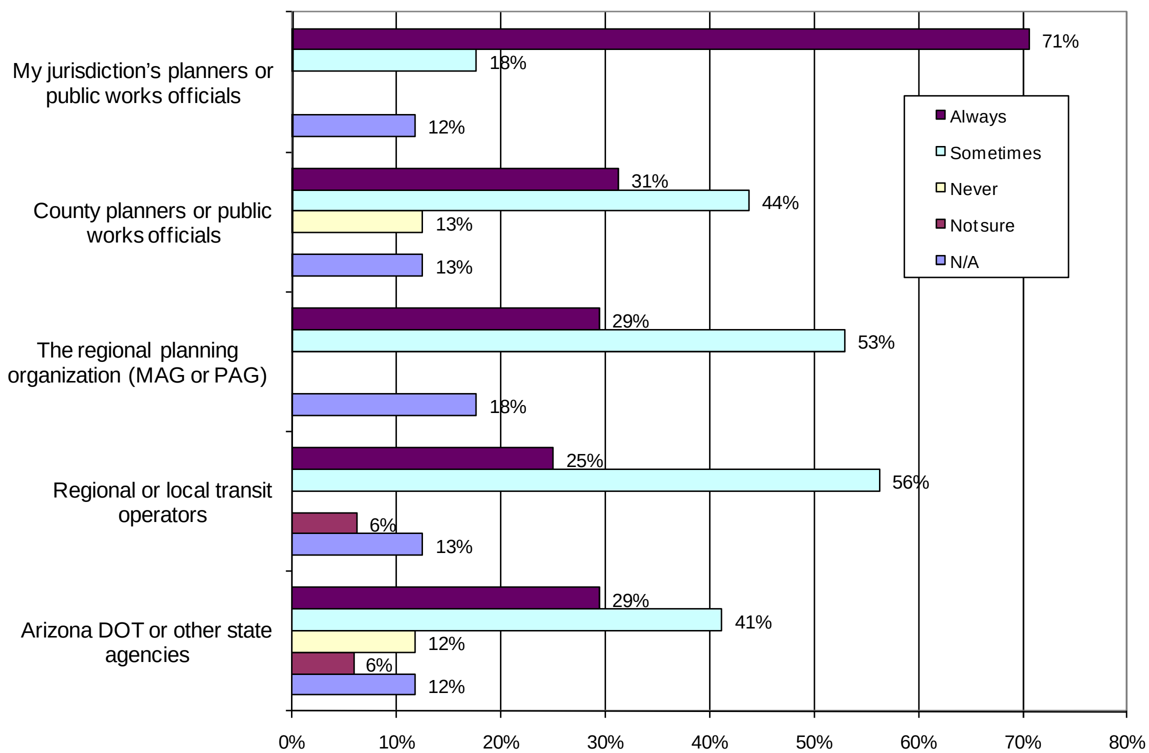

Figure 10. Coordination between Elected Officials and Other Organizations on Development Plans or Transportation Impacts (Question 6).

A final question to elected officials in this general area (Question 8) probed their knowledge of the existence of recent discussions, ordinances, studies, or procedural or policy requirements in their jurisdiction that addressed the issue of critically including transportation considerations in land use or development decisions. All officials answered in the affirmative, indicating that they were aware of such efforts. However, when asked to provide a citation, four of the 17 respondents either left the field blank or responded with N/A. Those who did offer citations suggested the following:

- ADOT, MAG, Maricopa County, and Avondale's transportation plans.
- Proposition 400 and how it affects our general plan. Making the council and staff aware of Valley Metro plans as well.
- Surprise transportation plan that is part of the general plan.
- The general plan for the development of 1275 acres of state land recently annexed required a transportation plan, which was developed.
- Comprehensive plans for Pima and Pinal counties; general plans and transportation forums.
- Our park-and-ride lot at 99th and Glendale Avenue.
- Too numerous to name.
- Transportation issue regarding new state trust land annexation and future development (1275 acres).
- Light rail studies.

- TOD zoning along our light rail route (implemented); density bonus along light rail line (study); our general plan 2020.
- Large employers, large retail projects, new residential, freeway openings.
- Economic positioning study and special planning area reports.

Planning and zoning officials were asked a similar series of questions . The first question (Question 4) asked about the extent and manner in which transportation impacts or potential transportation system capacity needs were considered when the official or the jurisdiction was reviewing a development application. Responses are profiled in Figure 11. Overwhelmingly, 94 percent of planning and zoning officials indicated that they always requested input from their professional planning staff.

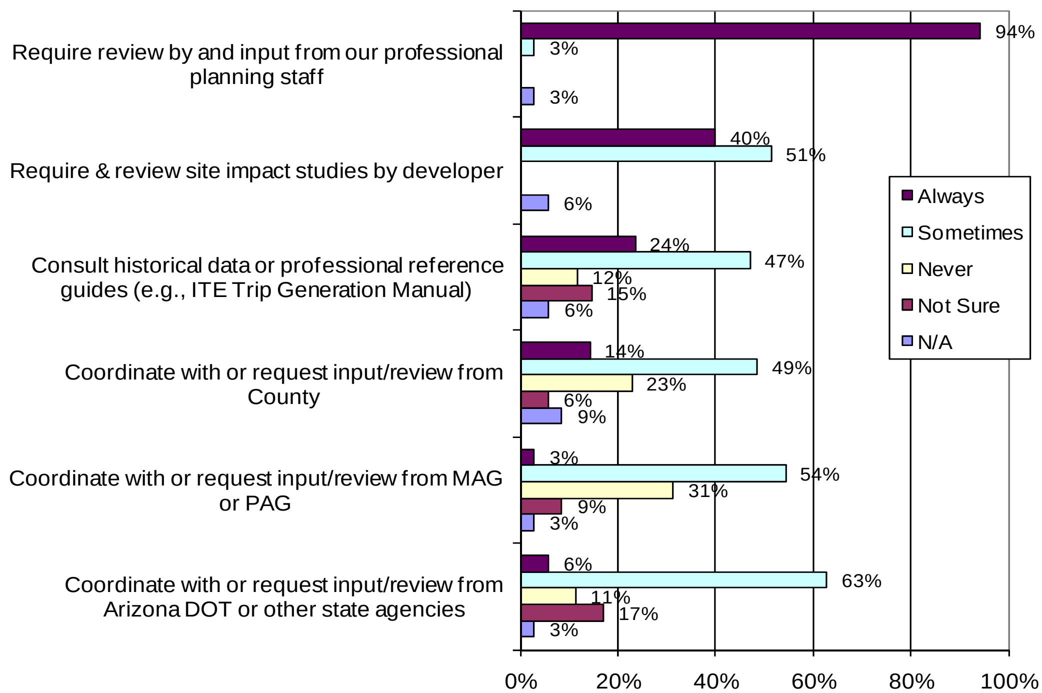

Figure 11. Extent and Manner in which Planning and Zoning Officials Consider Transportation Impacts.

Somewhat surprising, perhaps, is that only 40 percent indicated that the project developer would be required to produce a traffic analysis, while 51 percent said that such studies were sometimes required. Presumably this reflects the fact that a size threshold defines those projects that require separate traffic studies. Another somewhat interesting response was the relatively infrequent use of historical data on development/traffic or the use of professional reference guides, such as the ITE *Trip Generation* manual. Only 24 percent of the respondents reported that this type of information was always used in traffic impact evaluation vs. 47 percent who said it was sometimes used, 12 percent who felt that it was never used, and 15 percent who were unsure. This response may have something to do with either these investigations being given over to the planning staff or that not all development applications were subjected to traffic analyses. Finally, in relation to coordination with or requesting information from higher level agencies (the county, regional MPO, or state), such coordination would appear to occur on a fairly infrequent basis, with coordination between the jurisdiction and either the regional MPO or the county being the least common practice.

If transportation impact assessments were performed, respondents were then asked to indicate how broad an impact area was considered. As shown in Figure 12, most of these impact assessments were restricted to effects at or immediately adjacent to the site (85.3 percent) or nearby intersections (79.4 percent). Very few indicated a more comprehensive traffic review test, extending to key transportation arteries elsewhere in the jurisdiction or the region. This is not an unusual or unexpected result, and is fairly common practice around the country. It is also perhaps a key reason why the full impact of development projects on the transportation system is never fully appreciated or accounted for. Among those responding with other, the type or scope of analysis given included:

- Citywide.
- Depends on size/impact/location of project (could be all of these, or just one).
- Is there funding for improvements.
- Usually only related to freeway intersections or planned freeway extensions.
- Planning relies on [Maricopa County DOT] review comments.
- Multiuse pedestrian and bike possibilities.

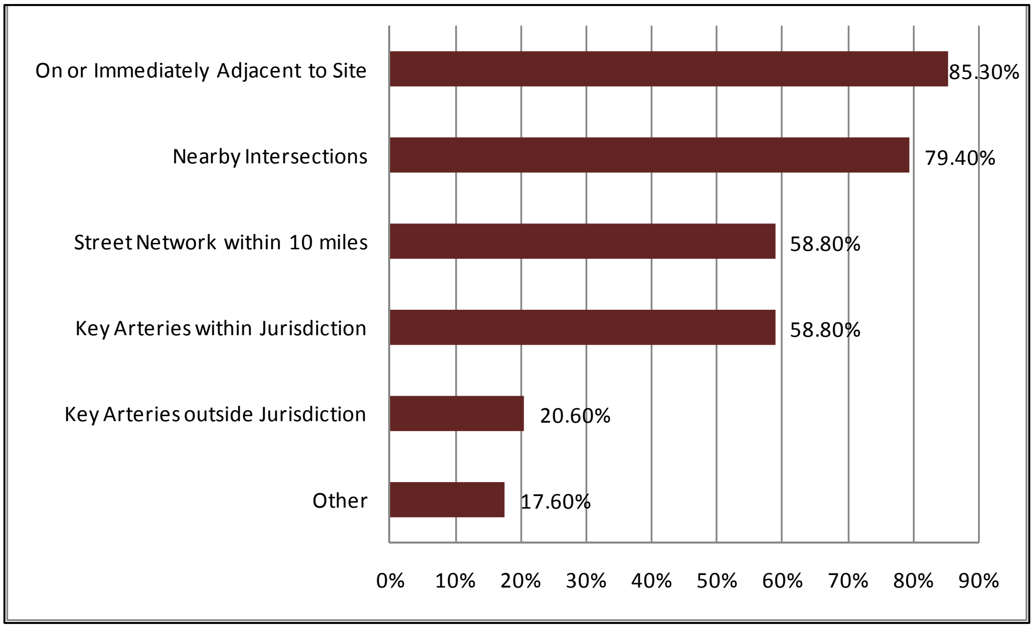

Figure 12. Level at which Planning and Zoning Officials Consider Transportation Impacts.

A subsequent question was whether the planning and zoning officials were aware of whether their planning specialists ever used transportation models to quantify or analyze transportation needs or traffic impacts associated with development projects. Their responses are shown in Figure 13. While 31 percent indicated that these tools were available and used, and some believed they were used sometimes (8 percent), a surprisingly high 41 percent of officials did not know whether such tools existed. Those indicating that the tools did exist and they were sometimes used reported that the circumstances under which they might be used would be governed by one of the following:

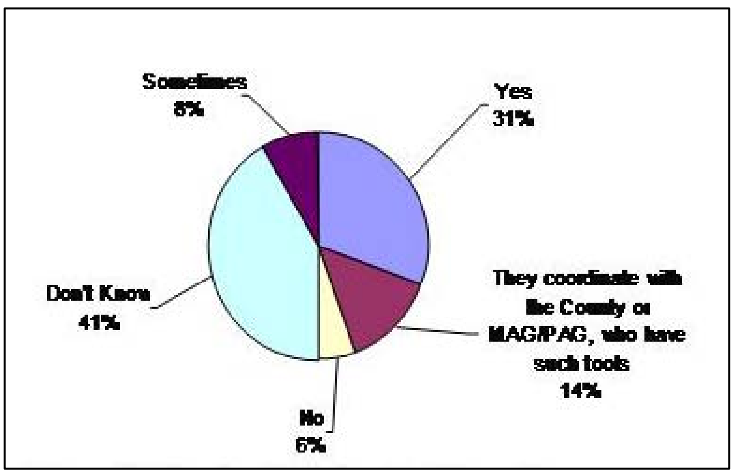

Figure 13. Planning and Zoning Officials' Awareness of Transportation Modeling Tools for Impact Assessment.

- Depends on size of project and location.
- Generally done for master planned communities or major cores with high-rises.
- Usually done by applicant who has tools.

And finally, planning and zoning officials were asked whether their agency had any studies, memoranda, reports, policies, or plans that were available for use in quantifying transportation needs or impacts. In response, 55.6 percent indicated that they were aware of such reference materials or guidelines, while 2.8 percent said they were not, and 41.7 percent either didn't know or had not used these aids. Of the respondents replying in the affirmative, 75 percent (16 of 20) provided follow-up information about how these resources could be obtained or further investigated.

The third group of officials responding to this question set was local planning professionals. The first question (Question 4) explored their involvement in land development and use review processes (at the request of elected officials or planning and zoning officials). Responses are summarized in Figure 14.

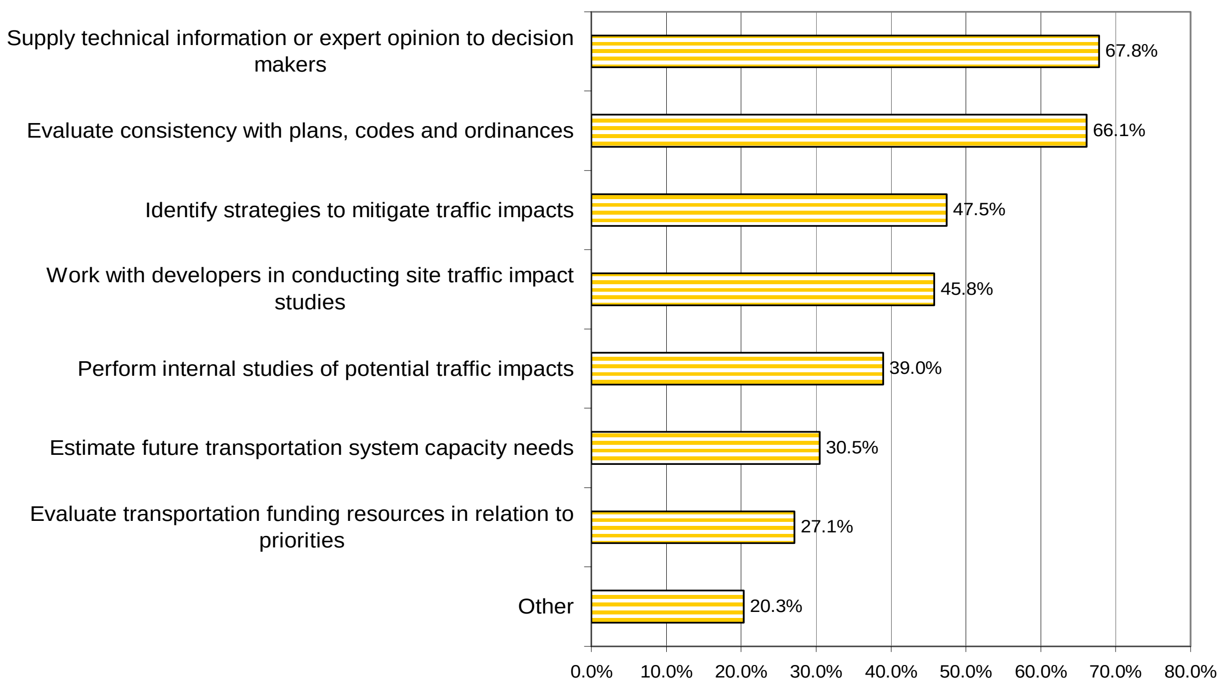

Figure 14. Participation of Local Planners in Land Use/Development Review Process.

The most common involvement reported was to provide technical input to decision-makers, noted by 67.8 percent of the respondents, closely followed by activities to evaluate consistency with controlling plans, codes, or ordinances. Then there appears to be a tangible drop in the percentage of respondents indicating involvement in the aspects of ascertaining traffic impacts, estimating transportation capacity needs, or seeking mitigation remedies. However, at this level it is relevant to look at the type of planning professional who is responding.

The discussion of the survey sample composition at the beginning of this chapter indicated that the survey group "local planning professionals" consisted of traditional planners, traffic engineers, engineering or public works officials, economic development specialists, transportation commissioners, and academics. Viewed from the vantage point of these specialties, the responses have the characteristics shown in Table 6. From this perspective, it is clear that the traffic engineers and the engineering and public works specialists are routinely involved in the traffic and transportation issues related to development projects. However, given this finer inspection of the data, it is perhaps worth noting that the actual "planners" in the group are only infrequently involved in these aspects. This may be a meaningful finding in that this group of professionals often has the greatest involvement in land use concepts and decisions, yet they appear to not be particularly close to these important analyses.

For those local planning professionals who are asked to get involved in traffic impact analysis, Question 5 asked about the geographic scale at which those impacts were reviewed. The responses shown in Figure 15 compare very closely in magnitude and distribution to those denoted previously from the planning and zoning officials. Obviously, the greatest attention is given to the intersections and facilities closest to the site, with a tangible drop in the frequency with which assessments are made further from the site. A small number of respondents supplemented their response with information about factors or parameters that would dictate the scale of the assessment. Generally, the trend in these responses was toward broader scales of analysis for larger projects; however, no particulars were given as to thresholds for making such a distinction.

Table 6. Participation of Local Planners in Development Review or Traffic Impact Evaluations, by Job Category.

	Planner	Traffic Engr	Engr & Pub Wks	Econ Devel	Trans Comm	All
Supply technical information or expert opinion to decision-makers	75%	82%	90%	11%	0%	68%
Evaluate consistency with plans, codes, and ordinances	85%	64%	80%	44%	38%	66%
Identify strategies to mitigate traffic impacts	35%	100%	90%	0%	13%	47%
Work with developers in conducting site traffic impact studies	40%	82%	80%	22%	0%	46%
Perform internal studies of potential traffic impacts	30%	82%	70%	0%	0%	39%
Estimate future transportation system capacity needs	15%	82%	50%	11%	0%	31%
Evaluate transportation funding resources in relation to priorities	20%	36%	60%	11%	0%	27%
Other	5%	0%	10%	11%	50%	20%
Sample Size	20	11	10	9	8	60

(Sum of individual groups does not equal 60 because two academic respondents were not included.)

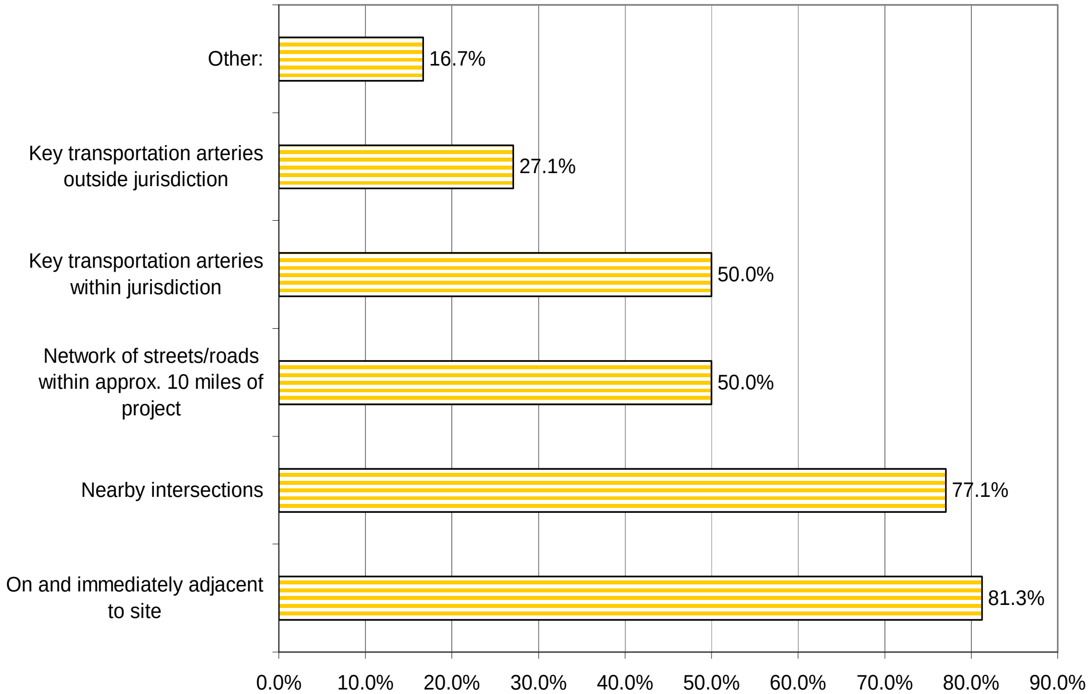

Figure 15. Geographic Scale at which Local Planners Reviewed Traffic Impact Analysis.

In Question 6, planners were also asked to indicate the types of tools they had available or procedures they would undertake to evaluate the transportation impacts of development projects or other land use related issues. The results are presented in Figure 16 and indicate clearly that these evaluations usually depend on traffic engineering guidelines and/or traffic studies required of the developer. Only a small percentage reported that they had their own transportation models and used them for this purpose. If a modeling approach were to be used, it would most likely entail cooperation with the respective MPO or the state, or by hiring consultants with models.

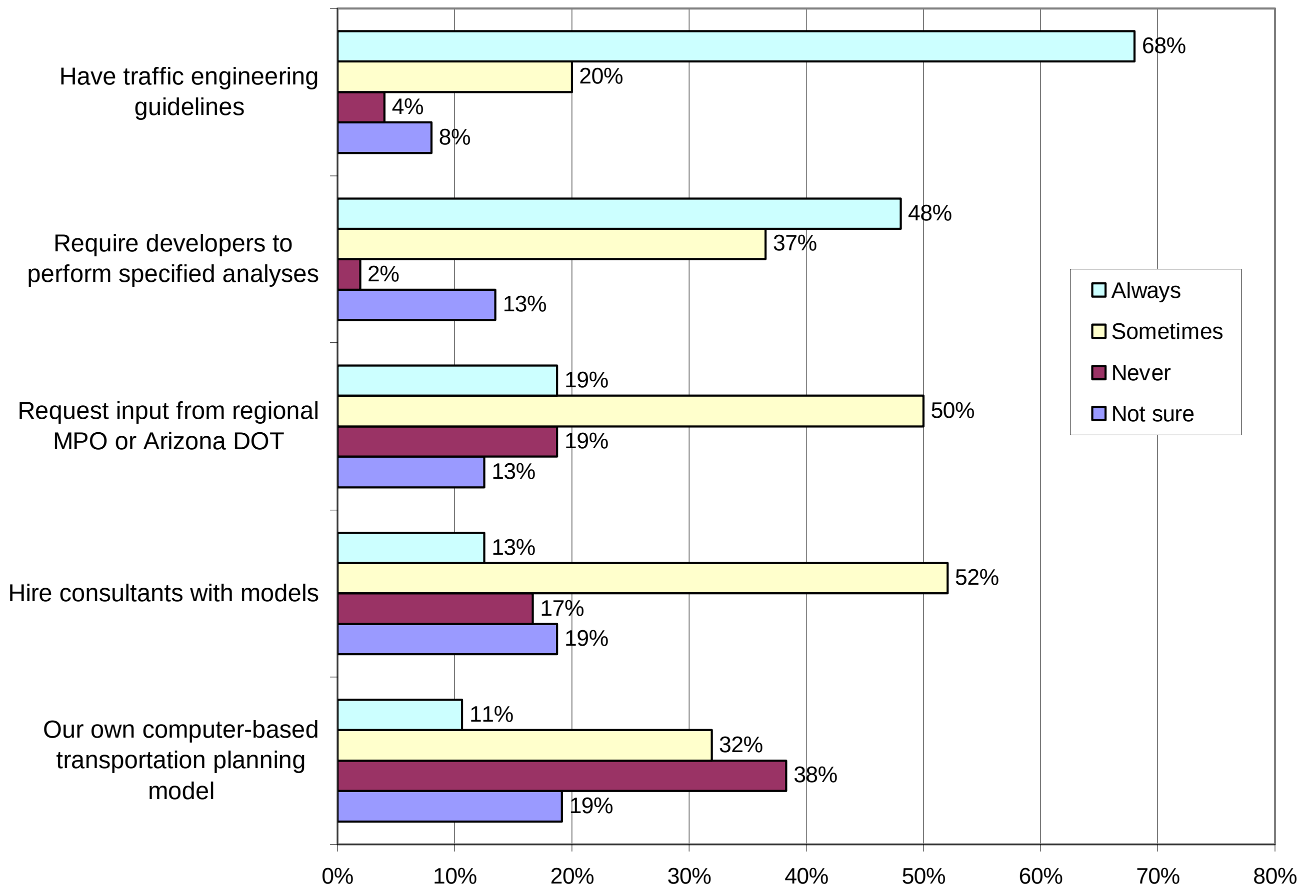

Figure 16. Tools or Procedures Local Planners Used to Evaluate Transportation Impacts.

In the final question (Question 7), local planners were asked whether their agency or jurisdiction obtained data on development traffic impacts. As seen in Figure 17, the majority (62 percent) reported affirmatively, while 14 percent said they did not, and 24 percent were not sure. In all, 36 respondents answered “yes” and 28 of these responded with additional detail on the type of information obtained or available.

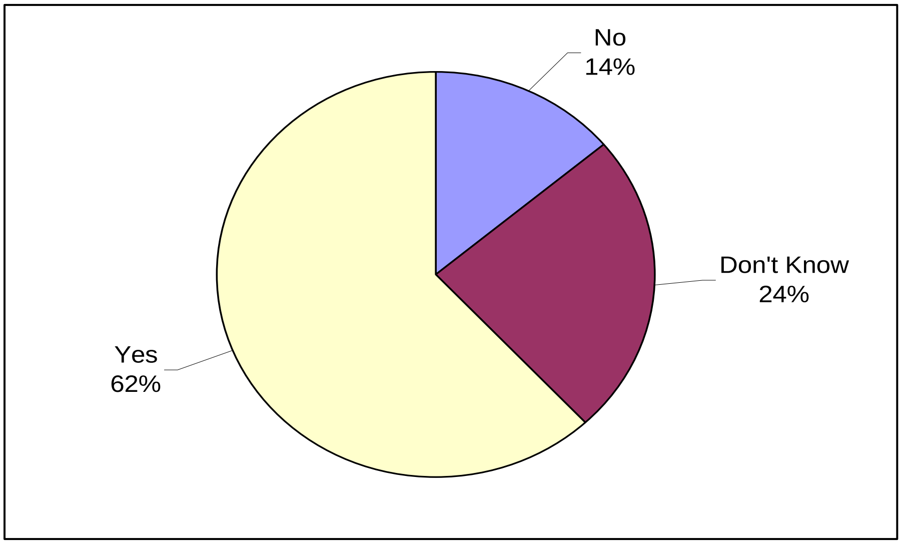

Figure 17. Development Traffic Impact Data Obtained from Local Planners' Agency or Jurisdiction.

Relatively few specific citations or leads were obtained, however. The following is a list of the open-end responses:

- Developers are required to perform traffic analysis impact studies.
- Speed studies, traffic signal warrants, traffic counts, turning movement counts, traffic signal phasing and timing analysis. This information is used for posting appropriate speed limits; justifying traffic signal installations or not; planning capacity improvements; adjusting signal phasing, timing, and cycling; and adjusting pavement marking and signage.
- Use for historical purposes to establish parking and verify parking studies. Do not retain information.
- We do annual traffic counts but these do not show trip origins.
- Traffic counts, mostly ignored.
- Use consultants.
- Occasionally, traffic volume data is collected and compared to before data.
- Constant assessment using local data, APA (PAS) data, ULI reports, etc. All commonly available.
- We don't conduct formal "after" evaluations, but traffic conditions are constantly monitored citywide and reports are received about traffic conditions adjacent to new developments on an informal basis.
- I've reviewed reports of traffic levels and of transit use in reports from City staff. They could report in more detail the specifics of studies.
- Visually observe conditions in the field.
- As a member of the Transportation Commission, I have seen data, but [do] not create data.
- See attached TIA procedures/requirements.
- ITS data to justify cost of installation of ITS.
- Require overall build-out model, then require phasing model that includes previous development.

- Refer to traffic section of public works transportation division.
- Traffic counts and accident records.
- Traffic studies, MAG studies.
- Obtained through city transportation staff.
- We require traffic impact studies from developers.
- Speed studies, signal warrants, and turning movement counts.
- Models and forecasts.
- Traffic engineer requires TIS or other studies.
- Traffic projections and potential activity.
- Traffic counts on an as-needed basis. If we have what you are looking for (in reference to above question).
- The number of daily trips generated is estimated for every rezoning case. This information is provided by Pima Association of Environment and placed on our website.

The last group of officials questioned on this topic was the state and regional transportation officials group. The participants were first asked (Question 4) to indicate the ways in which their office or organization was requested by local jurisdictions to provide input or assistance in the local land use decision-making process. Results are summarized in Figure 18. The responses reflect something of a mixed bag, with these officials both being asked to provide specialized expertise to complex planning decisions as well as simply to help find ways to solve transportation capacity or access problems to accommodate new development. Almost three-fourths (73.7 percent) were asked to participate in the planning process, while 63.2 percent were asked to help identify strategies to mitigate traffic impacts or to help determine transportation capacity needs. However, at the same time, 73.7 percent of state and regional transportation officials were asked to help provide new transportation capacity, 68.4 percent were asked to help improve regional access to the jurisdiction, and 57.9 percent were asked to help evaluate transportation funding sources. A disappointingly small percentage was asked to either supply technical information or expertise to decision-makers (31.6 percent) or to provide information on alternative land use or development concepts (21.1 percent).

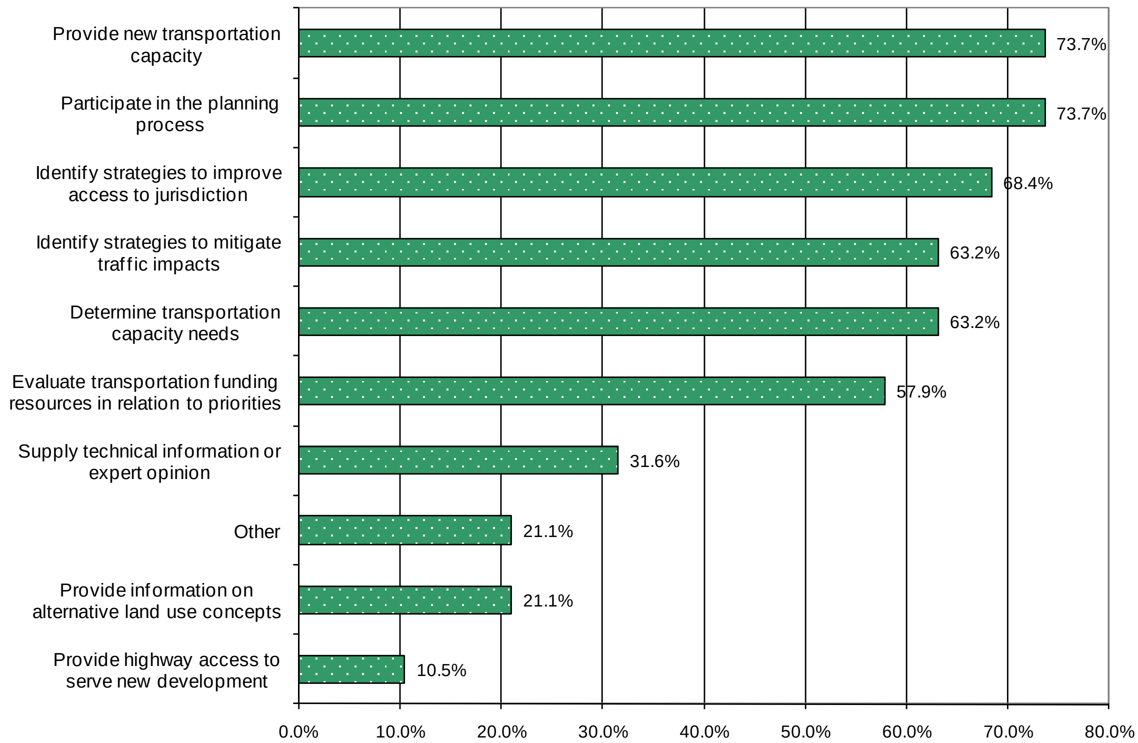

Figure 18. Participation of State and Regional Officials in Local Land Use Decisions.

Among those responding with other, the following specific types of input or involvement were described:

- Route design and infrastructure.
- TOD guidelines and TOD zoning overlay district.
- Types of technical information: neighboring jurisdictions ask for comments about major general plan amendments and rezoning cases on the borders and in the town's planning area.

State and regional officials were then asked whether their organization ever monitored, studied, or obtained data about the traffic effects (local or regional) of development projects or land use patterns (Question 5). Results in Figure 19, indicate that 74 percent believed that their organization obtained and compiled such data and shared it with local jurisdictions for planning or decision-making. Only 4 percent didn't know, and 22 percent said that their office or organization did not provide such information.

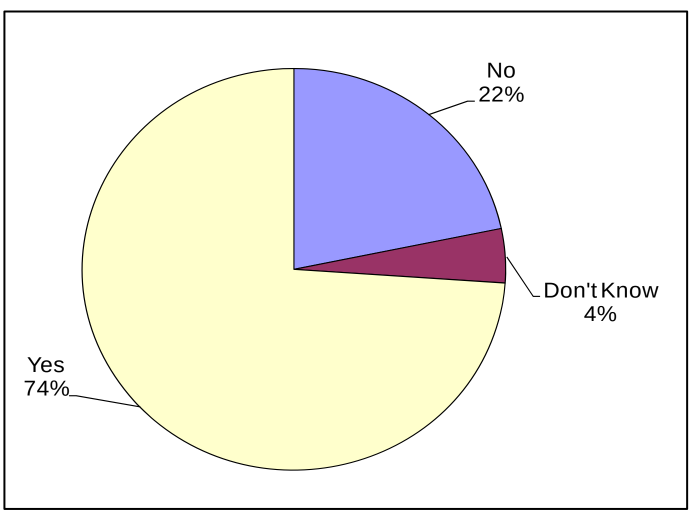

Figure 19. State and Regional Officials' Organization Obtained Traffic Impact Data.

Among the types of information collected or shared were:

- Traffic counts on an as-needed basis.
- Traffic impact reports, corridor studies, and road studies.
- Traffic counts; Travel Reduction Program Employee Survey.
- Traffic impact studies.
- Requirements that new development provide a traffic study showing post-development impacts. These are localized studies, but as development and rezoning occurs, data are fed to regional models (analyzed by others).
- Traffic engineering studies for new projects as warranted by circumstances of project.
- Crash data: police (local) and ADOT; ADT - ADOT; road inventory.

State and regional officials were then questioned about the extent to which their organization coordinated with a variety of other state, regional, or county-level organizations in relation to land use planning and associated transportation impacts or needs (Question 6). The results in Figure 20 indicate that the given state or regional organization communicated most frequently with the respective regional planning organization, followed by the regional or local transit operator, city or county planning departments, and (least frequently) ADOT.

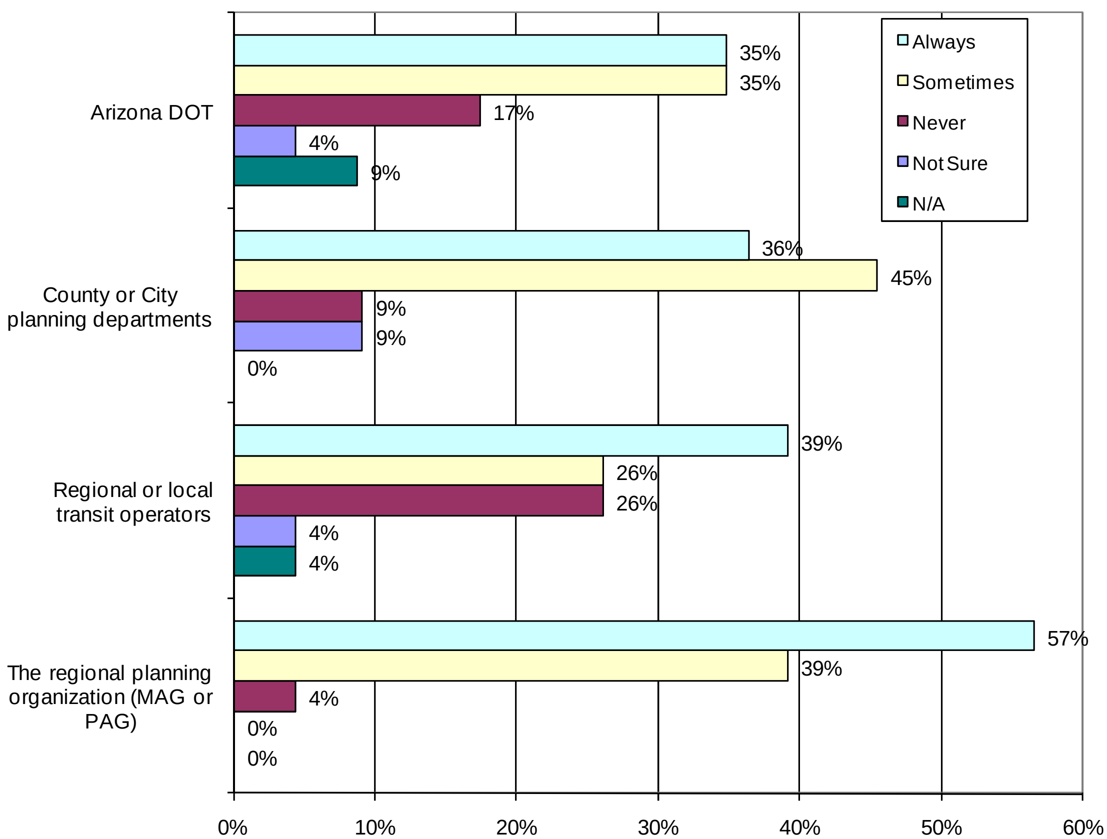

Figure 20. State and Regional Officials' Organizations Coordinate with Other Agencies about Land Use.

Experience with Mixed-Use Development Concepts

A central question from this survey was the level of knowledge and familiarity with compact, mixed-use development concepts. This type of development is often generalized as "high density" and therefore presumed likely to generate more traffic than conventional low-density, single-use patterns. The purpose of this set of questions was not to advocate for a particular position but to ascertain the degree to which various professionals included in this survey have been exposed to this concept and sufficiently understand its behavior to advise on its treatment in the planning process. The same set of questions was asked of each survey group, allowing for direct comparison of responses across the four groups.

The first question asked whether the given individual had direct experience with mixed-use projects, defined as "projects that combine more than one land use at the same site, may be of somewhat higher density, and are designed to encourage pedestrian movement and transit use." Participants were further advised to "think of this type of development in contrast to conventional low-density, auto-oriented, single-use designs." Responses are summarized in Figure 21.

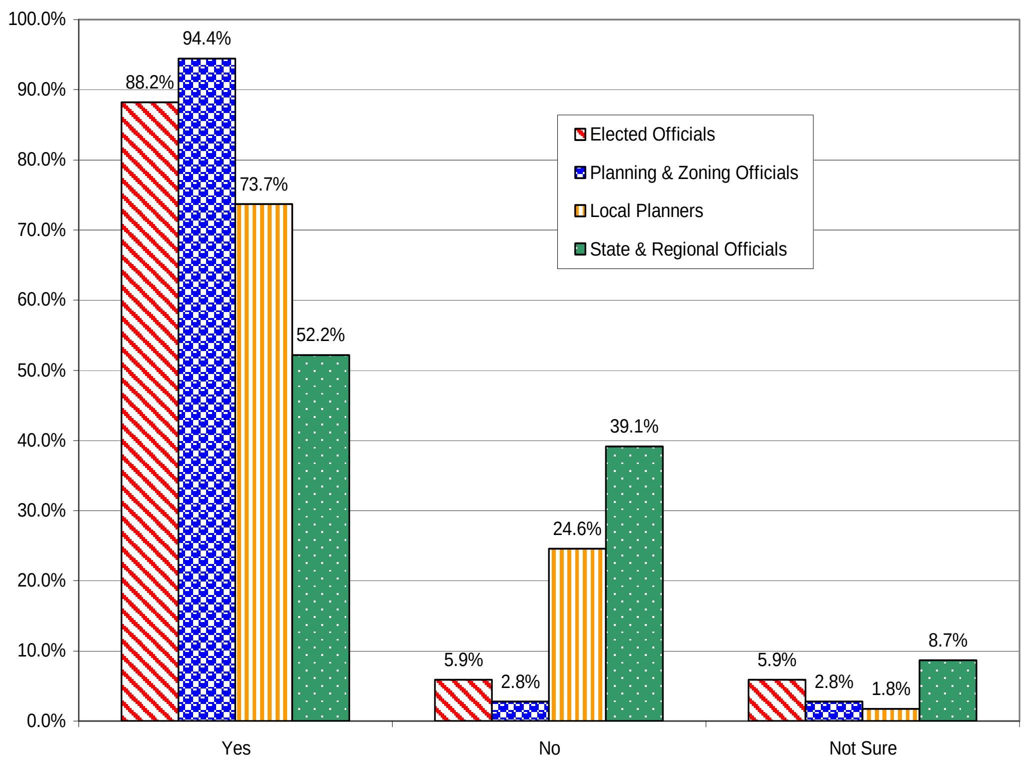

Figure 21. Extent of Direct Experience with Mixed-Use Projects.

Of all the groups, the planning and zoning officials contend to have the most direct experience with the mixed-use concept, with 94.4 percent answering yes. At 88.2 percent, elected officials were the next most likely to claim familiarity, followed by planners at 73.7 percent,

and state and regional officials at 52.2 percent. This result may be counterintuitive, especially in regard to the last two groups claiming less familiarity than the elected officials.
Figure 22 corroborates the answers to the initial question, with almost the same percentages of officials in the first three groups saying that they had actually received applications for these kinds of projects. State and regional officials were not included in this question for reasons of applicability.

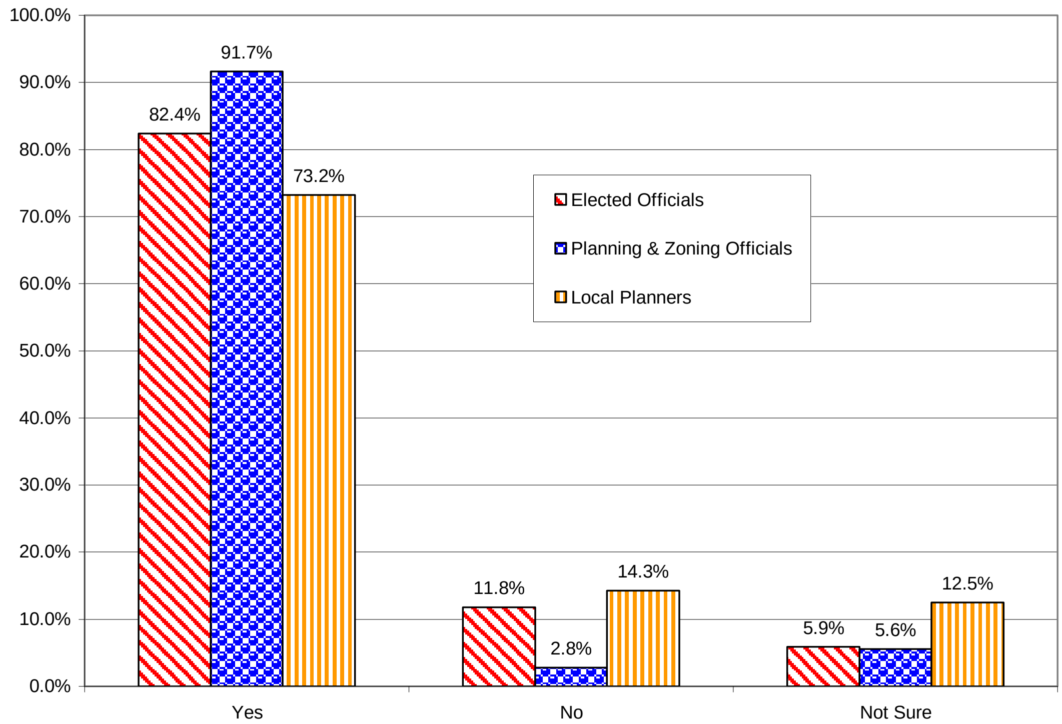

Figure 22. Officials Who had Received Applications for Mixed-Use Projects.

A substantial majority of officials responding in all groups indicated that they had actually helped encourage developers to submit applications for projects with these characteristics. Figure 23 shows that 80.6 percent of planning and zoning officials, 70.6 percent of elected officials, 61.8 percent of planners, and 69.6 percent of state and regional officials said that they—directly or indirectly—encouraged consideration of mixed-use projects. Obviously, the elected officials and the planning and zoning officials are in the best position in terms of authority to provide leadership in this area, while the other two groups would tend to advocate in a more indirect way, either through technical materials or assisting in project impact analyses.

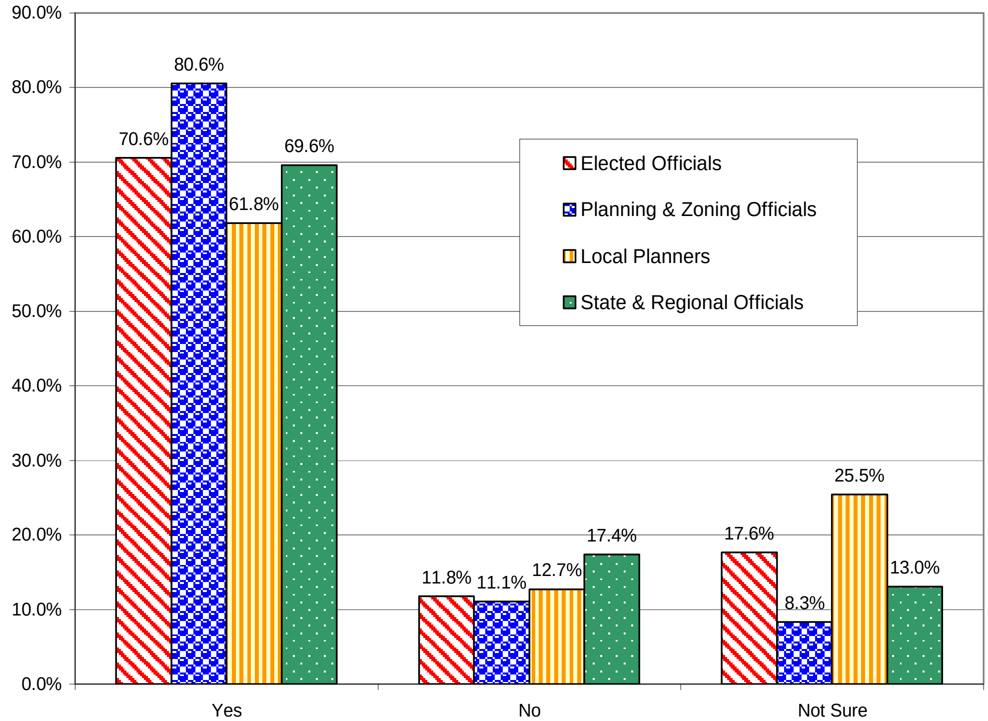

Figure 23. Officials Who Encouraged Applications for Mixed-Use Projects.

Anticipated Effect of Mixed-Use Development on Travel

The next series of questions examined respondents' perceptions of the likely impact that mixed-used development projects would have on traffic congestion, transit use, and bike/pedestrian travel. Figure 24 shows the perceived effect on traffic congestion. The largest percentage of respondents (39 to 42 percent) believed that compact, mixed-used developments would contribute less to traffic congestion than conventional development. Only 32 percent of the local planners believed that mixed-use development would have less traffic impacts, although that group was also most inclined (32 percent) to provide the conditional answer "it depends," meaning that other factors would have to be considered. However, only 11 percent of the local planners believed that mixed use would cause more traffic, followed by 17 percent of state and regional officials, 25 percent of planning and zoning officials, and 29 percent of elected officials.

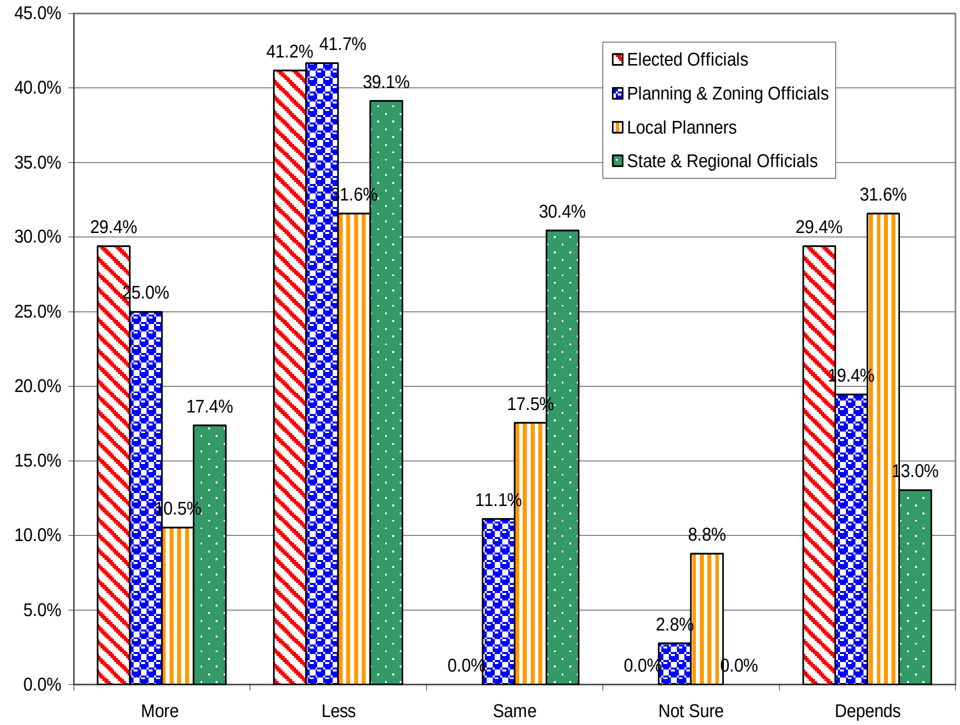

Figure 24. Expected Effect of Mixed-Use Development on Traffic Congestion.

Participants listed quite a number of conditional responses to clarify the "it depends" response to traffic congestion impact. The complete responses are listed in Appendix A and summarized below (roughly in order of the most frequently mentioned):

- Depends greatly on scale, the types of uses being mixed, and their proportions.
- Depends also on availability of transit and quality of the walk/bike environment.
- Depends on the extent to which the uses generate uses from the outside (e.g., stadiums).
- Depends on whether residents would also find jobs in these areas, others did not.

In contrast to the question on traffic congestion, a much higher percentage of all groups felt that mixed-use development would lead to greater transit use than conventional development. As shown in Figure 25, almost two-thirds (65 percent) of elected officials felt that mixed-use development would favor more transit use, followed by 52 percent of state and regional officials, 50 percent of planning and zoning officials, and 47 percent of local planners. The latter two groups were the most likely to respond with the conditional "it depends" (25 percent and 26 percent, respectively). Only 16 percent to 22 percent felt that the type of land use would make no difference in transit use.

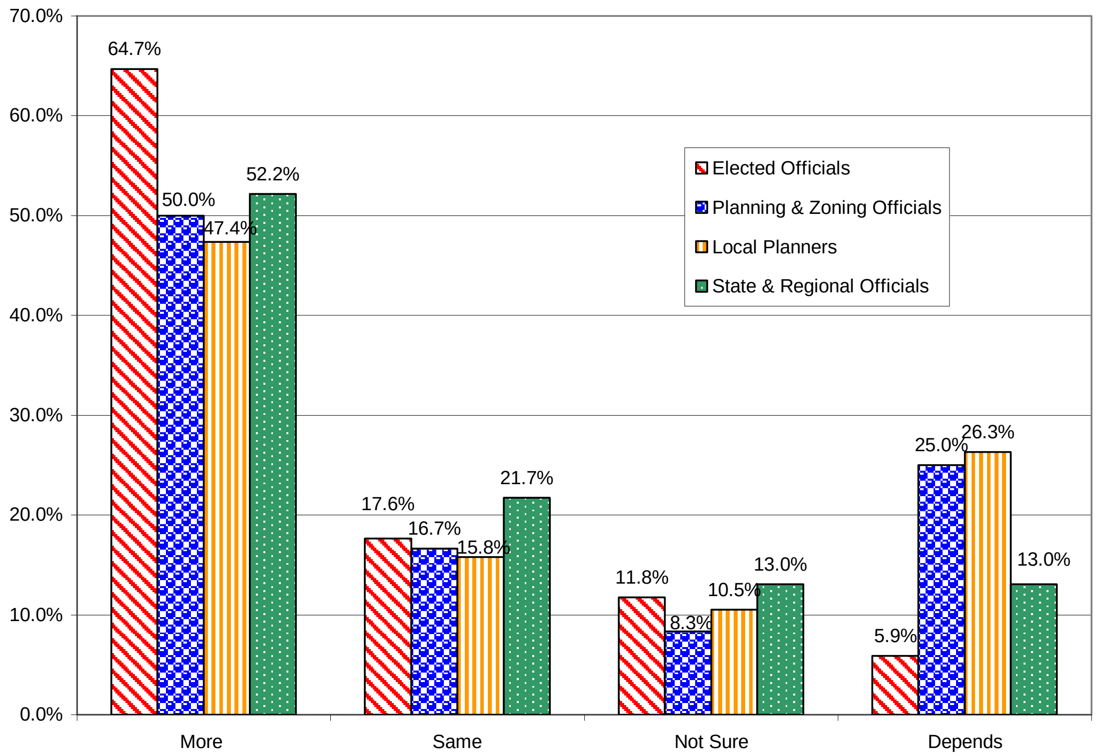

Figure 25. Expected Effect on Transit Use.

Those answering "it depends" offered the following qualifications. Again, open-ended responses are listed in full detail in Appendix A and summarized below in decreasing order of frequency:

- Depends on the existence, quality, and integration of transit service.
- Depends on the type, mix, and density of development.
- Depends on the quality, safety, and ease of access to transit.
- Depends on the nature of the residential development and price ranges of housing.
- Depends on other regional conditions, e.g., employment reachable by transit.
- Depends on whether the mixed use is accompanied by reduced parking.
- Depends greatly on scale, the types of uses being mixed and their proportions.

An even higher across-the-board percentage of officials from each group felt that compact, mixed-use development would lead to greater bicycle and pedestrian travel. Figure 26 shows that 81 percent of planning and zoning officials, 77 percent of elected officials, and more than 60 percent of local planners and state and regional officials felt that compact, mixed-use development would have a positive effect on walking and biking. While local planners and planning and zoning officials continued to be the groups most likely to respond "it depends," this was the least frequent occurrence (both at14 percent).

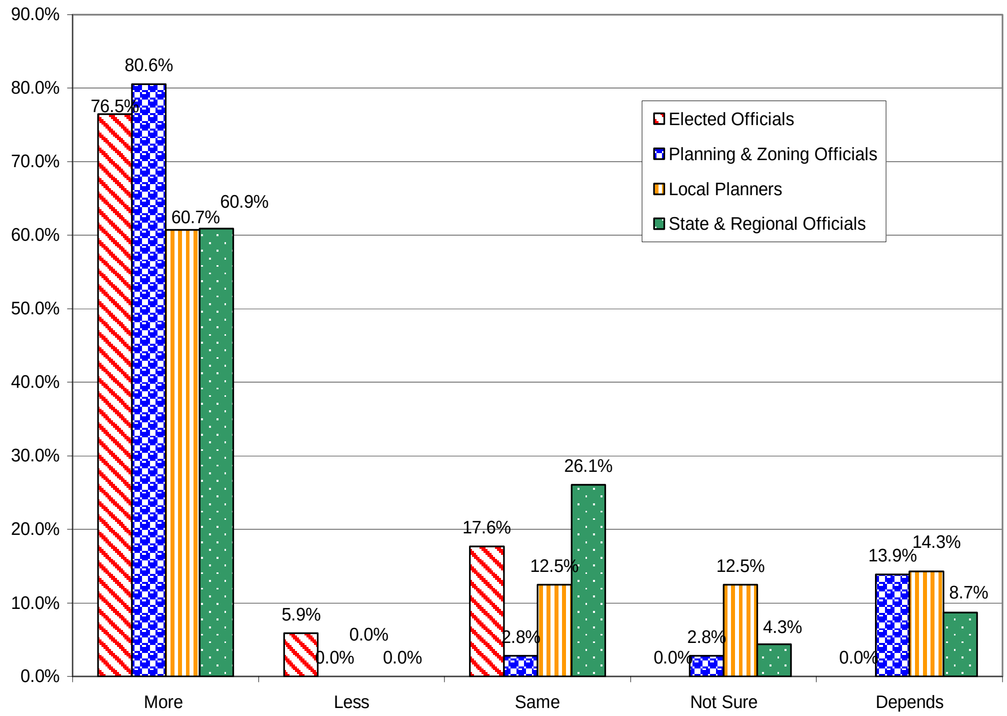

Figure 26. Expected Effect on Pedestrian and Bicycle Travel.

The qualifications provided for the response "it depends" are very similar to those for transit use. Again, the complete open-ended responses are listed in Appendix A and summarized below in decreasing order of frequency:

- Depends on the context, mix, and design of the development as well as connections with other nearby—possibly conventional developments.
- Depends on the quality of the walk environment, sidewalks, amenities (e.g., trees), and weather.

Community Acceptance of Mixed-Use Concepts

A surprisingly high percentage of officials felt that their communities would probably support compact, mixed-use development. As shown in Figure 27, 82 percent of elected officials, 83 percent of planning and zoning officials, and 77 percent of local planners reported that their communities would be supportive of these kinds of projects. State and regional officials were not asked the question for reasons of applicability.

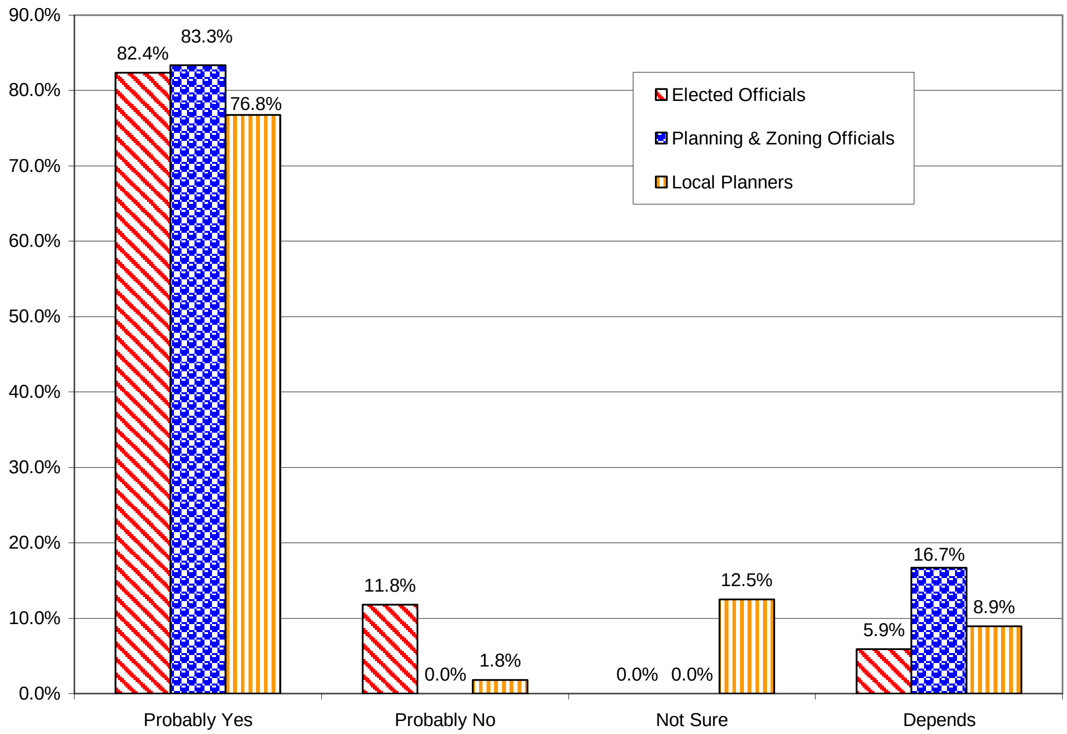

Figure 27. Community Support for Mixed-Use Development.

Those responding conditionally to this question of acceptance offered the following qualifications (listed in their entirety in Appendix A):

- Depends on the development—whether it falls within guidelines and regulations, and if it is attractive and offers amenity.
- Depends on scale, intensity, and location.
- Must be consistent with the vision for the neighborhood and community.

Availability and Usefulness of Information on Mixed-Use Development

When respondents were asked whether sufficient information existed about the impacts of mixed-use development on traffic and congestion to make informed decisions, a rather surprising 88 percent of elected officials responded yes (Figure 28). Planning and zoning officials were less sure (64 percent), followed by 54 percent of local planners, and only 18 percent of state and regional officials.

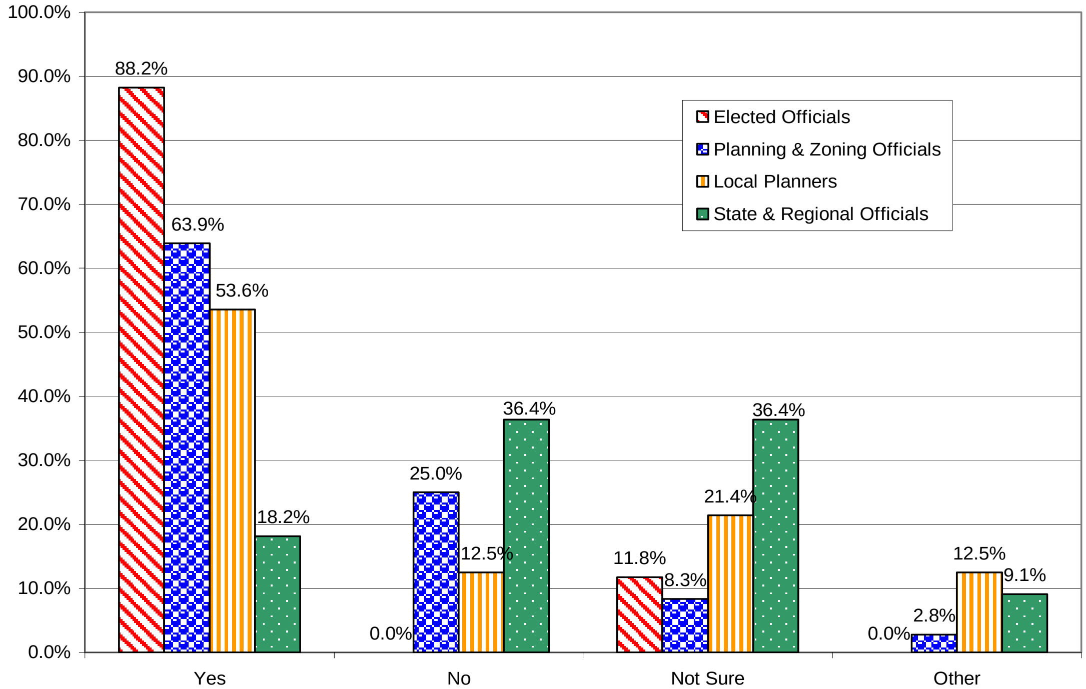

Figure 28. Sufficient Information to Make Informed Judgments about Traffic Impacts.

Nevertheless, when asked if they would use additional information if it were available (Figure 29), the great majority (88 percent) of those same elected officials said that they would find it useful, 65 percent said they would be likely to use it, and 47 percent said that they would recommend that appropriate parties use it. None said that it would be irrelevant and probably not make a difference. Similarly, while 64 percent of planning and zoning officials said that there was sufficient information, 86 percent said that additional information would be useful, 50 percent said they would use it, and 50 percent said that they would recommend that appropriate parties use it. With local planners, while earlier 54 percent said that there was sufficient information, 55 percent said that additional information would be useful, 45 percent said that they would probably use it, and 36 percent said they would recommend that appropriate parties use it. Hence, it is unclear from this pattern of responses as to just how much officials feel they currently know about mixed-use development impacts, and how much they truly would use additional or improved information.

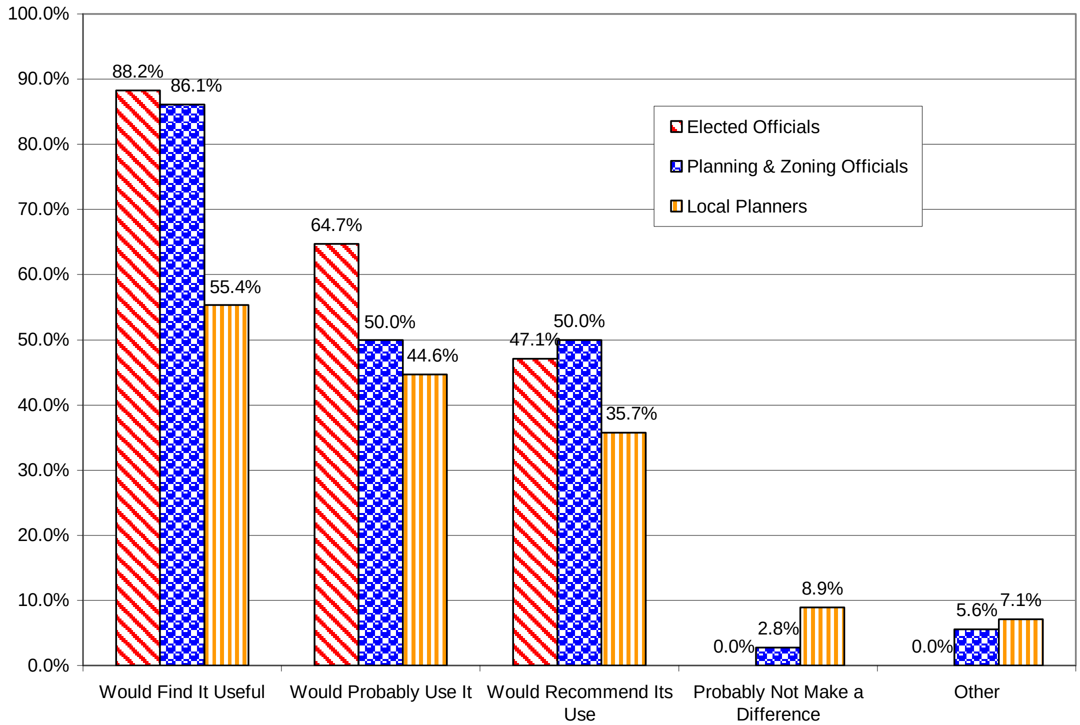

Figure 29. Value of Additional Information on Impacts.

Several respondents offered additional detail to this question. The general nature of these comments was that more information was better, but that much depended on the context. Respondents were skeptical about controlling for such variables as the number of developments occurring in the same area, the scale of the developments, and the range of factors that would be accounted for in the projections. The full set of responses is listed in Appendix A.

State and regional transportation officials were asked the question somewhat differently, given their perspective of how others would use this type of information. In this group, 82 percent of local jurisdictions would use this additional information if it were available, 68 percent believed it would be useful for the regional planning process and 68 percent thought it could be useful in helping to evaluate highway and transit needs and projects (Figure 30). Only a very small percent (less than 5 percent) said that it would not make a difference.

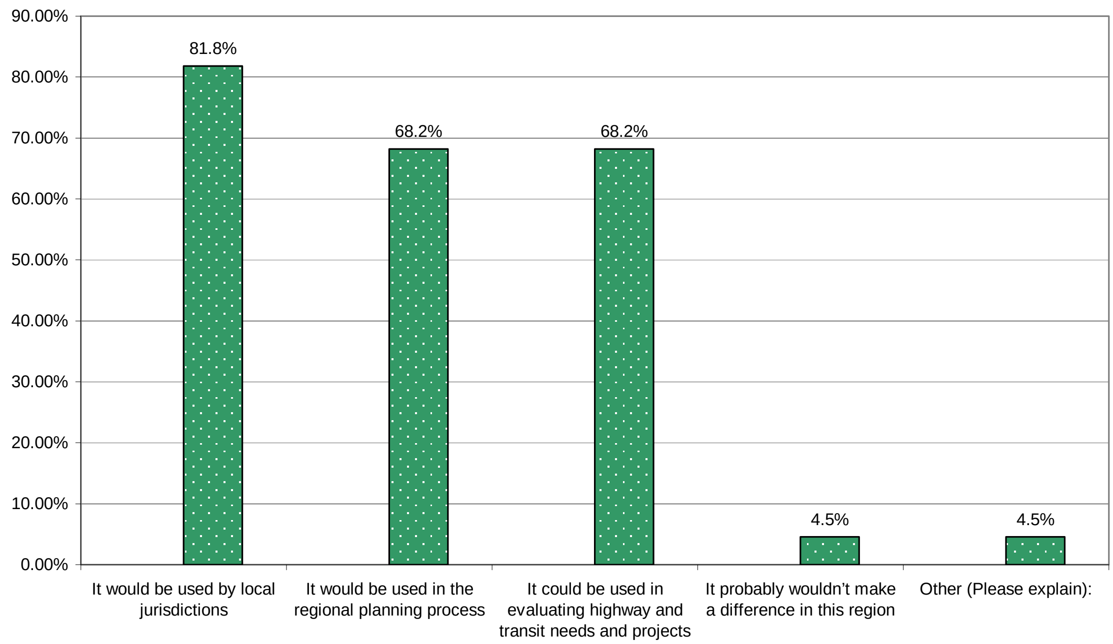

Figure 30. Perceived Value of Additional Information.

Views on Appropriate Development Types

As a logical follow-up to the questions on knowledge of mixed-use development and perceptions of its comparative impacts, officials were then asked to rank the most appropriate types of future development—first for their own community and then for the region as a whole. As before, state and regional transportation officials were asked a slightly different version of these questions. They were not asked about appropriate development for their community since that would be out of context. However, they were asked—along with the other groups of officials—about the most appropriate types of development for their region, and in addition, what types of development were likely to be constructed in the region.

Figure 31 shows the rating of development types for the respondent's own community. Differences among the groups are evident, and these differences are made clearer in Table 7, which compares the ranking for each group to the ranking for all groups combined. The three groups tended to behave similarly in the following areas:

- All three groups voted similarly on the top three most appropriate land uses: residential and retail mixed use, retail and office mixed use, and neighborhood retail. These were the most representative of mixed-use formats (although elected officials were not as supportive of retail/office mixed use, instead making single-family residential their No. 2 choice).

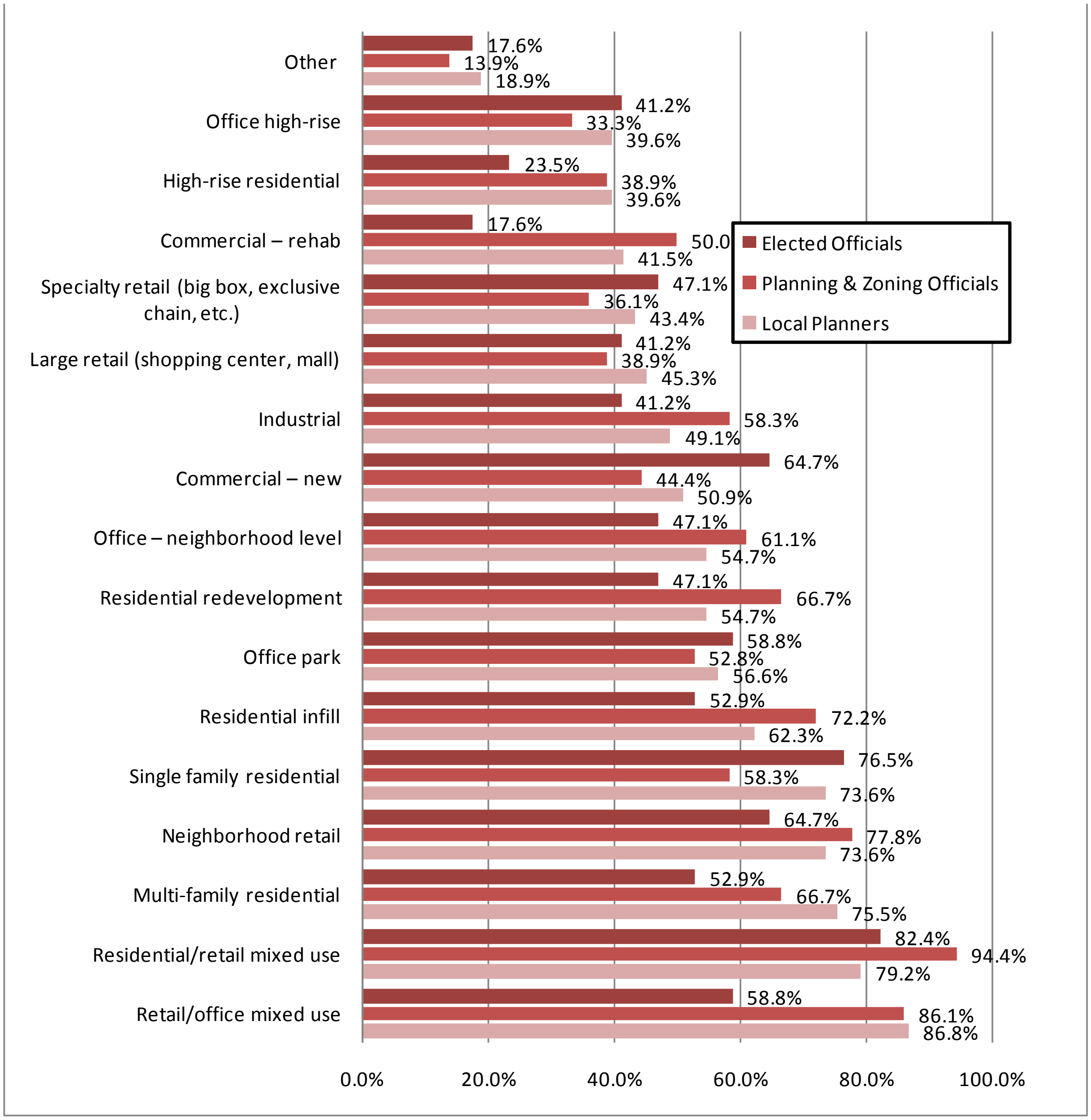

Figure 31. Most Appropriate Future Development Type for My Jurisdiction.

- The land uses that are consistently ranked at the bottom of the list are high-rise office or residential, and large retail (shopping centers or malls).

In contrast, areas where important differences are seen among the three groups include:

- Planning and zoning officials and local planners ranked multifamily residential above single-family as a fairly high priority (No. 5 and No. 3, respectively), directly opposite the priority of elected officials who ranked single-family as No. 2 and multifamily as No. 8.

- Similarly, elected officials ranked new commercial (No. 3) and office park (No. 5) close to the top of the list, whereas planning and zoning officials ranked them at No. 12 and No. 10, respectively, and planners as No. 10 and No. 7, respectively.
- Elected officials seem to be much more supportive of specialty retail (big box, exclusive chains) than the other two groups, ranking this land use at No. 9 whereas planning and zoning officials ranked it No. 15 and planners as No. 13.
- Planning and zoning officials and local planners seem to be more comfortable with residential redevelopment and residential infill than elected officials, who seem to favor new single-family residential.

Table 7. Appropriate Land Use for My Community.

	Elected Officials	Planning & Zoning Officials	Local Planners	Average Rank
Residential/retail mixed use	1	1	2	1.33
Retail/office mixed use	6	2	1	3.00
Neighborhood retail	4	3	4	3.67
Single family residential	2	8	5	5.00
Multi-family residential	8	5	3	5.33
Residential infill	7	4	6	5.67
Office park	5	10	7	7.33
Commercial – new	3	12	10	8.33
Residential redevelopment	11	6	8	8.33
Office – neighborhood level	10	7	9	8.67
Industrial	14	9	11	11.33
Specialty retail (big box, exclusive chain, etc.)	9	15	13	12.33
Large retail (shopping center, mall)	13	13	12	12.67
Commercial – rehab	17	11	14	14.00
Office high-rise	12	16	16	14.67
High-rise residential	15	14	15	14.67
Other	16	17	17	16.67

In addition to the generic categories for local land use provided above, respondents provided other ideas and concepts including flexible light industrial; small specialty retail areas; retail/commercial redevelopment; more parks and community recreation; lodging; residential and commercial redevelopment, remodeling, and adaptive reuse; converting residential structures to commercial use; and revitalization of neighborhoods, retail centers, and downtowns. (A full listing is provided in Appendix A.)

The follow-up question for all four groups was in assessing the most appropriate type of development for the respondent's region. These responses are shown graphically in Figure 32. Again, while there are some general similarities across the four groups, there are also some important differences that are better seen in the comparison of rankings in Table 8.

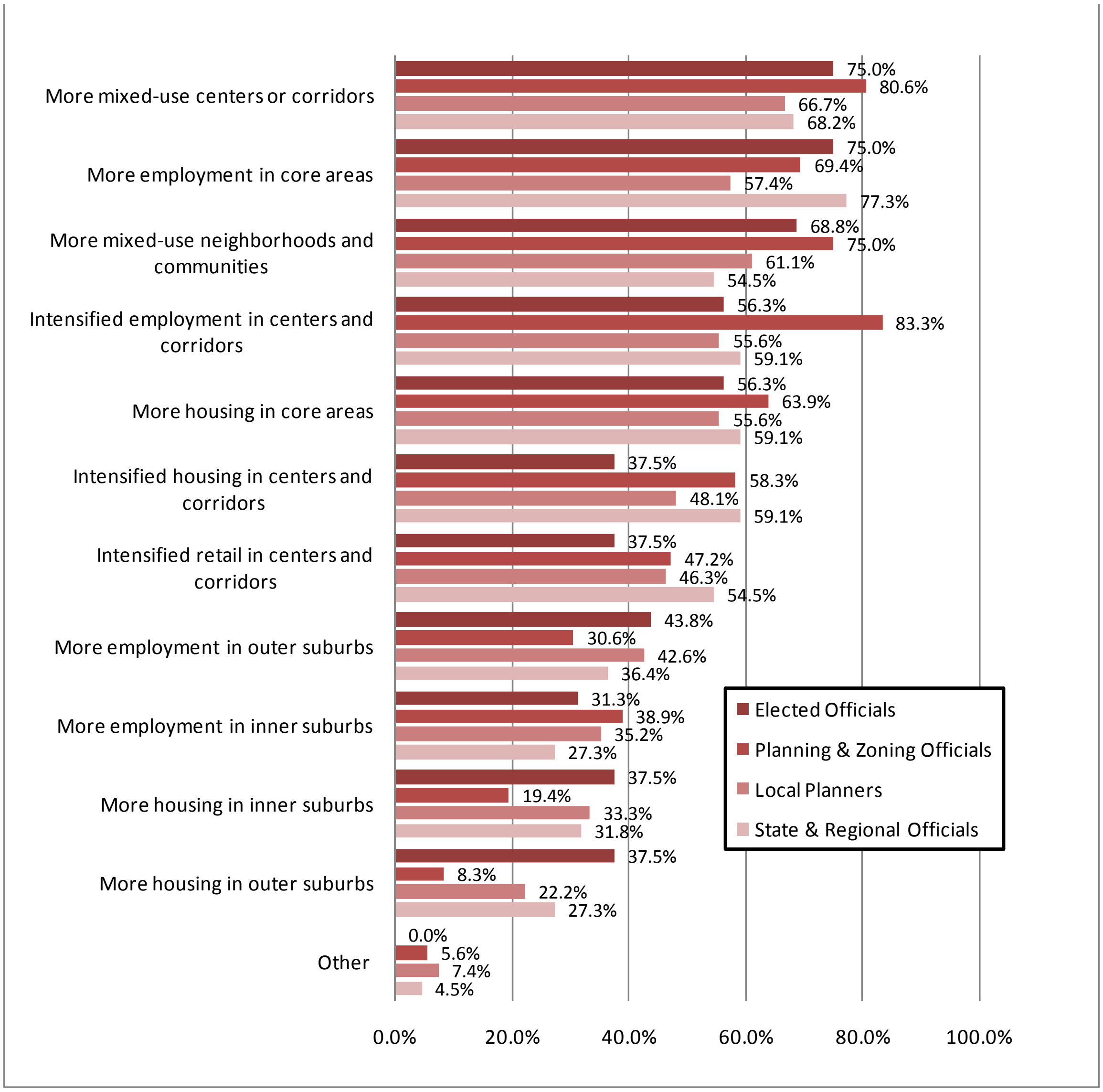

Figure 32. Most Appropriate Future Development Types for Region.

Key trends seen in responses are as follows:

- All groups believed that more development sited in mixed-use centers or corridors was a top priority, ranking as either No. 2 or No. 1 for each.
- Somewhat surprisingly, in contrast, more development in mixed use neighborhoods and communities did not rank at the top of many lists, rating only No. 6 among state and regional officials and No. 3 among elected officials and planning and zoning officials—perhaps because respondents perceived that they needed to take a macro view when considering the region.
- Both elected officials and state and regional officials ranked more employment in core areas at the top of their lists, despite the fact that neither the MAG nor PAG regions have particularly well-defined or transit-served downtowns.

- Also rated fairly high by planning and zoning officials (No. 1) and state and regional officials (No. 3) was intensified employment in centers and corridors. Without an equivalent balance of residential development to supply workers or retail to balance the uses, concentration of employment is often a major contributor to auto dependency.
- Similarly surprising was a relatively low score for intensified housing in centers and corridors and intensified retail in centers and corridors. These land uses provide the critical elements of mix, but received average rankings of 6.75 and 7.5, respectively, suggesting that they were not seen as valuable concepts. More housing in core areas scored fairly well, at 4.5 on average, which is seen as a positive result, and perhaps suggests that respondents regarded core areas as more characteristic of urban places than centers and corridors.
- Those land uses which were fairly consistently rated at the bottom of all lists were more housing in either inner or outer suburbs, and more employment in either inner or outer suburbs.

Table 8. Appropriate Land Use for Region.

	Elected Officials	Planning & Zoning Officials	Local Planners	State & Regional Officials	Average Ranking
More mixed-use centers or corridors	2	2	1	2	1.75
More employment in core areas	1	4	3	1	2.25
Intensified employment in centers and corridors	5	1	4	3	3.25
More mixed-use neighborhoods and communities	3	3	2	6	3.5
More housing in core areas	4	5	5	4	4.5
Intensified housing in centers and corridors	10	6	6	5	6.75
Intensified retail in centers and corridors	9	7	7	7	7.5
More employment in outer suburbs	6	9	8	8	7.75
More housing in inner suburbs	8	10	10	9	9.25
More employment in inner suburbs	11	8	9	10	9.5
More housing in outer suburbs	7	11	11	11	10
Other	12	12	12	12	12

Respondents suggested additional regional development concepts, including defining growth boundaries before embarking on any new growth; emphasizing affordable housing instead of just more housing; realizing that no concept is good or bad, but need a balance of all concepts;

and recognizing that price and availability of fuel, plus the availability of water, will determine the type and distribution of new land uses. (A full listing is provided in Appendix A.)

In a slight variation of the question about appropriate development for the region, state and regional officials were separately asked (based on their presumed broader view of the region) to also comment on what types of land uses were most likely to occur in the region. Their responses are illustrated in Figure 33.

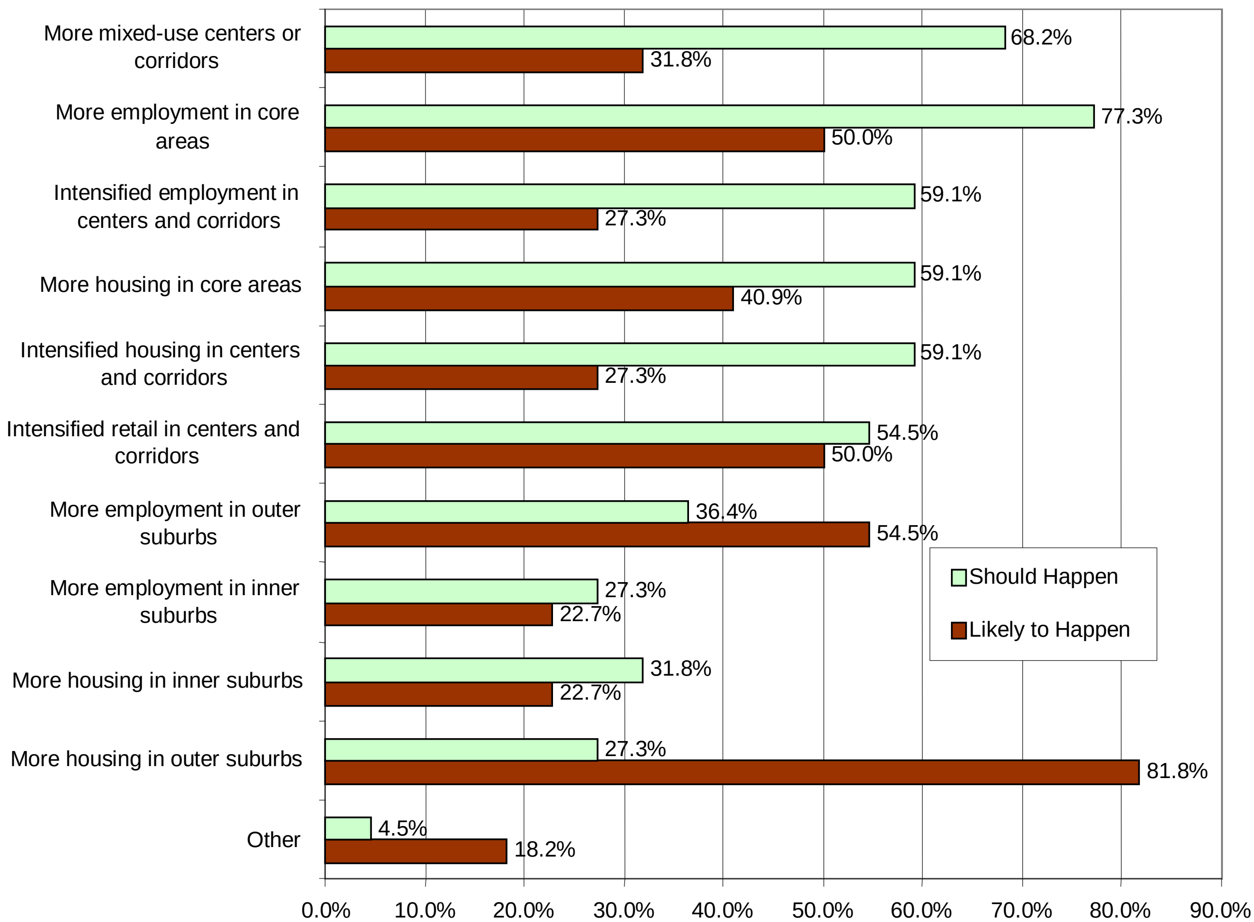

Figure 33. Development that Should Happen in Region vs. What is Likely to Happen.

Despite feeling that the most appropriate types of development were more employment and housing in core areas, more mixed use centers and corridors, and more employment and housing in centers and corridors, state and regional officials said that the most likely trend for the region was for more housing in the outer suburbs (82 percent) and more employment in the outer suburbs (55 percent). The only areas where their opinions about the right types of development compared closely with the type that they felt would occur were with intensified retail in centers and corridors (55 percent vs 50 percent) and in more employment in inner suburbs (27 percent vs 23 percent).

Identification of Congestion Trouble Spots

The final set of questions in the survey asked respondents to identify the two most congested corridors in their jurisdiction. In conjunction with this identification they were also asked to indicate:

- Which activity center or centers were served by this corridor/segment.
- The time period or periods during which congestion problems were worst.
- The extent to which they believed the traffic congestion problem was attributable to development in their own jurisdiction vs. development activity outside their community.

A large number of roadway facilities at all functional classification levels were named, ranging from interstates to major and minor arterials, and even some collectors. The full listing is provided in Appendix B, with the most frequently named corridors given below**:**

- Bell Road, traffic associated with local commercial activity.
- Interstate 10, primarily associated with travel to downtown Phoenix.
- I-17, also associated with activity in the city of Phoenix.
- Highway 101, primarily associated with commercial activity.
- Broadway Boulevard, associated with activity in downtown Tucson, the University of Arizona, and associated malls and strip commercial centers.
- Grant Road, for reasons of both adjacent commercial development and through traffic.
- Oracle Road, particularly in relation to the Tucson Mall in downtown Tucson as well as regional through traffic.
- Scottsdale Road, relating to the city of Scottsdale and the Airpark.
- Shea Boulevard, linked to commercial activity, a major hospital, and the nearby freeway.
- Thunderbird Road, due to shopping and commercial activity.
- US 60, with broad contributions from both downtown Phoenix and regional through traffic.

As seen in Table 9, most respondents identified corridors that were primarily congested during weekday peak periods. Between 94 percent and 97 percent of the first corridors identified were linked to peak period traffic problems, and only slightly less for the second corridor identified. In the majority of cases, the second corridor was more likely to represent a midday or weekend congestion situation.

Table 9. Time Periods of Most Severe Congestion.

Group	Choice	AM/PM Peak	Midday	Weekend	Other
Elected Officials	First	94%	12%	12%	6%
	Second	93%	27%	27%	7%
Planning & Zoning	First	97%	21%	24%	9%
	Second	90%	26%	23%	16%
Local Planners	First	96%	25%	27%	8%
	Second	96%	17%	15%	11%
State & Regional	First	96%	18%	18%	9%
	Second	100%	30%	25%	0%

Another characteristic of the congested corridor asked of respondents was the proportion of the traffic congestion that they felt was attributable to development activity within their own jurisdiction (given that they were asked to identify a corridor in their jurisdiction). Results shown in Table 10 indicate that elected officials identified corridors with traffic that they attributed to sources outside their jurisdiction, whereas planning and zoning officials were more likely to have identified corridors whose primary impact was attributed to development inside their jurisdiction. Local planners fell somewhere in between. It is unclear whether the answers had to do with the specific facility identified or the perspective of the particular respondent group.

Table 10. Source of Congestion in Named Corridor.

	Corridor 1		Corridor 2	
Group	Development Inside My Community	Development Outside My Community	Development Inside My Community	Development Outside My Community
Elected Officials	51%	55%	51%	57%
Planning & Zoning	59%	47%	61%	39%
Local Planners	48%	54%	54%	47%

Because of their lack of affiliation with a specific jurisdiction, state and regional officials were asked the question in a slightly different manner. They were asked to suggest the proportion of traffic in the corridor that might be attributed to the "center" served by the corridor, the development activity within the corridor itself, or development activity located outside the corridor (and simply generating through travel). Answers are shown in Table 11 and show an almost even split between development within the corridor vs. at a center served by the corridor, but with the proportion of impact coming from outside the corridor registering the greatest impact.

Table 11. State and Regional Officials---Source of Congestion in Named Corridor.

	Development at Center Served by Corridor	Development Activity Along the Corridor	Development Activity Elsewhere in Region
Corridor 1	26%	24%	51%
Corridor 2	32%	29%	41%

These data identifying congested corridors receive much greater study in the next portion of the report, where they are used to identify a sample set of corridors for analysis and investigation of the source of the traffic impacts.

CHAPTER 4. ANALYSIS OF CORRIDORS

INTRODUCTION

Findings presented in Chapter 2 provided strong evidence of the effects of compact, mixed land use in reduced household vehicle use and VMT generation. Unresolved, however, is the question about the nature of the relationship between intensified land use and increased traffic congestion in the adjacent corridor or corridors. This chapter reports on special research that was conducted to investigate conditions in a sample of highly developed corridors selected from Arizona's metropolitan areas to determine the extent to which adjacent land use impacts travel and traffic congestion in the corridors.

The survey of local officials and agency staff reported in Chapter 3 solicited identification of particular corridors in the Phoenix and Tucson areas where traffic problems exist and where adjacent development may be a contributing factor. These suggestions were reviewed and ranked in relation to how frequently they were mentioned and using criteria of representativeness and contrast. Data were obtained from and discussions held with MPO staff in both Tucson (PAG) and Phoenix (MAG). From this review, four corridors were selected for detailed case study. The process of corridor selection is documented in Appendix C.

For reasons of both comparability and capabilities of supporting data, the four sample corridor areas were all selected from the MAG region, though examples from Tucson (PAG) and elsewhere were carefully considered. The following is a brief description of the selected areas. The definition of a "corridor" here is purposely vague and includes not just a major facility but also the adjacent area and its parallel and intersecting roads/streets. This definition acknowledges the need to look at any travel corridor as a system of supporting facilities and recognizes that local development impacts are imparted not just by the street-front activity, but by the character of development in the immediately adjacent area.

- **Scottsdale Road:** This area is the older, more traditional "Old Town" section of Scottsdale, roughly associated with the intersection of Scottsdale Road and Indian School Road. It has some of the highest densities and most comprehensive mix of land uses in the region in a relatively attractive pedestrian-friendly setting.
- **Bell Road:** This area focuses on the western section of Bell Road between the north L101 loop and Grand Avenue, selected as an example of high congestion in an intensely developed but relatively low-density conventional suburban setting.
- **Central Avenue:** This area, which lies north of the Phoenix central business district, has some of the highest densities in the MAG region, and is well-served by transit. It is now the northern terminus of the region's inaugural light rail system. Despite high densities, its land use mix is not ideal, and its location north of the central business district positions it as a major conduit for regional through traffic.
- **Tempe:** Tempe's character is significantly defined by the presence of Arizona State University, whose main campus lies at the center of this study area. Mill Avenue and Apache Boulevard are the principal facilities used to define this corridor, which also serves as the southern alignment for the region's new LRT transit line. It is an area

with fairly high density, good mix, and in some areas is similar in design to Scottsdale in pedestrian friendliness.

APPROACH

To investigate the broad issue of whether compact mixed-land use is a major contributor to traffic congestion problems, researchers framed a series of hypotheses :

1. **Compact (intensified) mixed-land use is about more than density.** While density is certainly likely to be greater in compact, mixed-use (or smart growth) areas, it is only one dimension. The desired land use model is better described in terms of the 4Ds—density, diversity, design, and destinations. Density is important in bringing people and activities closer together, but it does not have to be as high as might be seen in older core cities to be effective. Diversity is needed to ensure there is a good mix and balance of uses (especially residential and retail); design is about making sure people on foot can get around as easily and safely as people in cars. Destinations represent the number of opportunities that exist elsewhere in the region, and the relative difficulty in traveling to them. So, in addition to density as a measure of intensified land use, this study will also be concerned with the nature of that density as defined in terms of the other Ds.
2. **Compact, mixed-use areas don't necessarily have to have more traffic than their low-density counterparts.** Their residents or workers should generate much less vehicle demand, both trips and miles, because more opportunities are nearby and many can be reached by walking. Because these areas are more readily served by transit, more travelers are more likely to reach or pass through the area as transit passengers. High bus volumes may themselves discourage nonessential vehicle travel, as do roadway features such as frequent stoplights, narrower lanes, and on-street parking.
3. **Traffic in higher-density areas is not necessarily generated by the adjacent development.** Traffic congestion in corridors traversing higher-density places may have a high proportion of through trips, where neither origin nor destination falls within the area. This raises both the question of the source of the traffic congestion—whether it is the adjacent higher-density development or pass-through traffic—and of equity in terms of who is being asked to bear the impact of the traffic.
4. **Travel alternatives are more effective in higher-density areas.** Residents traveling outside the area are more likely to be close to transit and see it as an alternative (provided the destination is also well-served), plus own fewer vehicles—also a factor in transit and nonmotorized mode choice. Meanwhile, visitors to the area are more likely to use transit or rideshare given generally superior transit service and access, the proximity of activities and services reducing the need for a car once there, and probable limitations in parking (or parking fees) due to the higher densities and higher land values.
5. **Residents in compact-mixed use areas are more likely to use opportunities closer to home.** Even if traffic density does increase in these areas, it does not necessarily mean that residents or workers are worse off since their ability to access needed activities, which are located closer to home or work locations, is less dependent on vehicle use and less influenced by speeds on arterials and regional highways. Thus,

they may be less car-dependent and spend less time and distance traveling to fulfill daily needs.

6. **Vehicle travel may be more effectively managed by an urban street grid.** In a typical suburban area where it is expected that virtually all trips will be made by auto, there are fewer streets with more lanes, fewer intersections, and fewer opportunities to turn. Not only does this make walking difficult, but it limits route options for vehicle traffic that would enable drivers to work around flow problems. Urban grids, with streets spaced at one-eighth to one-quarter mile intervals—clearly a much finer level than Phoenix and Tucson's big 1mile grids—provide more options for motorists and for traffic engineers to manage flow. This includes the option of diverting through traffic away from local traffic and congestion bottlenecks. (These characteristics are discussed in more detail in a later section titled "Existing Road Capacity and Traffic Conditions.")

To investigate these hypotheses, a number of quantitative tests and corresponding performance measures were devised using outputs from MAG's regional travel forecasting model and various traffic databases:

- **Traffic Conditions:** Documentation of existing traffic conditions on the main streets and road facilities serving each study area, consisting of directional V/C ratios for both the midday and PM peak period time periods. This analysis also investigates the importance of the shape and size of the local street network/grid and its role in accommodating and managing vehicle travel demand.
- **Through Traffic:** Application of "select link" analysis to determine the composition of traffic on particular selected road segments, largely to address the question of the proportion of the traffic stream that may be linked to activity in the study area vs. that which is unrelated to and essentially passing through the study area.
- **Alternate Mode Use:** Rates of transit use for work (peak) and nonwork (off-peak) travel to and from each of the study areas are compiled using MAG's travel model outputs. Walk trip rates are investigated using data from the 2001 regional household travel survey.
- **Capacity of Mixed-Use Areas to Capture Residents' Trips:** Trip table information is examined to determine the proportion of trips made by study area residents who have internal destinations vs. destinations outside the study area. This assessment helps describe the extent to which the opportunities and design of the study area are successful in retaining trips internally (so-called internal capture rate) vs. necessitating travel elsewhere to satisfy those activity needs. This is done for all five MAG trip purposes: home-based work, home-based university, home-based other, nonhome-based work-related, and nonhome-based other. This analysis also examines differences in average trip length for these respective trip movements to determine whether having closer access to opportunities translates to less distance traveled (and fewer vehicle miles of travel generated).

CHARACTERISTICS OF STUDY AREAS

Scottsdale

Scottsdale Road was frequently cited as a traffic congestion example in the project survey. The area, shown in Figure 34, extends from Chaparral Road on the north to Thomas Road on the south, and from North 68th Street on the east to Hayden Road on the west. Chaparral, Camelback and Indian School roads were also cited as traffic congestion examples in the survey, though not as commonly as Scottsdale Road. The section of Scottsdale Road that lies at the center of the study area is interesting in that it runs through some of the most dense development in the region, but the area is distinct in both having a high degree of mix of uses—especially retail—in a setting that is particularly beckoning to visitors and foot traffic. The area also contains a goodly amount of conventional auto-oriented development, including the Scottsdale Fashion Mall on the northern end of the district (northwest corner of the intersection of Scottsdale and Camelback roads, which is a major regional attraction). A large part of the attraction of the core portion of the study area, known as Old Town, are myriad shops, boutiques, and restaurants, all within easy walking distance and arrayed along smaller streets with short blocks and on-street parking. Parking is not particularly restrictive in the older part of Scottsdale, although locals describe extensive use of valet parking in the town center, especially on weekends.

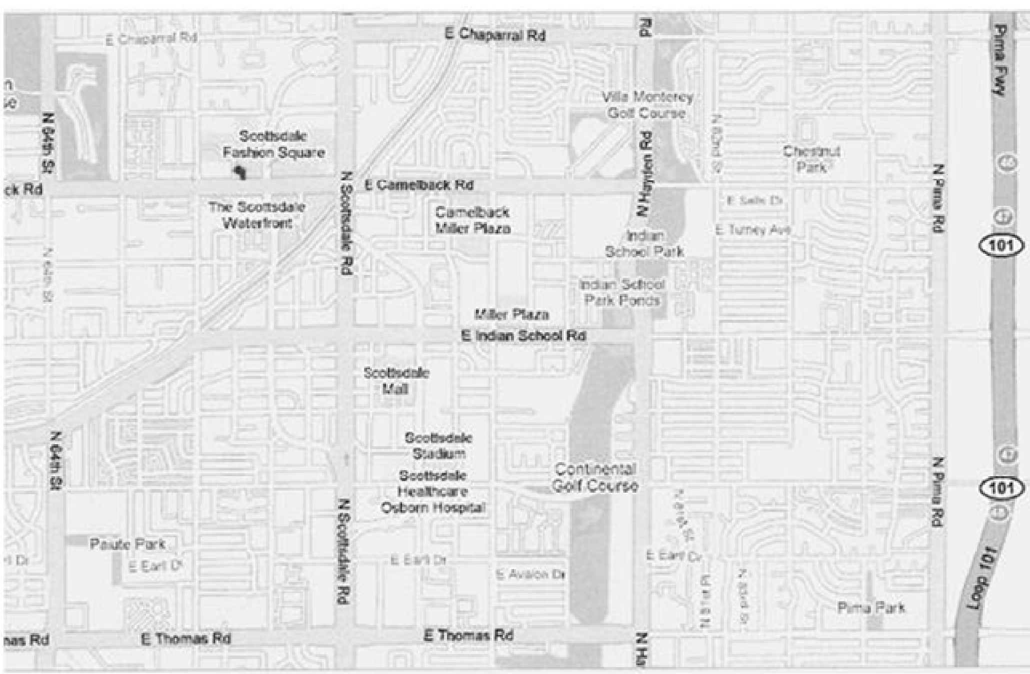

Figure 34. Scottsdale Study Area.

Bell Road

The section of Bell Road between the North L101 Loop and Grand Avenue was at or close to the top of survey respondents' list of regional traffic congestion examples. The absence of clear geopolitical, natural, or transportation barriers made it difficult to define the boundaries of the study area, so the area was defined simply in terms of the TAZs that border Bell Road throughout this length (Figure 35). Bell Road was initially constructed to serve the Sun Cities in the 1950s, a massive set of planned retirement and golf communities that surround the corridor on the north and south. Unplanned, however, was all the growth that has subsequently occurred in the area west of Grand Avenue, particularly in the City of Surprise. While the Sun Cities were designed to be self-contained and self-sufficient, with internal shopping and other services to satisfy residents' activity needs, a large number of senior residents still make use of the commercial services along Bell Road as well as the major commercial activities at Union Hills (north of Bell Road and bordering L101) and just east of L101 in Peoria. The newer, predominately bedroom communities to the west also make use of the above commercial opportunities, but more importantly rely on Bell Road to access jobs in the eastern portion of the region. Because of the river barrier, only Bell Road and Grand Avenue offer east-west crossings. There are no other continuous east-west highways, particularly for travelers wishing to connect with the L101 Loop. West Greenway and Waddell roads provide east-west arterial service, but terminate at Grand Avenue. Apart from the services designed into the Sun Cities retirement communities, there are no mixed-use centers in the corridor or on either end, only shopping centers and the malls near the L101 interchange.

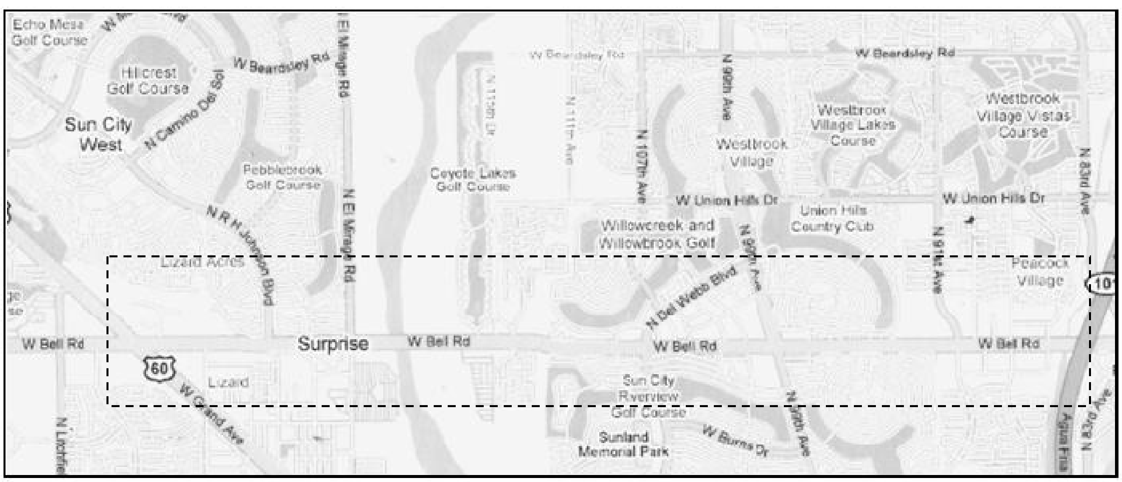

Figure 35. West Bell Road Study Area.

Central Avenue

This study area focuses on Central Avenue, a major north-south arterial, and includes the parallel arterials of 7th Avenue on the west and 7th Street on the east. As seen in Figure 36, the study area extends north to south from Camelback Road to McDowell Road. Perhaps one of the most interesting characteristics of the area is that neither Central Avenue nor the parallel 7th Avenue/7th Street facilities were mentioned as locations of major traffic congestion in the survey. This area supports some of the highest densities in the region and even has a fair amount of residential and retail development and good pedestrian characteristics, but the distribution of the residential and retail activity is such that they are not conveniently near each other. The area primarily presents itself as an office employment district. It is well-served by transit, with a number of regional bus routes dedicated to Central Avenue, and it is also the principal northern alignment of the region's inaugural LRT route.

Figure 36. North Central Avenue Study Area.

Tempe

Apart from Scottsdale, Tempe is perhaps the only other noncentral activity center in the MAG region with a somewhat urban character, due in large part to the presence of the university and its large student and faculty population. As defined, the study area extends from Mill Avenue on the west to the L101 Loop on the east, and from the Salt River on the north to Broadway Road on the south (Figure 37). The university lies in the northwest corner of the study area, extending from Mill Avenue on the west to McClintock Road on the east, and from Rio Salado Parkway on the north to Apache Boulevard on the south. The main campus lies mainly south of University Drive, however, with primarily athletic and maintenance facilities in the tracts north of University. While the university's influence was likely felt throughout the study area, it is the northwestern portion along Mill Avenue, mainly north of University Drive, that reflects the expected college town theme, with numerous shops and attractions set in an inviting, pedestrian-friendly environment. Buildings face the street, and the streetscaping includes trees and curb parking. Mill Avenue and Apache Boulevard also roughly constitute the southern alignment of the new LRT line, although the tracks actually run diagonally through the area along Veterans Way and Terrace Road. East of the university, the study becomes more typically suburban, with larger blocks, more auto-oriented design, and less mix and integration of land use. However, there is a large measure of multifamily, fairly high-density housing in this area that largely serves students. The portion of the study area that lies north of University Drive is sparsely developed, with the easternmost tract between McClintock Road and L101 supporting light industrial and other low-rise business development. The less developed of these areas, moving closer to the river/lakefront, are beginning to transition to intensified residential development, attracting singles, young couples and empty nesters who are attracted to a more urban environment with easy access to cultural and entertainment amenities. Because Tempe is space-constrained, its planning leaders have recognized that any additional growth will require more intensive and integrated land use approaches, and have adopted a smart growth perspective in their planning.

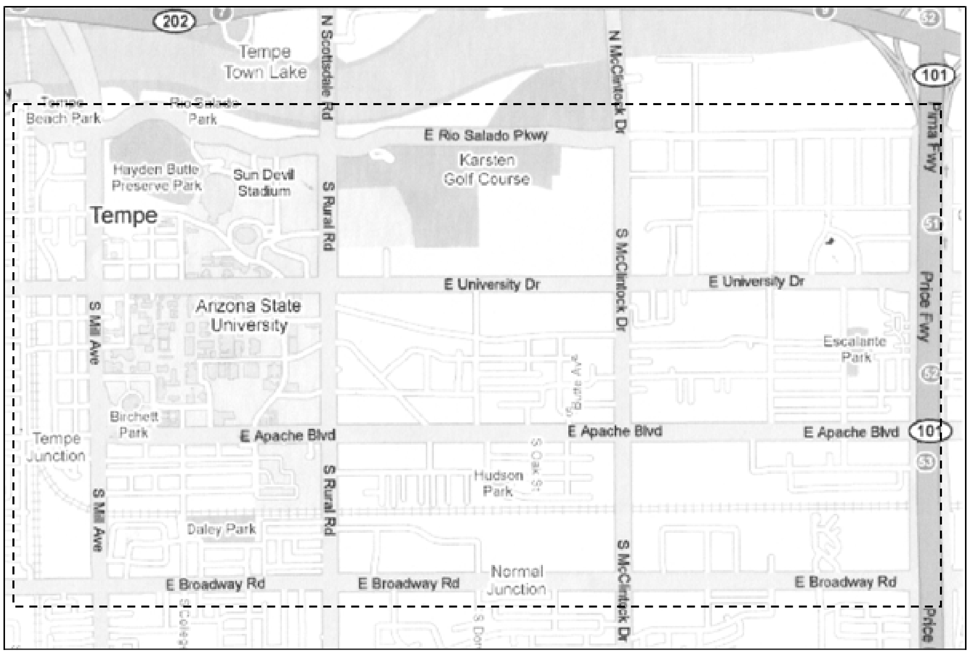

Figure 37. Tempe Study Area.

Table 13 provides a comparison of several important characteristics in these areas, including:

- **Land Area:** The sites range in size from 3.12 square miles in the Central Avenue corridor to 17.3 square miles in the Bell Road study area. However, reflecting its more suburban nature and corresponding lower density, Bell Road is represented by only 13 TAZs compared to 22 in the Central Avenue area, 17 in Tempe (5.2 square miles), and 34 in Scottsdale (8.98 square miles).
- **Population and Employment:** Each of these subareas has enough population and jobs to virtually qualify as a medium-size city. The differences, of course, have to do with the balance between households and jobs, and between standard employment and the existence of jobs that offer relevant services to residents. Scottsdale has the greatest number of households (29,913) and the second largest number of jobs (42,324). Bell Road has almost as many households (28,293) but far fewer jobs (14,102), most likely because it has such a large proportion of retirees. The Central Avenue corridor is the opposite of Bell Road, with a large number of jobs (56,842) and a modest number of

households (10,226). And finally, Tempe seems somewhere in the middle with 16,457 households and 37,784 jobs, although it is unique in having a substantial university population and employment base. The jobs/housing ratio reported at the bottom of Table 12 confirms the intuitive balance of Central Avenue as "jobs rich" at 5.6, Tempe somewhat jobs rich at 2.3, Scottsdale at 1.415 (slightly below the regional average of 2.05), while Bell Road clearly supports a surplus of households over jobs with a ratio of 0.498.

- **Population Characteristics:** Obviously, the dominant proportion of persons and households in each of the areas are full-time residents, accounting for 80 percent or more, with a regional average of 92.5 percent. Tempe is the only area with a high percentage of persons (19.8 percent) and households (9.2 percent) residing in group quarters (institutional residents), attributable to its student population. In terms of transient population, 3.6 percent of the region's population and 5.6 percent of its households are classified as transient (temporary residence in the process of moving into or out of the region). In this category, the population in the Central Avenue corridor is considerably above average (15.8 percent of persons, 20.1 percent of households), while Scottsdale (9.4 percent/11.7 percent) and Tempe (7.5 percent/10.9 percent) are above average, while Bell Road (3.6 percent/4.3 percent) is roughly at the average. Bell Road distinguishes itself in terms of seasonal residents (maintain a residence, but inhabit for only a portion of the year), which make up 7.5 percent of its persons and 8.1 percent of its households, compared to 3.2 percent and 4.5 percent for the region. Each of the other three areas has less than the regional average percentage of seasonal households. Unfortunately, the TAZ level data supplied by MAG does not contain information on household composition from which details regarding life cycle, professional orientation, or vehicle ownership might be determined.
- **Level of Affluence:** Table 12 also presents information on the relative level of affluence in each of the study areas. Households are distributed into regional income quintiles, with 5 representing the highest income category and 1 the lowest. An average was computed for each TAZ by weighting the number of households in each quintile by the quintile rank (1 through 5). This measure shows, of course, an average of 3.0 for the region, but—perhaps surprisingly—each of the four study areas is below the average. Scottsdale has the highest value with an average quintile ranking of 2.87, followed by Bell Road at 2.70, Central Avenue at 2.57, and Tempe at 2.0. This finding, tempered by the realization that Tempe's lower score is probably skewed by its university student population, is positive in showing that the areas are quite similar with regard to income, and that none are either especially affluent or poor; hence, travel characteristics should not be disproportionately influenced by income.
- **Employment Characteristics:** Regionally, retail employment accounts for the highest single percentage of job types, at 28.6 percent, followed by office employment at 23.3 percent, industrial at 22.7 percent, public at 15.0 percent, and other at 10.4 percent. Against this regional profile, Scottsdale has above-average proportions of retail (45.7 percent) and office (32.3 percent) employment and very little industrial employment (1.5 percent). Bell Road is interesting in that it has a much higher proportion of retail employment (62.4 percent) than the regional average, but it must be noted that the <u>total</u> number of jobs in the study area is still well below average for

Table 12. Characteristics of the Four Study Areas.

	MAG Region	Scottsdale	Bell Road	Central Ave	Tempe
Land Area	6,498 sq. mi.	8.98 sq. mi.	17.3 sq. mi.	3.12 sq. mi.	5.21 sq mi.
	3,754,765 acres	5,747 acres	11,053 acres	1,996 acres	3,334 acres
Number TAZs	1,995	34	13	22	17
Population (Pop)	**4,608,714**	**59,886**	**56,152**	**20,560**	**38,154**
Residents in Households	92.5%	87.2%	88.2%	83.2%	71.8%
Residents in Group Quarters	0.7%	0.7%	0.6%	0.2%	19.8%
Transient	3.6%	9.4%	3.6%	15.8%	7.5%
Seasonal	3.2%	2.7%	7.5%	0.8%	1.0%
Households (HHs)	**1,785,546**	**29,913**	**28,293**	**10,226**	**16,457**
Full-Time Resident HHs	89.5%	85.1%	87.4%	78.9%	78.7%
Group Quarters HHs	0.4%	0.3%	0.3%	0.1%	9.2%
Transient HHs	5.6%	11.7%	4.3%	20.1%	10.9%
Seasonal HHs	4.5%	2.9%	8.1%	0.9%	1.2%
Income					
Avg HH Quintile	3.00	2.87	2.70	2.57	2.00
Employment (Emp)	**1,942,488**	**42,324**	**14,102**	**56,842**	**37,784**
Other Emp	10.4%	11.6%	16.0%	15.3%	4.0%
Public Emp	15.0%	8.9%	10.3%	2.9%	29.8%
Retail Emp	28.6%	45.7%	62.4%	9.6%	24.3%
Office Emp	23.3%	32.3%	7.6%	72.1%	10.7%
Industrial Emp	22.7%	1.5%	3.7%	0.1%	31.1%
Densities					
Pop per sq mi	710	6,667	3,251	6,590	7,323
HH per acre	0.31	5.20	2.56	5.12	4.94
Emp per acre	0.63	7.36	1.28	28.47	11.33
Retail jobs per acre	0.18	3.37	0.80	2.73	2.76
Density Ranking (No. Zones in top 100)					
HH per acre	NA	11 (of 34)	none	5 (of 22)	9 (of 17)
Emp per acre	NA	12 (of 34)	1 (of 13)	14 (of 22)	4 (of 17)
Retail jobs per acre	NA	14 (of 34)	1 (of 13)	6 (of 22)	5 (of 17)
Mix & Balance					
Jobs per HH	2.05	1.415	0.498	5.6	2.3
Retail Jobs per HH	0.586	0.647	0.311	0.559	0.558

Transient households: Number of occupied transient units. Hotel, motel, resort rooms, and some private dwellings are transient units. The number of transient households is the average of peak (January) and low (July) seasons.

Resident population in group quarters (excluding correctional, institutional, and military group quarter facilities): All people not living in housing units are classified by the Census Bureau as living in group quarters. Two general categories are recognized: institutionalized and noninstitutionalized. This data field is the number of noninstitutionalized people in group quarters. Examples include college dormitories and other group quarters households.

Seasonal households: Number of occupied seasonal units. RV and mobile home parks as well as vacant housing units used only in certain seasons, for weekends, or other occasional use throughout the year. The number of seasonal households is the average of the peak (January) and low (July) seasons.

than-average share of public employment (29.8 percent), about average retail (24.3 percent), and a surprisingly high rate of industrial employment (31.1 percent).

- **Densities:** Compared to averages across a very large and highly spread-out region, the residential and employment densities in the four study areas are —by design—well above average. Bell Road, however, only has about half the population density of the other three sites (about 2.5 households per acre vs. about 5 per acre) and is far below the other sites in employment density (at 1.28 jobs per acre vs. 7.36 in Scottsdale, 11.33 in Tempe, and 28.47 in the Central Avenue corridor). It also has only about one-quarter to one-third the retail job density.
- **Density Ranking:** To create a sense of the relative amount of density as well as its location within the respective study area, maps were created to show the levels of household, employment and retail employment density in each TAZ (Figures 38 through 41). A background color scheme is used to reflect the intensity of residential density in terms of population per square mile. Note, however, that the color gradations are scaled differently for each study area, so it is important to consult the respective legend and not attempt to compare colors directly between maps.

  Residential density is expressed in terms of households per acre, a somewhat different measure than the population per square mile metric reflected in the color shading scheme for the background. Retail employment is singled out from among the other employment categories because of its importance in representing shopping and other nonwork related opportunities in the TAZ.

  Using MAG's database of TAZ characteristics for 2008, measures of household, employment and retail employment density were computed for all of the 1,995 TAZs in the region, and the zones were then ranked from highest to lowest. The top 100 zones (highest density) in each category were identified, representing the top 5 percent of TAZs in the region. From this list, researchers noted the zones in the respective study areas that fell in the top 5 percent by category.

  In the Scottsdale area, represented by 34 zones, 11 zones fell in the top register for residential density, 12 were in the top for employment density, and 14 were in the top for retail job density. Looking at the map in Figure 38, it is apparent that the greatest concentrations of these high-density zones fall in the center of the study area, presumed to be the intersection of Scottsdale and Indian School roads. TAZs 1123 through 1129 and 1134 through 1140 all have regionally high levels of development, and in most cases it is a mix of residential, total employment, and retail employment. This reflects a good balance to support internalization of trip needs.

  In the Bell Road Corridor, as illustrated in Figure 39, quite the opposite situation exists. Despite the presence of several enormous housing developments, none of the zones in the corridor ranked in the top 100 for residential density, and only one zone—386—qualified for employment and retail density due to a major regional shopping mall.

  The Central Avenue corridor, illustrated in Figure 40, has some of the highest densities in the region, certainly for office employment density all along Central Avenue. Zones 765, 766, and 769 through 773 on the western side of Central Avenue and Zones 776 through 779 and 781 through 783 on the eastern side are all in the top rankings for employment density. However, a number of these zones are also among the region's highest in retail activity—Zones 764, 767, 770, 771, and 778—and five are among the highest density residential zones—765, 769, 1829, 770, and 781. Despite carrying some of the highest densities in the region, and even showing some evidence of mix of uses, there is some question as to the balance and location of the different uses that would encourage high rates of local travel, particularly by walking, as compared to Scottsdale.

Finally, in the Tempe area, shown in Figure 41, nine of the 17 zones that define the study area have residential densities in the top 5 percent, as do four of 17 for employment and five of 17 for retail. The most intense development, both residential and commercial, borders Mill Avenue on the west—Zones 1167 and 1168—and between Apache Boulevard and University Drive east of ASU—Zones 1176, 1865, 1869, and 1871.

- **Mix and Balance:** As stated earlier, density is but one measure of compact, mixed-use development, with the mix of uses and their balance being much more important from a transportation perspective. Table 12 shows that two of the examples, Scottsdale and Tempe, offer a good balance between jobs and housing, whereas Bell Road is imbalanced in the direction of residential development and Central Avenue in the direction of employment. However, perhaps more important than the balance between residents and jobs, is the balance between residents and the activities they need to run their lives. Retail employment is perhaps the best indicator of these other activities, which include shopping, services, personal business, school and children’s activities, and entertainment. As can be seen in Table 12 in the retail jobs/housing ratio, the region as a whole offers an average of 0.586 retail jobs per household. Much, however, depends on the distribution of these jobs and, hence, the proximity to households as affects travel. Statistics from a National Household Travel Survey (Federal Highway Administration 2009) show that 75 percent or more of household vehicle travel is associated with nonwork related activity, so that efficiently satisfying these activity needs in terms of travel patterns depends strongly on their location. In this regard, Scottsdale may be seen to have the highest ratio of retail jobs to households in the sample at 0.647, while Tempe and Central Avenue are about average at 0.558 and 0.559, respectively, and Bell Road is at only about half that level at 0.311.

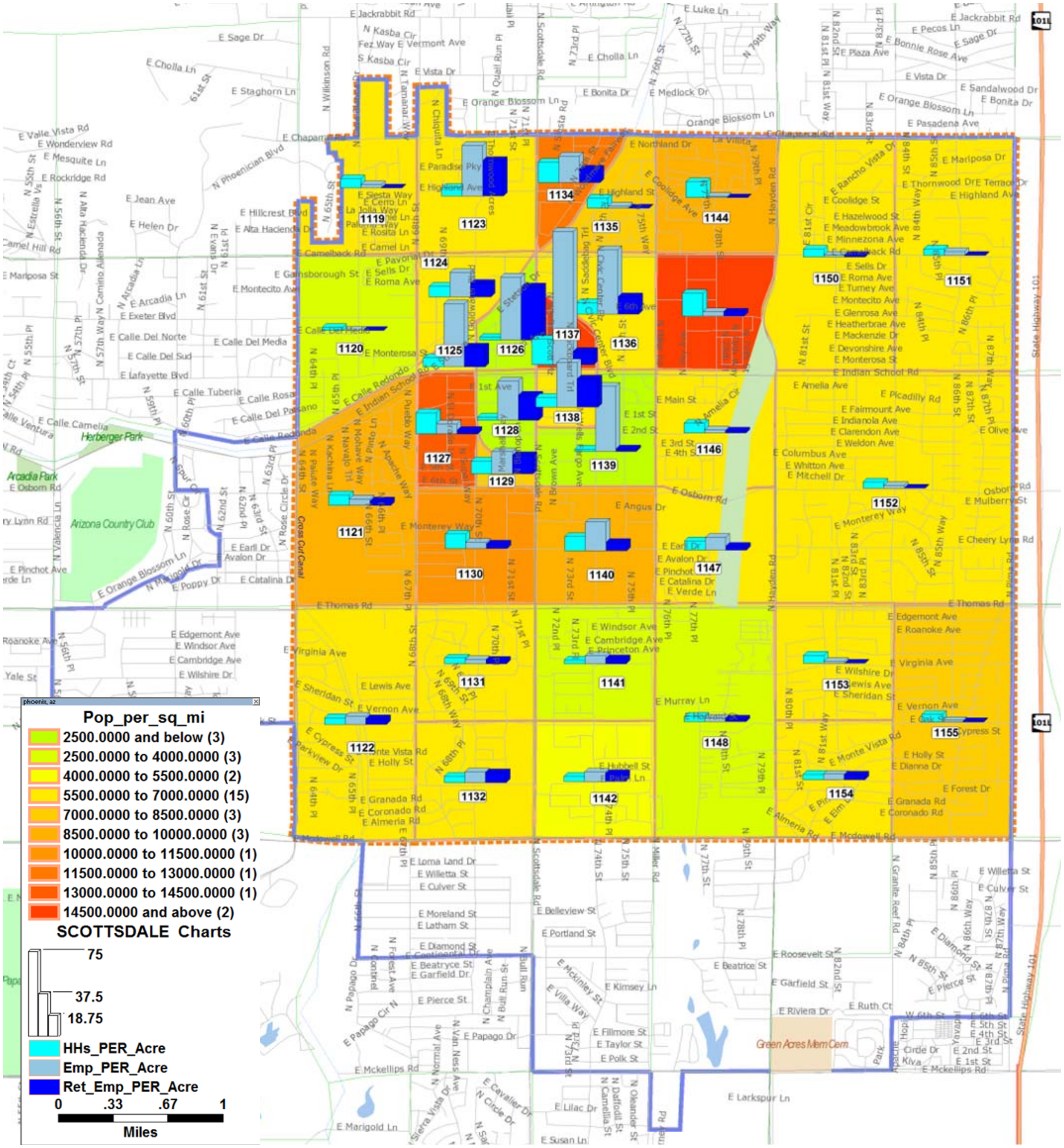

Figure 38. Scottsdale Road Study Area Development Characteristics.

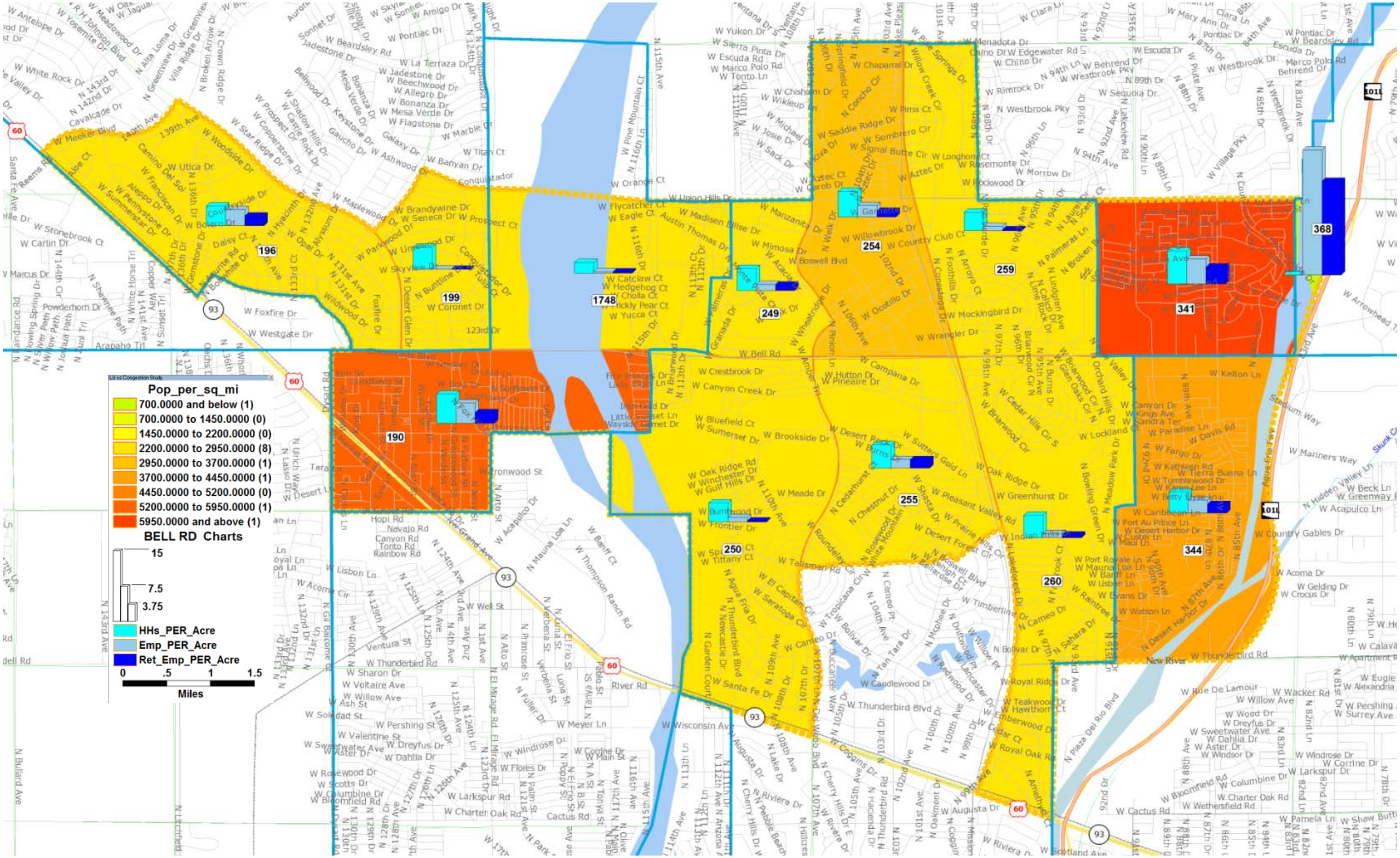

Figure 39. Bell Road Study Area Development Characteristics.

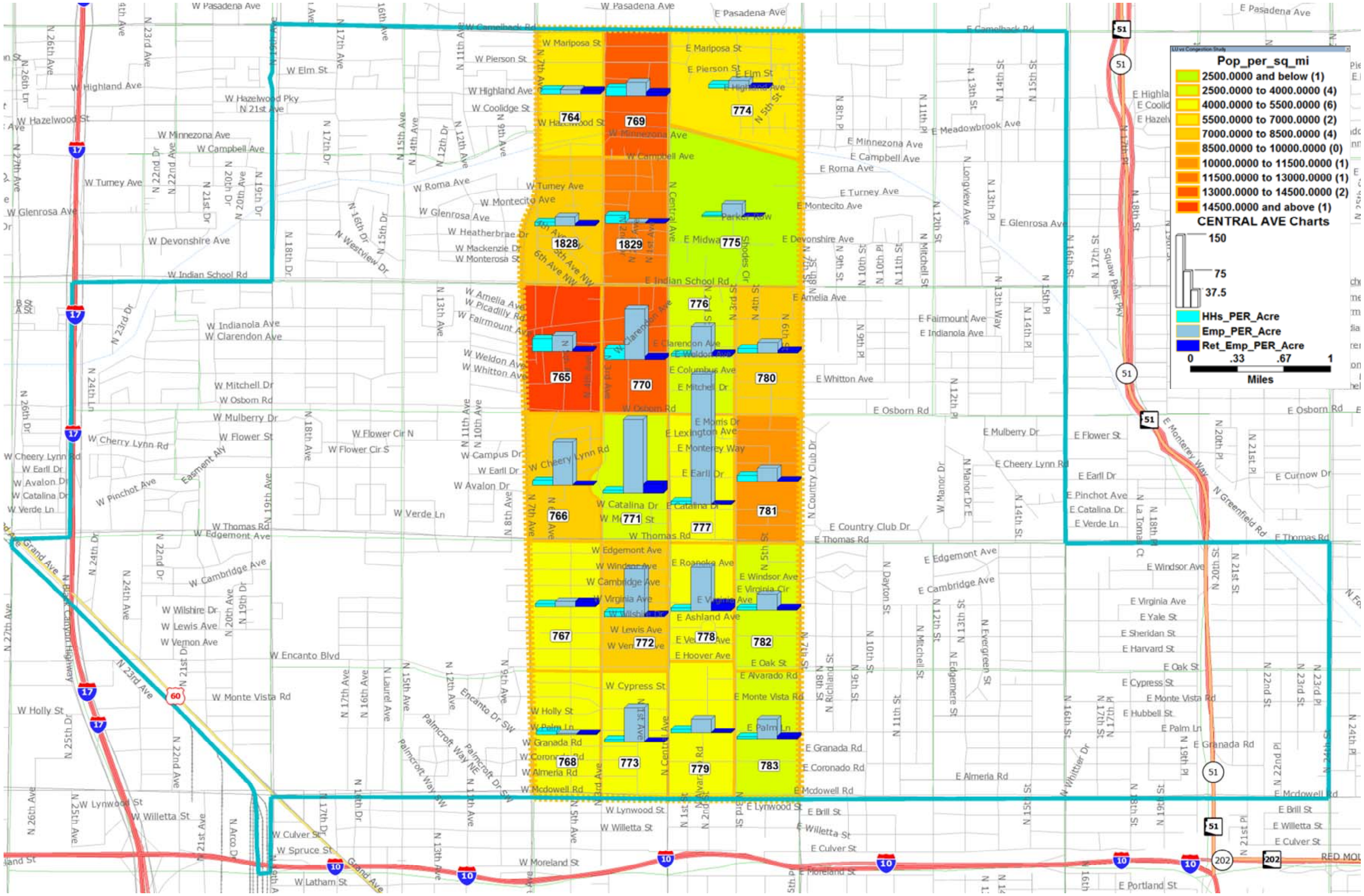

Figure 40. Central Avenue Study Area Development Characteristics.

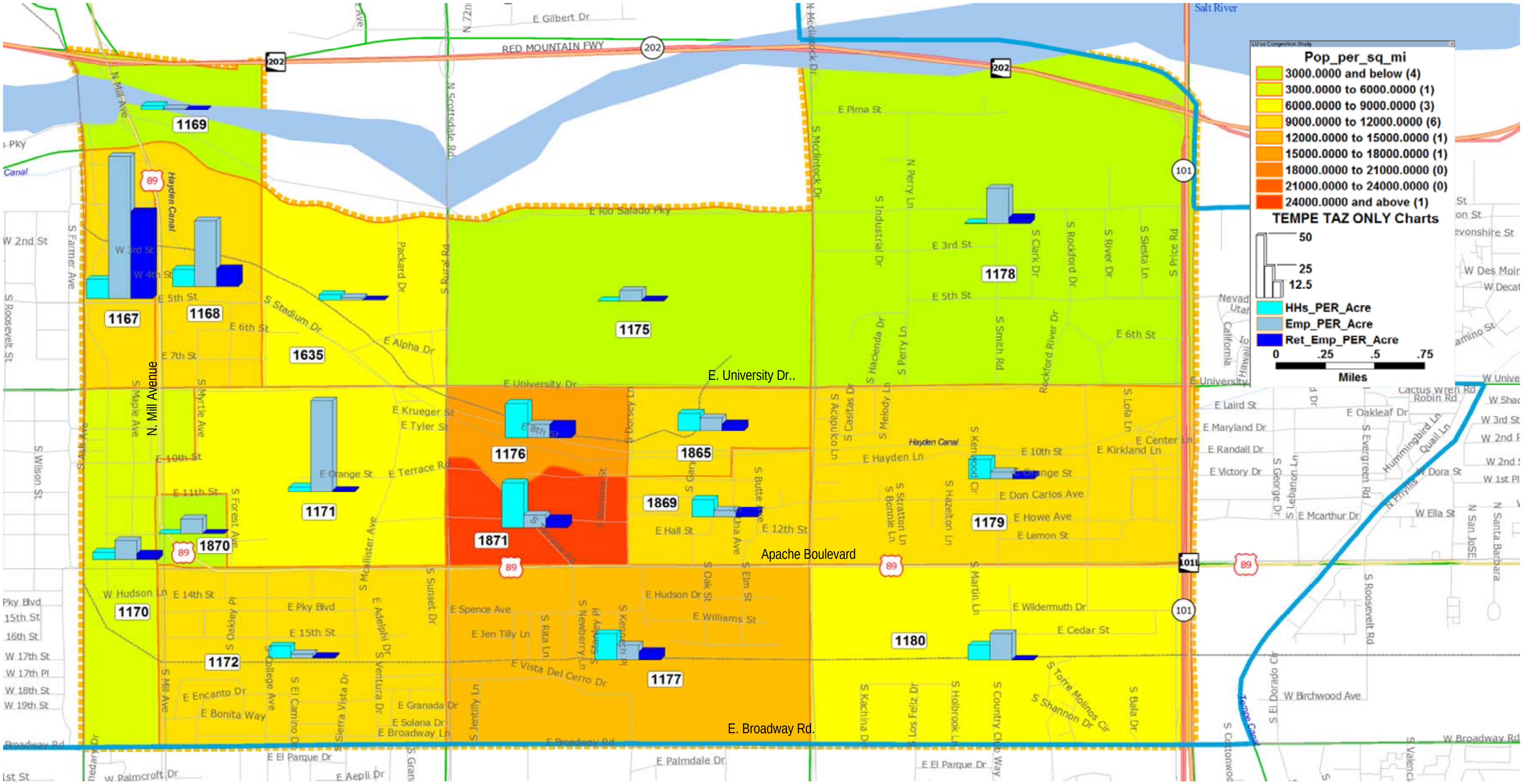

Figure 41. Tempe Study Area Development Characteristics.

EXISTING ROAD CAPACITY AND TRAFFIC CONDITIONS

This section documents the existing transportation networks and traffic conditions in the four study areas. To begin this process, Figures 42 through 45 show the street and highway network in each area using the same geographic boundaries as defined in Figures 38 through 41. The principal arterial roadways and adjacent freeways are labeled, and the number of lanes in each direction is shown adjacent to the respective link (as coded in the MAG network).

The focus of this study is primarily on the arterial and street network, not the freeway system. While a number of freeway segments were mentioned as congestion examples in the project survey, freeways more typically accommodate longer and cross-regional trips. There are certainly occasions when freeway systems are used for short trips, where travelers "hop on" for only a one- or two-segment connection between arterials, particularly when the local network is congested or offers poor connectivity. However, the issue in this study has been framed as one of proximity, where the concern is in drawing a connection between higher-density land use and traffic impacts on the adjacent transportation facilities. Each of the four study areas is near a freeway facility, but not so near that the freeway would seem to have a direct impact on travel within the area, or at least the portion of the area as it has been framed for the case study. In no case does the freeway system run immediately through the high-density center of the study area. So while the presence of the freeway system is acknowledged as the "layer" of the transportation system that dominates intraregional travel, it is felt that the influence on the specific arterials named in the study areas can be reasonably parsed out, or at least neutralized.

Another vital transportation network characteristic that should be further articulated here is the reference to an urban street grid and the role it may play in impacting travel behavior and traffic congestion. Studies of urban form tend to distinguish between traditional urban designs, as seen in older cities and inner suburbs, and the conventional suburban designs that proliferated in the second half of the 20th century. The transportation network in the traditional neighborhood is characterized by a grid-shaped street system with small blocks, mostly continuous streets, sidewalks, and on-street parking. In contrast, the suburban networks feature an auto-focused hierarchy of local streets, collectors, and arterials, each designed to feed into the next higher category, and usually the freeway system. The suburban residential communities themselves are designed to limit egress and ingress points, and employ a meandering system of curvilinear streets and residential cul-de-sacs to discourage through traffic. These designs tend to put even more demand on the often-sparse arterial street network, while also impacting walkability and access to transit. (Residents may have to walk over a mile to reach a nearby store or a bus stop because there is no direct path.) In contrast, the traditional urban grid system does not limit through traffic, but creates multiple route options for traffic so that individual streets need not experience serious congestion.

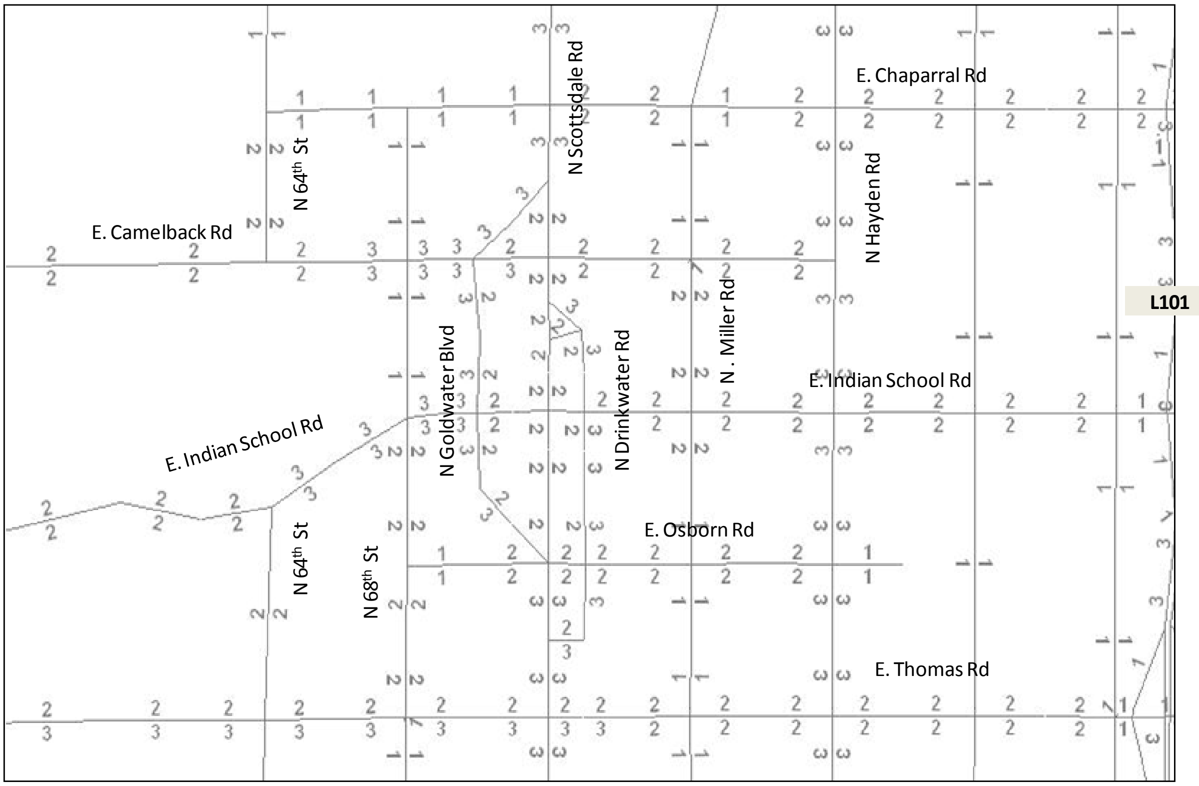

Figure 42. Scottsdale Study Area: Major Roadways and Number of Lanes.

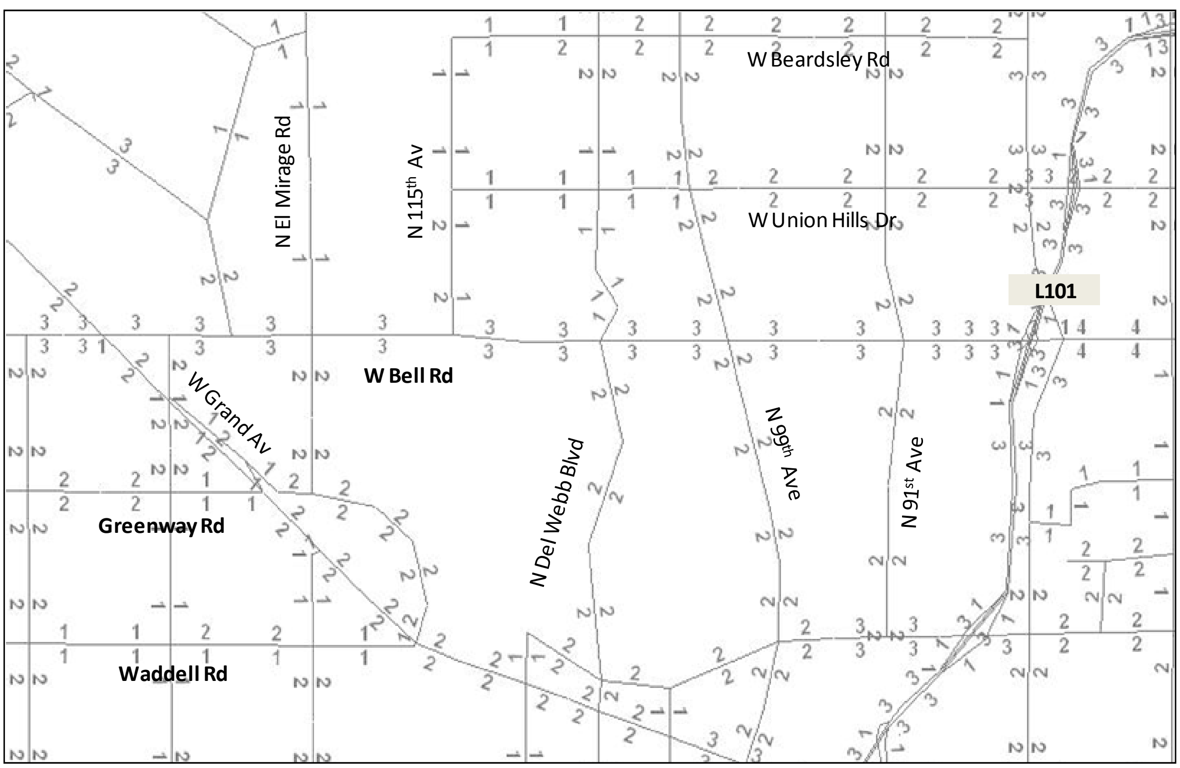

Figure 43. Bell Road Study Area: Major Roadways and Number of Lanes.

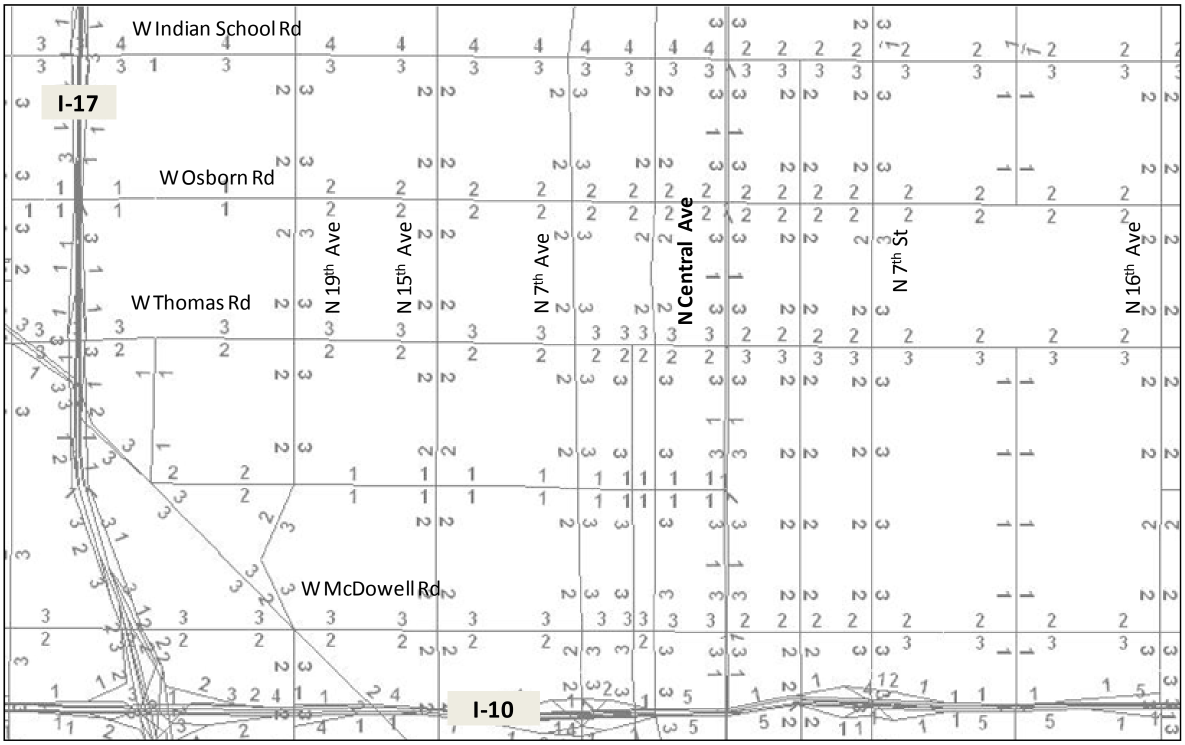

Figure 44. Central Avenue Study Area: Major Roadways and Number of Lanes.

(Note: The Central Avenue corridor map does not extend fully to the northern end, which is defined by West Camelback Road. Through this portion of the network, Camelback is a six-lane arterial (three lanes each direction) with occasional four-lane segments to accommodate turning movements. West of Central Avenue, Camelback is divided to incorporate the light rail line in its median.)

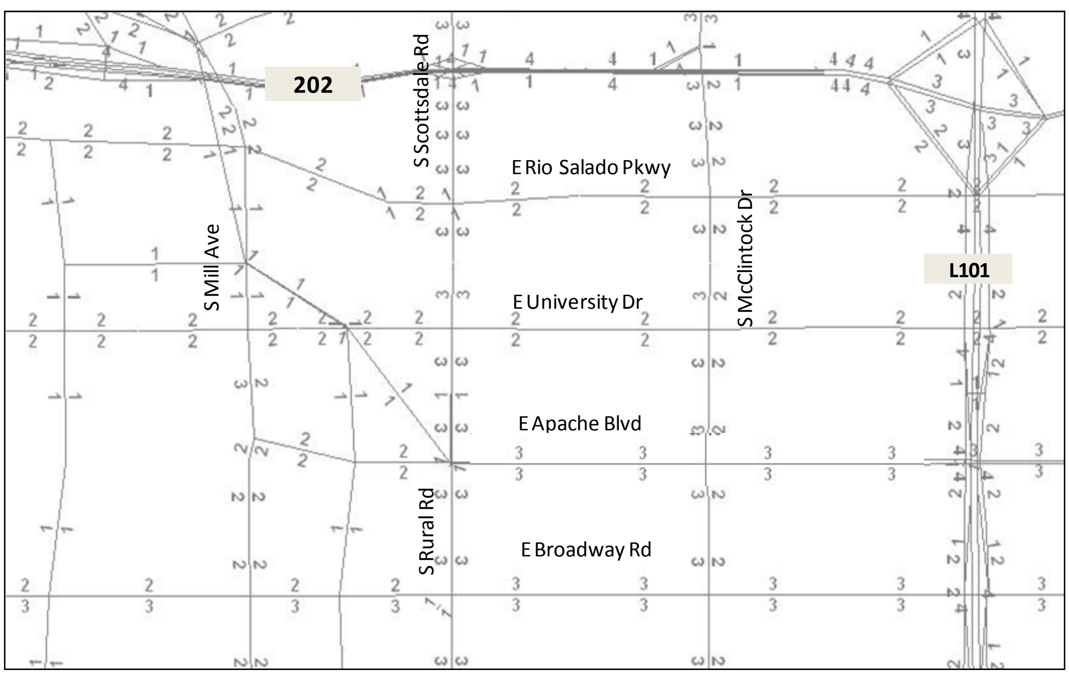

Figure 45. Tempe Study Area: Major Roadways and Number of Lanes.

A number of researchers have examined whether urban street grids are more efficient than their suburban counterparts. They not only hypothesize that rates of walking are higher in urban grid environments but vehicle traffic also moves more efficiently. The reasons for this include the greater choice of routes, consequent dispersion of traffic and lower number of traffic signals, narrower streets, and more efficient intersections. A 1990 study by Kulash performed an analysis that compared a traditional grid network with a conventional suburban network assuming the same land use and quantity of travel. The study found that internal VMT was 57 percent less in the traditional network, though with more traffic on local streets (vs. collectors and arterials). The traditional network yielded lower travel speeds, but over-the-road trip lengths were also shorter. A similar study by McNally and Ryan in 1993 assessed traffic flow conditions in comparable traditional grid vs. suburban road networks, calculating both link V/C and intersection level of service performance. Through travel was actually increased by 5 percent for the traditional scenario in recognition of the greater ability of through traffic to penetrate a grid network, although the analysis showed that the traditional network had 10 percent fewer vehicle kilometers of travel, average trip lengths that were 15 percent shorter, and with 27 percent fewer vehicle hours of travel expended (Kuzmyak et al. 2003).

While cities like Tucson and Phoenix are laid out on a regional grid, that grid consists primarily of arterials on one mile spacing intervals. This is quite different from the scale of an urban grid, in which separation is between one-eighth and one-quarter of a mile or less. Planners and engineers have attempted to devise parameters and guidelines for proper design of traditional street networks. A joint effort between ITE and the Congress for New Urbanism (CNU), *Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities* provides insight for designing roads, streets, and networks that are appropriate for their context (ITE 2006). The manual provides guidelines on street and block sizing, spacing, sidewalk dimensions, landscaping, and integration with adjacent development.

TRANSPORTATION NETWORK CHARACTERISTICS

The principal characteristics of each study area’s transportation network are described below. Given the importance of factors like shape of the street grid, block size, and sidewalk coverage in contributing to walking potential, researchers made an effort to develop a connectivity index type of measure for the study areas based on a computation of intersection density. Unfortunately, the effort had to be abandoned because MAG’s highway network does not include secondary streets. This is not an oversight of the MAG model: The road network in most metropolitan planning models does not extend down to collectors and local streets because of the magnitude of additional links that would have to be processed if facilities at this level were included.

Scottsdale

The principal facilities of interest are Scottsdale Road, Indian School Road, Goldwater Boulevard and Drinkwater Boulevard. Scottsdale Road is four lanes in each direction through the internal section that is parallel to and relieved by Goldwater Boulevard through the central section of Scottsdale, then widens to six lanes north and south of that junction with Goldwater. Goldwater Boulevard, which lies west of Scottsdale Road, provides reasonably direct access to the Scottsdale Fashion Mall from the south, thereby taking pressure off of Scottsdale Road. In fact, Goldwater and Drinkwater boulevards (east of Scottsdale Road), both of which are five-lane facilities, effectively serve as a buffer that allows through traffic to bypass the town center area. Indian School Road, the major east-west facility through the study area, is six lanes approaching from the west, but then drops to four lanes once inside the urban network east of Goldwater Boulevard. From that point onward to the east, Indian School remains at four lanes. The street network within Scottsdale includes many block faces that are quite urban in scale, at one-eighth of a mile, with extensive sidewalks and pedestrian crossing opportunities. The lone freeway in the area, Loop L101 (Price Freeway), passes 2.2 miles east of Scottsdale Road and the town center, offering an alternative path for longer regional trips, though likely not performing a significant reliever function for Scottsdale Road. The area bordering L101 has been designated an economic development zone and has seen several recent commercial developments that draw commuters from adjacent communities, including Scottsdale; however, given the proximity to L101, much of this travel would seem to take advantage of L101 for its primary access.

Bell Road

West Bell Road is a six-lane arterial through the entirety of the study area, covering a distance of almost seven miles between Grand Avenue and L101. East of L101, Bell Road becomes eight lanes wide, which may help ease eastbound flows but is felt to present a bottleneck for westbound traffic moving past L101. There is not much parallel capacity in the area for east-west travel, with the nearest parallel facility to the south being three miles away and Union Hills Drive to the north approximately 1.5 miles away. Even the principal north-south facilities are only four lanes, with intervals of a mile or more between all facilities. The location and design of the Sun City retirement communities serve to significantly restrict traffic flow in any direction through this area. The rapid development of bedroom communities beyond Sun City West generates major travel volumes as residents seek to access employment centers to the east in the Central Valley, which clearly adds to peak period traffic congestion on Bell Road. Without Bell Road, residents of these bedroom communities would be obliged to rely on Grand Avenue to access L101 and the central valley; many already do, and Grand Avenue is also very congested.

While Bell Road is the transportation backbone for this portion of the region, it has no features that intrinsically invite people to leave their cars. It is not, and was never intended to be, pedestrian- or transit-oriented in scale or design. There is no street grid with blocks, but rather typical suburban curvilinear residential street networks in the subdivisions, where sidewalks are primarily for recreational and not utilitarian use.

Central Avenue

The three mile stretch of Central Avenue through the study area is six lanes wide and now features a new LRT right of way in its center. The major parallel facilities of 7th Avenue and 7th Street are also six lanes wide though this section, with center turning lanes at key intersections, as are McDowell, Thomas, Indian School and Camelback roads traversing west to east. Both 7th Avenue and 7th Street also feature reversible lanes, which are used to provide additional capacity during peak periods. Indian School Road, in the center of the district, is seven lanes wide from Central Avenue west, and then drops to five lanes, like Thomas and McDowell, as it moves farther east. While turning lanes are provided at most major intersections, left turns are prohibited during peak periods on many crossing corridors. As was earlier noted, there is substantial bus activity through the corridor, with a concentration of routes on many of the north-south and east-west arterials. I-10 passes below the southern end of the study area, with access points at 7th Avenue and 7th Street, but not Central Avenue. I-17 and the Piestewa Freeway (State Route 51) border the corridor on its west and east sides, respectively, and offer options for longer distance regional trips; however, they are between 2 and 2.4 miles from Central Avenue.

In terms of the street network, it is clearly a rectilinear grid, with most blocks ranging in size from one-eighth to one-quarter of a mile, and with good sidewalk coverage throughout. However, the development facing Central Avenue, while architecturally attractive, is not particularly beckoning or relevant to pedestrians. Distances between buildings are considerable as are the building setbacks, and there appear to be few retail attractions that are not primarily auto-oriented. Parking lots or other empty spaces magnify these distances at a pedestrian scale.

Tempe

The Tempe study area is somewhat less urban than Scottsdale or Central Avenue, but still offers a fair number of situations that facilitate local circulation and walking, such as block sizes in the one-eighth to one-quarter of a mile range, and good sidewalk coverage. This is particularly true in the university area and along Mill Avenue. However, apart from these areas the land uses—while having reasonably high density—are not well mixed in terms of co-location, and the retail is predominately auto-oriented. University Drive, Apache Boulevard, and Broadway Road are the major east-west arterials, and are spaced at roughly one-half mile apart. University and Rio Salado to the north are four lane facilities, while Apache and Broadway are six lanes. Mill Avenue, Rural Road (which becomes Scottsdale Road further north), and McClintock Drive (which becomes Hayden Road) are the major north-south arterials, with Mill and McClintock being five lanes each and Rural Road having six lanes. Price Freeway (L101) borders the study area on the east, with primary access via Apache Boulevard, while the Red Mountain Parkway (L202) borders it on the north, accessed via Rural/Scottsdale Road; however, both expressways lie at least two miles from the center of the study area.

TRAFFIC CONDITIONS

Figures 46 through 53 illustrate traffic flows and congestion levels on the respective street networks in the four study areas. Each page displays two maps of the same area, with the first depicting congestion levels as represented by V/C ratios and the second showing vehicular volumes. The first set of four figures (46 through 49) reflect traffic conditions during the midday period, while the remaining four (50 through 53) describe conditions in the PM peak period. Volumes shown are for the entire time period (9 a.m. to 3 p.m. for midday, 3 p.m. to 6 p.m. for PM peak period), but the V/C ratios represent conditions for an average hour during the period (i.e., not the maximum hour).

These volume and level of service maps were developed using MAG's regional travel forecasting model with 2008 data and networks. Therefore, the volumes and congestion relationships shown in the figures and discussed below are estimates generated by the MAG model and are the result of the model's traffic assignment procedure and not actual in-field measures. The limitations of such an approach should be noted, since model estimates of link volumes may vary from actual counts. There are several reasons for this, the first being a high degree of daily variation in the counts themselves, and the second being the accuracy level of the models. Regional (four-step) travel forecasting models such as MAG's are not intended to predict link-level volumes at a high level of accuracy, particularly at the fine-grained level of the local street grid where small, local streets are generally not even included in the network. The validity of the models in terms of matching observed volumes is typically tested at the major corridor and screenline level, with calibration adjustments made to satisfy the larger flow criteria. To achieve the same tolerance levels at the local grid level would be virtually impossible.

To try to account for this issue, the study accessed physical traffic counts for approximately the same period to examine the degree of comparability between the model-predicted volumes vs. actual measurements. These counts were taken from MAG's 2006/2007 Regional Traffic Volume Study and consisted of raw, unadjusted counts by 15 minute blocks over the course of a 24 hour day. Unfortunately, because detailed traffic counts are resource-intensive to obtain, they are only available for select locations. This meant that it was not possible to do a perfect matchup of count stations with the exact roadway segments that had been selected to represent the study areas. Since the study was not funded to obtain new counts, it was necessary to make do with the data available, which meant making the count-vs.-prediction comparison as close to the selected analysis sites as possible. The specific comparisons are summarized in Table 13. The detailed count data for these segments is presented in Appendix D.

Table 13. Comparison of MAG Model Assigned Link Volumes with Actual Traffic Counts.

Facility/Study Area	Segment	2008 Traffic Counts		2008 MAG Model		2008 Traffic Counts		2008 MAG Model	
		NB/EB	SB/WB	NB/EB	SB/WB	NB/EB	SB/WB	NB/EB	SB/WB
Scottsdale: Scottsdale Road	Camelback Rd to Chaparral Rd	4,469	4,267	7,697	7,073	2,513	2,214	4,080	4,014
	Model vs. Actual			72%	66%			62%	81%
Scottsdale: Indian School Rd	Scottsdale Rd to Hayden Rd	7,680	6,793	5,279	5,269	5,437	2,852	3,772	2,466
	Model vs. Actual			-31%	-22%			-31%	-14%
Scottsdale: Camelback Rd	64th St to 68th St	4,918	5,163	6,103	6,340	3,494	3,780	3,671	3,836
	Model vs. Actual			24%	23%			5%	1%
Bell Rd: Bell Road	Johnson Blvd to El Mirage Rd	12,430	10,251	9,951	10,094	5,580	5,927	5,290	6,104
	Model vs. Actual			-20%	-2%			-5%	3%
Central Ave: Central Ave	Camelback Rd to Missouri Rd	3,040	3,517	5,008	4,824	3,121	1,903	4,444	4,069
	Model vs. Actual			65%	37%			42%	114%
Central Ave: Thomas Rd	7th Ave to Central Ave	8,263	7,506	6,723	7,278	3,691	6,294	3,475	4,800
	Model vs. Actual			-19%	-3%			-6%	-24%
Central Ave: 7th Ave	I-10 to McDowell Rd	5,145	5,153	6,379	5,427	2,404	2,682	4,666	3,608
	Model vs. Actual			24%	5%			94%	35%
Central Ave: 7th St	I-10 to McDowell Rd	10,772	9,397	9,284	8,803	6,528	5,495	5,795	5,472
	Model vs. Actual			-14%	-6%			-11%	0%
Central Ave: 7th St	Indian School to Camelback Rd	7,536	7,835	5,522	3,674	7,032	4,076	4,968	2,863
	Model vs. Actual			-27%	-53%			-29%	-30%
Central Ave: Indian Sch. Rd	3rd St to 7th St	4,924	5,327	9,277	7,112	3,691	6,294	5,565	4,510
	Model vs. Actual			88%	34%			51%	-28%
Tempe: Apache Blvd	Mill Ave to Rural Rd	3,347	3,630	6,740	6,661	2,887	2,045	4,075	3,450
	Model vs. Actual			101%	83%			41%	69%
Tempe: Broadway Rd	Mill Ave to Rural Rd	5,618	5,106	7,824	6,146	4,046	2,689	5,891	2,541
	Model vs. Actual			39%	20%			46%	-6%
Tempe: Mill Ave	Apache Blvd to University Dr	5,939	5,488	6,582	6,798	2,821	4,387	3,402	4,454
	Model vs. Actual			11%	24%			21%	2%
Tempe: Rural Rd	Apache Blvd to University Dr	5,365	3,975	11,278	11,096	2,878	1,873	5,661	6,803
	Model vs. Actual			110%	179%			97%	263%
	Average Predicted vs. Actual Volume			30.3%	27.5%			26.9%	33.3%

The comparisons in the table indicate the degree of variation between predicted and measured volumes. Predicted volumes range from 263 percent greater than the equivalent measured volume to as much as 53 percent lower. No obvious patterns seem to exist in terms of which facilities tend toward over- or underprediction, except that the tendency to over- or underpredict does seem to be consistent for the same roadway under both peak and off-peak conditions, and generally in each flow direction. For each time period and direction column, there are nine occasions where the model predicts volumes that are greater than the equivalent counts vs. five occasions where the predicted volumes are less than the counts. On average, the model forecasts tend to be greater—by 27 percent to 33 percent—than the actual counts.

These comparisons lead to two conclusions. First, it confirms that regional travel forecasting models must be used cautiously for analysis of volumes and traffic conditions on arterials and local roads. The models were simply not intended for this scale of analysis, and the calibration tolerances are less at the lower functional classes. Second, to the extent that these model forecasts differ from actual counts, there appears to be a greater tendency to overpredict than underpredict arterial volumes. The implication of this finding is that the V/C ratios displayed in Figures 46A through 53A and discussed below will in most cases be an overstatement of the severity of congestion on the respective facilities.

Computation of the effects of these predictions vs. actual discrepancies is provided in Tables 14A and 14B. Table 14A shows the V/C values calculated from the MAG forecast volumes as illustrated in Figures 46 through 53, while Table 14B shows what the V/C ratio would be if the volumes for the respective link were adjusted to the actual counts. For example, on Apache Boulevard in Tempe between Mill Avenue and Rural Road, the model is predicting volumes that lead to a midday V/C of 1.06 to 1.16 eastbound in the midday and 1.04 to 1.15 westbound. However, because the model is estimating 6740 trips in the eastbound direction vs. 3347 actually measured, the overestimate of 101 percent means that the actual V/C is more like 0.52 to 0.58, while in the westbound direction an overestimate of 83 percent means that the V/Cs in that direction are more like 0.57 to 0.62. In general, it would appear that in most of the corridors examined below—and especially those in the higher-density mixed-use areas such as Scottsdale Road, Central Avenue, Mill Avenue, Rural Road, Apache Boulevard, and Broadway Road—the actual congestion will be less than what is being depicted in the maps based on the model estimates. On Bell Road the opposite is true, and the V/C would actually be higher.

Table 14A. 2008 V/C Ratios on Selected Links Based on MAG Model Forecasts.

Study Area	Location	Mid-Day		PM Peak	
		North/ East	South/ West	North/ East	South/ West
Scottsdale	Scottsdale Rd, N of Indian School	1.02	0.95	1.07	1.10
	Indian School, W of Scottsdale Rd.	0.80	0.70	0.85	0.87
	Goldwater Rd., N of Indian School	1.33	1.17	1.39	1.25
	Drinkwater Rd., N of Indian School	0.34	0.41	0.37	0.56
Bell Road	Bell Road, bet. El Mirage and 115th	1.57	1.60	1.60	1.97
Central Avenue	Central Ave, N of Osborne	0.68	0.88	0.84	1.04
	Thomas Rd., W of Central Ave	1.07	0.81	1.05	1.02
Tempe	Mill Av., North of University Dr.	1.53	1.55	1.61	1.73
	Rural Rd., North of University Dr.	1.26	1.28	1.39	1.39
	Apache Blvd, W of McClintock	1.12	1.06	1.40	0.94
	Broadway Blvd, W of McClintock	0.98	0.89	1.40	0.82

Table 14B. V/C Ratios on Selected Links Adjusted to Reflect Actual Counts.

Study Area	Location	Mid-Day		PM Peak	
		North/ East	South/ West	North/ East	South/ West
Scottsdale	Scottsdale Rd, N of Indian School	*0.59*	*0.57*	*0.66*	*0.61*
	Indian School, W of Scottsdale Rd.	*1.05*	*0.85*	*1.11*	*0.99*
	Goldwater Rd., N of Indian School	*NA*	*NA*	*NA*	*NA*
	Drinkwater Rd., N of Indian School	*NA*	*NA*	*NA*	*NA*
Bell Road	Bell Road, bet. El Mirage and 115th	*1.88*	*1.63*	*1.68*	*1.91*
Central Avenue	Central Ave, N of Osborne	*0.41*	*0.64*	*0.59*	*0.49*
	Thomas Rd., W of Central Ave	*1.27*	*0.83*	*1.11*	*1.26*
Tempe	Mill Av., North of University Dr.	*1.38*	*1.25*	*1.33*	*1.70*
	Rural Rd., North of University Dr.	*0.60*	*0.46*	*0.71*	*0.38*
	Apache Blvd, W of McClintock	*0.56*	*0.58*	*0.99*	*0.56*
	Broadway Blvd, W of McClintock	*0.71*	*0.74*	*0.96*	*0.87*

Perhaps the more intriguing possibility in looking at the prediction biases is that the overpredictions seem to occur in areas with good land use. This raises the possibility that the MAG modeling process attributes more vehicle trip generation to areas like Tempe, Scottsdale, and Central Avenue than occurs in practice. If the research findings on the importance of the 4Ds are accurate, they suggest that residents in these three areas would generate fewer vehicle trips and less VMT than equivalent households residing in less compact, mixed-use locations. Therefore, if the MAG trip generation and distribution processes uses similar relationships regardless of land use (and most four-step models do) there could be a built-in bias that overestimates locally generated vehicle volumes in areas with good land use. This possibility will be investigated further in the next phase of the project.

The following observations are offered upon studying the traffic data for the four study areas.

Scottsdale

What is perhaps most interesting in the Scottsdale example is the relatively modest traffic congestion in the highest-density portion of the study area—the town center sections of Scottsdale Road and Indian School Road between Goldwater Boulevard and Drinkwater Boulevard, which appear to function as reliever facilities—as shown in Figures 46A and 50A. The V/C on Indian School Road west of Scottsdale Road is 0.8 midday in the eastbound direction, and 0.85 in the peak, while Scottsdale Road north of Indian School Road is 1.02 midday in the northbound direction and 1.07 in the peak. However, given that the Scottsdale Road volumes may be overestimated by 60 percent to 80 percent (see Table 13), Scottsdale Road is actually probably operating at a very tolerable V/C in the range of 0.59 midday/0.66 peak (see Table 14B). Meanwhile, the same logic suggests that the eastbound volumes on Indian School Road may be underestimated by 31 percent, which would mean that the V/C range there could be in the 1.07 to 1.10 range during midday and peak, respectively. The significance of this finding can be appreciated by comparing the relatively moderate V/C relationships on Scottsdale Road with the location and intensity of development in the surrounding TAZs as shown in Figure 46A. However, while V/C ratios greater than 1.0 are observed on a number of facilities leading into and out of the central area, particularly along Indian School Road before Goldwater Boulevard and then on Goldwater Boulevard north of Indian School, Scottsdale Road itself, Indian School Road, and Drinkwater Boulevard within the central area have V/C ranges that suggest urban conditions but seem well short of gridlock given the intensive development activity in that area. Travelers passing through Scottsdale may avoid Scottsdale Road because it is specifically not designed to encourage vehicle traffic. There are fewer lanes; more distractions (activities, parking); and signal operations that make it difficult to travel rapidly through this area. To save time, travelers are more likely to use a bypass road like Goldwater Boulevard or perhaps even L101 (two miles to the east) to get to Scottsdale. Also, the central portion of Scottsdale contains a fairly fine-grained street grid, which gives traffic in the vicinity of Scottsdale and Indian School roads opportunities to bypass intermittent congestion.

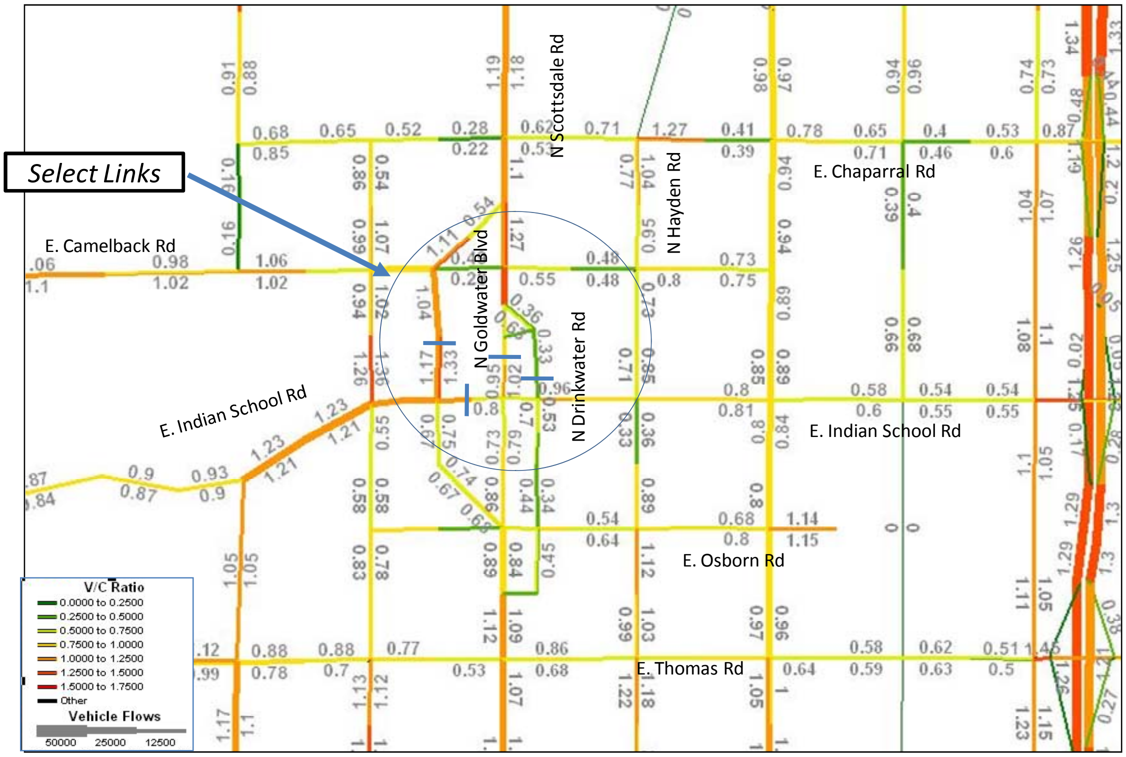

Figure 46A. 2008 Midday V/C Ratios on Scottsdale Road.

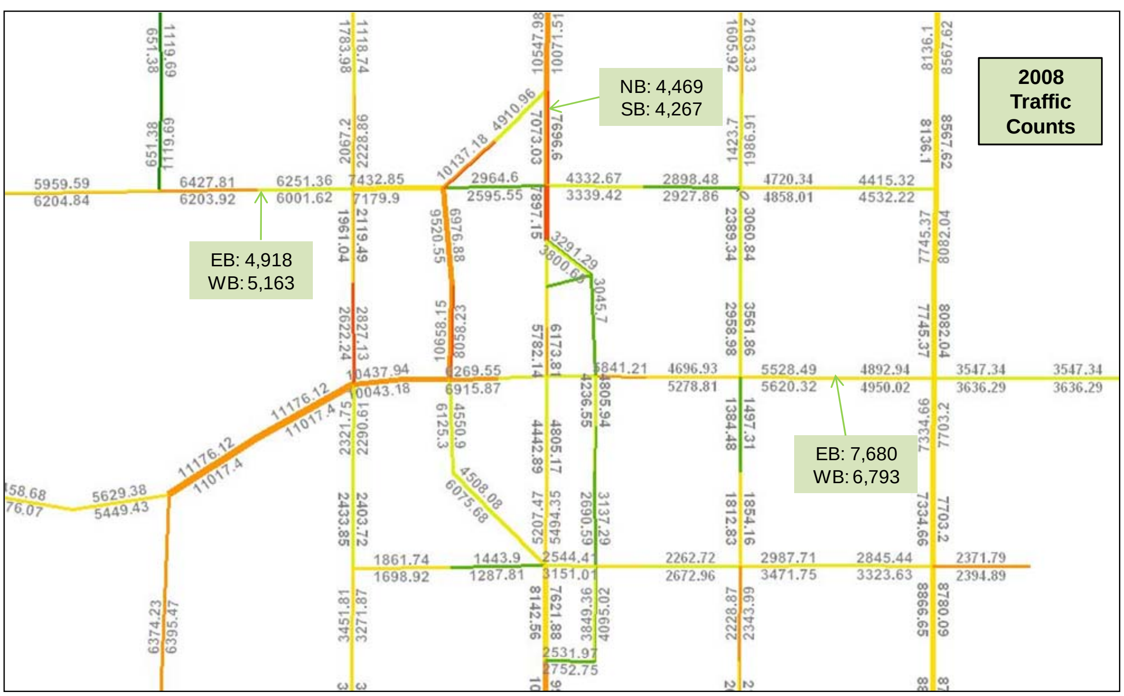

Figure 46B. 2008 Midday Vehicular Volumes on Scottsdale Road.

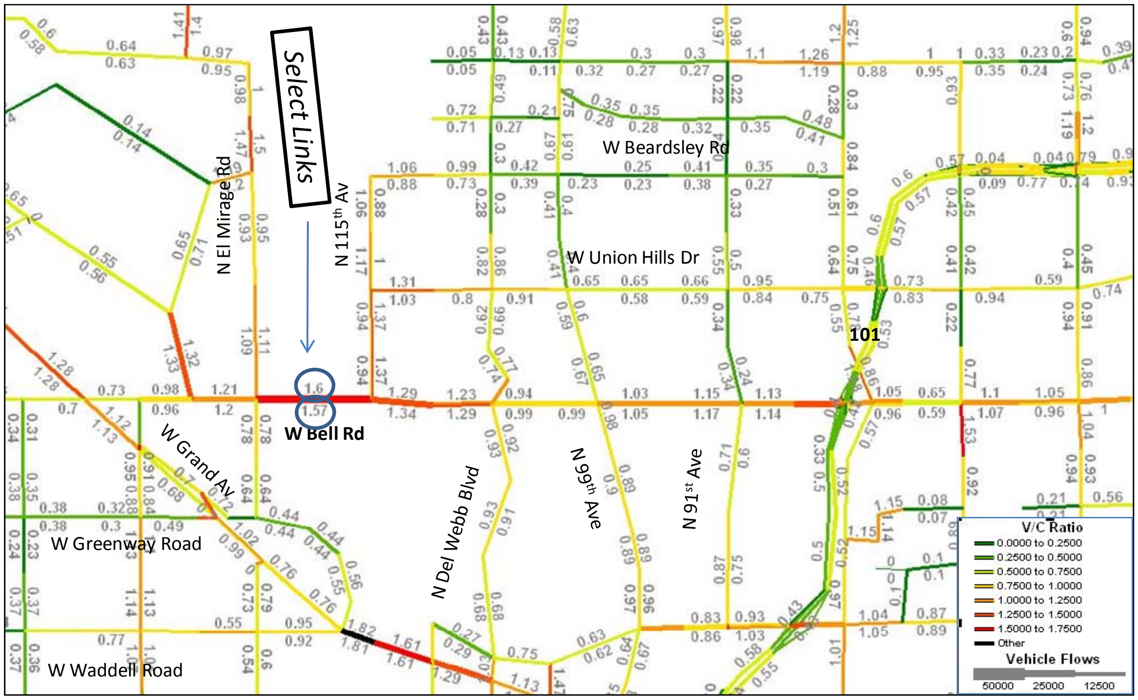

Figure 47A. 2008 Midday V/C Ratios on Bell Road.

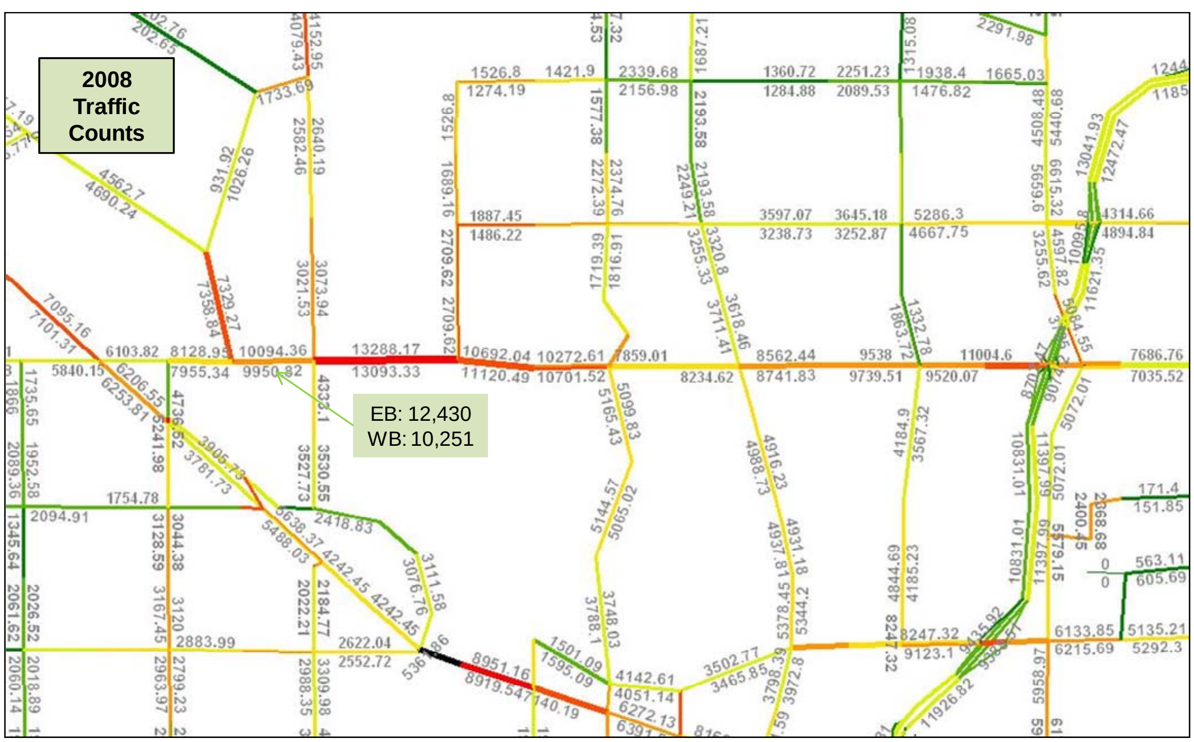

Figure 47B. 2008 Midday Vehicular Volumes on Bell Road.

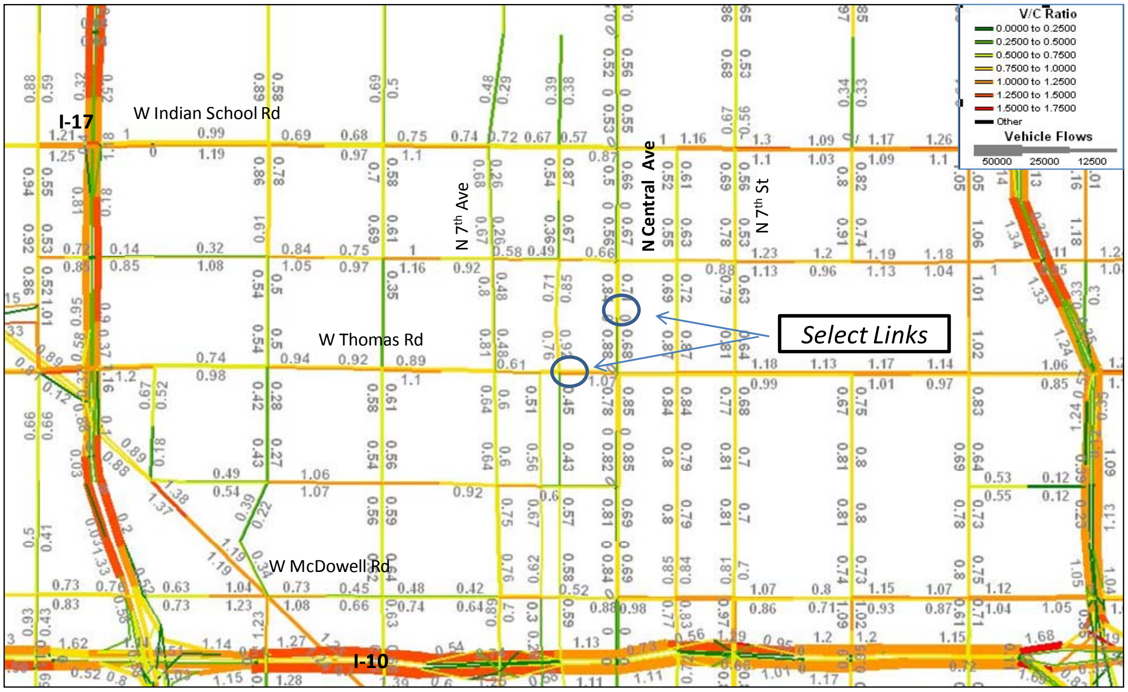

Figure 48A. 2008 Midday V/C Ratios on Central Avenue.

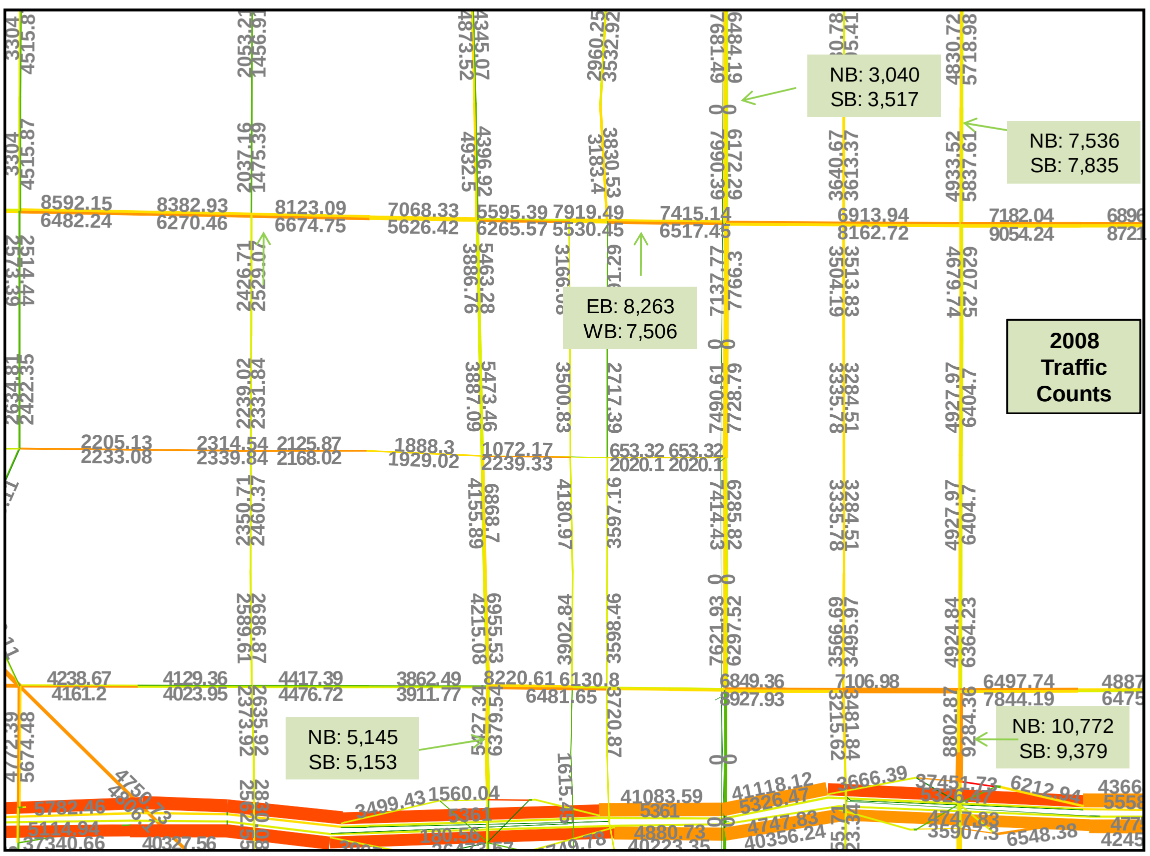

Figure 48B. 2008 Midday Vehicular Volumes on Central Avenue.

Figure 49A. 2008 Midday V/C Ratios in Tempe.

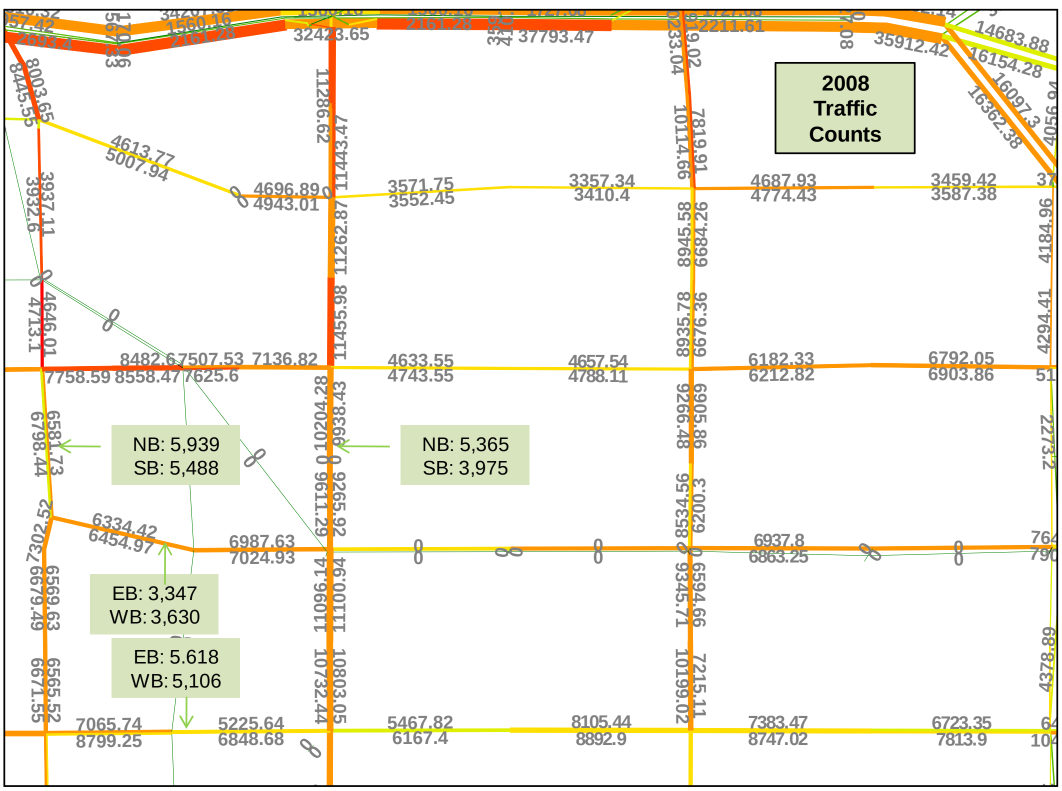

Figure 49B. Midday Vehicular Volumes in Tempe.

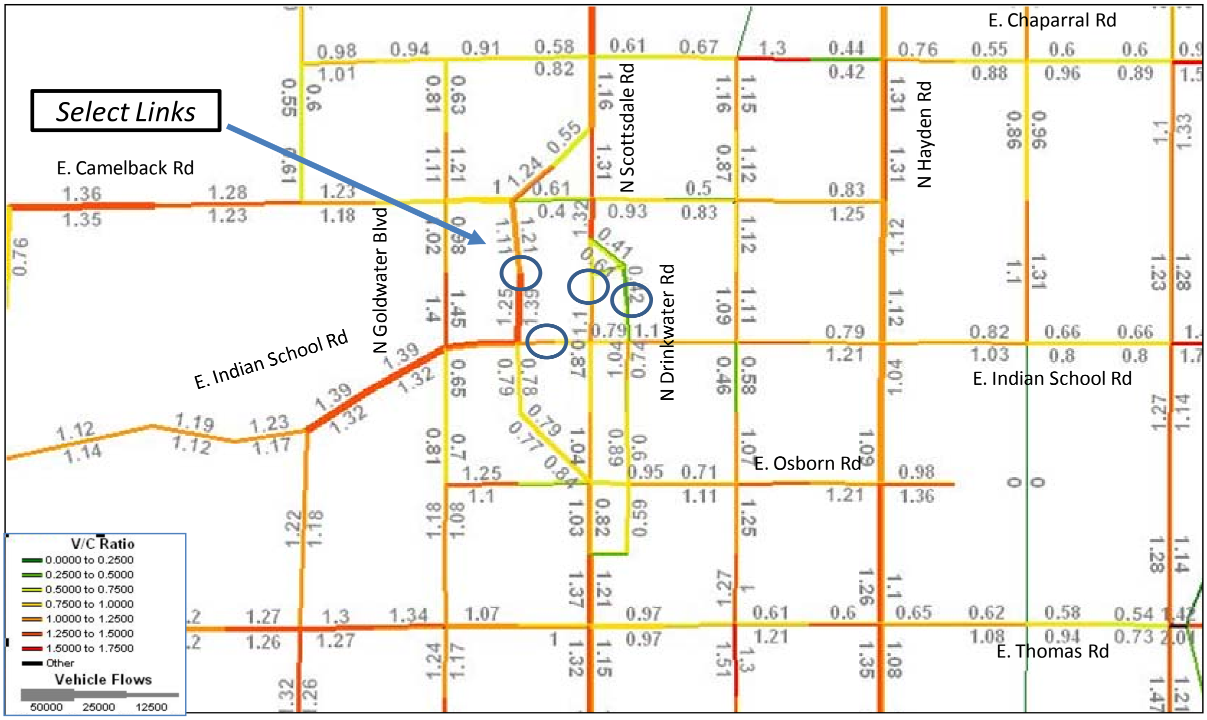

Figure 50A. 2008 PM Peak Period V/C Ratios on Scottsdale Road.

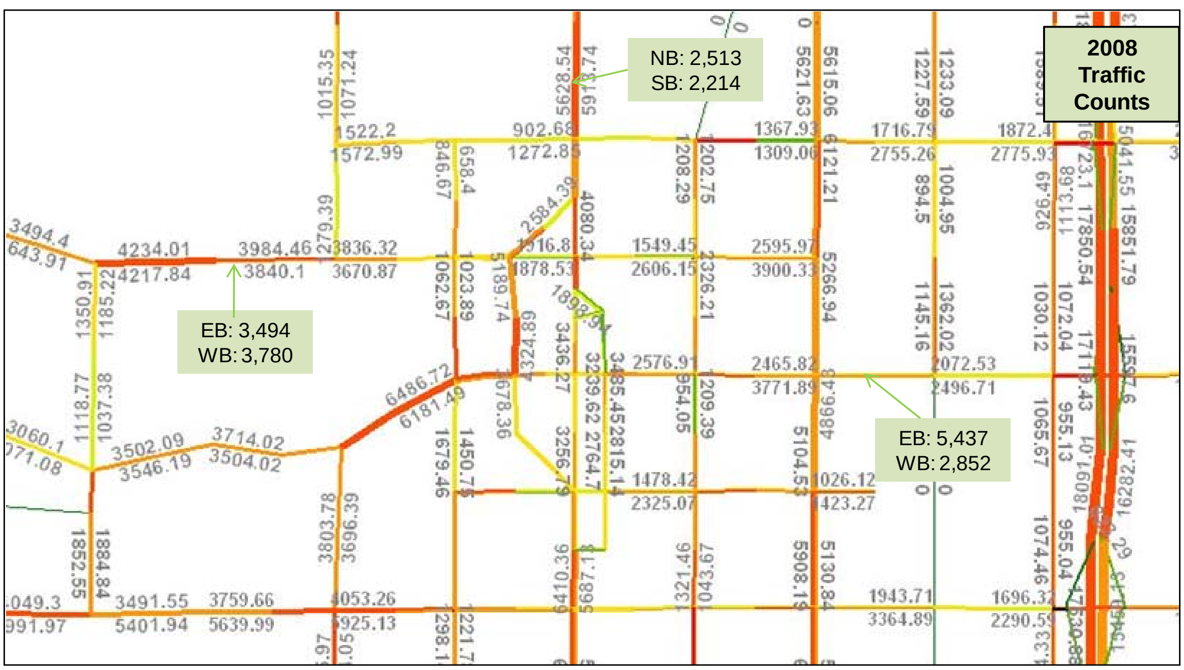

Figure 50B. 2008 PM Peak Period Vehicular Volumes on Scottsdale Road.

Figure 51A. 2008 PM Peak Period V/C Ratios on Bell Road.

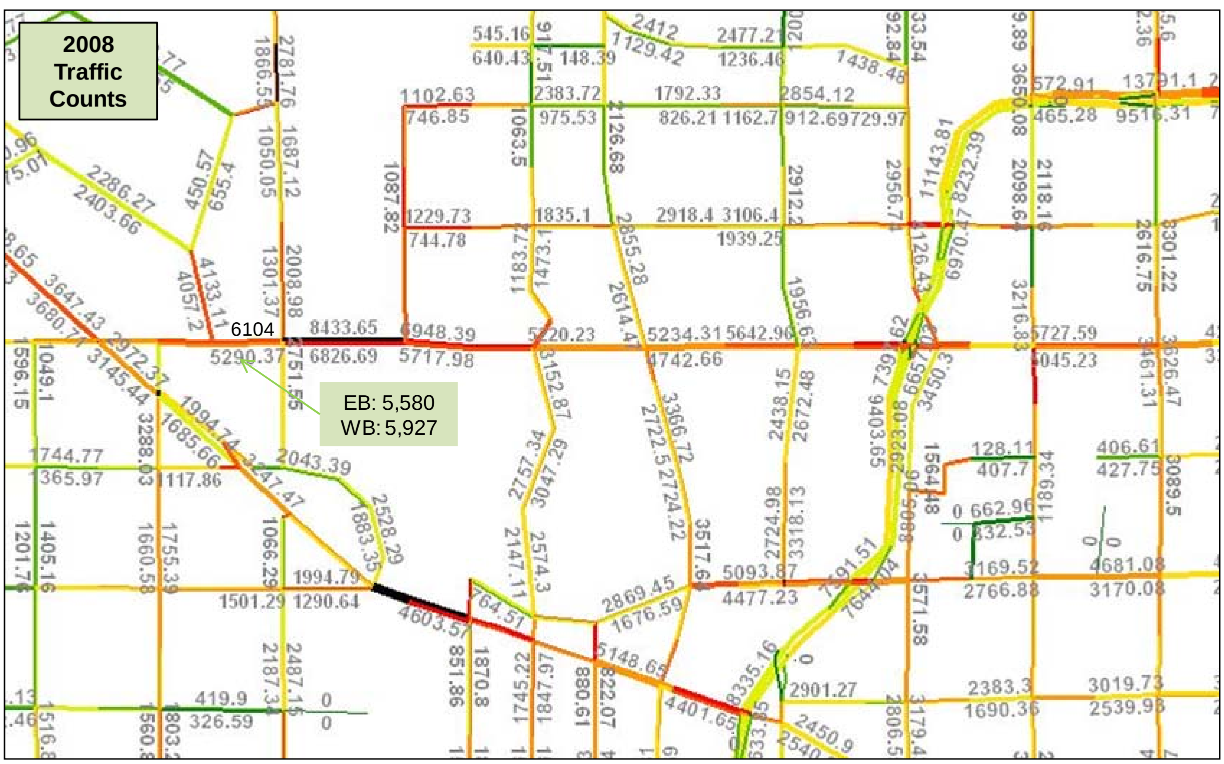

Figure 51B. 2008 PM Peak Period Vehicular Volumes on Bell Road.

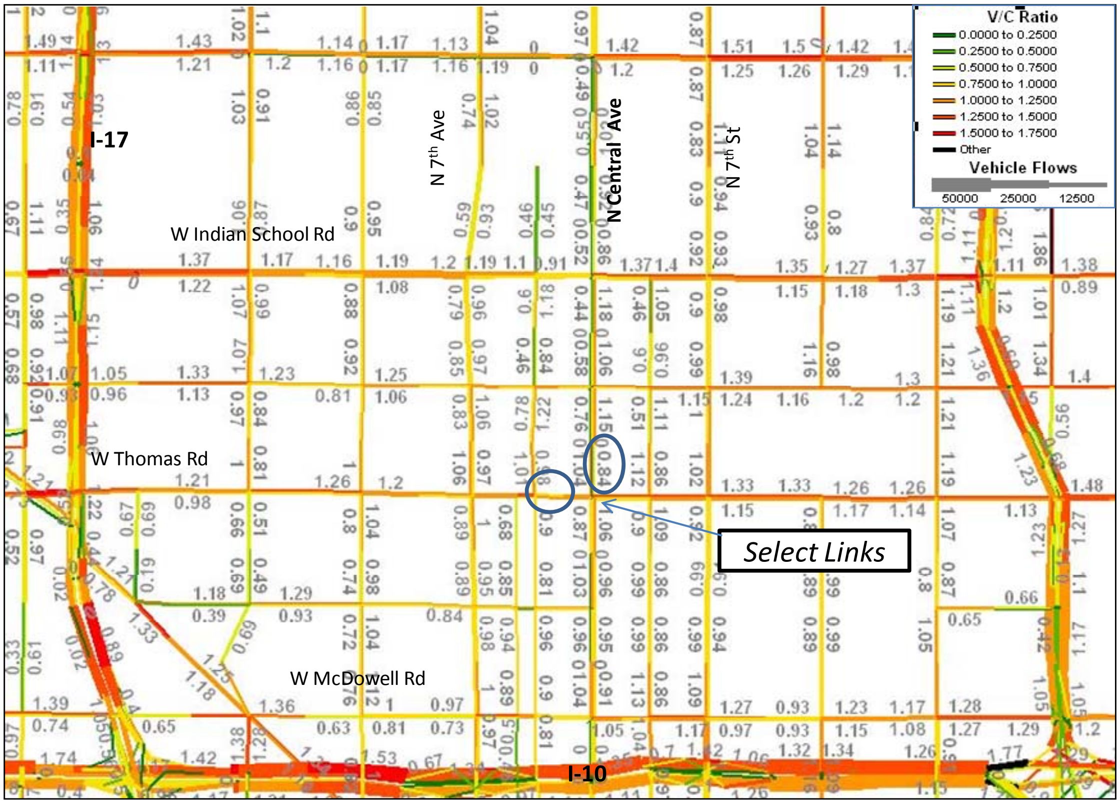

Figure 52A. 2008 PM Peak Period V/C Ratios on Central Avenue.

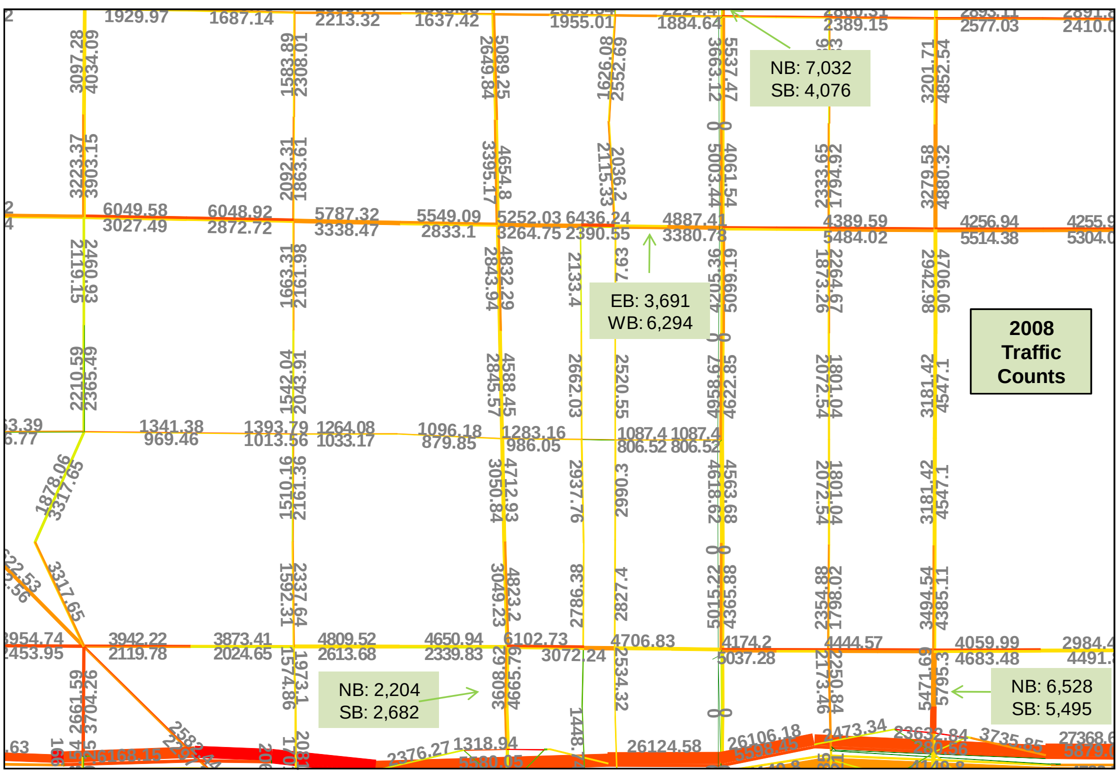

Figure 52B. 2008 PM Peak Period Vehicular Volumes on Central Avenue.

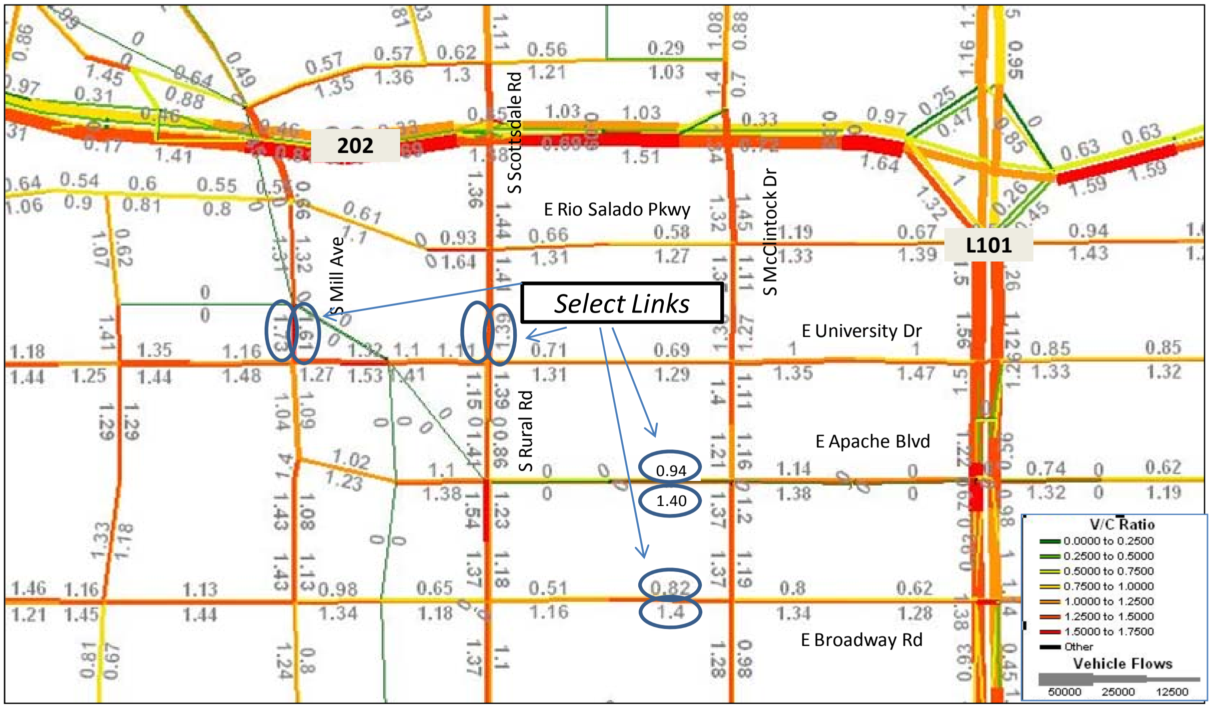

Figure 53A. 2008 PM Peak Period V/C Ratios in Tempe.

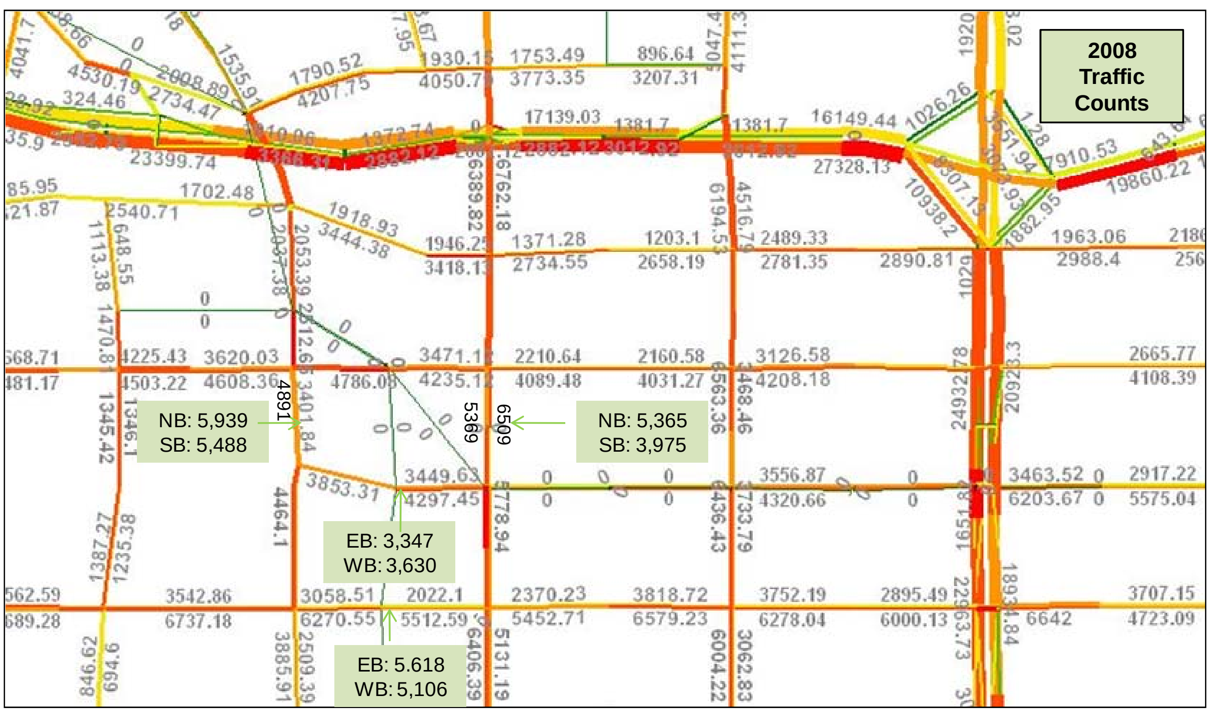

Figure 53B. PM Peak Period Vehicular Volumes in Tempe.

Bell Road

As seen in Figures 47A and 51A, Bell Road has major traffic congestion along most of its length both in the midday and particularly in the PM peak period, despite the absence of major density in the TAZs along its approximately 6.5 mile length (Figure 47B). V/C ratios in the critical segment between 115th Avenue and El Mirage Boulevard are about 1.6 in each direction in the midday and between 1.6 and 2.0 in the peak. Table 13 indicates that if anything, the MAG model is slightly underpredicting volumes on Bell Road, so the V/Cs may be slightly worse than shown. The entire length of Bell Road through the study area shows V/C ratios of 1.0 or greater in both the midday and PM peak periods. Beardsley Road and Union Hills Drive, and North 115th Avenue that connects them with Bell Road, are beginning to show congestion in the midday, but are already seriously congested in the PM peak period. Grand Avenue, which shared duty with Bell Road in connecting commuters from the western region east to L101 or jobs in the central valley, has congestion levels as severe or more severe as Bell Road. (The critical link is the river crossing.) This speaks both to the land use in the corridors themselves as well as the lack of sufficient east-west capacity to support a significant auto-oriented population. The sparse suburban road network with relatively little redundancy (as would be found in a grid) offers few alternative travel paths.

Central Avenue

Similar to Scottsdale in its conditions, the Central Avenue corridor and its main parallel arteries of 7th Street and 7th Avenue, all appear to flow remarkably well during the midday and surprisingly well in the PM peak period, although the east-west movements seem to be more affected by congestion (Figures 48A and 52A). The moderate midday conditions are perhaps to be expected, since the area is primarily an office employment destination, but the peak period conditions are less intuitive, given the presence of some of the highest employment densities in the region, as illustrated in Figure 40. The section of Central Avenue north of Thomas Road has a V/C of 0.68 northbound in the midday and 0.88 southbound, while in the PM peak period these numbers increase to 0.84 and 1.04, respectively. However, Table 13 suggests that the MAG model may be overestimating the volumes on northern Central Avenue by as much as 67 percent in the midday and 114 percent in the peak. If these adjustments are factored in, the northbound/southbound V/Cs on Central Avenue drop to 0.41 and 0.64 in the midday, and 0.59 and 0.49 in the peak. The crossroads are more congested, with Thomas Road west of Central Avenue having a midday V/C of 1.07 eastbound and 0.81 westbound, and PM peak period V/Cs of 1.05 eastbound and 1.02 westbound. Since the MAG model was found to underestimate volumes on these links, the respective V/Cs would become even higher. The reason for this may be the imposition of turn restrictions onto the north-south facilities which, if deemed a significant impediment to traffic flow, might be ameliorated through alternative traffic engineering strategies. At the mid part of the corridor on Indian School Road, the V/Cs on the link east of Central Avenue are 0.86 eastbound and 1.02 westbound at midday, and 0.9 eastbound and 1.4 westbound in the peak. However, all but the peak period westbound flow (1.4) are based on potentially overestimated volumes by the MAG model, so adjusted V/Cs for this link would be 0.45 eastbound and 0.76 westbound midday, and 0.60 eastbound and 1.94 westbound in the peak. As in Scottsdale, while some of these links are clearly experiencing urban traffic conditions, flows on most of the key corridor facilities are surprisingly modest, **considering the high** development densities through which they pass. A significant part of the credit for the absence of severe congestion may be the fine-grained street grid in the corridor, with north-south alternative routes available roughly every one-eighth mile.

Tempe

Perhaps owing to its university influence and some of the associated shopping attractions, traffic in Tempe seems to be as or more intense in the midday than it is in the PM peak period. As seen in Figure 41, the most intense development in the Tempe study area lies along Mill Avenue in TAZs 1167 and 1168 (mainly employment and most of the retail), north of University Drive. The other major employment areas are at the university in Zone 1171 and in Zone 1178 in the northeast, which is largely light industrial and service employment. The most intense residential development lies between University and Broadway in the tract between Rural Road and McClintock in TAZs 1871, 1176, and 1177, although there are a significant number of multifamily residential complexes in zones 1865, 1869, 1179, and 1180. Based on predicted link volumes from the MAG model, traffic congestion appears to be substantial along each of the facilities chosen for study. Mill Avenue at East University Drive is high in both peak and off-peak periods (Figures 49A and 53A), showing a maximum V/C of 1.5 in the link just north of University Drive in the midday in both directions, and 1.6-1.7 during the PM peak period. Rural and McClintock roads also show V/Cs greater than 1.0 in both midday and peak periods. And in the residential areas adjoining and east of the university along University Drive, Apache Boulevard, and Broadway Road, traffic levels are somewhat less, although still near or exceeding V/Cs of 1.0.

Comparing counts with the MAG link forecasts in Table 13 suggests that the shown volumes on each of the four facilities may be high in both directions and in both time periods. On Mill Avenue, the overprediction is 11 percent northbound and 24 percent southbound in the midday, and 21 percent northbound and 2 percent southbound in the PM peak period. So even with adjustment, the V/C ratios show that Mill Avenue is congested. However, as with Scottsdale Road, Mill Avenue was not designed to carry heavy vehicle volumes or serve as a through artery. Its features of street activity, landscaping, parking, medians, and bike lanes serve as a signal that it is not intended for major vehicle throughput. Adjacent Rural and McClintock roads, however, do appear to serve this function, with more lanes, bigger intersections, and less intense adjacent development. While it registers as congested in the MAG model estimates, Rural Road's traffic may be significantly overestimated (between 100 percent to almost 300 percent), which means that it may not be particularly congested at all. The same applies to east-west arterials Apache Boulevard and Broadway Road. Based on the model forecast volumes, these roads are operating at close to capacity, while if actual counts are used the adjusted V/Cs may be more like 0.56 eastbound and 0.58 westbound on Apache Boulevard in the midday and 0.99 eastbound and 0.56 westbound in the PM peak period, while on Broadway the V/Cs would be revised to 0.71 eastbound and 0.75 westbound in the midday and 0.96 eastbound and 0.88 westbound in the PM peak period.

To summarize, it appears that of all four facilities, Mill Avenue is the most verifiably congested, while the remaining three may or may not be. However, Mill Avenue is carrying only a fraction of the volume of the other three, because its design, based on the environment it serves, doesn't encourage vehicle traffic. The people traveling on Mill Avenue are likely making a conscious choice to endure the traffic because they have a need to be there, whereas travelers passing through the area are likely to find ways to avoid Mill Avenue. This is explored further in the select link analysis in the following section, which shows that the through traffic share on Mill Avenue is fairly small. Also, the area around the congested segment of Mill Avenue includes a fairly fine-grained street grid so that circulation may very well be maintained despite slow speeds.

COMPOSITION OF TRAFFIC ON KEY FACILITIES

Simply measuring the level of traffic congestion on a street or highway does not give much information as to the cause or sources of that traffic. The analysis in the previous section simply looked at the correspondence between development density and traffic levels on the adjacent facility or facilities. However, the composition of that traffic stream may have much or very little to do with the adjacent development.

To better understand the nature of the corridor traffic flows, researchers performed a series of select link analyses. In this travel model-aided analysis, researchers select a specific numbered link in the highway network and then, through reanalysis of the traffic assignment results, investigate the origin and destination of the trips on that link. Researchers can then determine what proportion of trips are being made by travelers residing inside the study area vs. nonresidents in a given time period (midday, peak), and whether those trips are headed to internal or external destinations. This can be a fairly fine-grained assessment, focusing on trips from individual zone to individual zone, but it becomes more tractable (and accurate) if done at a somewhat higher level of aggregation, say, for a political jurisdiction or a planning district. Regrettably, it cannot be done for individual trip purposes since the trip tables for all purposes are combined for a given time period prior to network assignment in the modeling process.

The particular links selected for this analysis for each study area have been highlighted in Figures 50A, 51A, 52A, and 53A, and are also listed in Tables 15A and 15B for midday and PM peak period conditions, respectively. Whereas travel patterns between the study area and a number of distinct adjacent areas have been examined (using MAG Regional Activity Zones or Metropolitan Planning Areas aggregations), the results shown in Tables 15A and 15B have been reduced to a much more condensed format to focus on the extent to which the traffic problems of the given areas are a function of their own activity or the activity of the surrounding region. To characterize this analysis, the trip movements in Tables 15A and 15B are categorized into four primary groups: internal origins to internal destinations , internal origins to external destinations , external origins to internal destinations, and external origins to external destinations.

Some primary questions to consider when looking at these relationships are:

- How much of the traffic stream—and, hence, what portion of the congestion—is simply due to through traffic, that has no bearing on the development character of the area?
- How much is due to visitors from the outside and conceivably is stimulated by the level and type of development?
- How much is generated by residents of the area itself?

The following observations are made for each study area in relation to its selected links.

Scottsdale

Four select links were designated for this study area: the northbound lanes on Scottsdale Road, Goldwater Boulevard and Drinkwater Boulevard immediately north of Indian School Road; and Indian School Road eastbound immediately before the intersection with Scottsdale Road. On Goldwater Boulevard, in the very congested segment just north of Indian School Road, a high percentage of the traffic stream consists of trips coming from outside the study area. During the midday, a combined 61.6 percent are coming from external locations and are headed either to a destination in the Scottsdale study area (34 percent) or are passing directly through (27.6 percent). In the PM peak period this percentage is even higher, with 63.4 percent coming from external sources and going to either an internal destination (35.2 percent) or directly through (28.2 percent). So indeed Goldwater Boulevard is functioning as intended: to steer visitor or pass-through traffic from the west away from and around the activity center itself (Scottsdale Road at Indian School Road) to the north. At the same time, the percentage of traffic that does occur on the Scottsdale Road and Indian School Road links at the main intersection has a notably high percentage of trips coming into the center from outside. On Indian School Road, fully 58.1 percent of the trips during the midday and 54.8 percent in the PM peak period have external origins and are coming to an internal destination. Presumably these are travelers who actually must reach a destination close to the prime intersection (where some of the highest densities are located) and have directed their trips directly to that location. A similar breakdown occurs on Scottsdale Road north of Indian School, where 44.0 percent of midday trips and 42.5 percent of PM peak period trips are external-internal. Even with this major influx from the outside, the V/C ratios for these links are reasonable in both time periods, presumably because there is a relatively small percentage of trips with internal origins, and it may be possible (and desirable) to move about this area on foot once the traveler is parked. Still another reason for the lower volumes may be that the design of the area, perhaps pedestrian activity or the duration of stoplights and crossings, makes this area less attractive for efficient vehicle travel.

Bell Road

The select links on Bell Road were drawn from the segment between North El Mirage Road and North 115th Street, which is where the highest V/C ratios were observed in both peak (1.97/1.60) and midday (1.60/1.57) periods. About half of all traffic during both of these periods is passing completely through the study area, and the second largest group consists of trips that are leaving the area for somewhere else—between 23.3 percent and 26.2 percent in the midday and between 16.4 percent and 27.9 percent in the PM peak period (Tables 15A and 15B). This result suggests that there are relatively few destinations in the Bell Road study area that attract visitors, either from the inside or the outside, and hence much of the traffic on Bell Road is composed of travelers going someplace else to satisfy their activities. Looking at the more detailed breakdown of these trips by source, the great majority of trip movements on Bell Road in the select segment—either eastbound or westbound—are between Surprise, Peoria, Glendale, and Phoenix, and are simply using Bell Road as a “bridge.”

Central Avenue

Traffic on the two select link segments in the Central Avenue corridor show patterns that might be expected given the makeup of the area as primarily an office employment corridor. During the midday, when most trips are for nonwork purposes, the primary movements on Central Avenue north of Osborn Road are either people coming to the area from the outside (33.3 percent), probably to attend meetings or conduct other business; leaving the area (29.8 percent), conceivably to satisfy activity needs such as shopping that are not found in the area; or traveling through (25.8 percent) because it is a major north-south artery. During the PM peak period, when traffic conditions worsen, the situation changes character, with the majority of traffic either moving directly through the area (48.6 percent) or workers leaving the office environment to return home (28.5 percent). Only a small percentage of traffic in either period is internal-internal. The other link samples traffic patterns west-to-east through the corridor, along Thomas Road (just west of the intersection with Central Avenue). Here, a much higher percentage of though traffic is evidenced, with more than 57 percent of traffic volumes in both midday and PM peak periods being external-external. It is worth noting, therefore, that the high V/C ratios on this facility in both periods are largely a function of through traffic movements and not to development in the Central Avenue corridor itself.

Tempe

The select link examinations in the Tempe area are performed in both east-west (Apache Boulevard and Broadway Road) and north-south (Mill Avenue and Rural Road) facilities—since the corridor is somewhat L-shaped through Tempe, more or less following the south/eastern alignment of the new LRT line. Flows are evaluated in both directions on all facilities.

The north-south arterials of Mill Avenue and Rural Road both show considerable congestion in both midday and peak periods. However, the facilities, their design and setting, and the environments they serve are quite different, which is evident in the traffic composition. Mill Avenue north of University Drive is one of the most pedestrian-friendly areas in Phoenix, boasting multiple shops and attractions that abut the street, tree-lined sidewalks, and curb parking. While the street probably has the width to operate as a six-lane arterial, its design discourages through travel. Dedicated bike lanes are provided in both directions, while landscaped medians and turning lanes channel traffic such that there are only effectively three lanes (one northbound, two southbound) providing continuous through service. This section of Mill Avenue exhibits high V/C ratios in both midday and peak, but as seen in Tables 15A and 15B, only a very small portion is through traffic (less than 10 percent). The greatest proportion of trips are by travelers coming to or going from the study area from the outside (between 46 percent and 60 percent) in both the midday and peak. And a fairly substantial percentage—between 19 percent and 21 percent—are trips being made entirely within the study area.

Table 15A. Composition of Travel on Selected Links—Midday Period.

Study Area	Location	Internal-Internal	Internal-External	External-Internal	External-External
Scottsdale	EB Indian School, W of Scottsdale Road	9.6%	5.3%	58.1%	27.0%
	NB Scottsdale Road, N of Indian School	23.5%	9.5%	44.0%	23.0%
	NB Goldwater Road, N of Indian School	19.3%	19.1%	34.0%	27.6%
	NB Drinkwater Road, N of Indian School	34.5%	42.7%	22.8%	0.1%
Bell Road	WB Bell Road, between El Mirage and 115th	9.2%	26.2%	15.3%	49.3%
	EB Bell Road, between El Mirage and 115th	9.4%	23.3%	17.2%	57.2%
Central Avenue	NB Central Avenue, N of Osborn	11.1%	29.8%	33.3%	25.8%
	EB Thomas Road, W of Central Avenue	2.3%	23.3%	17.2%	57.2%
Tempe	WB Apache Boulevard, W of McClintock	18.9%	3.6%	69.3%	8.3%
	EB Apache Boulevard, W of McClintock	17.7%	70.5%	2.7%	9.6%
	WB Broadway Boulevard, W of McClintock	0.0%	14.3%	34.2%	51.5%
	EB Broadway Boulevard, W of McClintock	0.0%	28.2%	16.2%	55.6%
	NB Mill Avenue, North of University Drive	21.1%	22.7%	51.3%	4.9%
	SB Mill Avenue, North of University Drive	21.1%	52.0%	20.9%	6.0%
	NB Rural Road, North of University Drive	1.6%	64.4%	1.5%	32.4%
	SB Rural Road, North of University Drive	1.6%	1.6%	58.9%	38.2%

Table 15B. Composition of Travel on Selected Links—PM Peak Period.

Study Area	Location	Internal-Internal	Internal-External	External-Internal	External-External
Scottsdale	EB Indian School, w of Scottsdale Road	9.9%	6.7%	54.8%	28.6%
	NB Scottsdale Road, N of Indian School	24.7%	10.7%	42.5%	22.1%
	NB Goldwater Road, N of Indian School	18.7%	17.9%	35.2%	28.2%
	NB Drinkwater Road, N of Indian School	32.2%	46.4%	21.3%	0.0%
Bell Road	WB Bell Road, between El Mirage and 115th	9.3%	27.9%	16.5%	46.3%
	EB Bell Road, between El Mirage and 115th	10.2%	16.4%	27.0%	46.4%
Central Avenue	NB Central Avenue, N of Osborn	5.6%	28.5%	17.2%	48.6%
	EB Thomas Road, W of Central Avenue	3.5%	22.2%	16.4%	57.9%
Tempe	WB Apache Boulevard, W of McClintock	22.7%	3.9%	65.7%	7.7%
	EB Apache Boulevard, W of McClintock	8.6%	68.9%	1.9%	20.7%
	WB Broadway Boulevard, W of McClintock	0.0%	15.7%	37.7%	46.6%
	EB Broadway Boulevard, W of McClintock	0.2%	35.1%	10.0%	54.7%
	NB Mill Avenue, North of University Drive	19.4%	26.7%	46.2%	7.6%
	SB Mill Avenue, North of University Drive	19.3%	58.6%	13.7%	8.3%
	NB Rural Road, North of University Drive	0.1%	74.1%	0.1%	25.8%
	SB Rural Road, North of University Drive	1.2%	1.5%	48.1%	49.2%

In marked contrast, Rural Road, which becomes Scottsdale Road as it moves north of the Salt River, is much more of a through artery by design. It is not richly developed as is Mill Avenue and features six lanes of unobstructed capacity for vehicles, plus separate turning lanes. The volumes carried by Rural Road are almost three times those using Mill Avenue, and this shows up in local use rates that are almost nil (1.6 percent midday and 1.2 percent or less during the peak), while through trip rates are between 32 percent and 38 percent midday, and 26 percent to 49 percent during the peak. The major share, however, is composed of trips entering or leaving the area from the outside, which would appear to be encouraged by the connection with the L202 freeway north of the Salt River as Rural Road becomes Scottsdale Road and, importantly, continues on north into Scottsdale.

The traffic flows on Apache Boulevard are similar in character to those on Mill Avenue, while those on Broadway are more like those on Rural Road. Broadway seems to serve primarily a through trip market, while Apache Boulevard seems much more linked with the activities of the university. Apache Boulevard not only serves as the east-west transportation spine of the university campus, but offers direct connection with the L101 freeway some two miles to the east; this appears to be a major travel corridor for students who attend the university (or employees) but live elsewhere in the region. (A similar relationship likely explains the high internal/external travel on Rural Road.) Based on MAG trip table data, it appears that only about 22.9 percent of student trips originate in the study area (destined to the university in TAZ 1171); another 9.6 percent start from somewhere else in Tempe, while 67.5 percent come from elsewhere in the region. Trips by employees are even more skewed, with only about 10 percent living in Tempe and the remaining 89.5 percent traveling from elsewhere in the region.

A different situation is presented on Broadway Road at the southern edge of the study area, where the predominant trip movements are through the study area (external-external), although the next largest share is again internal-external in the eastbound direction and external-internal in the westbound direction.

TRANSIT USE

Transit is another factor that impacts the degree of vehicle traffic and congestion that is generated by intensified land use. For transit to be a viable alternative to driving, it must serve destinations that are within convenient walk access. Although transit riders, particularly those making long trips like commuters, are willing to drive to a park-and-ride lot at the beginning of the trip, only the most economically dependent travelers will endure a transit trip that requires a transfer, due to the extra time and uncertainty which that entails. Therefore, use of transit to access a destination area depends on not only the density of the area but the array of opportunities also located there, the ability to walk to the primary destination, and the ability to reach other activities once there without need of a car. The other factors influencing choice of transit are frequent service and convenient access on the origin end (with the allowance for auto access in outlying areas) as well as competitive door-to door travel times. Typically, these conditions are more likely to occur in more urban (dense, mixed-use, walkable) settings. Restricted and priced parking at the destination is another inducement to consider transit, as are high fuel costs.

Phoenix currently offers only bus transit—both local and express—although the initial Central Avenue to Tempe LRT line began service in December 2008. The Scottsdale and Tempe study areas also offer free local circulator service. Scottsdale has both the Downtown Trolley, which operates on 10 minute headways, and the Neighborhood Trolley that has 20 minute headways. Tempe has five “Orbit” routes that are mainly university-oriented, each of which is free and operates on 15 minute headways as well as a community shuttle (FLASH).

Using data from MAG’s travel forecasting model, current rates of transit use to and from the four study areas were analyzed. Results are summarized in Table 16 by trip orientation and for peak and off-peak time periods. MAG regards peak-period travel to be composed of primarily work and school trips, while off-peak is assumed to consist of primarily nonwork trip purposes.

Table 16. Comparative Transit Mode Share by Study Area.

Time Period	Study Area	Internal - Internal (I-I)	Internal - External (I-X)	External - Internal (X-I)
Peak	Scottsdale	5.5%	5.5%	3.0%
	Bell Road	0.8%	0.8%	0.4%
	Central Avenue	8.4%	6.5%	6.7%
	Tempe	2.8%	10.0%	4.5%
Off-Peak	Scottsdale	1.0%	1.0%	1.0%
	Bell Road	0.0%	0.1%	0.0%
	Central Avenue	0.9%	0.8%	3.1%
	Tempe	0.6%	0.9%	0.9%

Looking at the table affirms that, first, peak period transit use rates are much higher than off-peak, given traditionally higher reliance on transit for daily routine work trips when transit service is better and road congestion is generally worse. The table also shows that the Central Avenue corridor has the highest transit use rates of all areas, but primarily in the peak period, given the concentration of employment in the corridor and that Central Avenue is itself a transit corridor with multiple lines and good service. Central Avenue supports numerous local and four express bus lines. The local services include the Blue Line (15 to 30 minute headways), Route 0 (6 to 12 minutes peak and 15 minutes off-peak) and Route 10 (15 minutes peak and off-peak); these are major north-south routes. The Red and Yellow lines, which are predominantly east-west lines, also briefly run north-south along the lower portion of Central Avenue, serving to facilitate inter-route transferring and also adding to bus activity. When these services are looked at as a group, Central Avenue enjoys a very high level of transit service and connectivity to the region. Between 6.5 percent and 6.7 percent of persons either leaving the area or coming to the area in the peak period use transit, and 8.4 percent of trips made internally are made by transit. This is an important contribution to mobility levels in the corridor, as these are trips that would otherwise have been made by private vehicle and contributed to a higher V/C ratio. In the Central Avenue study area, 3.1 percent of its off-peak visitors also arrive by transit.

The Scottsdale study area ranks second in transit use, with 5.5 percent of its residents using transit for peak period trips either inside or outside the study area, and 3.0 percent of visitors to the study area using transit. The Tempe study area has a higher share of visitor trips arriving by transit (4.5 percent) than Scottsdale (3.0 percent), and fewer internal trips made by transit (2.8 percent vs. 5.5 percent). However, the rate of use for trips outside the study area is the highest of any area at 10.0 percent in the peak period. Off-peak rates of transit use in any of the first three areas are unremarkable, averaging at or below 1 percent of trips. It is impossible to tell from the data available what portion of these trips are enabled by or carried entirely on the free shuttle services described above.

Transit use in the Bell Road study area is very sparse, averaging less than 1 percent for peak period trips and 0.1 percent or less in the off-peak. Transit service in the corridor is rather limited. It is primarily oriented to travel outside the corridor and elsewhere in the region, with the nearest access point being the Arrowhead Towne Center east of L101.

DIRECTIONALITY OF TRAVEL AND INTERNAL TRIP CAPTURE

A central tenet to good land use design is that it integrates enough of the services that households and workers need such that a high proportion of those needs can be satisfied internally. This should show up in several ways: a higher percentage of trips made to internal destinations; shorter trip lengths; and ideally, fewer trips by vehicle and more by walking, biking, or local transit.

To examine this property among the four study areas, MAG trip table data for 2008 were obtained and processed to analyze the directionality of trip flows into, out of, and within each area. This was done separately for each of the five trip purposes: home-based work, home-based university, home-based other, nonhome-based work, and nonhome-based other. Definitions of the trip purposes follow:

- **Home-based Work (HBW):** The traditional commute trip, typically capturing the trip from home to work and its return. It may also cover trips from home to a work-related activity, such as a business meeting or a telework center. If the trip from home to work is interrupted by a stop for another purpose (e.g., shopping), then the trip is generally reported as a home-based other trip followed by a nonhome-based work trip (NHW).
- **Home-based University (HBU):** As above, but with the destination as a college or university campus or facility.
- **Home-based Other (HBO):** Every other trip to or from home that is not for the purpose of work or attending college, including shopping, social, recreational, personal business, etc.
- **Nonhome-based Work (NHW):** Trips made to a work-related location, but not from home.
- **Nonhome-based Other (NHO):** Similar in purpose to HBO, but not starting from home.

Since these data are compiled at the TAZ level, the analysis aggregated TAZs to represent not only the study area but principal locations generating or attracting travel outside the study area.

The essential findings from this analysis are summarized in Table 17. It shows the number of trips made for each of the five trip purposes by their essential orientation: internal-internal, internal-external, and external-internal. External-external trips are not meaningful in this context, so they have not been reported. While through trips have an important impact on traffic levels in a study area, the proper way to gauge them is through a select link analysis, as was done in a previous section, since the great majority of other trips occurring in the region are unlikely to pass through the given study area.

In addition to showing the relative proportions of trips made by purpose, Table 17 provides two statistics that help characterize the nature of the area as a net importer or exporter of travel. The internal capture rate measures the percentage of all trips generated by study area trip makers that remain within the study area, as opposed to going outside to be served. The second statistic measures the percent of all trips by purpose with destinations in the study area that are made by study area residents, as opposed to being imported from the outside. The following observations were made from the data in Table 17.

Scottsdale

As the project's best example of compact, mixed-land use, the Scottsdale study area's major indicator of success is its high internal capture rates for HBO, NHW, and NHO trips. While it is also a major employment area, Scottsdale is typical of many other areas around the country where residents choose to live there for a variety of reasons but may very well work someplace else. As stated earlier, the two most significant effects of land use on travel that have been found in the research are reduced levels of household vehicle ownership and fewer VMT for nonwork activities. Thus, only 21.2 percent of the HBW trips made by Scottsdale residents are made to work destinations within the study area. Based on more detailed study data, the highest percentage of these trips are going to Phoenix (34.3 percent), with acceptably large numbers going to the remainder of Scottsdale (17.5 percent) and Tempe (14.5 percent). It was also observed in the preceding section that 5.5 percent of these HBW trips are being made by transit. However, the major indication of Scottsdale's composition is the rate at which it captures residents' HBO (62.6 percent), NHW (34.7 percent), and NHO (55.2 percent) travel—clearly the highest of the four study areas. The high rates of visitation from origins outside the study area (X-I) also give evidence to the draw of this area to the rest of the region as an attractive destination.

Table 17. Trip Orientation and Internal Capture Rates by Trip Purpose.

Scottsdale

Trip Purpose	Internal - Internal (I-I)	Internal - External (I-X)	Total Internally Generated Trips (I-I + I-X)	Internal Capture Rate	External - Internal (X-I)	Total Trips w/ Internal Destination (I-I + X-I)	Percent of All Trips Internally Served
Home-Based Work	8,740	32,449	41,189	21.2%	48,033	56,773	15.4%
Home-Based University	176	3,909	4,085	4.3%	1,279	1,455	12.1%
Home-Based Other	55,509	33,231	88,740	62.6%	79,790	135,299	41.0%
Non-Home-Based Work	13,893	26,166	40,059	34.7%	27,049	40,942	33.9%
Non-Home-Based Other	34,042	27,684	61,726	55.2%	29,473	63,515	53.6%
ALL	112,360	123,439	235,799	47.7%	185,624	297,984	37.7%

Bell Road

Trip Purpose	Internal - Internal (I-I)	Internal - External (I-X)	Total Internally Generated Trips (I-I + I-X)	Internal Capture Rate	External - Internal (X-I)	Total Trips w/ Internal Destination (I-I + X-I)	Percent of All Trips Internally Served
Home-Based Work	3,023	19,529	22,552	13.4%	17,255	20,278	14.9%
Home-Based University	2	1,424	1,426	0.1%	112	114	1.8%
Home-Based Other	46,031	64,184	110,215	41.8%	64,964	110,995	41.5%
Non-Home-Based Work	5,858	14,980	20,838	28.1%	14,336	20,194	29.0%
Non-Home-Based Other	23,425	22,825	46,250	50.6%	22,504	45,929	51.0%
ALL	78,339	122,942	201,281	38.9%	119,171	197,510	39.7%

Central Avenue

Trip Purpose	Internal - Internal (I-I)	Internal - External (I-X)	Total Internally Generated Trips (I-I + I-X)	Internal Capture Rate	External - Internal (X-I)	Total Trips w/ Internal Destination (I-I + X-I)	Percent of All Trips Internally Served
Home-Based Work	2,767	10,248	13,015	21.3%	72,697	75,464	3.7%
Home-Based University	0	967	967	0.0%	0	0	NA
Home-Based Other	6,241	22,474	28,715	21.7%	31,126	37,367	16.7%
Non-Home-Based Work	5,130	22,120	27,250	18.8%	22,809	27,939	18.4%
Non-Home-Based Other	2,230	9,649	11,879	18.8%	9,931	12,161	18.3%
ALL	16,368	65,458	81,826	20.0%	136,563	152,931	10.7%

Tempe

Trip Purpose	Internal - Internal (I-I)	Internal - External (I-X)	Total Internally Generated Trips (I-I + I-X)	Internal Capture Rate	External - Internal (X-I)	Total Trips w/ Internal Destination (I-I + X-I)	Percent of All Trips Internally Served
Home-Based Work	3,709	16,987	20,696	17.9%	47,074	50,783	7.3%
Home-Based University	12,744	1,125	13,869	91.9%	44,484	57,228	22.3%
Home-Based Other	18,620	28,199	46,819	39.8%	51,553	70,173	26.5%
Non-Home-Based Work	6,716	23,548	30,264	22.2%	24,219	30,935	21.7%
Non-Home-Based Other	10,673	19,169	29,842	35.8%	20,183	30,856	34.6%
ALL	52,452	89,028	141,480	37.1%	187,512	239,964	21.9%

Bell Road

Based on the arguments used to commend Scottsdale's performance on land use to internalize a high percentage of its trips, it would appear difficult to rationalize the results seen for the Bell Road corridor. It is not surprising that the percentage of HBW trips retained internally is so small (13.4 percent) given that the study area does not contain a great deal of employment. Indeed, looking at the more detailed data, these trips are going to a broad distribution of locations across the region. Only modest shares of HBW trips are made to adjacent Peoria (18.9 percent), Surprise (8.5 percent), Glendale (3.2 percent), or Phoenix (2.4 percent), which means that more than half (53.6 percent) of all HBW trips are going to destinations elsewhere in the region. In terms of nonwork travel, however, the Bell Road study area is exhibiting internal capture shares almost on a par with Scottsdale, with 41.8 percent of HBO trips, 28.1 percent of NHW trips, and 50.6 percent of NHO trips made within the Bell Road study area. In addressing this apparent contradiction with the principles of good land use (compact, mix of uses, pedestrian scale accessibility) illustrated by Scottsdale, several factors must be considered.

First, it is likely that there are enough shopping centers in the Bell Road corridor to meet its population's basic needs for groceries, household items, services, and even entertainment. However, the Bell Road study area covers the largest land area of any of the four areas. Its 13 TAZs cover 17.3 square miles compared to Scottsdale's 34 zones covering only 8.9 square miles, Central Avenue's 22 zones covering 3.1 square miles, and Tempe's 17 zones covering 5.2 square miles. It should not be surprising, therefore, that these travel activities can be contained within the study area boundaries. The questions then become how long are these trips and how many vehicle miles does it take to accomplish them? This characteristic will be explored in the next section. It has already been determined that only a very small percentage of these trips are made by transit.

Central Avenue

While density and possibly design are working in its favor, the Central Avenue corridor suffers in the dimension of diversity in terms of mix and balance. The data show that the area is a net importer of trips and that only a fairly small percentage of its HBO, NHW, and NHO trips are internally retained. Also adding to this relationship, however, is the size of the area, which is the smallest of all the study areas at 3.1 miles. Hence, the more detailed analysis indicates that 46.6 percent of its HBW trips are made to an adjacent regional activity zone (or multizone cluster defined by MAG to represent a planning district), as are 58.4 percent of its HBO trips and 49.6 percent each of its NHW and NHO trips. Again, the next test for these relationships is to look at average trip length, since travelers may go outside the study area but they may not need to go significantly far.

Tempe

As earlier determined, land use in the Tempe study area falls short of the ideal mainly in terms of its design, wherein its land uses are mixed but are not laid out in a way that facilitates easy local access, particularly on foot. This is clearly reflected in its internal capture statistics. It does retain 91.9 percent of its internally generated university trips, but only 22.3 percent of HBU trips are made by persons living in the study area; almost 80 percent of trips to the university originate outside the Tempe study area. In terms of the other trip types, the study area retains only 17.9 percent of its HBW trips, 39.8 percent of its HBO trips, 22.2 percent of its NHW trips, and 35.8 percent of its NHO trips. As with Bell Road, the Tempe study area is large enough at 5.2 miles to contain enough attractions to satisfy its population’s needs, but the nature of the mix and particularly the design of the area apparently do not compel a high degree of internal activity satisfaction. Again, examination of average trip lengths may provide some additional insight as to whether Tempe’s land use conveys any notable efficiency.

AVERAGE TRIP LENGTHS

Perhaps the most definitive test of efficiency associated with land use is trip length, which, when combined with mode choice (decision to drive, in particular), results in VMT, the primary element in traffic congestion. VMT generation is perhaps the single most relevant performance indicator in analyzing traffic congestion since the longer the trip, the more miles of street and highway facility that are impacted. This means that trips that are generated in an outlying suburb will also impose impacts on facilities that are quite distant from their origin and contribute to the respective recipient area’s traffic loads and congestion.

The trip table data presented in the previous section was mated with zone-to-zone travel distances for the same origin-destination trips. Researchers obtained averages by multiplying the number of trips in each set of origin-destination movement with the respective trip distance, and then computing the average distance for a single representative trip. The results are given in Table 18 by trip purpose and for the primary internal to internal, internal to external, all internally generated, and external to internal trip movements.

Perhaps the most relevant comparative statistic in each case is the average trip length for all internally generated travel. This measure not only accounts for a higher percentage of trips that may be retained within the study area (and, hence, be expected to be shorter than trips outside), but also reflect the proximity associated with good land use mix both inside and outside the study area.

Below are the comparative trip lengths across the four study areas:

- HBW: Even though work travel is typically the purpose least influenced by local land use, and relatively few of any study area residents work in their own study area, proximity is still a factor in determining trip length. This is seen in trip lengths of 9.3 to 10.1 miles among the three more urban and close-in study areas vs. 21.8 for the Bell Road study area. Moreover, these differences do not account for the higher use of transit in the Scottsdale, Central Avenue, and Tempe study areas, which would also translate to less VMT for the indicated miles traveled.

Table 18. Average Trip Lengths by Trip Purpose (in miles).

Scottsdale Rd Corridor

	HBW	HBU	HBO	NHW	NHO
Internal-Internal	1.38	1.87	1.26	1.31	0.99
Internal-External	12.43	3.89	8.13	13.51	10.31
All Internally Generated	10.08	3.80	3.83	9.28	5.17
External-Internal	23.09	15.43	11.27	14.98	12.20

Bell Rd Corridor

	HBW	HBU	HBO	NHW	NHO
Internal-Internal	2.14	2.66	1.61	1.99	1.33
Internal-External	24.85	20.45	26.56	23.83	22.16
All Internally Generated	21.81	20.43	26.53	17.69	11.61
External-Internal	29.97	30.50	23.07	24.61	23.04

Central Ave. Corridor

	HBW	HBU	HBO	NHW	NHO
Internal-Internal	1.03	NA	0.96	0.94	0.79
Internal-External	11.54	11.42	11.30	12.67	11.52
All Internally Generated	9.30	11.42	9.05	10.46	9.51
External-Internal	17.05	NA	11.71	13.17	12.03

Apache Blvd Corridor

	HBW	HBU	HBO	NHW	NHO
Internal-Internal	1.09	0.87	0.93	0.98	0.62
Internal-External	11.34	10.58	10.38	12.62	10.91
All Internally Generated	9.50	1.66	6.62	10.03	7.23
External-Internal	15.95	15.10	12.12	13.32	11.90

- HBU: The number and location of university destinations is limited across the region so it is difficult to draw conclusions about the impacts of land use on trips for this purpose. Predictably, Tempe has the shortest combined trip length (1.66 miles) while neighboring Scottsdale is a close second (3.8 miles).
- HBO: This and NHO are perhaps the most significant trip purpose categories regarding land use importance since they account for about 80 percent of all household travel and are most likely to be affected by the shape of development closer to home. In this regard, the 3.83 miles per average HBO trip in Scottsdale contrasts sharply with 26.53 miles in the Bell Road corridor, despite having similar rates of internal capture. Both differences in mix and compactness are reflected in these comparisons. Central Avenue study area residents average 9.05 miles per HBO trip, given the less than desirable mix within that study area, and 6.62 miles in Tempe—midway between Scottsdale and Central Avenue—owing to a better mix than Central Avenue, but still not the proximity afforded by the design in Scottsdale.
- NHO: The average NHO trip length in the Bell Road corridor falls significantly, to 11.61 miles per trip. In order of magnitude, it is not nearly as disproportionate to the others as is HBO, with Scottsdale registering 5.17 miles; Central Avenue, 9.51 miles; and Tempe, 7.23 miles. However, considering that nonhome based trips are frequently the next trips in a trip tour (chain), and hence will be shorter in length if the next related activity is nearby, the average in-between trip in the Bell Road area is still twice as far as the equivalent trip in Scottsdale.
- NHW: If this trip purpose covered all work-based trips—work-related and discretionary—it would reflect good land use in the vicinity of employment centers. Workers would be able to make more trips from work either without using cars or through short trips. However, these are trips made for a work purpose, but not originating from home, so they may be trips to meetings or trips from a nonhome origin to a workplace that could occur anywhere along the trip between home and work or work and home. Still, the data show the longest trip lengths occurring in the Bell Road study area (17.69 miles), followed by a closely grouped Central Avenue (10.46 miles), Tempe (10.03 miles), and Scottsdale (9.28 miles).

WALK AND BIKE USE

Having demonstrated that transit use is greater in the higher-density mixed-use areas and that trip lengths are shorter due to internal capture, researchers examined whether rates of walk and bike use are higher in these places also. Since MAG's model (like virtually all regional four-step travel forecasting models) does not incorporate nonmotorized modes in the analysis process, researchers used data from the 2001 MAG regional household travel survey. These surveys follow a fairly standard format of collection of trip data in 48 hour travel diaries from all members of a surveyed household regardless of age. The survey collected data from 4,018 households in Maricopa and a small portion of Pima County, amounting to information about 10,030 individuals and 78,511 trips.

Trip records were processed for all households residing in TAZs that defined the four individual study areas. For each zone, the analysis determined the number of households surveyed, the total number of trips made by purpose, and the portions of those trips that were made by walking or bicycling. The results are summarized in Tables 19A, 19B, and 19C, which indicate, respectively, the number of trips by purpose and mode for each of the four areas (19A), the average daily trip rates by purpose and mode per household in the four study areas (19B), and the percentage of trips by each purpose that were made by walking or biking (19C).

Perhaps the most relevant table in addressing question of whether walk or bike use is greater in the more urban, mixed-use areas is Table 19C, which shows the percentage of trips of particular purposes that are made by walking and biking. Overall, the table shows that the Tempe area has the highest rates of walk and bike use, amounting to 10.01 percent and 8.72 percent, respectively, followed by Scottsdale (5.35 percent walk and 1.17 percent bike), Central Avenue (3.34 percent walk and1.67 percent bike) and Bell Road (3.17 percent walk and 0.85 percent bike). Among the most popular trip purposes for walking are changing mode of transportation (all areas), recreational (Scottsdale and Tempe), fitness activity (Tempe, Bell Road, and Scottsdale), attending school (Central Avenue, Bell Road, and Tempe), attending school-related activities (Tempe and Scottsdale), entertainment (Tempe and Scottsdale), eating a meal (Tempe and Scottsdale), and other personal business (Tempe and Scottsdale). Biking is less common than walking in all areas and for all purposes, except in Tempe, where rates of bike use are greater than walking for purposes like Work and School, and are also high for Fitness and School Activities. Bike use is extremely limited in the other three study areas.

Despite the appearance of confirming expected trends, the authors caution against reading too much from these data, however. The overall household trip rates seem very low in comparison to national standards, and indeed, when these rates are inspected at the level of individual TAZs, there are quite a few cases where the average household trip rate for a zone is less than 1.0 (which is very unlikely) and a surprising number of zones where no household trips were recorded at all, even with 10 or more households making up the sample. The survey may have been affected by the unfortunate occurrence of its timing with the September 2001 terrorist attacks, which may have dissuaded people from unnecessary travel or from effectively participating in a survey. Whatever the cause, researchers suggested that these relationships be considered for broadly qualitative purposes only.

Table 19A. Daily Household (HH) Trips by Purpose and Mode.

		Scottsdale (705 HH)			Bell Road (483 HH)			Central Ave (490 HH)			Tempe (630 HH)		
ACT 1	Purpose	Tot Trips	Walk	Bike	Tot Trips	Walk	Bike	Tot Trips	Walk	Bike	Tot Trips	Walk	Bike
1	Work at home	3	0	0	0	0	0	1	0	0	1	0	0
2	Shop from home	0	0	0	0	0	0	0	0	0	0	0	0
3	All other home activities	936	30	9	724	13	7	275	5	4	502	40	38
4	Change mode of transportation	36	11	0	6	1	0	7	4	0	12	6	0
5	Pick up passenger/self	38	0	0	32	2	0	11	0	0	27	0	0
6	Drop off passenger/self	69	0	0	46	0	0	12	0	0	30	0	0
7	ATM, gas, quick stop	35	3	0	17	1	0	5	0	0	13	0	0
8	Shopping	147	7	3	140	6	1	38	0	0	64	10	3
9	Banking, post office, pay bills	36	0	0	32	0	0	2	0	0	11	0	0
10	Other personal business	89	9	0	51	0	2	28	0	0	38	5	2
11	Work or regular volunteering	182	15	5	80	0	2	61	4	2	116	5	17
12	Work related	28	0	0	40	4	0	11	2	0	15	2	1
13	Attend school	41	2	1	15	4	0	5	2	0	53	8	18
14	Other school activities	8	2	0	10	0	0	4	0	0	12	7	3
15	Childcare/daycare	2	0	0	5	0	0	0	0	0	4	0	0
16	Eat meal	76	8	1	49	3	0	19	1	0	32	7	2
17	Medical	29	0	0	26	0	0	9	0	1	5	0	0
18	Fitness activity	26	4	0	32	7	0	7	0	2	15	7	4
19	Recreational	16	5	0	14	0	0	5	0	0	10	1	0
20	Entertainment	34	4	0	12	1	0	14	0	0	10	2	0
21	Visit friends/relatives	65	3	4	35	2	0	21	0	0	18	0	0
22	Community/civic	9	0	0	5	0	0	0	0	0	0	0	0
23	Occasional volunteer work	16	2	0	2	0	0	0	0	0	3	0	0
24	Church/temple/religious	13	0	0	22	0	0	0	0	0	2	0	0
25	Accompany another person	8	0	0	9	0	0	2	0	0	10	1	0
97	Other	19	0	0	15	1	0	2	0	0	6	0	0
	Total	1961	105	23	1419	45	12	539	18	9	1009	101	88

Table 19B. Daily Household (HH) Trip Rates by Purpose and Mode.

		Scottsdale (705 HH)			Bell Road (483 HH)			Central Ave (490 HH)			Tempe (630 HH)		
ACT 1	Purpose	Tot Trips	Walk	Bike	Tot Trips	Walk	Bike	Tot Trips	Walk	Bike	Tot Trips	Walk	Bike
1	Work at home	0.004	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.002	0.000	0.000
2	Shop from home	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	All other home activities	1.328	0.043	0.013	1.499	0.027	0.014	0.561	0.010	0.008	0.797	0.063	0.060
4	Change mode of transportation	0.051	0.016	0.000	0.012	0.002	0.000	0.014	0.008	0.000	0.019	0.010	0.000
5	Pick up passenger/self	0.054	0.000	0.000	0.066	0.004	0.000	0.022	0.000	0.000	0.043	0.000	0.000
6	Drop off passenger/self	0.098	0.000	0.000	0.095	0.000	0.000	0.024	0.000	0.000	0.048	0.000	0.000
7	ATM, gas, quick stop	0.050	0.004	0.000	0.035	0.002	0.000	0.010	0.000	0.000	0.021	0.000	0.000
8	Shopping	0.209	0.010	0.004	0.290	0.012	0.002	0.078	0.000	0.000	0.102	0.016	0.005
9	Banking, post office, pay bills	0.051	0.000	0.000	0.066	0.000	0.000	0.004	0.000	0.000	0.017	0.000	0.000
10	Other personal business	0.126	0.013	0.000	0.106	0.000	0.004	0.057	0.000	0.000	0.060	0.008	0.003
11	Work or regular volunteering	0.258	0.021	0.007	0.166	0.000	0.004	0.124	0.008	0.004	0.184	0.008	0.027
12	Work related	0.040	0.000	0.000	0.083	0.008	0.000	0.022	0.004	0.000	0.024	0.003	0.002
13	Attend school	0.058	0.003	0.001	0.031	0.008	0.000	0.010	0.004	0.000	0.084	0.013	0.029
14	Other school activities	0.011	0.003	0.000	0.021	0.000	0.000	0.008	0.000	0.000	0.019	0.011	0.005
15	Childcare/daycare	0.003	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000
16	Eat meal	0.108	0.011	0.001	0.101	0.006	0.000	0.039	0.002	0.000	0.051	0.011	0.003
17	Medical	0.041	0.000	0.000	0.054	0.000	0.000	0.018	0.000	0.002	0.008	0.000	0.000
18	Fitness activity	0.037	0.006	0.000	0.066	0.014	0.000	0.014	0.000	0.004	0.024	0.011	0.006
19	Recreational	0.023	0.007	0.000	0.029	0.000	0.000	0.010	0.000	0.000	0.016	0.002	0.000
20	Entertainment	0.048	0.006	0.000	0.025	0.002	0.000	0.029	0.000	0.000	0.016	0.003	0.000
21	Visit friends/relatives	0.092	0.004	0.006	0.072	0.004	0.000	0.043	0.000	0.000	0.029	0.000	0.000
22	Community/civic	0.013	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	Occasional volunteer work	0.023	0.003	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000
24	Church/temple/religious	0.018	0.000	0.000	0.046	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000
25	Accompany another person	0.011	0.000	0.000	0.019	0.000	0.000	0.004	0.000	0.000	0.016	0.002	0.000
97	Other	0.027	0.000	0.000	0.031	0.002	0.000	0.004	0.000	0.000	0.010	0.000	0.000
	Total	2.782	0.149	0.033	2.938	0.093	0.025	1.100	0.037	0.018	1.602	0.160	0.140

Table 19C. Percent of Daily Household (HH) Trips by Purpose (Walk or Bike).

		Scottsdale (705 HH)			Bell Road (483 HH)			Central Ave (490 HH)			Tempe (630 HH)		
ACT 1	**Purpose**	**Tot Trips**	**Walk**	**Bike**	**Tot Trips**	**Walk**	**Bike**	**Tot Trips**	**Walk**	**Bike**	**Tot Trips**	**Walk**	**Bike**
1	Work at home	3	0.00%	0.00%	0	NA	NA	1	0.00%	0.00%	1	0.00%	0.00%
2	Shop from home	0	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA
3	All other home activities	936	3.21%	0.96%	724	1.80%	0.97%	275	1.82%	1.45%	502	7.97%	7.57%
4	Change mode of transportation	36	30.56%	0.00%	6	16.67%	0.00%	7	57.14%	0.00%	12	50.00%	0.00%
5	Pick up passenger/self	38	0.00%	0.00%	32	6.25%	0.00%	11	0.00%	0.00%	27	0.00%	0.00%
6	Drop off passenger/self	69	0.00%	0.00%	46	0.00%	0.00%	12	0.00%	0.00%	30	0.00%	0.00%
7	ATM, gas, quick stop	35	8.57%	0.00%	17	5.88%	0.00%	5	0.00%	0.00%	13	0.00%	0.00%
8	Shopping	147	4.76%	2.04%	140	4.29%	0.71%	38	0.00%	0.00%	64	15.63%	4.69%
9	Banking, post office, pay bills	36	0.00%	0.00%	32	0.00%	0.00%	2	0.00%	0.00%	11	0.00%	0.00%
10	Other personal business	89	10.11%	0.00%	51	0.00%	3.92%	28	0.00%	0.00%	38	13.16%	5.26%
11	Work or regular volunteering	182	8.24%	2.75%	80	0.00%	2.50%	61	6.56%	3.28%	116	4.31%	14.66%
12	Work related	28	0.00%	0.00%	40	10.00%	0.00%	11	18.18%	0.00%	15	13.33%	6.67%
13	Attend school	41	4.88%	2.44%	15	26.67%	0.00%	5	40.00%	0.00%	53	15.09%	33.96%
14	Other school activities	8	25.00%	0.00%	10	0.00%	0.00%	4	0.00%	0.00%	12	58.33%	25.00%
15	Childcare/daycare	2	0.00%	0.00%	5	0.00%	0.00%	0	NA	NA	4	0.00%	0.00%
16	Eat meal	76	10.53%	1.32%	49	6.12%	0.00%	19	5.26%	0.00%	32	21.88%	6.25%
17	Medical	29	0.00%	0.00%	26	0.00%	0.00%	9	0.00%	11.11%	5	0.00%	0.00%
18	Fitness activity	26	15.38%	0.00%	32	21.88%	0.00%	7	0.00%	28.57%	15	46.67%	26.67%
19	Recreational	16	31.25%	0.00%	14	0.00%	0.00%	5	0.00%	0.00%	10	10.00%	0.00%
20	Entertainment	34	11.76%	0.00%	12	8.33%	0.00%	14	0.00%	0.00%	10	20.00%	0.00%
21	Visit friends/relatives	65	4.62%	6.15%	35	5.71%	0.00%	21	0.00%	0.00%	18	0.00%	0.00%
22	Community/civic	9	0.00%	0.00%	5	0.00%	0.00%	0	NA	NA	0	NA	NA
23	Occasional volunteer work	16	12.50%	0.00%	2	0.00%	0.00%	0	NA	NA	3	0.00%	0.00%
24	Church/temple/religious	13	0.00%	0.00%	22	0.00%	0.00%	0	NA	NA	2	0.00%	0.00%
25	Accompany another person	8	0.00%	0.00%	9	0.00%	0.00%	2	0.00%	0.00%	10	10.00%	0.00%
97	Other	19	0.00%	0.00%	15	6.67%	0.00%	2	0.00%	0.00%	6	0.00%	0.00%
	Total	1961	5.35%	1.17%	1419	3.17%	0.85%	539	3.34%	1.67%	1009	10.01%	8.72%

SUMMARY

This analysis has conducted a series of tests to investigate the relationship between intensified land use and traffic congestion. The question behind the analysis is whether the adoption of higher-intensity land use—often referred to high-density development—cancels out any potential travel efficiencies by creating new and larger local traffic congestion problems. Using a study design that has incorporated four representative case studies taken from metropolitan Phoenix, researchers used traffic data and modeling tools to investigate key land use characteristics and transportation outcomes in these four areas. The major findings from this analysis are summarized below. This discussion and the vital comparisons are also summarized in Table 21.

Land Use

Research shows that land use which is effective in reducing auto dependency and VMT generation must include some density in order to bring activities and people closer together, but it must also include a mix and balance of uses, an environment in which people as well as cars can access activities easily, and good transit service that provides access to opportunities elsewhere in the region. Among the four study areas used in this investigation, the Scottsdale area was found to possess the best overall combination of 4D attributes: moderate to high density, a good mix and balance of uses, seemingly the best design in terms of pedestrian scale and friendliness, and moderate to good regional transit access. In comparison, the Central Avenue corridor exhibits even higher density, better transit service, and good pedestrian access, but has a much less optimal mix and distribution of the different land uses. Its residential and retail land uses are overwhelmed by the concentration of office employment activity for the area to function as a community. The Tempe study area falls somewhere in between. The northwestern portion of the study area along Mill Avenue is highly urban, with exemplary density, mix of uses, and pedestrian-friendly design. However, moving east past the university campus, the area becomes much more suburban. While there are a number of high-density housing complexes, overall density is not particularly high, and retail activity is low and packaged for primarily auto access. While sidewalk coverage is good, block size is large and the major arterials limit easy pedestrian crossing. Finally, West Bell Road has no major density nodes, but follows a more typical suburban design of large, self-contained residential subdivisions; separate commercial development in shopping centers along major arterials (reachable only by vehicle); virtually no functional walkability (i.e., for purposes other than pleasure walking); and transit service that is almost exclusively oriented to commuting destinations outside the study area.

Table 20. Comparative Characteristics and Performance of the Four Study Areas.

	Scottsdale	Bell Road	Central Avenue	Tempe
Land use				
Density	High	Low-Medium	High	Med High
Mix	Good-Very good	Poor	Fair-Good	Good-Very good
Design	Good-Very good	Poor	Good-Very good	Good-Very good
Road network				
Alternate routes	High	Poor	High	Very good
Manageable grid	High	Poor	High	Good-Very good
Traffic congestion				
Midday	Moderate	Very High	Moderate	High
Peak	Moderate	Severe	Moderate	High
Transit				
Service/serviceability	Good/Good	Low/Poor	Very good/ Very good	Good/Good
Utilization	Good	Low	Very good	Good-Very good
Through traffic	Moderate	High	Moderate-High	Moderate-High
Internal trip capture				
Work	Moderate	Low	Moderate	Moderate
Nonwork	Very high	High	Low	Moderate-High
Average trip length				
Work	Third shortest	Longest	Shortest	Second shortest
Nonwork	Shortest	Longest	Third shortest	Second shortest
Walkability				
Walk/bike trip rates	Second highest	Lowest	Third highest	Highest

Road System and Traffic Conditions

Examining traffic congestion levels in the four study areas revealed some important and perhaps counterintuitive results in terms of the density/traffic question. The central portion of Scottsdale (along Scottsdale Road, near the intersection with Indian School Road where the greatest concentration of activity is found) shows only moderate traffic congestion, with V/C ratios in the range of 0.61 to 0.66 in both PM peak period and midday time periods. Border roads, such as Goldwater Boulevard, do carry heavy traffic volumes and have V/C ratios that exceed 1.0, but their function (and design) is to carry a greater share of the traffic load and spare the town center area. This appears to illustrate the value of a more urban street grid, where motorists are given the opportunity and encouragement to choose routes that avoid the town center, while the design of Scottsdale

Road itself (less capacity, more signal delay) discourages its unnecessary use. The Central Avenue corridor shows similar results, with congestion along Central Avenue only reaching V/C levels of 0.41 to 0.64 in mid-day and 0.49 to 0.59 in the PM peak period, despite some of the highest employment densities in the region. Again, the urban grid may be a major factor in this result since motorists have alternative north-south routes every one-quarter mile, so they can choose the route that is flowing best at the time. In addition, the multiple transit routes running along Central Avenue probably also discourage its use for all but the most necessary trips.

In Tempe, congestion was documented on three of the four major facilities investigated: Rural Road, Apache Boulevard, and Broadway Road. The reason for this, including the presence of Arizona State University as a major regional trip generator, may be both the absence of a detailed local street network and the fact that Tempe employs traffic calming strategies on its secondary road network to discourage cut-through traffic, which has the effect of pushing traffic onto the major arterials. The fourth facility, Mill Avenue, is Tempe's urban Main Street, the location for shopping, restaurants, and gatherings. It runs through some of the densest development in the study area and has significant traffic congestion during both peak and off-peak periods. However, it is also not designed to be a major regional thoroughfare: its cross section is deliberately constrained by on-street parking, bike lanes, landscaped medians, and street trees. It carries only about half or less of the volume seen on Rural and McClintock roads, which are themselves able to accept additional flow if Mill Avenue traffic is an inconvenience. Noting that less than 10 percent of the traffic on Mill Avenue is pass-through, the congestion on Mill may be part of its design, while through travelers are left with other viable options.

And finally, the control example—Bell Road—appears to have the opposite result of what the study hypothesis would suggest: It has chronically high traffic congestion levels (among the highest in the region) despite having the lowest density of any of the case study areas. Clearly, its separation of uses, poor mix, and spread-out design make walking or biking for other than recreational purposes almost impossible. However, Bell Road's traffic problems are compounded by its dual function of also having to serve as one of only two east-west arterials providing access between the new communities west of Sun Cities and Grand Avenue and the L101 loop and the core of the Phoenix region. Both of these uses are almost exclusively auto-dependent and superimpose a heavy demand from two different travel markets on a transportation network with greatly limited route options.

Traffic Sources

One issue in making an association between intensified development and traffic congestion on an adjacent facility is the proportion of traffic that is accounted for simply by through trips that are not occasioned by the development there. In the Central Avenue corridor during the PM peak period when traffic conditions are at their worst, 48.6 percent of the traffic moving north is through traffic, and during the midday the proportion is 25.8 percent. On the internal links in Scottsdale (Scottsdale Road and Indian School Road), through traffic accounts for about one-quarter of the volume in both midday and PM peak periods. Hence, not only are traffic levels tolerable on these two links, but through traffic is discouraged from using it as a major route, thus helping to keep the service levels in check. In Tempe, through traffic accounts for half or more of the volume on Broadway Road, either in peak or midday period, while on Apache Boulevard, the traffic stream is dominated by travel into or out of the study area, presumably between the university area on the west and the L101 expressway on the east. On Bell Road, through traffic makes up about half of the volume in either direction in both peak and off-peak periods. As noted above, Bell Road carries the dual function of supporting both auto-exclusive local travel needs within the corridor and being a connecting link between the core region and the newer bedroom communities west of Grand Avenue. This results in heavy vehicle demand on a facility where there are virtually no alternatives. The result is V/C ratios in the 1.6 to 1.9 range (where 1.0 means volume is equal to the design capacity). In most of the study areas, with the exception of Bell Road, the freeway system is not seen as having a major impact on local traffic conditions. The regional freeway system borders each of the study areas, but in no case is the proximity closer than two miles. Hence, while the freeway system clearly has a role in supporting intra-regional movements that might otherwise have to use the arterial system, in no case does the freeway system directly serve the core areas under study, and hence are not seen as having a major role in either contributing additional volumes to the local arterial street network or relieving traffic from those facilities. In the Tempe study area, high volumes on Apache Boulevard and Rural Road may be attributable to use of those facilities as a primary connector to the L101 and L202 freeways lying to the east and north, and certainly on Bell Road, the role of connector from the western bedroom communities to L101 has to be a major factor in its traffic loadings. At the same time, both Scottsdale and Central Avenue have adjacent freeway systems, but a similar level of volume traversing roads to these facilities is not observed.

Transit

At present, all transit service in the MAG region is bus-oriented, though this is now changing with the December 2008 opening of the region's inaugural light rail line between north Central Avenue and Tempe. The location of the region's first rail service in this corridor is no coincidence, since it contains the highest density and most compact/mixed-use development in the region apart from Scottsdale. Clearly, the characteristics of the Scottsdale, Central Avenue, and Tempe areas are most supportive of transit service, and hence these areas have the most transit service and the highest utilization rates. There is little transit service in the Bell Road corridor, and that which exists is primarily commuter express operating from park and ride locations. Transit does not appear to be a viable alternative for the substantial vehicle travel from the western bedroom communities to the east region, as only about 0.1 percent of the HBW or HBU trips from Surprise to the region are made by transit.

Internal Trip Capture

Areas with good land use design should be capable of retaining a high percentage of their residents' or employees' trips with an ample supply of activities easily accessed within the community. Researchers found that the Scottsdale study area had a very high level of internal capture of trips, particularly for nonwork activity, with 62.6 percent of HBO trips and 55.2 percent of NHO trips remaining within the study area. These fractions were much less in the Central Avenue corridor, equaling 21.7 percent and 18.8 percent, respectively, owing to lack of mix and an insufficient menu of internal opportunities. In Tempe, internal capture rates were higher, at 39.8 percent of HBO trips and 35.8 percent of NHO trips, because of a better overall mix than Central Avenue. In the Bell Road example, high rates of internal capture for HBO trips at 41.8 percent and NHO trips at 50.6 percent were initially a surprise, until it was recognized that the large land area encompassed by the study area as defined would allow for most trips for shopping or other basic purposes to be made internally; however, the difference was expected to show up in the average length of the trip.

Average Trip Lengths

Indeed, when the analysis looked at the average length of trip weighted over all internally generated trips—those with destinations internal to the study area as well as those with external destinations—the differences proved remarkable. Scottsdale, the area with the best overall characteristics of density, mix, and design, had average trip lengths of 3.83 miles for HBO trips and 5.17 miles for NHO trips. In notable contrast was Bell Road, with trip lengths of 26.53 miles for HBO trips and 11.61 miles for NHO trips. The Central Avenue corridor averages were 9.05 miles and 9.51 miles, respectively, given the comparative lack of mix of uses. Tempe averaged 6.62 miles and 7.23 miles, respectively, given reasonable mix but only fair density and connectivity.

Walkability

If higher-density development raises concern about increased traffic congestion, one clear benefit is that persons either living in or visiting these areas should be able to be less dependent on vehicles for their travel needs. Not only should trips be shorter on average, but a higher percentage of trips should be made on foot or by bicycle, provided the design of the area is supportive. Data from the 2001 MAG regional household travel survey provides some evidence that rates of walking and biking are greater in places like Tempe, Scottsdale, and Central Avenue, while being virtually nonexistent in the Bell Road environment. However, these data show some signs of having been potentially compromised by the events of September 11, 2001, when the survey was conducted. Trip rates in general are low in the survey, so the accuracy of any travel recorded during that period should be regarded with appropriate care and suspicion.

CHAPTER 5. LAND USE IMPACTS ON TRAVEL

INTRODUCTION

The underlying question of this study is whether higher-density development does in fact generate less vehicle travel and VMT, and if so, why. Understanding the nature of the primary relationships that connect land use form with travel is essential to communicating the benefits of compact, mixed-land use, bringing the most important attributes into the planning and design process, and gaining acceptance for these concepts among the public and decision-makers.

Good land use is about much more than density. Indeed, if the only characteristic differentiating two development projects was their density—dwelling units or square footage of commercial development per acre—there is little doubt that the higher-density project would generate proportionately more trips and traffic. Much more important, however, are the components of density. The type of density associated with smart growth development patterns is compact, mixed-use, where density is part of an overall plan to bring different land uses strategically closer together because their functions are interrelated and the proximity greatly lessens the travel burden when the uses interact (e.g., a local business needing to copy and mail an urgent product). When the distances are not only close but the mix of uses and the design and layout encourage it, travelers can realistically consider making a considerable portion of these trips by walking or bicycling.

As mentioned earlier, planners and researchers refer to these attributes of compact, mixed land use as the 4Ds—density, diversity, design, and destinations. There are, of course, a multitude of other factors that influence residential choice, destination choice, and travel behavior. Sociodemographic factors such as age, employment status, life cycle, household structure, education, and even social and environmental views can have a marked effect on location and travel preferences. Advocates of traditional suburban land development patterns argue that it is still the dominant and preferred living circumstance for most Americans. However, as discussed at length in the chapter summarizing the literature review, there are a number of demographic segments whose size is increasing prefer an alternative, more urban and mixed-use setting. These include young single or childless professionals, empty nesters, or retirees who no longer appreciate the maintenance burden of a large, single-family detached home and instead would prefer less space but greater access and amenity. For this segment, the number of opportunities for living in a high-amenity, mixed-use setting is still well below measured market demand.

As reported in Chapter 2, research studies have found that when households reside in areas where the 4Ds are at favorable levels, those households tend to own fewer vehicles, make more trips by walking and transit, and make fewer and shorter trips by personal vehicle (Cervero and Radisch 1996; Rutherford, McCormack, and Wilkinson. 2001; Kuzmyak et al. 2003; and Kuzmyak, Baber, and Savory 2006). The net effect is considerably fewer VMT generated per household, even after accounting for such contributing factors as household size, number of workers and drivers, and income. So important is the role of land use that more and more transportation professionals and academics have been trying to quantify these relationships through statistical models. Achieving this goal has been made difficult, however, by the fact that the standard four-step transportation planning models in use by most regional planning agencies are ill-suited by their structure and supporting data to accommodate these characteristics. These models are almost exclusively based on the geography of transportation analysis zones (TAZs), which is a much larger scale of area than that at which the 4Ds are relevant. To discern the effects of land use on vehicle ownership and travel choice, it is necessary to drill down to virtually the level of individual households since it is from this perspective that decisions are made that involve vehicle ownership and destination choice. A common reference frame is the effective "walk shed" of the household, frequently defined as the world within one-quarter mile of the household. Increasingly capable and available GIS tools and data are making it possible to measure these conditions, although developing a means to accurately translate their relevance to the traditional four-step models is still a challenge that has not been fully solved.

Researchers believed this project would not be complete unless they explored the nature of the 4Ds factors and their relationship with travel in the local context—specifically, the Phoenix region, given the earlier selection of the four case studies from this area. That analysis, presented in Chapter 4, examined traffic conditions in a set of high-density activity areas. This analysis found that despite having some of the highest densities in the region, the case study areas of Scottsdale, Tempe, and the North Central Avenue corridor had surprisingly good traffic flow, whereas the one suburban corridor—West Bell Road—showed significantly higher levels of congestion despite considerably lower development densities.

Credit for this seeming contradiction was attributed to both the nature of development in the higher-density areas and the existence of a street grid. The street grid in the three urban settings was found to handle and dissipate traffic demands rather efficiently. In addition to Phoenix's ubiquitous one mile major arterial grid, these urban areas also contained a substructure of minor arterials and streets, on a spacing of one-quarter to one-eighth of a mile. A study of traffic flow patterns and conditions suggest that such a grid structure not only provides more net capacity, but offers a rich variety of route choices to the traveler. Through travelers are able to select paths that avoid local activity concentrations, while travelers who have business in the area may not be as concerned about local travel speeds but appreciate the ability to find on-street parking and to efficiently circulate within the activity districts. So in effect, the grid helps the traffic sort itself out, and also provides a set of strategic levers to traffic engineers to fine-tune operation of the grid to best achieve a balance of objectives.

In terms of the development itself, the case studies used fairly simple information to characterize local land use conditions and associated travel behavior. Population and employment densities taken from MAG travel model data were accompanied by measures of jobs-housing balance and level of retail activity within the respective TAZs.

Travel behavior relationships were similarly basic, focusing on average trip length and rates of internal trip capture. When compared to the density levels and mix of uses, the analysis showed a clear relationship between density and balance of uses with shorter trip lengths and a higher percentage of trips made locally. Also, these areas showed above-average rates of transit use by travelers to and from the area.

In the current analysis presented in this chapter, an effort was made to perform a finer-grained portrayal of land use conditions in the MAG region, using data from various GIS databases, and to link that information with household composition and travel behavior information from the 2001 regional household travel survey. The remainder of this chapter describes the approach used and conclusions derived from this analysis.

TRAVEL DATABASE

The travel information used in this analysis was derived from MAG's most recent regional household travel survey, performed between March 18 and November 20, 2001. In this travel study, researchers surveyed 4,018 households, capturing compositional information about the household and its vehicles, and also travel information on each household member. An activity-based approach was used in this survey, which is a somewhat more advanced method for acquiring travel data than conventional trip-based approaches. In this approach, an attempt is made to record all essential household activities that might involve travel, whether the individual traveled outside the household to accomplish that activity or not. Such activities could include working at home or shopping from home, which activity-based modeling approaches represent as potential alternatives to physical travel. The travel/activity data were obtained through 48-hour diaries with all days of the week sampled. Researchers received sufficient detail to determine which days of the week were represented in a given household record, and therefore to be able to distinguish between weekday and weekend travel.

Because the 2001 travel survey intersected with the terrorist attacks of September 11, 2001, some MAG planners voiced concern about whether the data were reliable. An examination of the sample indicated that about 41 percent of the surveys were completed after September 11, with roughly 3 percent (134 households) completed during the actual week including and following September 11. While no impact of the September 11 events was later seen to affect work travel in the study's regression models that incorporate the 4Ds, the models developed for nonwork travel did indicate a slight reduction in travel, which was explained by the inclusion of a post-September 11 dummy variable in these models (further discussed later in relation to the models). With this adjustment, researchers believed that the MAG data are sufficiently accurate for the types of comparative analyses performed here.

The household sample represents all of the metropolitan policy areas (MPAs) in the MAG region, although small sample sizes made it necessary to consolidate some of the areas into a composite area. At the same time, it was seen as useful to separate some of the MPAs into subareas, given presumed differences in their development character.

Table 21 lists the individual areas adopted for study, along with their respective sample size (*n*).

Table 21. MAG Study Areas from 2001 Travel Survey.

MPA	***n***	**MPA**	***n***
Apache Junction	30	West Phoenix	546
Chandler	208	South Scottsdale	181
Gilbert	99	Tempe/Guadalupe	261
Glendale	121	North Scottsdale	128
Maricopa County	33	Southwest (Avondale, Buckeye, Gila Bend, Goodyear, Litchfield Park, Tolleson)	68
Mesa	644		
Peoria	156	Northwest (El Mirage, Surprise, Wickenburg, Youngstown)	59
North Phoenix	528		
East Phoenix	628	Sun Cities (original Sun City and Sun City West)	118
South Phoenix	212	Total	4018

All statistics derived from the travel survey data were calculated using the supplied sample weights to ensure that any differences related to demographic or other characteristics would be controlled.

The trip data were derived from the travel activity diaries as those events involving actual travel. The 20-plus individual travel purposes were reduced to the eight primary purposes used by MAG in its regional travel forecasting process. They are:

- Home-based Work (HBW).
- Home-based Shopping (HBS).
- Home-based School (HBSc).
- Home-based University – Arizona State (HBASU).
- Home-based University – all other (HBU).
- Home-based Other (HBO).
- Non Home-Based Work (NHW).
- Non Home-Based Other (NHO).

For many of the analyses, it was more effective to further consolidate travel into only two primary purposes: work and nonwork. These categories were formed as follows:

- Work-related = HBW + NHW.
- Nonwork = HBS + HBSc + HBASU + HBU + HBO + NHO.

All travel logs covered two days of travel. While both Saturdays and Sundays were sampled, there were no cases where both household travel days were weekend days—at least one of the two days would be the preceding or following weekday. For comparison, weekdays and weekends were not combined in the travel analysis, and all travel was reduced to an average 24-hour day.

Measures of household VMT were created by accumulating vehicle miles for each trip purpose generated by household drivers.

LAND USE DATABASE AND VARIABLE CREATION

As previously discussed, one reason why land use effects on travel have been poorly understood and accounted for in the planning process is that their characteristics play out at a much smaller level of geographic resolution that the TAZs that comprise the building blocks of conventional transportation models. Extensive research has shown that the character of land use that best explains critical household decisions on vehicle ownership and destination choice occurs at the neighborhood level (i.e., within the distance that a household could technically function without a car) (Kockelman 1996, Steiner 1998, Solimar Research 2005, and Kuzmyak, Baber, and Savory. 2006). For most people, this distance is somewhere between one-quarter to one-half mile from home, which reflects how far people are reasonably willing to walk to an activity. Of course, these distances are merely a guide, since factors such as overall attractiveness of the area, number and variety of activities in place, ease and safety of walking, fear of crime, and extremes of climate and weather all come into play. For certain types of trips, such as travel to work, travelers have shown a willingness to walk as much as a mile to a transit station, assuming that the path is safe and pleasant.

To examine the interplay of conditions between local land use conditions and household travel behavior, GIS tools and various local data resources were used to construct measures of land use in the vicinity of the individual households in the 2001 travel survey. Using GIS, a one-quarter mile buffer was defined around each household. Then using GIS layering techniques, the character of the various land uses and the transportation network within this buffer were ascertained. The data sources for this work consisted of:

- A parcel-level land use database from MAG.
- A detailed street grid network file from the Maricopa County Board of Elections.
- Dunn & Bradstreet employer data.

A variety of different measures were constructed in this manner to quantify the 3Ds of local land use (fourth D of regional accessibility discussed later), as described in the following sections.

Density

Both residential and employment density measures were developed and tested. These densities were calculated in relation to the one-quarter mile household buffer by overlaying the household layer onto the respective census tract. Using the land use parcel database, it was possible to determine total residentially zoned land in each buffer, and thus calculate a net residential density (households per acre of residentially zoned land). This was found to be more accurate than the more typical gross density per acre for the entire area.

Diversity

A variety of measures were developed and tested to characterize the mix and balance of uses in the household buffer. One such measure commonly used by researchers like Cervero and Kockelman is entropy, which looks at the proportion of different land uses within a given area—such as the one-quarter mile buffer around the household—and computes a value between 0 and 1 that reflects both the degree of mix (number of uses) and relative balance among those uses.

Using year 2000 parcel-level land use supplied by MAG, a classification system of 109 detailed land use types was consolidated into a more realistic and comprehensible eight-category scheme, consisting of the following generic land use types:

- Residential—single family.
- Residential—multifamily.
- Commercial/retail.
- Office.
- Institutional.
- Industrial.
- Transportation.
- Open space (including water).

Knowing the proportion of land use by the eight types in each of the household one-quarter mile buffers, it was possible to calculate the entropy measure of land use mix using the formula in Eq. 1:

$$\boxed{Entropy = -\sum_j \frac{(P_j \times \ln(P_j))}{\ln(J)}}$$

where:

> j = one of the 8 land use types listed above
> P = the proportion of land area in the j_{th} use type
> ln = the natural logarithm.

The range of values computed from this formula conform to an index of 0 to 1, with 1 representing perfect mix and balance, i.e., that all uses are in equal proportions. In reality, not all of these land uses are seen positively, so a number of different combinations of uses were developed and tested in which certain uses were emphasized or minimized. In most entropy calculations, residential land use is not differentiated by single or multifamily dwelling units, though in this case entering them as separate land uses produced a stronger measure. Also, since the most compatible land uses for mixing with residential are generally retail/commercial and office, a version of the entropy measure was calculated with only five uses (with industrial, institutional, transportation, and open space grouped into one). However, this measure later proved to not be as useful in explaining VMT differences as the original based on eight land use types.

Design

The third D of local land use describes the layout and connectivity of the area, often referred to as its pedestrian friendliness. Early studies used a PEF index to scale various attributes of the physical environment in an attempt to quantify this dimension of design. These PEF measures consisted of ranking characteristics of the environment such as sidewalk coverage, building setbacks, topography, and safe crossings on a 3- or 5-point scale, and then summing the individual ratings into an overall score. The success of several areas (Portland, Oregon; Charlotte, North Carolina; and Montgomery County, Maryland) in developing and using such measures in their planning process was described in Chapter 2. Other researchers, most notably Kockelman (1996), however, were discouraged by the PEF approach because of its subjectivity and the time and effort needed to develop it.

Other methods that have been used to try to quantify the design characteristics of developed areas have ranged from fairly simple to rather complex approaches. Since data on sidewalks is not widely available, several researchers have experimented with connectivity indices, which try to place a value on the walk network by taking account of the number of intersections in a given land area. A higher number of intersections per acre or square mile is generally thought to reflect a more urban street grid with better walking opportunities. Some practitioners have enhanced this approach by using a weighting system that differentiates four-way intersections on local streets from those involving a major arterial or state highway, and also giving less value to three-way intersections since they tend to reflect a limitation on pedestrian path options. A weighted intersection measure was developed and tested in this current study.

As an example of a more advanced approach to measuring design, Goldberg and Frank et al. experimented with a walkability index that brought together elements of density, connectivity, and mix into a single measure to represent the desirability of walking (Frank et al. 2007). The measure is a sum of the "z-scores" of the normalized distributions of each of the three component measures. In statistics, a z-score is also known as a standard score, obtained by subtracting the population mean from score of an individual observation and then dividing the difference by the standard deviation, as shown in Eq. 2:

$$z = \frac{x - \mu}{\sigma},$$

where:

x = a raw score to be standardized
μ = the mean of the population
σ = the standard deviation of the population

The quantity z indicates how many standard deviations an observation is above or below the mean. The value of z is negative when the raw score is below the mean, positive when above. This measure of walkability was calculated and tested in the current analysis. It was found to vary from 59.1 to -15.97 in the MAG application, and did not prove to be particularly telling in relation to explaining travel differentials.

A gravity approach to measuring the value of local land use design from the standpoint of opportunities available and the ease of reaching them was tested by Handy and Niemeier as an alternative measure of accessibility (1997), shown in Eq. 3 below:

$$A_i = \sum_j (a_j * F(t_{ij}))$$

where:

A_i = the accessibility for residents living in zone i
a_j = the number of opportunities for activity type j
t_{ij} = the generalized travel cost from zone i to zone j
$F(t_{ij})$ = the inverse function of generalized travel cost $(t\text{^}-b)$

where $F(t_{ij})$:

Exponential: $F(t_{ij}) = exp(-c*(t_{ij}))$: $c > 0$
Inverse power: $F(t_{ij}) = t_{ij}\text{^}-b$: $b > 0$
Gamma (combined) function: $F(t_{ij}) = a*(t_{ij}\text{^}-b)*exp(-c*(t_{ij}))$: $a > 0, c >= 0$

Like most gravity expressions, this relationship compares the opportunities available to the traveler and discounts the value of those opportunities by the difficulty in reaching them, defined here as the generalized travel cost (though only travel time and not cost were used in its calculation). This measure was also calculated and tested in the current analysis. Its value was found to range from 0.01078 to -0.01646, which did not suggest great sensitivity to differences in the underlying land use patterns, and did not prove to be a good measure for explaining differences in travel behavior.

The final measure of design that was attempted was the walk opportunities index devised by Kuzmyak et al. in Baltimore, and subsequently calibrated and used in Los Angeles as part of the Compass Blueprint evaluation in 2008 (Kuzmyak, Baber, and Savory 2006). The motivation for developing this measure was the realization that the entropy-based measures of mix communicated very little about the types of activities that were attracting people to walk, nor did the intersection/connectivity measures relate to what they might be walking to. Employment data taken from Dunn & Bradstreet were able to identify the number and type of activities that might attract a traveler, with sufficient information as to the type of activity (in SIC or NAICS code) to be able to differentiate particular types of retail or service attractions from less relevant wholesale, manufacturing or utility activities. Since the employers in this database had also been geocoded to specific latitude-longitude locations, it was possible through GIS layering to ascertain exactly what activities lay in the buffer of each household. GIS programming skills were then applied to trace out walk paths from the household to each activity using the street network. The summation of all opportunities, weighted by the respective value and size factors, and discounted by the respective walk distance from home, provide a cumulative assessment of the design potential of the local environment. The walk opportunities measure is calculated using the following expression (Eq. 4):

$$H_i = \sum_i O_i((W_i * S_i) / D_i)$$

where:

H_i = opportunities for household i
O_i = opportunity within one-quarter mile of household i
W_i = importance weight for the opportunity O
S_i = (optional) size factor where:
small (<=10 employees) = 1
medium (11 <= S_i <= 100) = 2
large (>100 employees) = 3
D_i = distance from the household to the opportunity

Size weights were applied to try to account for the fact that larger establishments would be different in intangible ways from their smaller counterparts, offering in many cases greater selection and often discount prices. At the same time, given the land area that such a large establishment would require (e.g., a major supermarket would leave less remaining development area in the household buffer for other land uses, so there could be a trade-off in exclusivity vs. variety).

The value weights were introduced when it was recognized that not all opportunities would have the same attractiveness to households. The classic example would be the value of having a local grocery store vs. an antique store. Both would add to the amenity and variety of the neighborhood, but the grocery store would provide a convenience to the household that might be used on a daily basis. Rather than take a subjective approach to developing a set of value weights, a study was discovered that performed just such an assessment, focusing on neighborhoods in Los Angeles in the late 1980s. Residents were asked in surveys to rank the desirability of having any of a long list of activities in their neighborhood, and from such a ranking, researchers developed a value scale ranging from +1 to -1. With minor exceptions, this set of values appeared reasonable and was applied in the walk opportunities calculation. Activities that were not in the source list but were identified in the Dunn & Bradstreet breakdown of employers were assigned weights based on similar SIC/NAICS categories. A summary of these weights is provided in Table 22.

Destinations

The fourth D of land use is destinations, which measures accessibility to opportunities outside the community. These characteristics are measured through a gravity model relationship similar to the walk opportunities index just discussed above, but with the entire region as the applicable scale and traffic analysis zones as the units of analysis (rather than household buffers). This measure is computed using Eq. 5 below, which sums the number of jobs in each adjacent zone divided by the total travel time between the respective *i j* zonal pairs:

$$Accessibility_i = \sum_j \frac{Jobs_j}{Travel\,Time_{ij}}$$

Such a measure was developed separately for:

- Travel by auto or by transit.
- Jobs of all types vs. retail jobs only.
- Peak and off-peak travel time performance.

DATA ANALYSIS

With the above data compiled into household records, some simple analyses were performed using Excel spreadsheets and chart operations and the Statistical Package for the Social Sciences (SPSS) for more extensive analysis of statistical relationships. In general, while all data relationships were created from individual records, the results are presented in groupings by the 17 jurisdictions listed in Table 23.

Socioeconomic Characteristics of Jurisdictional Study Areas

Table 23 presents basic sociodemographic characteristics of each area for comparison, including household size characteristics (total members, workers, and students); average numbers of vehicles owned; and annual income. The characteristics are displayed graphically in Figure 54 to facilitate comparison.

Table 24 supplements this information with some other key socioeconomic descriptors, including:

- Number of single-person households.
- Number of households without motor vehicles.
- Number of English-speaking households (based on whether English or Spanish was used in the interview).
- Percent of households where race is white vs. nonwhite (as a measure of diversity).
- Percent of households living in single-family detached homes.
- Percent of households who own or are buying their home (as opposed to renting).
- Percent of households who have lived in their current home for four or more years (tenure, as a measure of stability and familiarity).
- Percent of households receiving some type of income assistance (may include welfare, Social Security, disability, veteran’s benefits, or other government benefits).

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Table 22. List of Opportunity Value Weights by SIC Code.

SIC Code	Value Weight	SIC Activity Description	SIC Code	Value Weight	SIC Activity Description	SIC Code	Value Weight	SIC Activity Description
5812	0.7	Eating and Drinking Places	5211	0.66	Lumber and Other Building Materials Dealers	7251	0.63	Shoe Repair Shops and Shoeshine Parlors
6531	0.52	Real Estate Agents and Managers	7241	0.75	Barber Shops	5736	0.72	Musical Instrument Stores
8111	0.52	Legal Services	5521	0.53	Motor Vehicle Dealers (Used Only)	6035	0.77	Savings Institutions, Federally Chartered
7231	0.75	Beauty Shops	5713	0.45	Floor Covering Stores	8221	0.34	Colleges, Universities, and Professional Schools
8011	0.77	Offices and Clinics of Doctors of Medicine	5961	0.72	Catalog and Mail-Order Houses	5714	0.45	Drapery, Curtain, and Upholstery Stores
8661	0.72	Religious Organizations	5719	0.45	Miscellaneous Homefurnishings Stores	8043	0.77	Offices and Clinics of Podiatrists
5999	0.72	Miscellaneous Retail Stores, NEC	5813	-0.07	Drinking Places (Alcoholic Beverages)	5993	0.72	Tobacco Stores and Stands
6411	0.52	Insurance Agents, Brokers, and Service	5611	0.66	Men's and Boys' Clothing and Accessory Stores	5571	0.53	Motorcycle Dealers
7538	0.53	General Automotive Repair Shops	8361	0.49	Residential Care	7832	0.58	Motion Picture Theaters, Except Drive-In
8021	0.77	Offices and Clinics of Dentists	6099	0.77	Functions Related to Deposit Banking, NEC	6061	0.77	Credit Unions, Federally Chartered
5411	0.91	Grocery Stores	7542	0.53	Carwashes	8412	0.34	Museums and Art Galleries
8322	0.49	Individual and Family Social Services	6021	0.77	National Commercial Banks	5431	0.91	Fruit and Vegetable Markets
5947	0.72	Gift, Novelty, and Souvenir Shops	7212	0.76	Garment Pressing, and Agents for Laundries and Drycleaners	4311	0.85	United States Postal Service
8211	0.72	Elementary and Secondary Schools	5942	0.72	Book Stores	9221	0.62	Police Protection
7299	0.52	Miscellaneous Personal Services, NEC	5722	0.72	Household Appliance Stores	8249	0.18	Vocational Schools, NEC
8049	0.77	Offices and Clinics of Health Practitioners, NEC	6141	0.77	Personal Credit Institutions	5551	0.53	Boat Dealers
8351	0.49	Child Day Care Services	7629	0.53	Electrical and Electronic Repair Shops, NEC	5441	0.91	Candy, Nut, and Confectionery Stores
5621	0.66	Women's Clothing Stores	7378	0.52	Computer Maintenance and Repair	7941	-0.13	Professional Sports Clubs and Promoters
5531	0.53	Auto and Home Supply Stores	7372	0.72	Prepackaged Software	6022	0.77	State Commercial Banks
7999	0.13	Amusement and Recreation Services, NEC	7841	0.58	Video Tape Rental	5451	0.91	Dairy Products Stores
4724	0.53	Travel Agencies	5651	0.66	Family Clothing Stores	4121	-0.05	Taxicabs
5734	0.72	Computer and Computer Software Stores	8042	0.77	Offices and Clinics of Optometrists	8243	0.18	Data Processing Schools
5932	0.26	Used Merchandise Stores	0781	0.53	Landscape Counseling and Planning	5599	0.53	Automotive Dealers, NEC
5712	0.45	Furniture Stores	5231	0.66	Paint, Glass, and Wallpaper Stores	5948	0.72	Luggage and Leather Goods Stores
5944	0.72	Jewelry Stores	5311	0.51	Department Stores	5946	0.72	Camera and Photographic Supply Stores
5499	0.91	Miscellaneous Food Stores	0742	0.39	Veterinary Services for Animal Specialties	8244	0.18	Business and Secretarial Schools
5699	0.66	Miscellaneous Apparel and Accessory Stores	5641	0.66	Children's and Infants' Wear Stores	5994	0.72	News Dealers and Newsstands
7291	0.52	Tax Return Preparation Services	5261	0.66	Retail Nurseries, Lawn and Garden Supply Stores	5561	0.53	Recreational Vehicle Dealers
5461	0.91	Retail Bakeries	7991	0.44	Physical Fitness Facilities	7992	0.13	Public Golf Courses
8299	0.18	Schools and Educational Services, NEC	5632	0.66	Women's Accessory and Specialty Stores	4493	-0.17	Marinas
5941	0.72	Sporting Goods Stores and Bicycle Shops	7514	0.53	Passenger Car Rental	4111	-0.05	Local and Suburban Transit
8041	0.77	Offices and Clinics of Chiropractors	5251	0.66	Hardware Stores	7993	-0.13	Coin-Operated Amusement Devices
4813	0.72	Telephone Communications, Except Radiotelephone	5943	0.72	Stationery Stores	4729	0.53	Arrangement of Passenger Transportation, NEC
5541	0.85	Gasoline Service Stations	7215	0.58	Coin-Operated Laundries and Drycleaning	8031	0.77	Offices and Clinics of Doctors of Osteopathy
5735	0.72	Record and Prerecorded Tape Stores	5421	0.91	Meat and Fish (Seafood) Markets & Freezer Provisioners	6029	0.77	Commercial Banks, NEC
5992	0.72	Florists	8331	0.18	Job Training and Vocational Rehabilitation Services	7933	0.13	Bowling Centers
7929	0.32	Bands, Orchestras, Actors, and Other Entertainment Groups	7622	0.53	Radio and Television Repair Shops	4822	0.72	Telegraph and Other Message Communications
5921	0.35	Liquor Stores	4812	0.72	Radiotelephone Communications	7996	-0.13	Amusement Parks
8641	0.17	Civic, Social, and Fraternal Associations	5331	0.51	Variety Stores	6062	0.77	Credit Unions, Not Federally Chartered
7221	0.52	Photographic Studios, Portrait	5399	0.51	Miscellaneous General Merchandise Stores	7515	0.53	Passenger Car Leasing
5912	0.91	Drug Stores and Proprietary Stores	7997	0.13	Membership Sports and Recreation Clubs	8222	0.18	Junior Colleges and Technical Institutes
5511	0.53	Motor Vehicle Dealers (New and Used)	5949	0.72	Sewing, Needlework, and Piece Goods Stores	4131	-0.05	Intercity and Rural Bus Transportation
5945	0.72	Hobby, Toy, and Game Shops	7334	0.52	Photocopying and Duplicating Services	6036	0.77	Savings institutions, Not Federally Chartered
7922	0.32	Theatrical Producers (Except Motion Picture) and Services	7631	0.53	Watch, Clock, and Jewelry Repair	8422	0.12	Arboreta and Botanical or Zoological Gardens
5731	0.72	Radio, Television, and Consumer Electronics Stores	5995	0.72	Optical Goods Stores	4173	-0.05	Terminal/Service Facilities for Motor Vehicle Pass. Transp.
7539	0.53	Automotive Repair Shops, NEC	7911	0.44	Dance Studios, Schools, and Halls			
6282	0.52	Investment Advice	8231	0.89	Libraries			
5661	0.66	Shoe Stores	4725	0.53	Tour Operators			

Table 23. Socioeconomic Characteristics of Study Areas (MAG Jurisdictions).

	HH Members	HH Workers	HH Students	HH Vehicles	Ann. HH Income [c]
Apache Junction	2.34	0.89	0.29	1.66	3.61
Chandler	2.72	1.53	0.77	1.90	4.53
Gilbert	3.02	1.62	1.04	1.99	4.91
Glendale	2.73	1.41	0.74	1.94	4.36
Maricopa County	2.42	0.70	0.59	1.49	4.09
Mesa	2.43	1.18	0.68	1.61	3.83
Peoria	2.46	1.12	0.59	1.67	4.21
North Phoenix	2.51	1.39	0.72	1.78	4.28
East Phoenix	2.22	1.03	0.50	1.37	3.52
South Phoenix	3.05	1.41	0.97	1.71	3.86
West Phoenix	2.94	1.26	0.80	1.64	3.44
S. Scottsdale	1.93	0.95	0.38	1.60	4.00
Tempe/Guadalupe	2.22	1.32	0.63	1.67	4.12
N. Scottsdale	2.30	1.19	0.55	1.82	4.85
Southwest (a)	2.96	1.29	1.13	1.69	3.72
Northwest (b)	2.50	1.04	0.52	1.51	3.76
Sun Cities	1.65	0.18	0.04	1.29	3.49
Total	2.50	1.20	0.66	1.64	3.93

(a) includes Avondale, Buckeye, Gila Bend, Goodyear, Litchfield Pk. & Tolleson

(b) includes El Mirage, Surprise, Wickenburg & Youngstown

[c] 1 = < $10,000 per year; 2 = $10,000 - $19,999; 3 =$20,000 - $34,999; 4 = $35,000 - $49,999; 5 = $50,000 - $69,999; and 6 = $70,000 or more

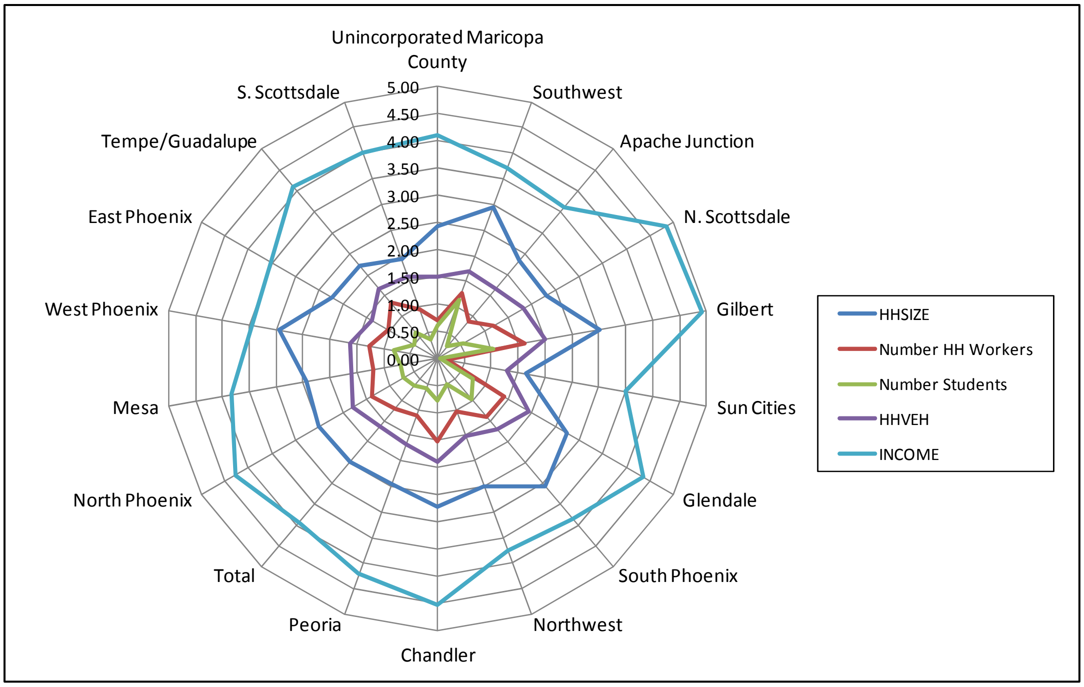

Figure 54. Comparison of Study Area Characteristics.

Table 24. Additional Socioeconomic Characteristics.

	Single person HHs	Zero Vehicle HHs	English Speaking HHs	Percent White	HHs in Single Family Detach. Home	Percent Own/ Buying Home	4 or more years at Current Residence	HHs Receiving Income Assistance
Apache Junction	28.6%	0.0%	100.0%	100.0%	44.8%	100.0%	55.2%	36.7%
Chandler	19.1%	2.9%	93.3%	78.2%	74.0%	70.8%	51.7%	15.2%
Gilbert	10.1%	0.0%	100.0%	92.9%	74.7%	75.8%	44.4%	5.1%
Glendale	20.7%	2.5%	94.2%	80.2%	85.8%	80.2%	52.1%	16.1%
Maricopa County	11.8%	9.4%	97.0%	65.6%	93.9%	84.4%	66.7%	30.3%
Mesa	29.5%	5.3%	93.8%	81.2%	54.1%	69.5%	49.1%	22.2%
Peoria	19.9%	3.2%	97.4%	82.6%	76.9%	85.3%	49.7%	17.5%
North Phoenix	25.6%	3.4%	95.6%	83.9%	67.2%	71.2%	54.3%	18.7%
East Phoenix	39.3%	14.5%	87.7%	69.1%	54.2%	57.1%	61.1%	36.3%
South Phoenix	17.9%	5.6%	79.3%	54.8%	77.8%	73.2%	58.8%	29.7%
West Phoenix	22.1%	8.9%	79.0%	55.7%	70.6%	72.4%	57.2%	34.3%
S. Scottsdale	40.3%	5.6%	96.7%	91.0%	52.2%	71.3%	72.2%	25.3%
Tempe/Guadalupe	30.8%	5.7%	98.1%	80.2%	57.5%	62.3%	55.4%	23.5%
N. Scottsdale	23.4%	0.8%	100.0%	96.8%	68.0%	83.6%	52.8%	19.0%
Southwest	17.9%	4.5%	82.1%	63.2%	71.6%	80.6%	57.6%	29.9%
Northwest	22.8%	1.8%	91.5%	63.8%	75.9%	78.0%	22.4%	20.7%
Sun Cities	37.3%	3.4%	100.0%	94.0%	66.4%	94.9%	70.7%	34.5%
Total	27.4%	6.3%	91.2%	75.6%	64.5%	71.0%	55.5%	25.6%

In addition to their regional location, the data in these tables suggest a variety of other ways in which these communities might be contrasted in terms of distinguishing characteristics. The major differences seem to relate to household size, composition, and income. An illustrative (albeit simple and imprecise) way of trying to distinguish among the communities demographically is to generalize these characteristics into two criteria: economic well-being and life cycle. For economic well-being, the sample area was divided into categories of well-off, average, and less well-off based on average household income, home ownership, number of household vehicles, and receipt of economic assistance using the statistics shown in Tables 23 and 24. This is not a particularly clean distinction in that, for example, Sun Cities[4] is classified as less well off, but this is more a function of its residents being on a reduced retirement income than being impoverished. (Economic assistance does not distinguish between pension or Social Security income vs. welfare or unemployment income supplements.) The life cycle dimension, on the other hand, attempts to differentiate between younger life cycle (young families with larger households, multiple workers, more children/students, and shorter housing tenure) at one end, older life cycle (older individuals, fewer families with children at home, longer housing tenures) at the other end, and mixed life cycle as essentially those falling in the middle (including medium-size households with more average numbers of workers,

[4] The term "Sun Cities" has been generically applied to the enclave of retirement communities that includes the original Sun Cities and the subsequent addition known as Sun Cities West.

students, and moderate rates of housing tenure). This approach results in the typology depicted in Table 25.

Also suggested in the table entries is a designation of where the communities lie in relation to the core of the region, with (C) representing “close in,” (M) representing “medium distance,” and (F) representing “far away”—or perhaps, city/inner suburbs vs. outer suburbs vs. rural. This classification is not intended to create hard and fast categories that will be used as a basis for claiming relationships, but only to provide an additional way to think about the various communities as the analysis examines differences in their land use and travel characteristics.

From this perspective, the sample of communities yields a reasonably balanced offering of young and older households and households that are more or less likely to be facing economic factors when making transportation decisions.

LAND USE CHARACTERISTICS

This section compares the 17 areas with respect to their land use characteristics, as captured in terms of the 4Ds variables outlined previously.

Density

The most basic measure of land use is density, usually measured in terms of the number of persons, households, or employees per unit of land area. The most common measure of density used in 4Ds analysis is residential density, measured in households per acre. However, researchers often differ on the more accurate and realistic of two measurement definitions—gross vs. net density. Gross residential density is the number of households divided by the entire neighborhood area (including all other land uses), whereas net residential density measures households only on the portion of neighborhood land area

Table 25. Sociodemographic Categorization of Study Areas.

	Economically Less Well-Off	**Economically Average**	**Economically Well-Off**
Older life cycle	Apache Junction (F) Sun City (M) East Phoenix (C)	Maricopa County (F) South Scottsdale (C)	North Scottsdale (M)
Mixed life cycle		Northwest (F) Peoria (M) Mesa (M) Tempe/Guadalupe (C)	North Phoenix (M) Glendale (M)
Young life cycle	Southwest (F) West Phoenix (C)	South Phoenix (C)	Chandler (M) Gilbert (F)

that is designated for residential use. While net density is often felt to be more accurate since it screens out adjacent land uses for employment, public, or other uses, it may not always depict the actual "feel" of the area. For example, a small number of residential parcels may contain a large number of dwelling units (perhaps even high rises), and thus constitute a high net density. However, the residential parcels may be surrounded by acres of unrelated uses, such as parking lots, parkland, or transportation facilities, such that the effective residential density of the entire neighborhood may not be very high at all. (A discussion of the alternative definitions of density and their interpretations may be found in Forsyth 2003.)

Residential density in this analysis has used the more broadly adopted net density definition. Values of net residential density are illustrated for each of the 17 areas in Figure 55, which ranks the areas in order of density, from South Scottsdale at the highest with an average of 6.94 households per acre, to Maricopa County (at large—not part of any MPA) as the lowest at 1.47 households per acre. The average for the region overall is 4.87 households per acre. Because these figures are expressions of net density, they are higher than might be expected. While the data to directly compare gross and net density in the MAG region were not readily available, Table 26 shows how these measures would compare for a place like the Los Angeles region. Overall for the region, net density is greater than gross density by 22 percent, but the difference seems to be greatest in the lowest density jurisdictions (e.g., it is only 15 percent higher in Los Angeles County but 50 percent higher in San Bernardino). By Eastern U.S. standards, all of these densities are effectively suburban in character. Gross residential densities in places like Baltimore and Washington, D.C., tend to range from 10 to 25 households per acre, while areas with high proportions of multifamily housing may greatly exceed this average.

Table 26. Comparison of Net vs. Gross Residential Density.

Counties in Los Angeles Region	Net Residential Density (HU/Acre)	Gross Residential Density (HU/Acre)
Imperial	3.42	2.41
Los Angeles	10.11	8.79
Orange	6.40	5.20
Riverside	3.86	2.88
San Bernardino	4.12	2.75
Ventura	4.76	3.63
Total	6.84	5.60

The communities in Figure 53 have also been shaded to reflect their distance from the regional core, according to the C, M, and F designations introduced earlier in the classification system. It is not surprising that the highest density areas are generally those older communities that are closer to the core, shown in the darkest shading in Figure 55, the exception being South Phoenix with below average density at 3.68 households per acre. Similarly, the communities characterized as medium distance from the core tend to have densities in the average portion of the distribution (from 4.92 to 3.24), while those communities that lie furthest from the core have the lowest average densities, between (4.0 and 1.47). Northwest is a bit of an anomaly with a higher density than the rest of its peers in this third category.

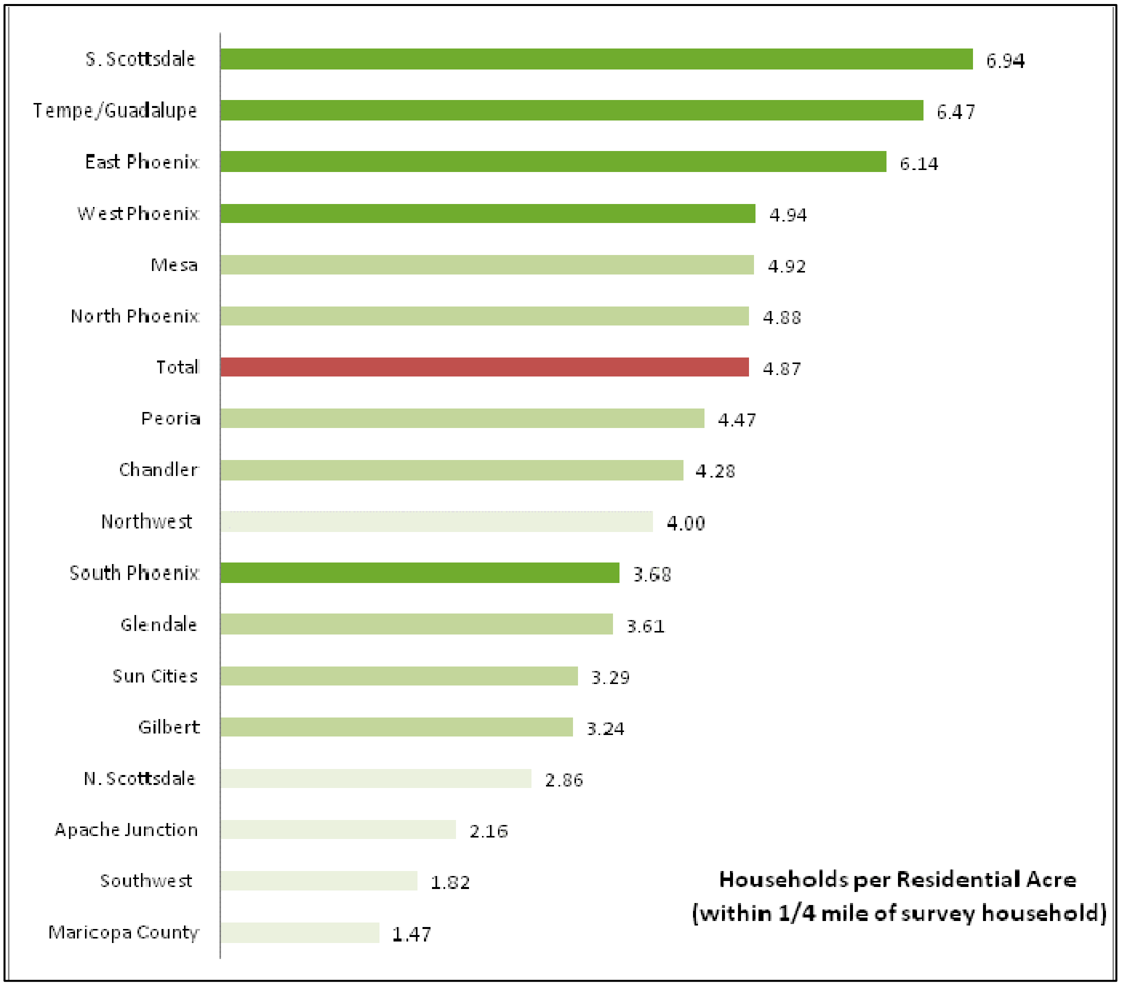

Figure 55. Study Area Net Residential Density.

Residential density level does not seem to have a particularly strong association with the other two community dimensions, stage of life cycle, and economic means, as illustrated in the Table 27. Younger households with children are more likely to reside in the lower-density suburban communities such as Chandler or Gilbert, unless they are of more limited economic means, in which case they are more likely to reside in South or West Phoenix. The older households tend to reflect a polarity in their residential preference, tending to live in either the more urban/higher-density areas, such as South Scottsdale, Tempe, and East Phoenix, or in the lowest density/least developed areas of the region, such as Apache Junction, North Scottsdale, Sun City, and unincorporated areas of Maricopa County. In general, the higher income households tend to reside further outside

Table 27. Residential Density by Area Classification.

Life Cycle	Economic Status	Area	Average Density (du/acre)	Maximum Density (du/acre)
Older	**Less Well-Off**	Apache Junction (F)	2.16	3.54
		East Phoenix (C)	6.14	24.40
		Sun City (M)	3.29	12.63
	Average	Maricopa County (F)	1.47	4.94
		South Scottsdale (C)	6.91	41.97
	More Well-Off	North Scottsdale (M)	2.86	8.13
Mixed	**Less Well-Off**	None		
	Average	Mesa (M)	4.92	22.52
		Northwest (F)	4.00	52.46
		Peoria (M)	4.47	39.91
		Tempe/Guadalupe (C)	6.47	59.70
	More Well-Off	Glendale (M)	3.61	9.60
		North Phoenix (M)	4.88	20.16
Younger	**Less Well-Off**	Southwest (F)	2.86	11.32
		West Phoenix (C)	4.94	31.06
	Average	South Phoenix (C)	3.68	11.75
	More Well-Off	Chandler (M)	4.28	17.38
		Gilbert (F)	3.24	9.26

the core, in areas such as North Phoenix, Chandler, Glendale, Gilbert, and North Scottsdale, with net densities ranging from 4.88 to 2.86 households per acre.

The measure of average density does obscure the fact that many of these areas, even those with very low average densities, have pockets of fairly high density, probably attributable to multistory apartments and condominiums and also the net land use calculation. This is also illustrated in Table 27, with notable examples in such low-density communities as Sun City (12.63 households per acre maximum), Mesa (22.52), Northwest (52.46), Peoria (39.91), Southwest (11.32), South Phoenix (11.75), Chandler (17.38), and Gilbert (9.26). However, this comparison of maximum with average density only serves to illustrate how low average densities are in all of the areas: These are residential densities that, on a national basis, are more likely to be found in a single family housing subdivision than throughout a major metropolitan area.

Still another way of illustrating the density composition of the 17 communities is through the comparative distribution graphic presented in Figure 56. The areas are again arranged in order of declining average residential density. The chart shows fairly clearly how monolithic the density distribution is in many of the newer, outlying areas.

Diversity

The second land use attribute is diversity, which describes the mix and balance of land uses. For this assessment, the land area associated with each parcel was categorized into eight elemental land use groupings: residential single family, residential multifamily, office;, commercial/retail, industrial, institutional, transportation, and open space. The distribution of these different land uses in each of the 17 study areas is shown in Figure 57.

Several important trends are evident in the information in Figure 57. First, while residential is the primary land use in all the areas, it is almost the exclusive land use in a number of the outer jurisdictions. This is particularly evident in Figure 58, where the percentage of land which is undeveloped has been removed, with the remainder being the distribution of uses on developed land. It can be seen that in places like North Scottsdale, Sun Cities, Glendale, Northwest, Peoria, and even North Phoenix, residential land uses account for 90 percent or more of all developed land—meaning that important complementary uses like retail and employment are in short supply, likely stimulating travel to access these needs. In a subset of these areas the distribution is even more monolithic, with few alternatives besides single-family detached residential development. In places like Peoria, Northwest, Southwest, Glendale, Apache Junction, and Maricopa County at large, multifamily residential accounts for less than 10 percent of all developed land uses (Figure 58).

In general, the more urban, close-in, and higher-density areas are more likely to have not only a mix of housing, but a mix of retail and employment activity. South Scottsdale, Tempe, East Phoenix, West Phoenix, Mesa, and South Phoenix all share the characteristic of being higher-density areas with an above-average mix of nonresidential land use as well as an above average share of multifamily residential. Somewhat surprising is the case of Gilbert, a newer, low-density area some distance from the regional core with an above-average proportion of nonresidential land use.

Of course, not all nonresidential land uses are likely to be valued the same by residents. Retail uses are perhaps the most desired since they supply the basic goods and services that households need for their daily living needs. In this regard, most of the low-density communities have retail land use shares of only 3 percent to 4 percent compared to about 7 percent to 11 percent in the higher-density areas. This is likely to constitute a significantly higher level of amenity.

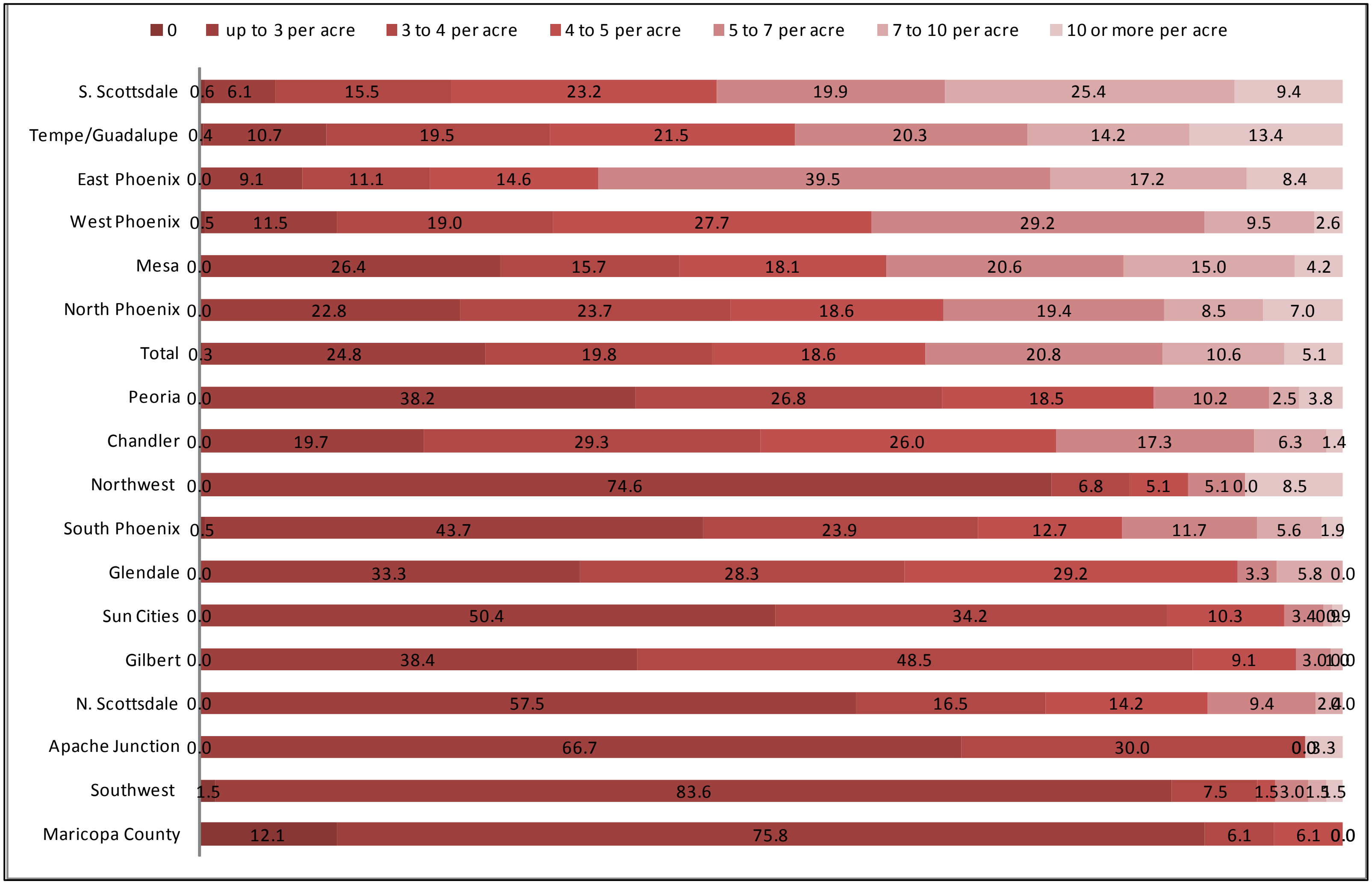

Figure 56. Residential Density—Percent by Group.
(Dwelling units per net residential acre)

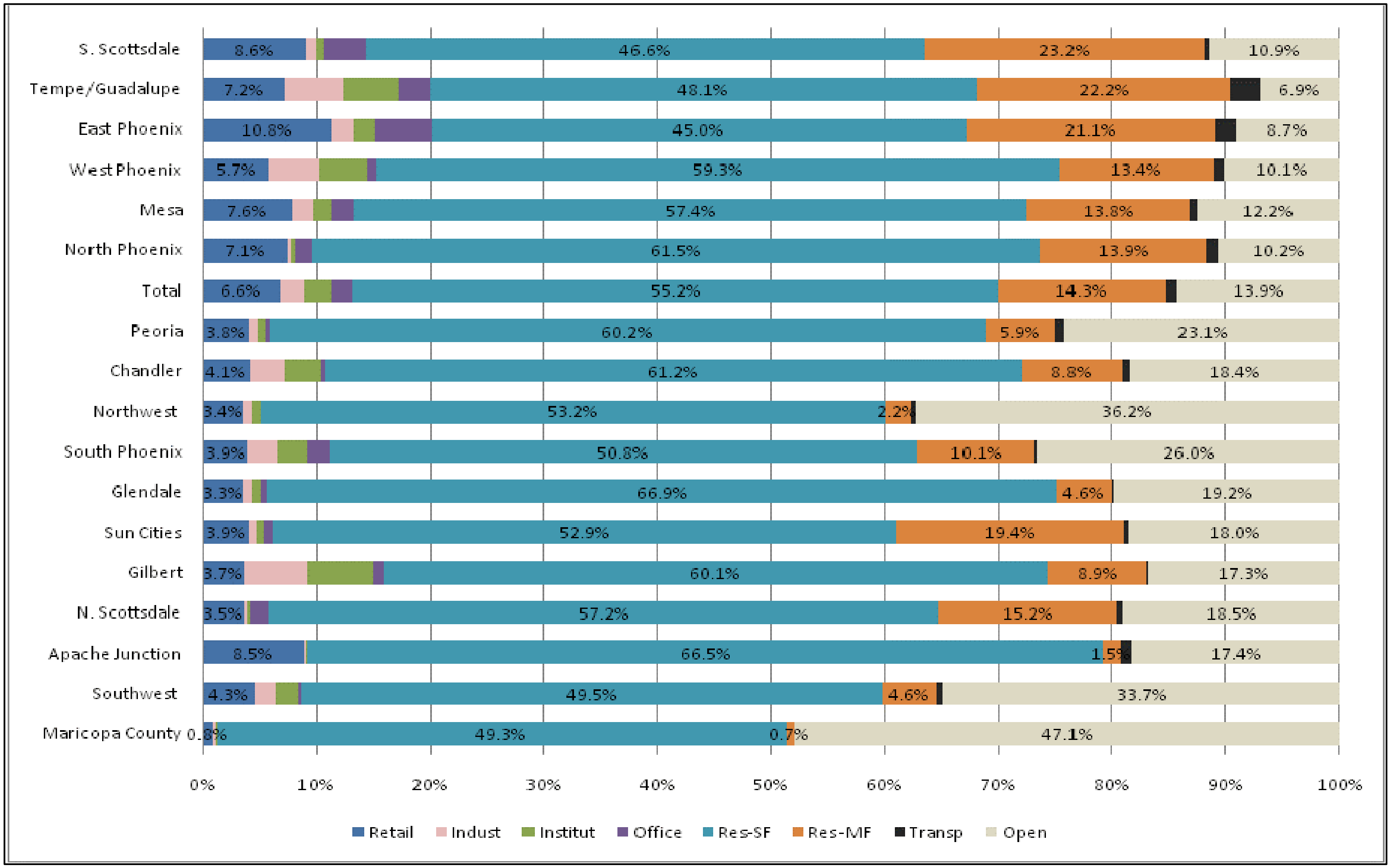

Figure 57. Distribution of Land Uses by Area.

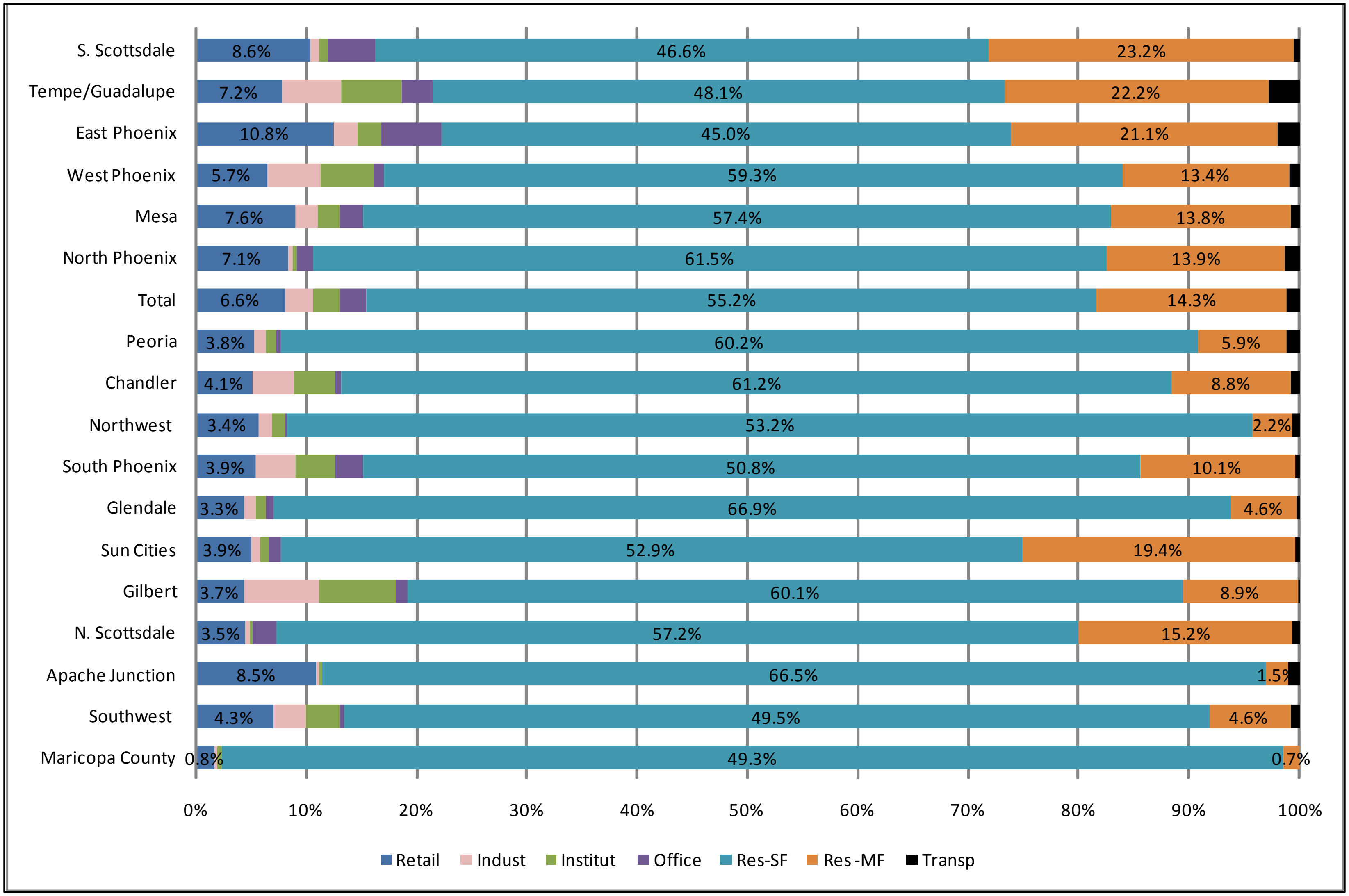

Figure 58. Distribution of Land Uses Net of Open Space.

In terms of the noncommercial land uses (office, institutional, and industrial), the valuation is less clear. Along with retail, these land uses represent employment opportunities for local residents; hence, higher proportions are likely to be more favorable for commuting purposes. However, various industrial and institutional land uses may not serve as ideal neighbors, particularly if they are located too close to residential concentrations. Obvious examples include factories that generate noise or emissions, or institutions such as prisons.

Land Use Mix (Entropy)

One of the key measures of land use diversity is entropy, introduced earlier. Expressed as an index, entropy is calculated from a proportioning formula to reflect the number of different land uses in a given area and the balance in their proportions. A larger number of different land uses and a uniform balance among them results in a value that is closer to 1, with 1 representing an ideal land use mix. As Figure 59 suggests, looking at the mean value of entropy across the 17 areas does not seem to show much variation. The sites are once again shown in declining order of density, but while there is a slight tendency toward a lower value of entropy as density declines, it is nowhere near as clear a relationship as density. While East Phoenix registers a high value of 0.56, Sun Cities shows a value of 0.43, and Southwest a value of 0.42—not a large proportional difference for areas that seem to be quite different. One major reason for this lack of sharp differentiation is that residential development is the dominant land use in all areas, and this has a strong centering effect on the calculated measure.

Important differences, however, may once again be seen in the distribution of values within each area, as shown in Figure 60. The higher-density areas earlier shown to have a greater variety of land uses show a much higher proportion of cases exceeding the value of 0.5, and even an appreciable number of cases where the value is in the 0.75 to 1.0 category. These differences within class (i.e., within the particular jurisdiction) become much more important when looking at individual cases within each area such as in regression analysis, when other attributes that may be favorable for that site (density, walkability, or regional transit accessibility) are accounted for simultaneously.

Design

Researchers tested a variety of measures to represent design, the feature that tries to reflect the quality of the walking environment. Ultimately, however, the walk opportunities index proved to be the most effective measure when applied in regression models to explain household VMT generation. Hence, discussion is focused on the value and variation of this measure across the study sites.

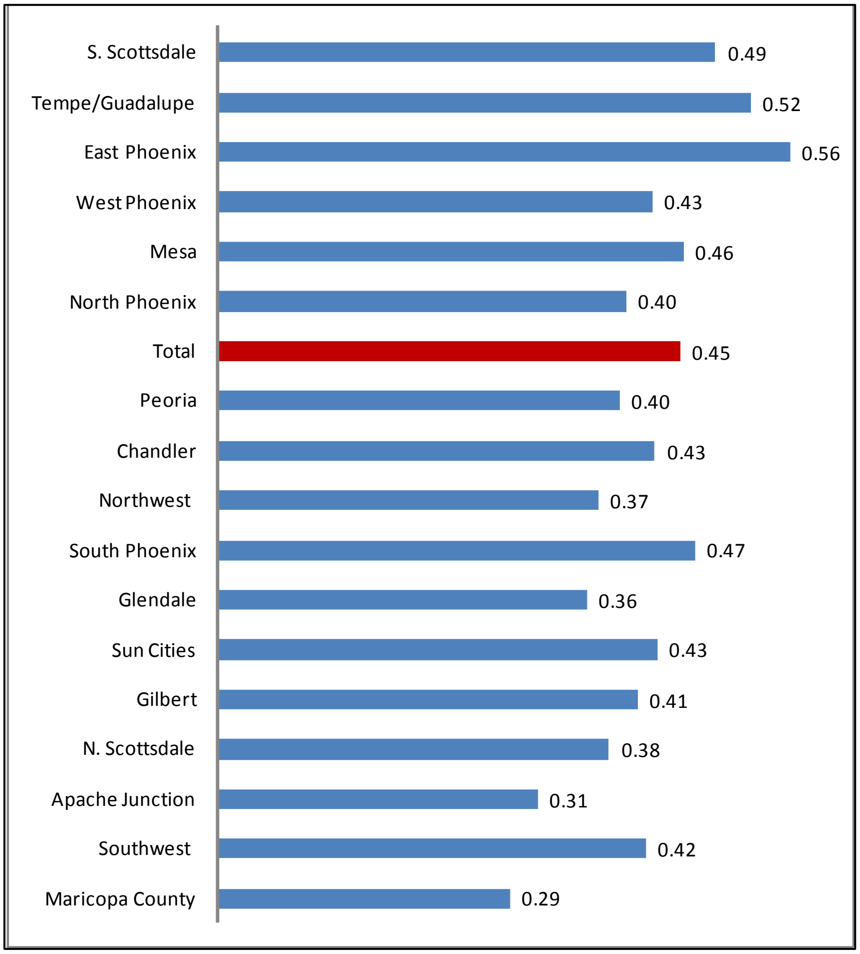

Figure 59. Entropy: Index of Land Use Mix and Balance.
(Value of 0 to 1, with 1.0 = ideal mix)

As illustrated in Figure 61, the average walk opportunities ranges from a high of 48.66 in East Phoenix to a low of 0.35 in Apache Junction, with an overall average of 26.67 for the region. Unlike the preceding entropy measure, this measure does track much more directly with density. However, there are still some anomalies showing, with places like Chandler and Sun Cities having higher values than might be expected in relation to their less urban character. While those two areas do not have above average levels of retail and office development in their mix, they may have acquired their higher scores by virtue of greater co-location of their commercial and residential areas and perhaps more direct walk paths. In contrast, Apache Junction, which does have a fairly decent proportion of local retail development, has the lowest average walk opportunities value. This appears to be the result of residential and retail activities being physically segregated, and lack of convenient walk access between.

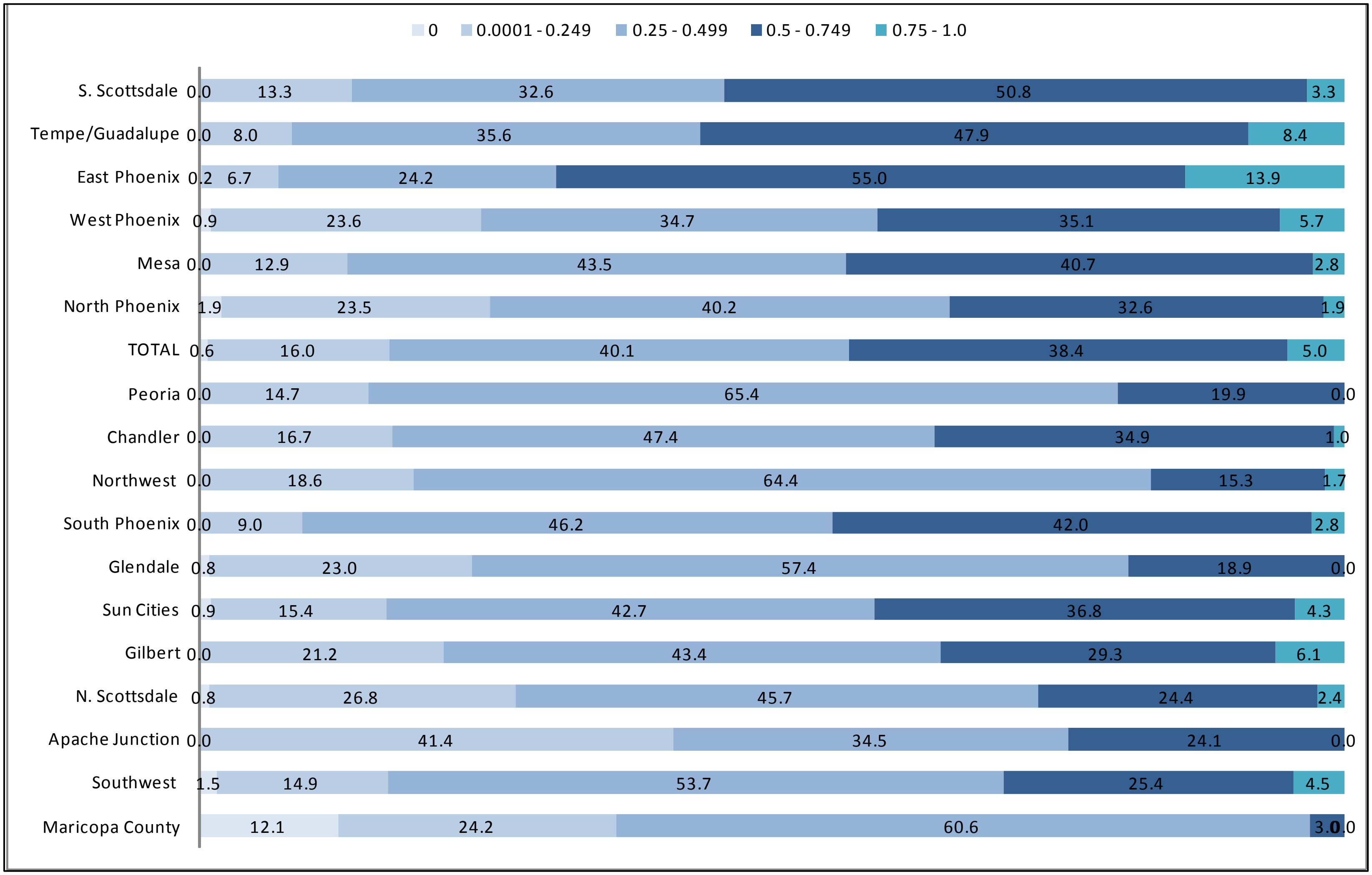

Figure 60. Entropy Index: Percent by Group.
(Value of 0 to 1, with 1.0 = ideal mix)

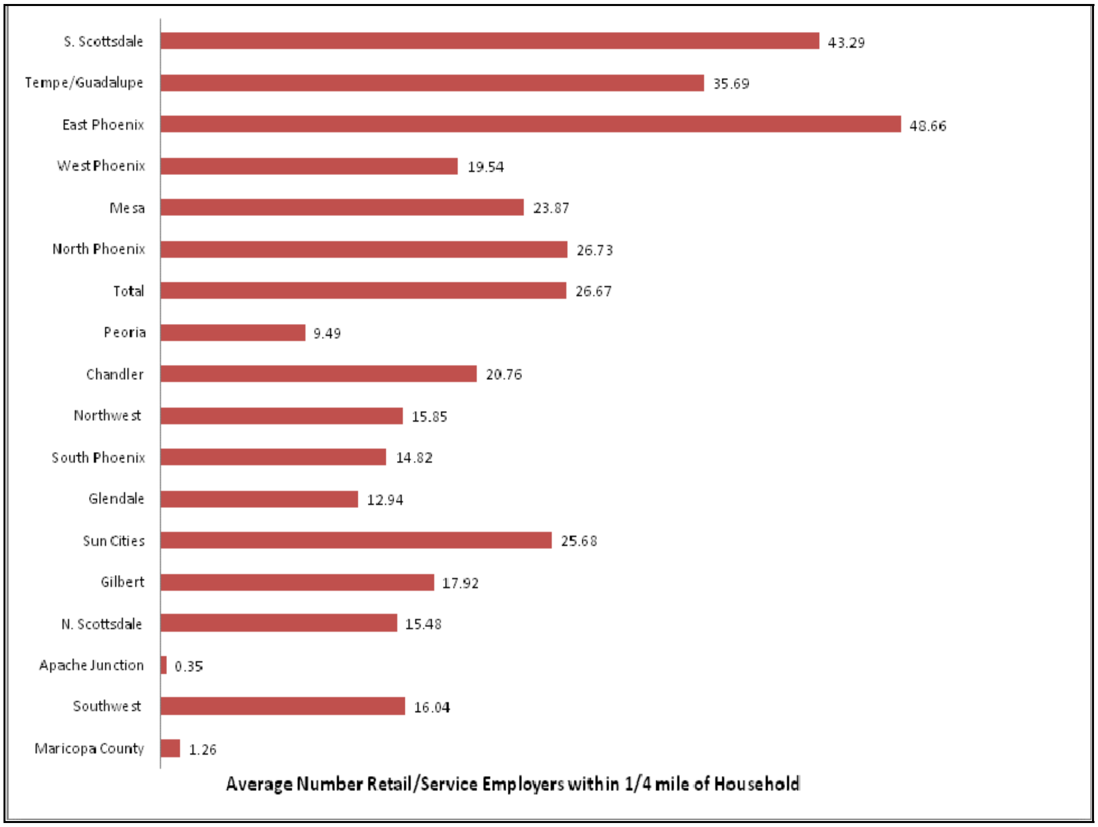

Figure 61. Walk Opportunities.

Again, the true nature of the measure is much more visible upon looking at the distributions of its value within each area, rather than simply the mean. This is evident from the data presented in Figure 62. While most areas have some examples of neighborhoods with good to excellent walk opportunities (i.e., 20 or more), it is fairly clear that the more urban, close-in areas like East Phoenix, Tempe, and South Scottsdale have many more of these examples than do more typical suburban areas like Glendale, Peoria, and Southwest. It is very evident from these data just how limited walk opportunities are in places like Apache Junction and the unincorporated areas of Maricopa County.

Figure 62. Walk Opportunities—Percent by Group.

Regional Accessibility

The final factor in the set of 4Ds —regional accessibility—is really a measure of land use outside the immediate vicinity of the household. It describes the number of opportunities in inverse proportion to the difficulty of traveling to them. In technical terms, it is calculated as the sum of opportunities (in this case, jobs) in each other regional TAZ, divided by the generalized cost of travel (in this case, travel time) from the origin zone to reach them.

Since accessibility means different things to different travel audiences, a range of accessibility measures were calculated and investigated for their value in explaining auto ownership and travel differences. Accessibility was calculated to jobs of all types (representing employment opportunities) and to only retail jobs (representing opportunities for shopping and services). The ability to reach all jobs and retail-only jobs was also calculated separately for travel by transit and by auto, and for each, separately under peak period (when travel conditions may be congested) and off-peak (when congestion may be less, but there may also be less transit service) travel conditions.

There are several hypotheses as to how accessibility affects travel. Overall high accessibility means more activities closer to home, which can compete with neighborhood opportunities, but which can also lead to shorter average trip lengths. If the measure is more total jobs close to home, the expectation would be for shorter commute trips while if the measure is retail jobs, then shorter shopping and other home-based and nonhome-based trips would be expected. If transit accessibility is high, that means that households have the option of reaching more activities outside the neighborhood by means other than driving, so the expectation would be for more transit trips, fewer auto trips, and potentially fewer vehicles owned. If auto accessibility is much greater than transit for the same household, the likelihood that the household will own fewer vehicles and, hence, drive less, is much less probable.

Figure 63 shows the average levels of regional transit accessibility across the 17 study areas. An obvious set of relationships exists between accessibility to all jobs vs. only retail jobs, with the former being much greater in most cases (except, for example, in South Scottsdale), and also that there are more jobs of both types reachable under peak period travel conditions than under off-peak (higher levels of peak service are presumably able to offset congested peak travel speeds).

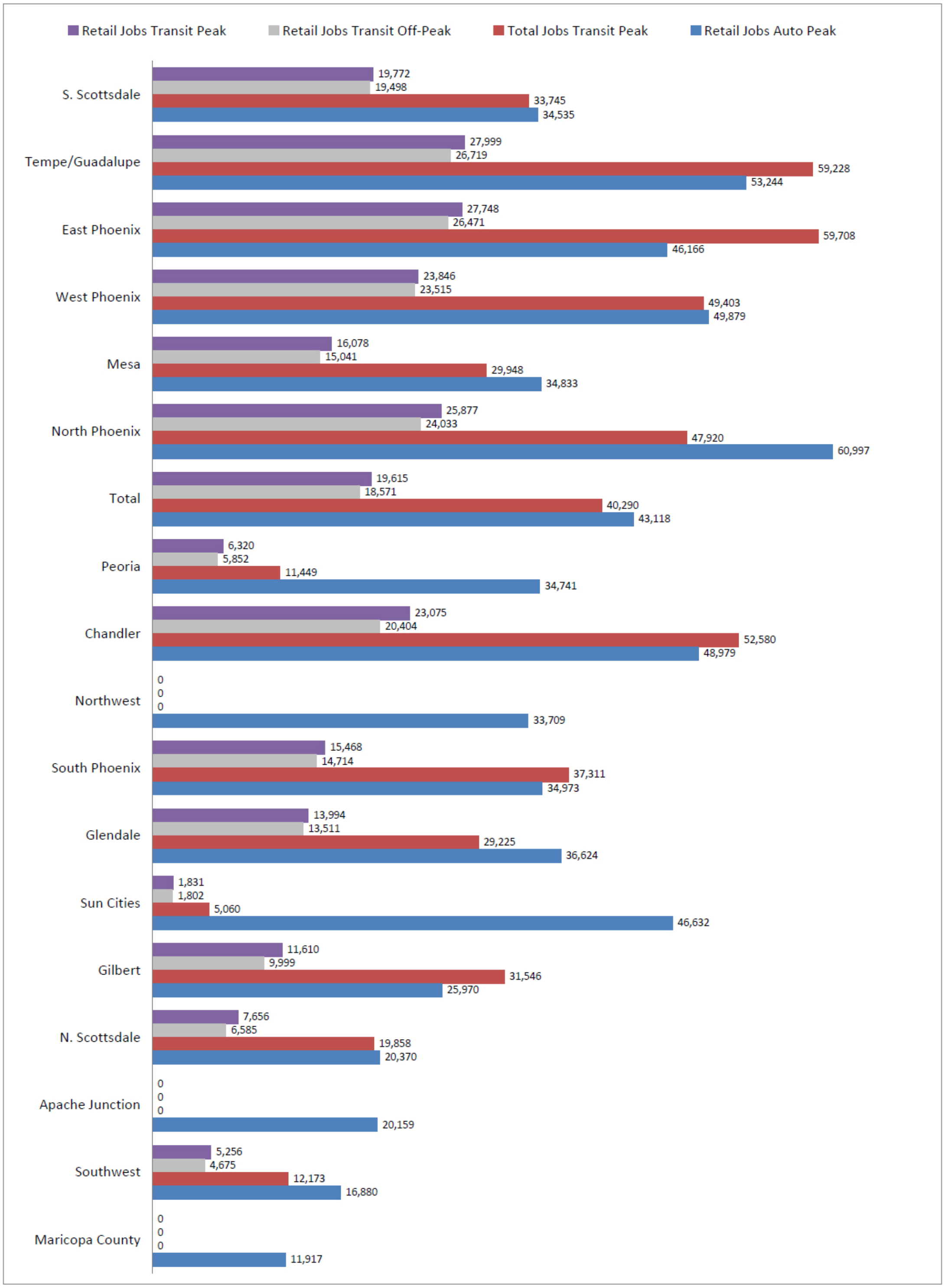

Figure 63. Regional Transit Accessibility.
(Total jobs of stated type discounted by peak/off-peak travel time)

Again, there is some correspondence between the level of transit accessibility and density, but a number of interesting anomalies begin to show. One such anomaly is how a place like South Scottsdale can have such low levels of Total Jobs accessibility in relation to less centrally located areas like North Phoenix and Chandler. In fact, South Scottsdale is almost on a par with such seemingly incomparable areas as Gilbert, Glendale, and Mesa. The explanation would appear to lay in the existence of much more extensive transit service provided to the three latter areas, most likely to address greater commuter volumes.

It is worth noting that transit service in several of the areas is extremely limited (Peoria, Southwest, North Scottsdale) or non-existent (Northwest, Apache Junction, Maricopa County), since that would serve to make these areas highly/exclusively auto dependent for their travel needs.

Figure 64 puts this advantage of transit accessibility into more of a relative perspective, by comparing each area's transit accessibility with the equivalent auto accessibility. Unsurprisingly, many more jobs of each type are accessible by auto than by transit. While centrally located places like Tempe and East Phoenix also enjoy excellent accessibility by auto, what starts to become clear is how some of the less-central areas begin to show their strategic advantages in relation to auto accessibility. North Phoenix, for example, has among the highest levels of auto accessibility in the region, attributable in no small part to its service by L101. Chandler also has a surprisingly high level of regional auto accessibility, most likely also due to its access to L101.

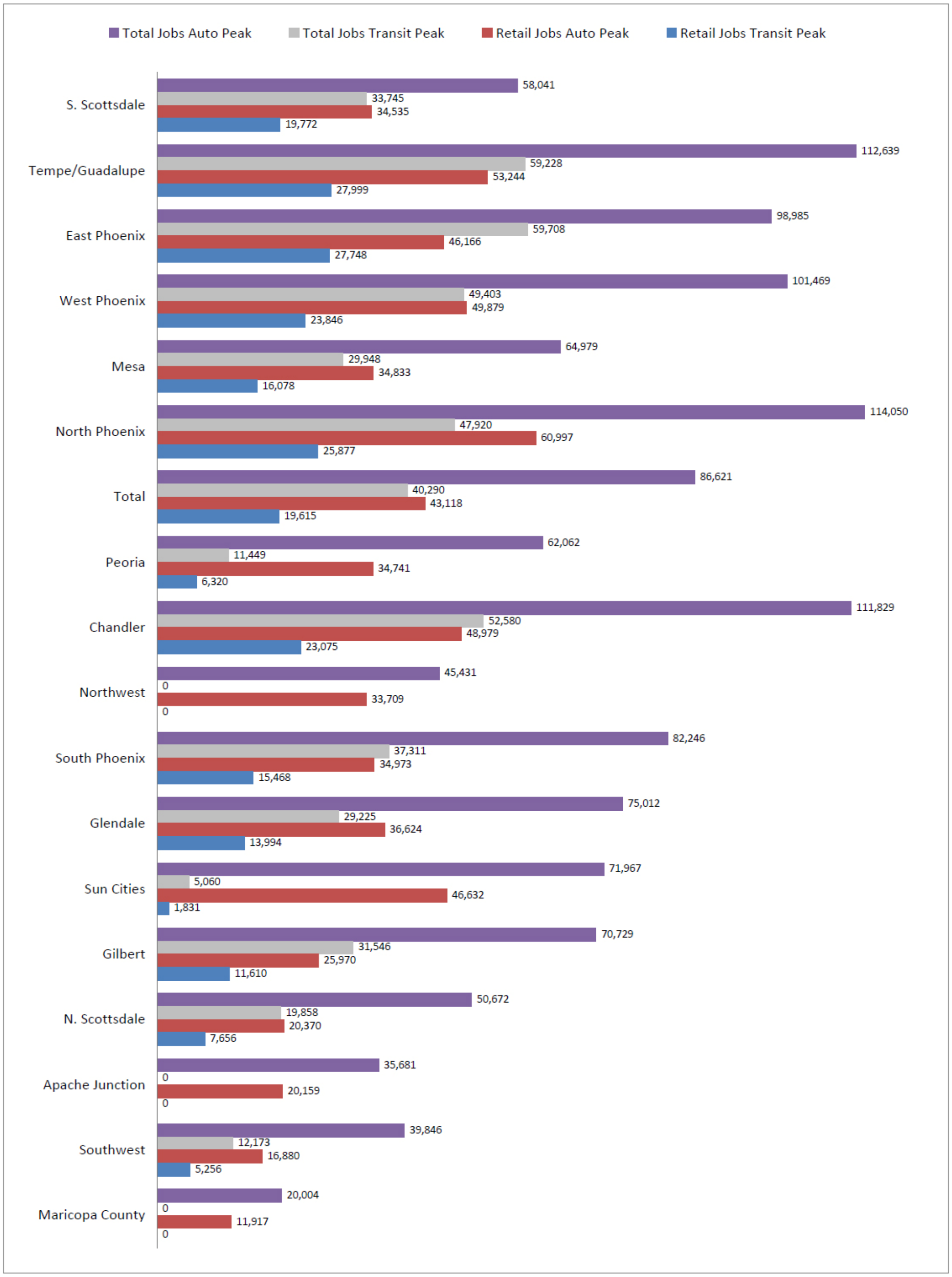

Figure 64. Regional Transit vs. Auto Accessibility.
(Total jobs of stated type discounted by peak/off-peak travel time)

Figure 65 shows directly the relationship between auto and transit accessibility by graphing the ratio of the two measures. This is shown in terms of a percentage—the number of jobs accessible by transit vs. the number of jobs accessible by auto. What this shows, for example, is that in places like East Phoenix that have very high auto accessibility, transit accessibility is also very high—in the absolute, and as a percentage. This suggests both excellent accessibility and a relative balance, meaning these residents have attractive alternatives. The same is true for South Scottsdale, though their overall accessibility levels are much less, and for Tempe/Guadalupe. Even Chandler, because of its good transit service (high regional accessibility to jobs by transit), shows very high regional accessibility and an above-average balance. Meanwhile, areas like Glendale, North Scottsdale, Peoria, and Southwest are much more one-dimensional in the choices they can provide.

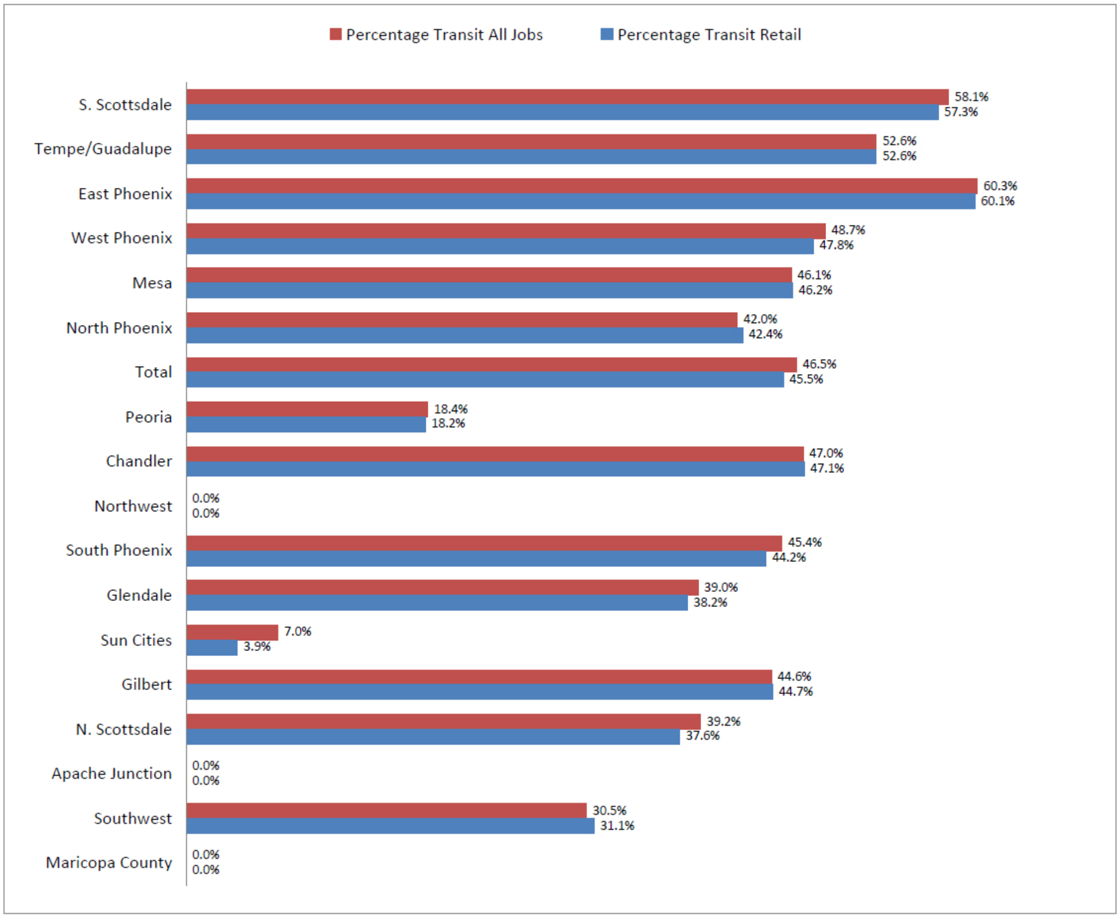

Figure 65. Ratio of Job Accessibility by Transit vs. Auto.
(Total jobs of stated type discounted by respective peak/off-peak travel time)

BASIC TRAVEL RELATIONSHIPS

Having established an understanding of how the various study areas compare with regard to demographic and land use characteristics, this section begins to examine the possible relationship between land use and travel behavior. These are very basic relationships, looking at essentially average trip lengths and VMT rates in relation to density and some of the other land use measures. In some cases the relationships appear obvious, though in others it is difficult to see a clear link. This is not surprising, since the way in which these factors impact travel is not linear, but is the way in which they combine to create the environmental context for the given household. Later in this chapter, a multivariate statistical approach—regression—is used to quantify these relationships and give validation to the implied role of the 4Ds.

The first set of relationships looks at the association between average trip lengths and density, since density has been the factor used to rank-order the study areas in all preceding discussions. In this manner, density is often used by planners as a simple way of depicting land use and is probably not a bad choice for simple comparisons such as these. Unfortunately, unless the contributing factors of diversity, design, and destinations are properly accounted for, density can be a statistical mask for these underlying variables and take away the understanding of what is really causing travel behavior differences.

Average Trip Lengths

One simple but telling measure of land use is average trip length. Generally, if land uses are more compact and there is good balance, shorter trips are possible. Figures 66 through 69 show the variation in average trip length for four trip purposes: home-based work, home-based shopping, home-based other and nonhome-based. Again, the 17 study areas are organized in declining order of residential density, and the density values are shown in light shading.

With respect to home-based work, Figure 66 suggests a trend toward longer trip lengths in the lower-density, outlying areas. With a regional average of 9.45 miles, the higher-density, closer-in, more urban areas like South Scottsdale, Tempe, and all of the Phoenix sites except North Phoenix are clearly below this average, while areas not fitting this description, like Peoria, Glendale, and North Scottsdale are measurably above. In the case of the most remote areas (Northwest, Southwest, and Maricopa County) the average length of a work trip is well above the regional average—in the range of 15 to 18 miles. The reason for the differences in the case of work travel may be less about compact local land use and more about a simple imbalance of jobs and housing. Indeed, looking at the comparative regional accessibility to jobs (by auto or transit) in Figure 64 makes it fairly clear that residents of these outlying districts have much less access to employment since the bulk of the region’s jobs are located in the central valley.

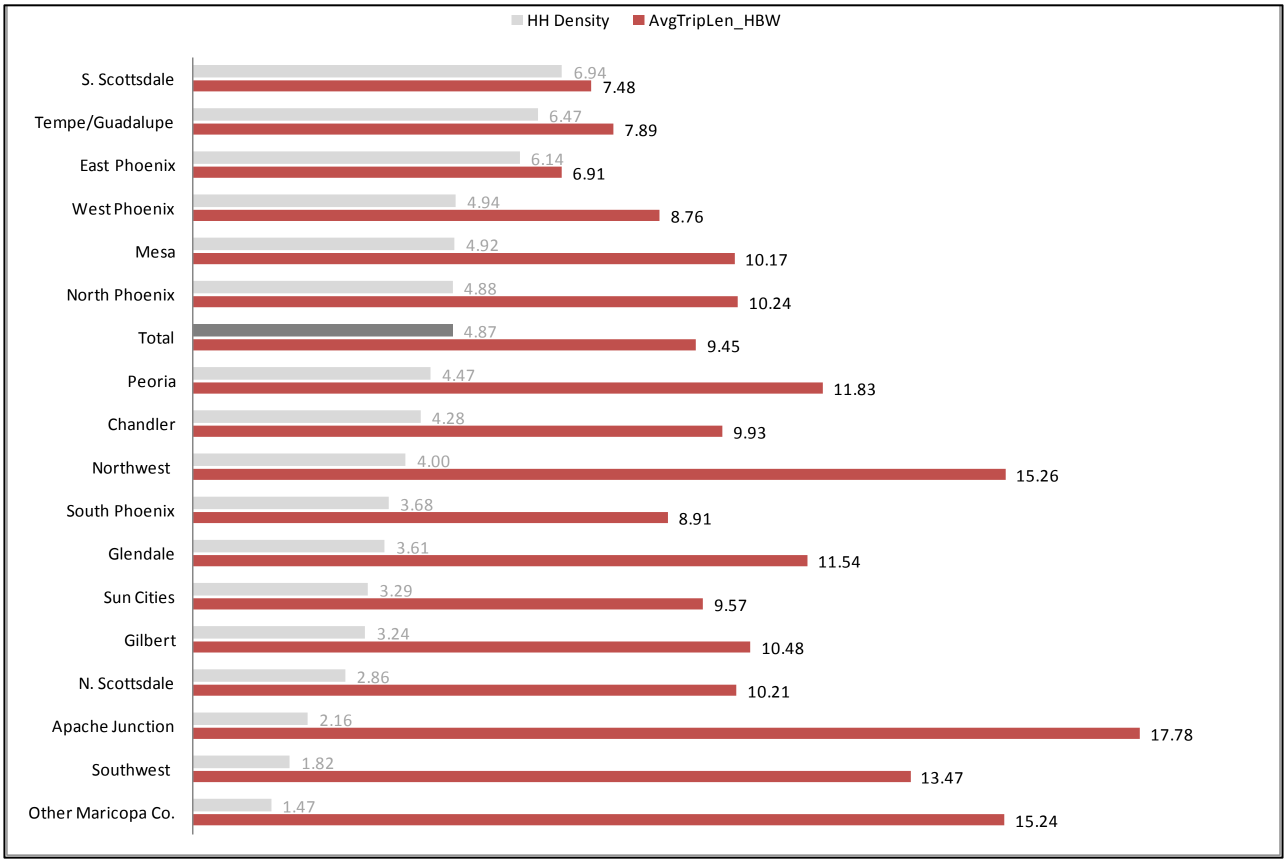

Figure 66. Average Trip Length (in miles)—Home-Based Work Trips.

A similar trend toward longer trip lengths with respect to lower-density and less mixed areas is also seen for home-based shopping travel in Figure 67. With an average trip length of 3.29 miles for the region, the inner areas of South Scottsdale, East, and West fall below or well below this average (a range of 2.27 to 3.08 miles), while the lower-density, less-mixed areas like Peoria, Chandler, Glendale, and Gilbert are above average (in the range of 3.67 to 4.88), while the outlying areas like Northwest, Southwest, and Maricopa County are in the range of 4.32 to 7.10. Apparent anomalies are Apache Junction and Sun Cities, which are low density but also have enough internal retail activity to satisfy most residents' shopping needs.

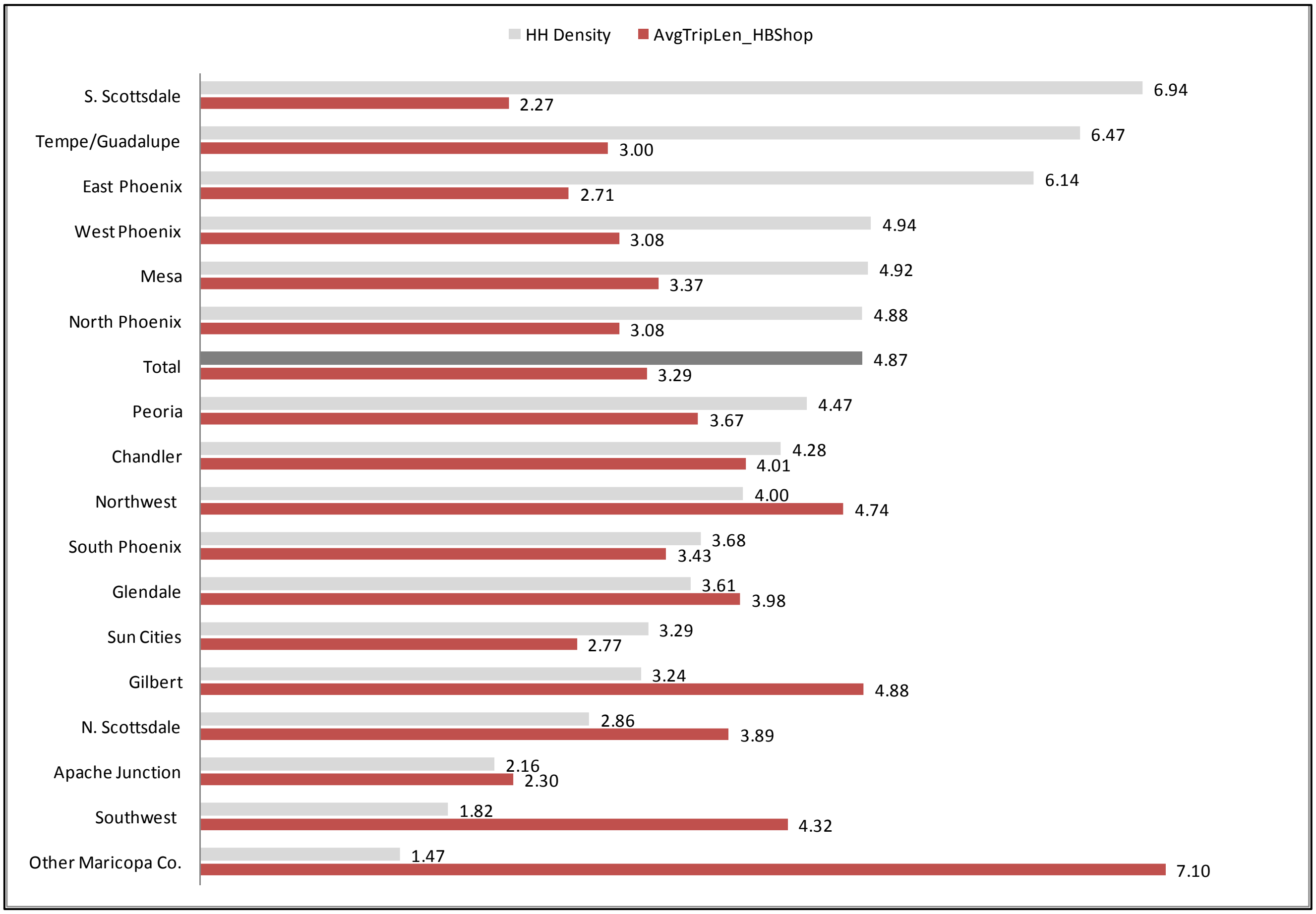

Figure 67. Average Trip Length (in miles)—Home-Based Shopping Trips.

With regard to home-based and nonhome-based other travel, as shown in Figures 68 and 69, the trends toward longer trip lengths in the lower-density, less-mixed areas are still somewhat in play, but are less robust than with the first two purposes. It would be expected that home-based other trips would have a similar pattern as home-based shopping trips and, in most cases, the home-based other trips are about 1.5 to 2 miles longer than the shopping trips for the same area, with some tendency toward proportionately longer trips in the lower-density areas. Nonhome-based trips should also be affected by compact land use, since the trip from one activity to the next would figure to be shorter when activities are more concentrated. However, the other behavior that begins to factor in with nonhome based trips is that travelers with difficult access to retail and services are more likely to group trips into tours so as to make each journey more efficient, whereas persons in areas with more opportunities close to home are likely to make more single-destination home-based trips. This may help explain the narrowing of distances across areas when comparing average nonhome-based trips.

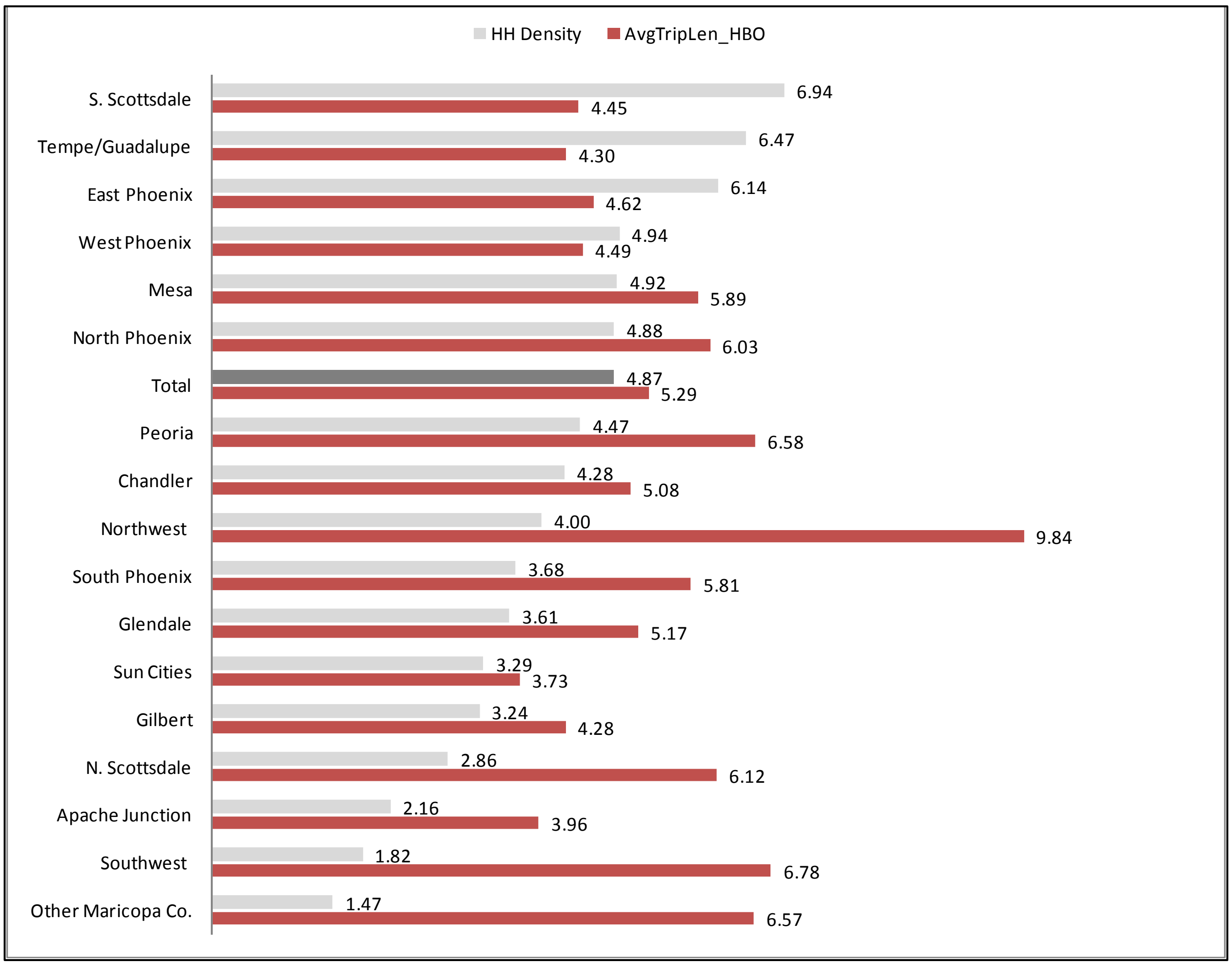

Figure 68. Average Trip Length (in miles)—Home-Based Other Trips.

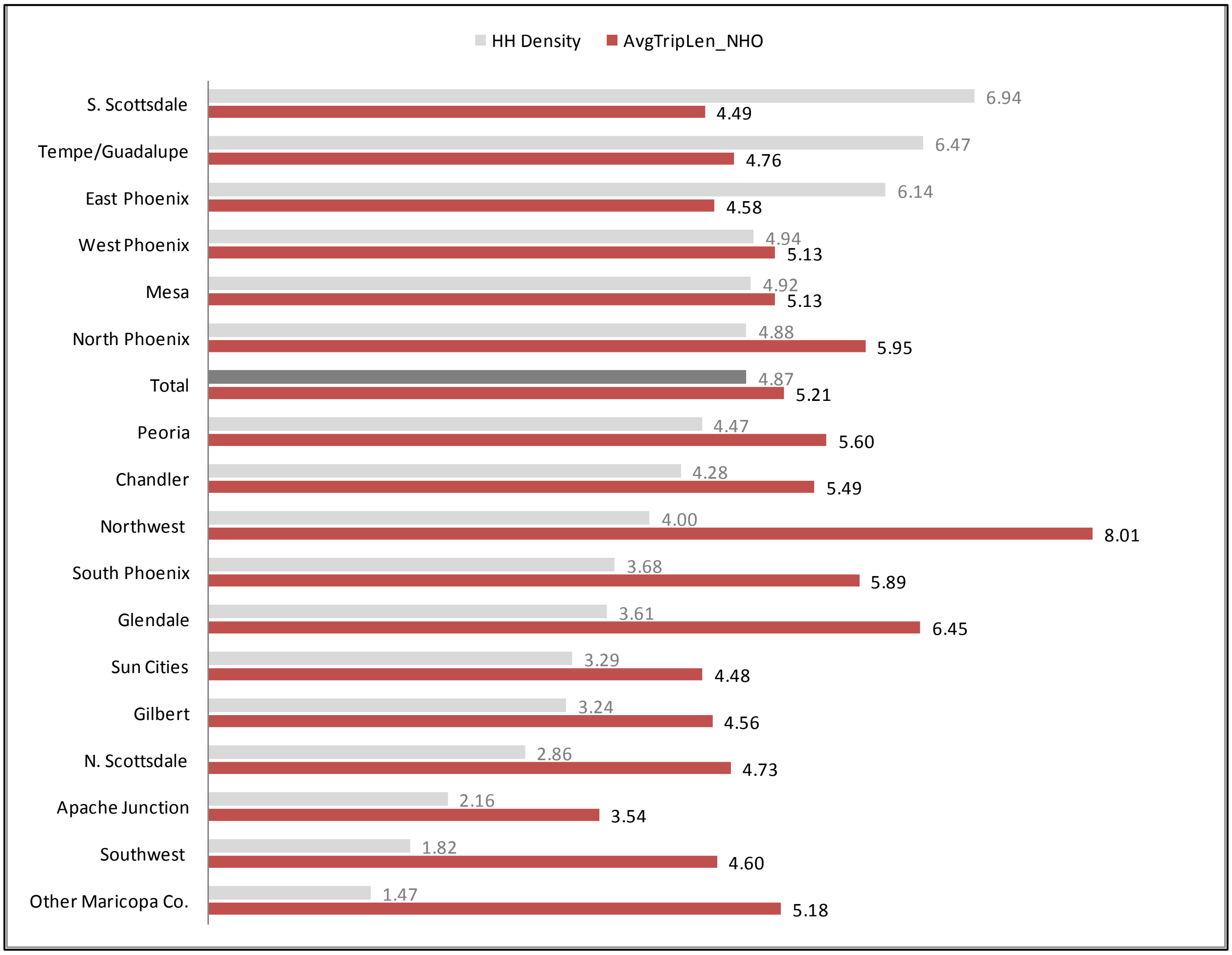

Figure 69. Average Trip Length (in miles)—Nonhome-Based Trips.

Figures 70 and 71 explore the possible role of land use mix and walk opportunities in affecting average trip length for home-based shopping and nonhome-based trips. While the scale differences between the two land use variables and the trip lengths make the comparison a little challenging, a close study does show a bit of the implied relationship that as local land use improves (more compact areas, mixed-use patterns), average trip length diminishes.

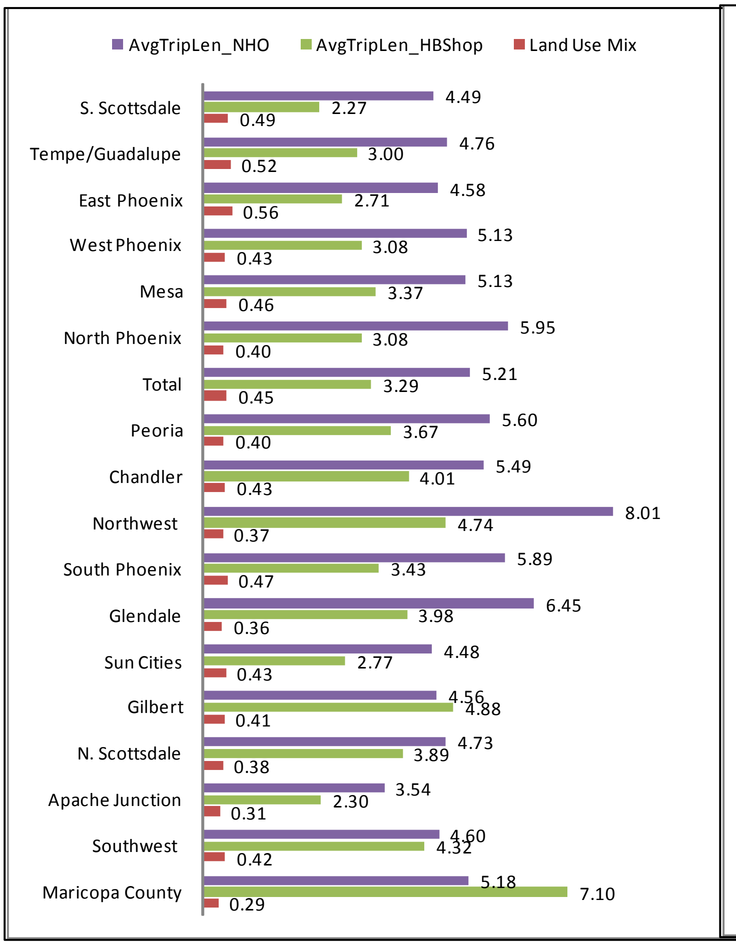

Figure 70. Nonhome-Based Other and Home-Based Shopping Trip Lengths in Relation to Entropy.

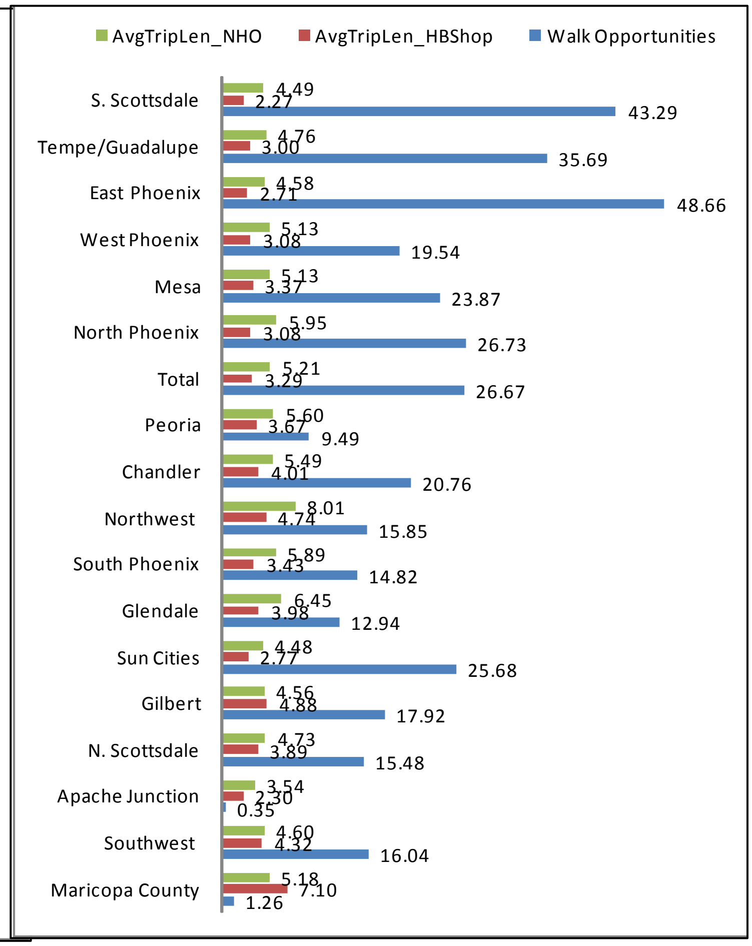

Figure 71. Nonhome-Based Other and Home-Based Shopping Trip Lengths in Relation to Walk Opportunities.

VMT RELATIONSHIPS

One of the most elemental relationships expected between compact, mixed-land use and travel is reduced rates of VMT. Several factors generally combine to cause this, including lower rates of household vehicle ownership, more trips made to destinations closer to home (in some cases by walking), and more trips made outside the neighborhood by transit. Figure 72 gives rates of daily weekday VMT per capita (total household VMT divided by the number of members). HBW, or work-related, VMT consists of both home-based work and nonhome-based work travel; NW, or non-work, VMT then contains all residual travel, including home-based shop, school, university, other, and nonhome-based travel.

The VMT numbers shown in this figure were calculated from the travel information provided by the 2001 travel survey households. Trip distance was determined based on the geocoded (latitude/longitude) origin and destination details provided for each trip record and represents over-the-road distance. VMT for each recorded trip was credited only to the household driver to avoid double-counting of miles when other household members may have been accompanying the driver on the trip. Using this standard

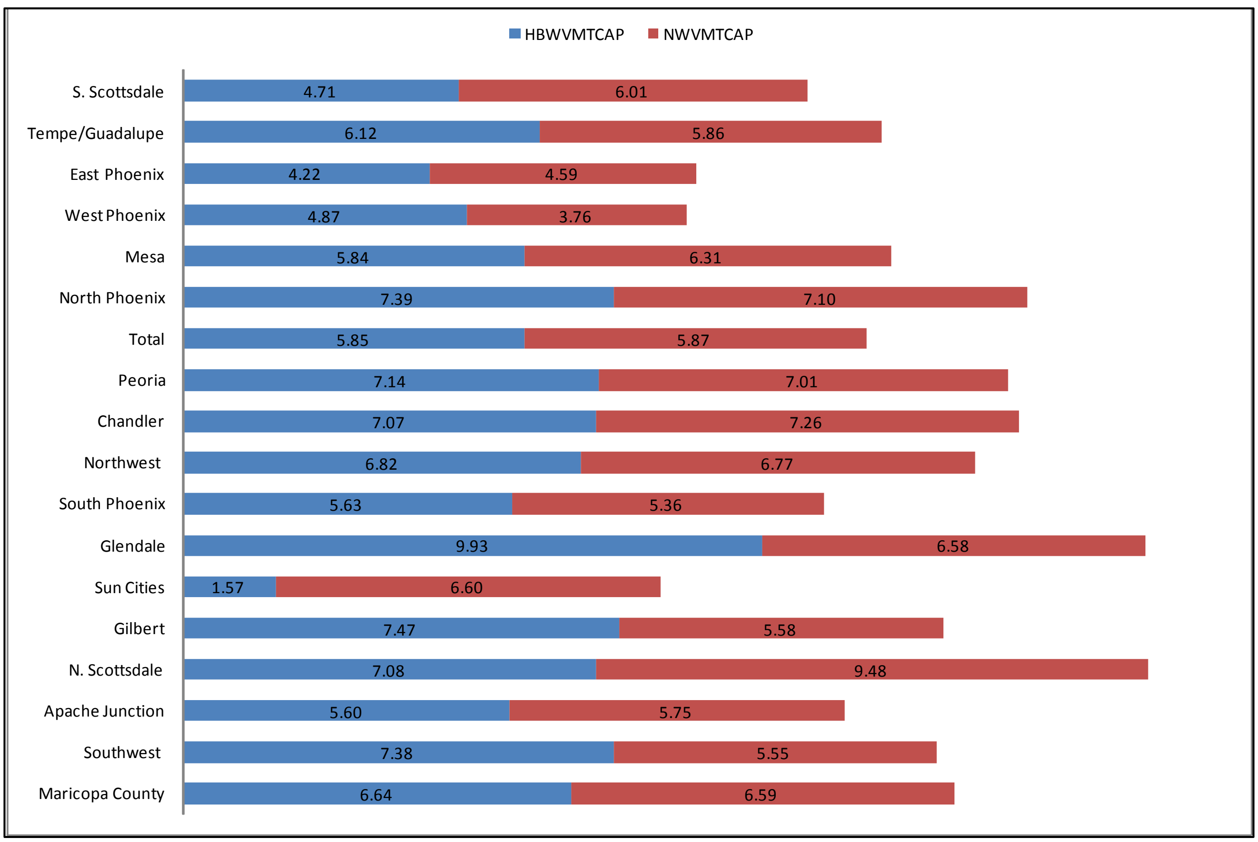

Figure 72. Daily Per Capita VMT (Weekday).
(Home-Based Work and Nonwork)

approach, however, the average weekday VMT per capita for the MAG region is 11.72 miles, which is considerably smaller than the average of 27.3 miles reported in the Federal Highway Administration's *Our Nation's Highways* summary for 2000. This difference may be due to the calculation of VMT in the BTS estimate using data from actual roadway volume counts, which would also include commercial and through traffic. If not, then this comparison indicates a major discrepancy. The weekend travel data from the MAG survey were not used in the calculation of total VMT above, but it is noted that their values appeared to be even more surprisingly low—on the order of 1.7 miles per capita per day for the region.

A side analysis was performed to examine the effects of September 11, 2001, on regional travel. The timing of the survey was such that 2400 households were interviewed before the September 11 events, and 1618 were surveyed on or after. Comparing the behavior of the sample before and after the September 11 events revealed an overall reduction in daily VMT per capita from 12.6 to 10.4 miles, or 17.3 percent. Nonwork travel declined slightly more (6.39 vs. 5.10 miles per capita, or 20.2 percent) than work travel (6.21 to 5.31 miles per capita, or 14.5 percent). However, even this difference does not account for the magnitude of discrepancy with the national statistics (and with comparable urban areas).

Because averages can often hide significant differences in behavior within a population, the per capita VMT data in Figure 72 were also summarized in distributional format as has been done with many of the preceding relationships. These relationships are shown in Figures 73, 74, and 75 for daily total, work, and nonwork per capita VMT, respectively, for each of the study areas. Per capita VMT was categorized into levels of zero, 0 to 5, 5 to 10, 10 to 20, 20 to 50, 50 to 100, and 100- plus miles per day. These figures also show considerable variation within each area (examples of households with very low rates of VMT generation and also examples of those with high rates).

A general conclusion that researchers reached was that multiple factors have a bearing on rates of vehicle travel, and these are not particularly well understood by simply comparing the different study areas. There tends to be as much variation in VMT within a given study area as there are across the areas. To begin to see how these factors work together, it is necessary to employ a different analytic approach that is designed to capture these interactions.

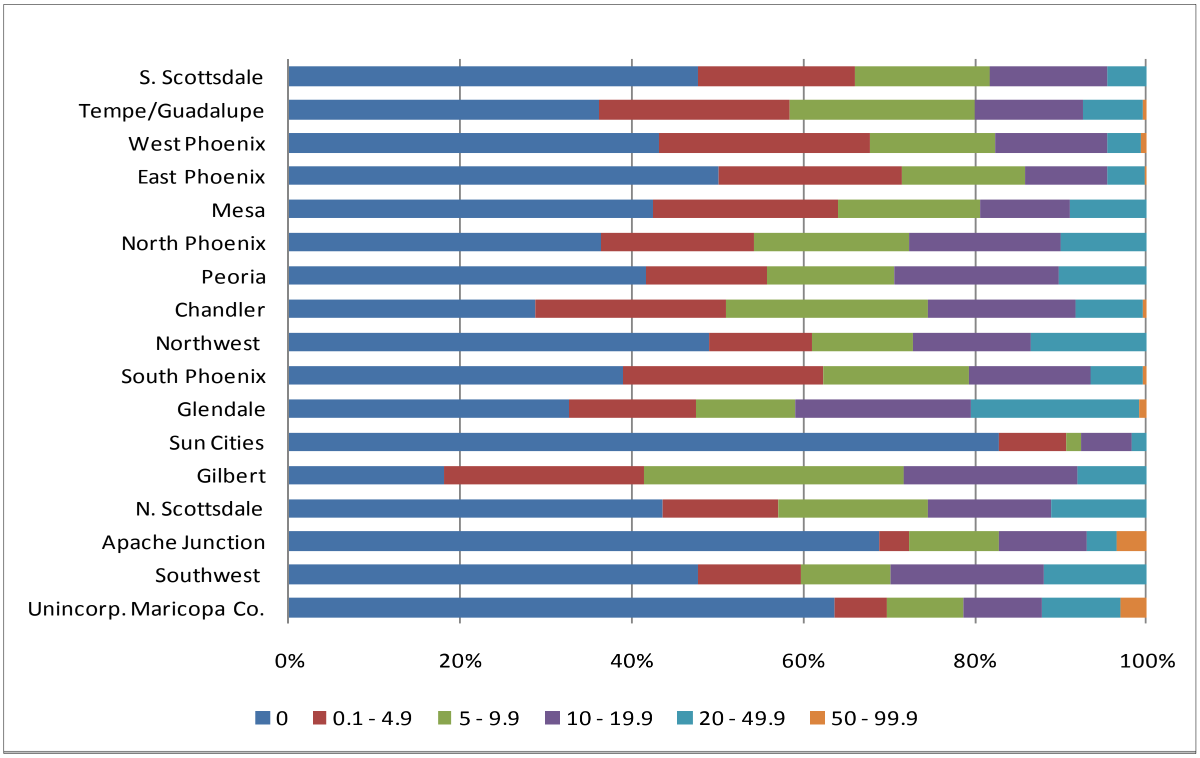

Figure 73. Total Daily VMT per Capita—Percent by Mileage Group.

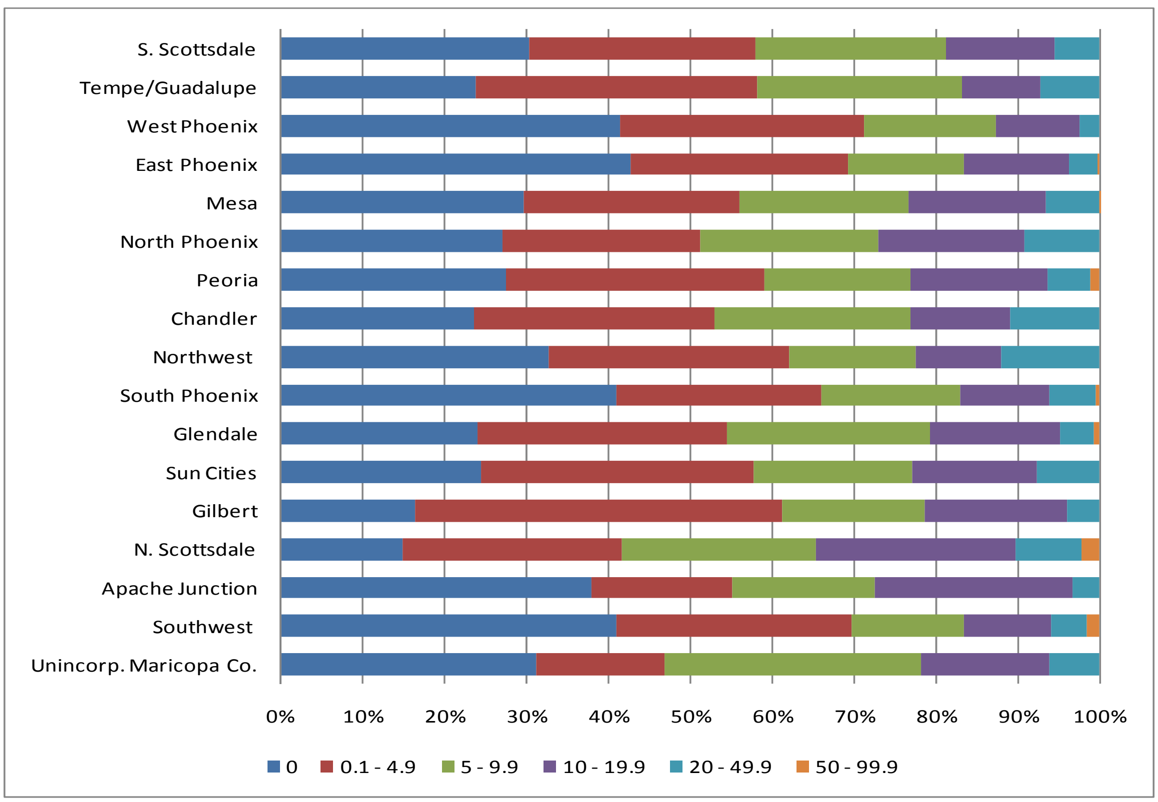

Figure 74. Daily HBW VMT per Capita—Percent by Mileage Group.

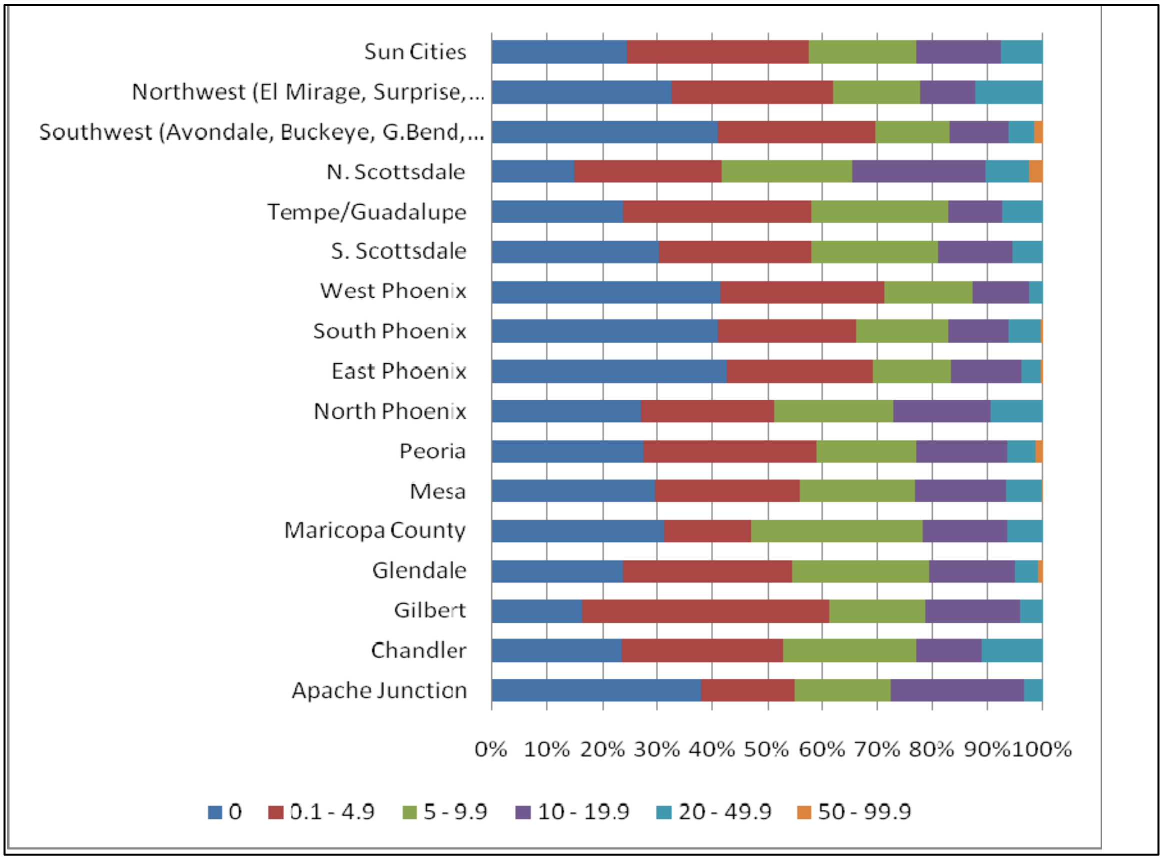

Figure 75. Daily Nonwork VMT per Capita—Percent by Mileage Group.

CLEAR RELEVANCE OF 4DS LAND USE RELATIONSHIPS

The preceding sections explored the potential influence of land use characteristics like density, diversity, design, and destinations through the comparison of regional jurisdictions. Unfortunately, the diversity within these study areas makes it difficult to see clear linkages to the 4Ds characteristics. It is actually easier to see the general importance of each of these factors by ignoring the jurisdictional approach and looking at simply the relationship between the factor and VMT. This has been in done in Figures 76 through 79 to illustrate the direct relationship between per capita VMT and each of the critical variables:

- Density (Figure 76): VMT declines from 17.17 to 9.12 miles as net residential density increases from less than 1 unit per acre to 10 or more units per acre.
- Diversity (Figure 77): Using entropy as the measure of proportional mix of different land uses, VMT declines from 15.2 for areas with no mix to 8.49 in areas with the best balance of land uses.

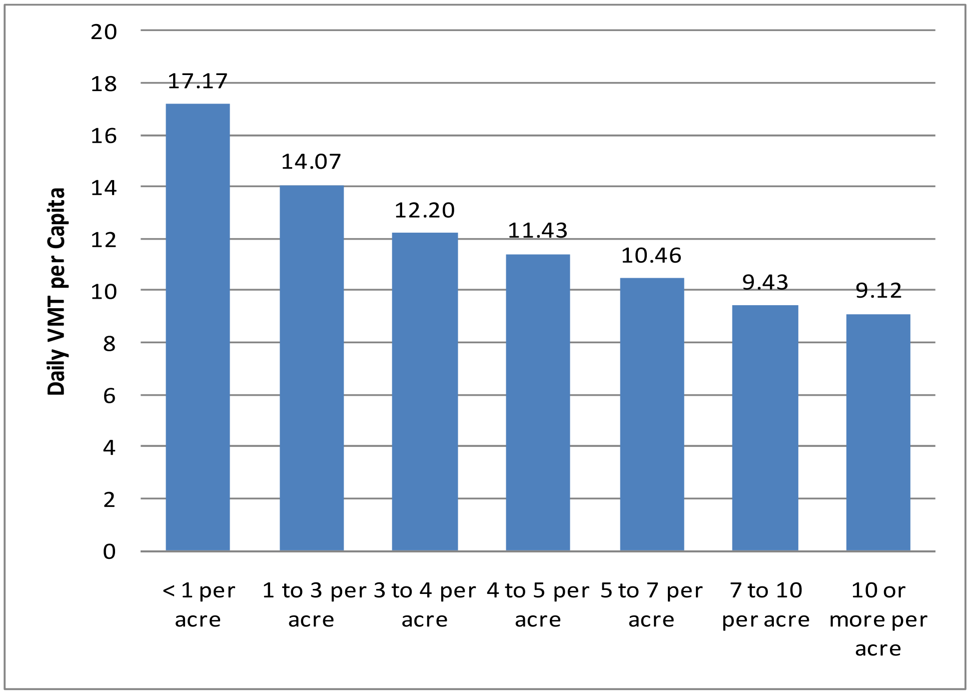

Figure 76. Daily VMT per Capita vs. Net Residential Density.

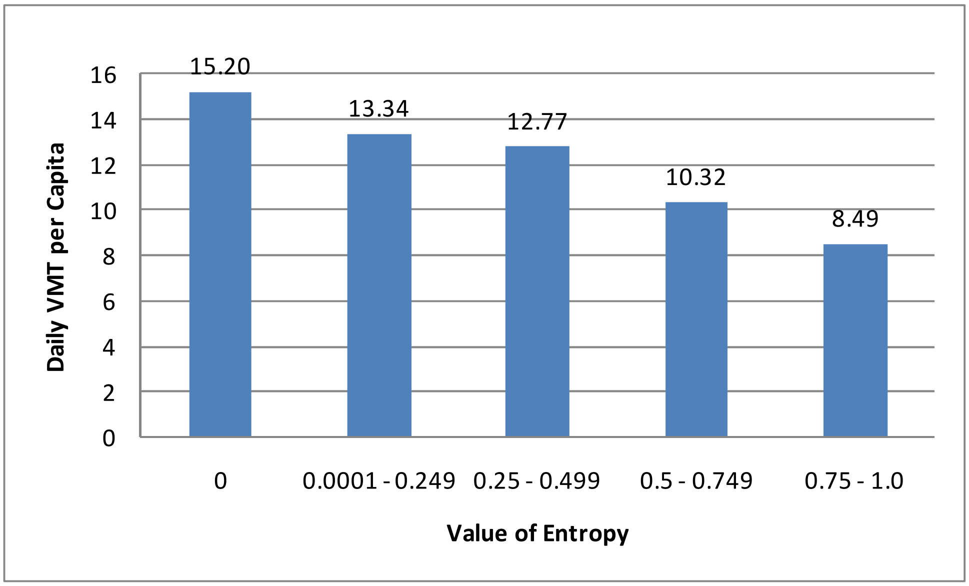

Figure 77. Daily VMT per Capita vs. Land Use Mix (Entropy).

- Design (Figure 78): Represented by walk opportunities within one-quarter mile of the household, VMT declines from 13.2 miles where there are no opportunities with walking distance to 9.97 where there are 40 or more opportunities.
- Destinations (Figure 79): Represented by regional jobs accessibility, VMT declines from 13.8 miles where there is no transit accessibility (service) to 9.28 where 100,000 or more jobs can be reached by transit.

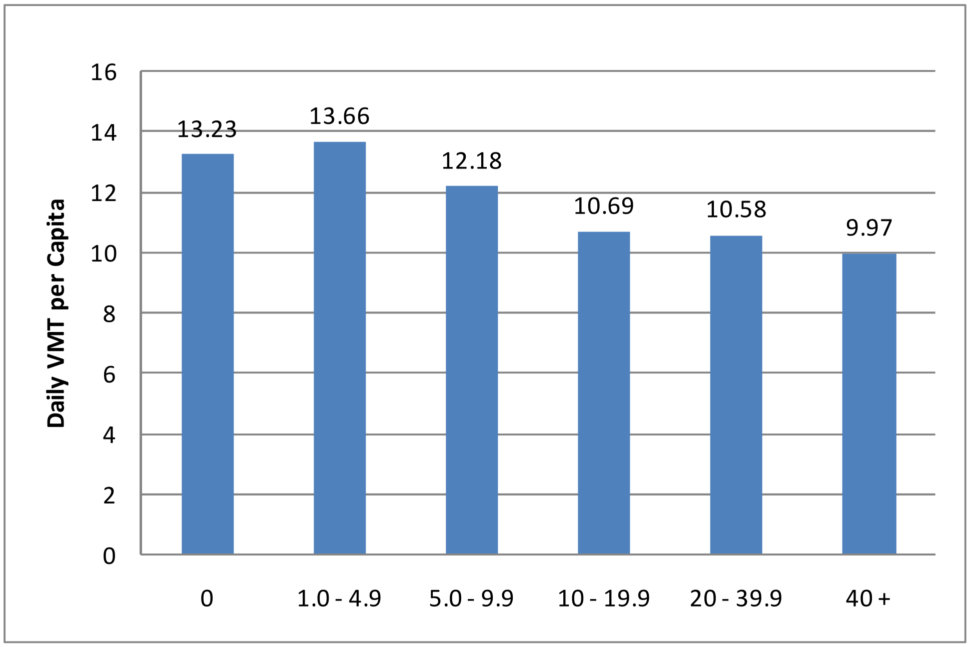

Figure 78. Daily per Capita VMT vs. Weighted Retail/Service Opportunities within One-Quarter Mile.

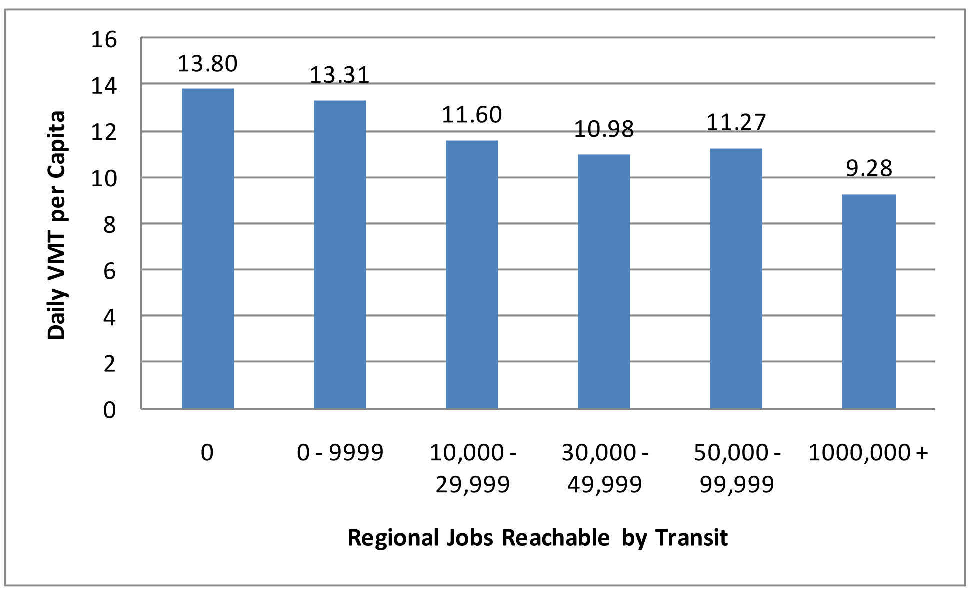

Figure 79. Daily VMT per Capita vs. Regional Transit Accessibility to Jobs.

REGRESSION ANALYSIS

Given that each of the land use factors above appears to have an obvious relationship with VMT production when viewed apart from its melding with other factors across a jurisdictions, it is of key interest to see if a different statistical approach can begin to sort out the numerous interactions that are obviously occurring within jurisdictions. In an attempt to sort out the multiple influences of land use environment, travel alternatives, and the socioeconomic characteristics of households on their travel, the various relationships explored above were examined using multiple regression analysis. Separate regression models (equations) were developed for household vehicle ownership and daily household VMT, reflecting—where statistically relevant—the contribution of each set of variables on the particular behavior. In addition to a total daily household VMT model, separate models of work and nonwork VMT were also developed.

The models resulting in the best fit of the respective dependent variable with the measures of household characteristics and land use created from the available data are summarized in Table 28. The R^2 statistics for the models, reflecting goodness of fit, are shown at the bottom of table along with the corresponding sample size. The R^2 values range from 0.384 for the vehicle ownership model to 0.106 for the nonwork VMT model. While higher R^2 values would be desirable, these are very acceptable statistics for cross-sectional models of this nature, particularly given the high degree of variation in daily VMT. More relevant is the statistical significance of the individual coefficient estimates, as represented by the *t* statistic in the adjacent column.

Table 28. Models of Household Vehicle Ownership and VMT for Phoenix/MAG Region (2001 HTS).

	Vehicle Ownership		Total VMT		Work-Related VMT		Non-Work VMT	
	Coefficient	t	Coefficient	t	Coefficient	t	Coefficient	t
Constant	0.541	9.787	-0.704	-0.371	-4.082	-3.174	3.479	3.196
After Sept. 11, 2001	---	---	-1.617	-2.039	---	---	-2.009	-3.564
Household Members	0.099	17.879	-1.47	-3.26	-0.512	-2.303	-0.82	-2.683
Household Workers	0.285	10.529	7.518	13.748	7.675	19.763	---	---
Household Students	---	---	3.243	5.589	---	---	2.877	6.961
Household Income	0.187	21.557	3.699	12.181	1.991	9.266	1.668	8.077
Household Vehicles	NA		5.89	10.754	2.65	6.835	3.109	8.303
Regional Transit Accessibility (Peak -- All Jobs)	---	---	-2.07E-05	-1.925	-2.15E-05	-3.708	---	---
Regional Transit Accessibility (Off-Peak -- Retail Jobs)	---	---	-4.94E-05	-2.131	---	---	-3.38E-05	-2.641
Household Density/Acre	-0.011	-3.205	---		---	---	-0.187	-2.35
Land Use Mix w Multi-Fam	-0.351	-5.036	-5.354	-5.354	-3.539	-2.26	---	---
Walk Opportunities	-0.001	-1.695	---	---	---	---	---	---
R-squared	0.384		0.296		0.275		0.106	
n	3615		3615		3615		3615	

Values of *t* greater than 2.24 reflect 99 percent confidence in the value of the respective coefficient with a sample of this size, and *t* values greater than 1.64 reflect a 95 percent level of confidence. Hence, each of the coefficients in Table 28 is significant at the 99 percent level, and the coefficient on the walk opportunities variable is significant at the 95 percent level.

Findings from these models are summarized below:

- **Vehicle Ownership:** The average household starts out with (a constant value of) 0.541 vehicles, and the number of vehicles goes up 0.099 with each household member, 0.285 with each household worker, and 0.187 with each level of household income (in six categories, explained in footnote 4). Household vehicle ownership is reduced in this equation by improved land use. Number of vehicles per household declines with increases in household density/acre, land use mix, and walk opportunities. Regional transit accessibility—either for all jobs or retail jobs only—did not have a significant relationship to vehicle ownership in Phoenix, although it was an important explanatory variable in similar models developed in Baltimore and Los Angeles.
- **Daily Household VMT:** Total daily household VMT in the model is most significantly influenced by the number of household workers, the number of vehicles, income, and the number of students. Increases to each of these variables increases daily VMT for the household, while household size itself carries a negative sign. This is in compensation to the coefficient values for household workers and students: If workers or students were not included as separate variables in the models, the coefficient on household size would be larger and have a positive sign. The land use variables included in the total VMT model are regional transit accessibility for both total jobs and retail jobs, and land use mix. Increases in any of these serves to reduce household VMT. Neither household density nor walk opportunities proved to be significant in this model, though their effects are represented indirectly through their relationship with vehicle ownership: as household density, land use mix, and walk opportunities increase, vehicle ownership rates decline, and a decline in vehicle ownership leads to a decline in household VMT. This model also includes a dummy variable to account for potential systematic effects of the September 11 attacks on overall travel. The coefficient on this model indicates a reduction of 1.617 daily VMT associated with travel in the period following September 11, 2001.
- **Daily Work-Related VMT:** The difference between this model and the model of Total VMT is the absence of an explanatory role for number of students or regional transit accessibility to retail jobs. Appropriately for work-related VMT (home-based and nonhome-based trips), transit accessibility to all jobs is significant. Once again, the sign on the coefficient for household size is negative, the result of a balancing relationship with number of workers. Increases in the value of the two land use variables, transit accessibility and land use mix, leads to reductions in work-related VMT, and as with the total VMT model, the role of household density, mix, and walk opportunities is represented indirectly through vehicle ownership. The September 11 variable did not prove significant in the

work-related model, implying that the events did not measurably impact work travel.

- **Nonwork VMT:** The structure of the nonwork VMT model is appropriately different from the work-related model in that it does include student members of the household, and does not include household workers. Also, the regional transit accessibility measure for retail jobs was significant in the model, whereas access to total jobs was not. For whatever reason, the most significant local land use variable to work in the model was residential density, having more explanatory power than land use mix or walk opportunities—a bit of a surprise. Again, however, the role of all three local land use variables is played out indirectly through vehicle ownership. The September 11 events did have an effect on nonwork travel, with a coefficient implying 2.009 fewer VMT per day traveled for nonwork purposes after September 11.

To gauge the absolute and relative importance of the independent (explanatory) variables in each model, it is more useful to look at their elasticities, calculated as the impact of a change in each on the dependent variable (vehicles or VMT) while all other variables are held constant. A summary of the elasticities for the coefficients in the four models is presented in Table 29. These are point elasticities, calculated as the percent change that would occur in the dependent variable in response to a 1 percent change in the mean value of the particular independent variable.

Table 29. Estimates of Point Elasticities.

	Mean Values	Vehicle Ownership	Daily HH HBW VMT	Daily HH NW VMT	Daily Total HH VMT
HH Size	2.5	0.124	-0.096	-0.163	-0.141
HH Workers	1.2	0.182	0.68	NA	0.346
HH Students	0.66	NA	NA	0.151	0.082
HH Income	3.93	0.424	0.578	0.523	0.558
HH Vehicles	1.64	NA	-0.318	-0.403	-0.367
Reg Tr Acc ALL	40290	NA	-0.065	NA	-0.032
Reg Tr Acc RET	18571	NA	NA	-0.05	-0.035
HH Density/acre	5.12	-0.063	NA	-0.076	NA
LU Mix	0.45	-0.125	-0.119	NA	-0.092
Walk Opportunities	26.6	-0.045	NA	NA	NA
Sept 11 Dummy	0.4	NA	NA	-0.064	-0.024
Model Prediction at Mean		1.63	15.52	12.55	26.08

Elasticities calculated as percent change in dependent variable (vehicle ownership or VMT) Induced by a 1 percent increase in the respective independent variable

In review of these relationships, the elasticities on the demographic variables have the largest values. This is a typical result, although it should be noted that from a policy perspective, these are not variables that are likely to change over time or in response to some planning initiative, whereas the land use variables can be so affected. Of all the demographic variables, the elasticities for household income and household vehicle ownership are the largest. While income is not affected by planning, vehicle ownership certainly can be by virtue of land use or other policy actions. The elasticities for local land use—density, mix, and walk opportunities—are about what would be expected based on research in Baltimore and Los Angeles. However, the surprise finding is the very minor role played by regional transit accessibility. In both the Baltimore and Los Angeles 4Ds models as well in the US EPA's Smart Growth Index Model, regional transit accessibility is typically the dominant environmental variable influencing vehicle ownership and VMT. In the Phoenix region, however, it virtually does not appear to matter. This may be because transit service is not as extensive as it is in the other metropolitan areas, or that the overall regional fabric of land use is so auto-oriented in its scale and layout that households truly cannot exist without ample private vehicle resources.

Model Validation

To test the accuracy of the vehicle ownership and VMT models, the models were used to estimate both vehicles and VMT for each household in the travel survey database. The results were then summarized by study area and compared with the values obtained directly from the survey. The results of this comparison are summarized in Table 30.

For the most part, the estimates of vehicle ownership and VMT predicted by the models are reasonably close to the equivalent averages for the respective study area. In 11 of the 17 cases the prediction of vehicle ownership is within 2.5 percent of the actual registered in the survey, and in only one case—Maricopa County—is the discrepancy greater than 10 percent. The correspondence between the model estimate of total VMT and that taken from the survey is not quite as sharp, although in 10 of the 17 cases the two estimates are within 10 percent. It is worth noting that the standard deviations for the model estimates are in every case less than the natural deviation found in the survey data.

What seems particularly interesting is the pattern in which the model is either over- or underpredicting VMT. It seems to systematically underpredict the amount of VMT that would be generated by households in the lower-density, less urban districts (Chandler, Gilbert, Glendale, Maricopa County, Peoria, North Phoenix, North Scottsdale, and Northwest), while overpredicting the level of VMT in the higher-density, more urban districts (East, South and West Phoenix, South Scottsdale, and Tempe/Guadalupe). This result suggests that there is something structurally missing in the current model specification that causes the models to not fully represent the difference between the two types of areas. In other words, even with the land use variables that are currently included, the models are not overemphasizing credit being given to land use, which presumably still hasn't been fully accounted for.

Table 30. Comparison of Model vs. Survey Estimates of Household Vehicle Ownership and VMT.

		Vehicle Ownership Model	Daily VMT Model	Vehicle Ownership Survey	Daily VMT Survey	Pred vs Actual Vehicles	Pred vs Actual VMT
Apache Junction	Mean	1.561	22.734	1.662	22.942	-6.0%	-0.9%
	Std. Deviation	0.627	14.986	0.653	26.267		
Chandler	Mean	1.893	32.439	1.898	33.938	-0.3%	-4.4%
	Std. Deviation	0.507	13.312	0.901	27.470		
Gilbert	Mean	2.020	36.286	1.993	38.390	1.4%	-5.5%
	Std. Deviation	0.449	12.371	0.815	28.978		
Glendale	Mean	1.854	32.041	1.938	36.940	-4.3%	-13.3%
	Std. Deviation	0.522	13.590	0.839	30.517		
Maricopa County	Mean	1.682	26.908	1.487	29.366	13.1%	-8.4%
	Std. Deviation	0.466	13.188	0.908	34.184		
Mesa	Mean	1.609	26.156	1.608	26.128	0.0%	0.1%
	Std. Deviation	0.517	13.174	0.884	25.963		
Peoria	Mean	1.697	28.327	1.671	31.794	1.5%	-10.9%
	Std. Deviation	0.527	13.602	0.822	31.128		
North Phoenix	Mean	1.771	29.906	1.779	32.628	-0.4%	-8.3%
	Std. Deviation	0.580	15.009	0.930	30.867		
East Phoenix	Mean	1.407	20.664	1.373	17.077	2.4%	21.0%
	Std. Deviation	0.546	14.143	0.896	19.946		
South Phoenix	Mean	1.754	28.827	1.713	27.087	2.4%	6.4%
	Std. Deviation	0.536	14.261	0.845	29.559		
West Phoenix	Mean	1.600	24.000	1.635	21.479	-2.2%	11.7%
	Std. Deviation	0.558	14.288	0.941	25.004		
S. Scottsdale	Mean	1.478	23.632	1.598	19.542	-7.5%	20.9%
	Std. Deviation	0.518	13.473	0.817	18.768		
Tempe/Guadalupe	Mean	1.631	27.126	1.674	24.240	-2.5%	11.9%
	Std. Deviation	0.537	13.197	0.905	22.869		
N. Scottsdale	Mean	1.861	32.863	1.823	35.142	2.1%	-6.5%
	Std. Deviation	0.516	13.690	0.781	30.123		
Southwest	Mean	1.716	29.189	1.690	28.862	1.5%	1.1%
	Std. Deviation	0.516	13.068	0.827	29.016		
Northwest	Mean	1.594	25.941	1.514	32.048	5.3%	-19.1%
	Std. Deviation	0.443	12.150	0.867	39.634		
Sun Cities	Mean	1.199	15.713	1.287	14.375	-6.9%	9.3%
	Std. Deviation	0.382	9.384	0.588	21.252		
Total	Mean	1.638	26.461	1.641	25.896	-0.2%	2.2%
	Std. Deviation	0.558	14.379	0.894	27.109		

Sensitivity Analysis of Land Use and Travel Behavior Relationships

To begin to project what effects improvements in regional transit service and land use might have on travel behavior, the vehicle ownership and household VMT models were used to estimate how VMT might change in each of the 17 study areas if current values of the transit and land use variables were increased in the direction of compact, mixed land use.

The approach was to examine the range of values of the existing transit accessibility and local land use measures as found in the survey database (i.e., as calculated based on the households location), and then test revised levels for those variables that represent reasonable improvements in relation to current ranges and in relation to peers. Results of the assessment are tabulated in Table 31.

Household vehicle ownership and daily VMT were first estimated for each area using the average values for all input variables, shown as the current mean in the first row. This computation is different from the one used in the preceding validation section, where the models were applied individually for each household, with the results then averaged for the study area. This is a more aggregate computation, used because the analysis of changes makes simple assumptions as to discrete changes in the key land use variables. Therefore, there are slight differences in the model-calculated VMT in the top row of Table 31 vs. those shown in Table 30.

The second row in each area's summary shows the maximum value recorded for a household in that location, to be used as a rough gauge on what levels of land use might be achievable. The third and fourth rows then show suggested values that might be introduced to these areas, say, in relation to a new development that might be planned. The models are then run with the new values to estimate the change in VMT generation that would be predicted to result.

This simulation of revised conditions is done in two steps. First, as shown in row three, the values of the local land use variables (i.e., the 3Ds of density, mix, and walk opportunities) are changed. Next, as shown in row four, the regional transit accessibility variables are also changed and added to the scenario, constituting revision to all 4Ds. The VMT predicted for the conditions reflected by the improved 3Ds and 4Ds are shown in column 7, with the net savings in daily VMT per household and the percentage reduction shown in the final two columns.

Table 31. Examination of VMT Sensitivity to Land Use Variables Using 4Ds Models

	Transit Access - All Emp	Transit Access - Ret. Emp	Resid Density (HH/Acre)	LU Mix	Walk Oppor.	HH DVMT (survey)	HH DVMT (Model)	Net VMT Savings	Percent Reduction
Apache Junction									
Current Mean	0	0	16.64	0.31	0.35	22.94	21.86		
Current Max	0	0	308.90	0.62	2.95	90.34			
Improve 3Ds			16.64	1.00	100.00		16.16	5.70	26%
Improve 4Ds	50,000	20,000	16.64	1.00	100.00		14.13	7.73	35%
Chandler									
Current Mean	52,580	20,404	4.28	0.43	20.76	33.94	31.08		
Current Max	202,165	92,954	17.40	0.79	1085.00	124.17			
Improve 3Ds			10.00	1.00	100.00		27.08	4.00	13%
Improve 4Ds	100,000	50,000	10.00	1.00	100.00		24.64	6.44	21%
Gilbert									
Current Mean	31,546	9,999	3.24	0.41	17.92	38.39	36.36		
Current Max	168,464	81,325	9.60	0.74	172.23	116.17			
Improve 3Ds			10.00	1.00	100.00		31.06	5.30	15%
Improve 4Ds	60,000	30,000	10.00	1.00	100.00		29.49	6.87	19%
Glendale									
Current Mean	29,225	13,511	3.61	0.36	12.94	36.94	31.64		
Current Max	168,464	81,325	9.60	0.74	172.47	208.98			
Improve 3Ds			10.00	1.00	100.00		25.96	5.68	18%
Improve 4Ds	60,000	30,000	10.00	1.00	100.00		24.51	7.13	23%
Maricopa County									
Current Mean	0	0	1.47	0.29	1.26	29.37	25.60		
Current Max	0	0	4.94	0.61	11.30	155.96			
Improve 3Ds			10.00	1.00	100.00		19.34	6.26	24%
Improve 4Ds	50,000	20,000	10.00	1.00	100.00		17.32	8.28	32%
Mesa									
Current Mean	29,948	15,041	5.31	0.46	23.87	26.13	25.73		
Current Max	148,413	114,845	216.12	0.89	264.73	143.52			
Improve 3Ds			10.00	1.00	100.00		20.97	4.76	18%
Improve 4Ds	60,000	30,000	10.00	1.00	100.00		19.61	6.12	24%
Peoria									
Current Mean	11,449	5,852	4.47	0.40	9.49	31.79	28.32		
Current Max	52,626	42,291	39.91	0.75	98.89	133.61			
Improve 3Ds			10.00	1.00	100.00		23.50	4.82	17%
Improve 4Ds	60,000	30,000	10.00	1.00	100.00		21.31	7.01	25%
North Phoenix									
Current Mean	47,920	24,033	4.88	0.40	26.73	32.63	29.83		
Current Max	418,162	152,630	20.16	0.82	2024.21	201.35			
Improve 3Ds			10.00	1.00	100.00		24.61	5.22	17%
Improve 4Ds	100,000	50,000	10.00	1.00	100.00		22.25	7.58	25%
East Phoenix									
Current Mean	59,708	26,471	6.65	0.56	48.66	17.08	20.29		
Current Max	634,556	358,856	408.65	0.93	643.79	127.15			
Improve 3Ds			10.00	1.00	100.00		16.51	3.78	19%
Improve 4Ds	100,000	50,000	10.00	1.00	100.00		14.52	5.77	28%

Table 31. Examination of VMT Sensitivity to Land Use Variables Using 4Ds Models. (Continued)

	Transit Access - All Emp	Transit Access - Ret. Emp	Resid Density (HH/Acre)	LU Mix	Walk Oppor.	HH DVMT (survey)	HH DVMT (Model)	Net Savings	Percent Reduction
South Phoenix									
Current Mean	37,311	14,714	3.68	0.47	14.82	27.09	27.73		
Current Max	198,723	55,578	11.75	0.85	122.90	176.86			
Improve 3Ds			10.00	1.00	100.00		24.26	3.47	13%
Improve 4Ds	60,000	30,000	10.00	1.00	100.00		23.03	4.70	17%
West Phoenix									
Current Mean	49,403	23,515	4.94	0.43	19.54	21.48	24.14		
Current Max	240,449	89,438	31.06	0.89	151.57	152.39			
Improve 3Ds			10.00	1.00	100.00		19.14	5.00	21%
Improve 4Ds	100,000	50,000	10.00	1.00	100.00		16.76	7.38	31%
S. Scottsdale									
Current Mean	33,745	19,498	6.94	0.49	43.29	19.54	23.05		
Current Max	243,123	194,170	41.97	0.79	559.08	90.95			
Improve 3Ds			10.00	1.00	100.00		18.73	4.32	19%
Improve 4Ds	60,000	30,000	10.00	1.00	100.00		17.60	5.45	24%
Tempe/Guadalupe									
Current Mean	59,228	26,719	6.47	0.52	35.69	24.24	26.68		
Current Max	273,588	123,504	59.70	0.89	329.23	127.96			
Improve 3Ds			10.00	1.00	100.00		22.50	4.18	16%
Improve 4Ds	100,000	50,000	10.00	1.00	100.00		20.51	6.17	23%
N. Scottsdale									
Current Mean	19,858	6,585	2.86	0.38	15.48	35.14	31.99		
Current Max	132,730	33,774	8.13	0.84	303.54	135.23			
Improve 3Ds			10.00	1.00	100.00		26.47	5.52	17%
Improve 4Ds	60,000	30,000	10.00	1.00	100.00		24.44	7.55	24%
Southwest (Avondale, Buckeye, G.Bend, Goodyear, Lit. Pk, Tolleson)									
Current Mean	12,173	4,675	1.82	0.42	16.04	28.86	29.08		
Current Max	57,503	16,275	11.32	0.77	122.48	127.82			
Improve 3Ds			10.00	1.00	100.00		23.75	5.33	18%
Improve 4Ds	50,000	20,000	10.00	1.00	100.00		22.21	6.87	24%
Northwest (El Mirage, Surprise, Wickenburg, Youngstown)									
Current Mean	0	0	4.00	0.37	15.85	32.05	26.02		
Current Max	0	0	52.46	0.76	221.45	170.81			
Improve 3Ds			10.00	1.00	100.00		20.46	5.56	21%
Improve 4Ds	50,000	20,000	10.00	1.00	100.00		18.43	7.59	29%
Sun Cities									
Current Mean	5,060	1,802	3.29	0.43	25.68	14.37	15.42		
Current Max	54,083	11,870	12.63	0.79	298.82	149.70			
Improve 3Ds			10.00	1.00	100.00		10.32	5.10	33%
Improve 4Ds	50,000	20,000	10.00	1.00	100.00		8.49	6.93	45%
Total									
Current Mean	40,290	18,571	5.12	0.45	26.67	25.90	25.90		
Current Max	634,556	358,856	408.65	0.93	2024.21	208.98			
Improve 3Ds			10.00	1.00	100.00		21.25	4.65	18%
Improve 4Ds	80,000	40,000	10.00	1.00	100.00		19.37	6.53	25%

The logic used in selecting the values of the 4Ds variables for the sensitivity test scenarios follows:

- **Residential Density:** Most areas were found to have existing examples of residential density greater than 10 households per acre. So 10 was picked as the target density for any new development in all areas, except for Apache Junction where the lowest density recorded was 16.64, which was subsequently used as the "floor."
- **Land Use Mix:** Being an index, this variable only has a range of 0 to 1, although the highest values seen in practice never exceeded 0.93. Researchers decided to set the test value to 1.0, assuming that in a new development, every effort would be made to balance the land uses as completely as possible.
- **Walk Opportunities:** Most areas had examples of areas with walk opportunities scores exceeding 100, so it was decided to assume this as a design target, particularly considering that this would be a desired attribute of any new development.
- **Regional Transit Accessibility:** Unlike the 3Ds variables above, improvements in regional transit accessibility only come at considerable investment cost. As a result, a set of targets were devised that seem possible for different peer groups, as follows:
  - For the most urban and centrally located areas (North Phoenix, East and West Phoenix, Tempe), assume 100,000 total jobs and 50,000 retail jobs reachable. Chandler is included in this group because of its already high existing levels of transit accessibility.
  - For the next tier of less-centrally located areas (Gilbert, Mesa, Peoria, South Phoenix, South Scottsdale, North Scottsdale), assume levels of 60,000 and 30,000 are achievable.
  - For the least urban and most poorly served areas (Apache Junction, Maricopa County, Southwest, Northwest, Sun Cities), assume that 50,000 and 20,000 levels would be achievable at new developments.

Using these assumptions, reductions in household VMT rates of between 13 percent and 33 percent are projected from improvements in the 3Ds alone, and between 17 percent and 45 percent from improvements in all 4Ds. For consistency, these reductions are calculated in relation to the baseline VMT estimated from the model, not the survey value. It is interesting to note that the most pronounced benefits from improved land use are not just in the most outlying areas with very limited use of compact mixed use development, but also in the higher-density inner areas. For example, South Scottsdale is projected to reduce its VMT rate by 19 percent to 24 percent in response to the 3Ds/4Ds improvements, vs. similar numbers in, say, Southwest or North Scottsdale. In some sense, this is a "rich get richer" proposition, where areas that already have decent land use benefit as much or more from additional improvements. Note, however, that the absolute savings (net miles saved) are generally greater in the outlying areas with the higher baseline VMTs.

CONCLUSIONS

The research presented in this chapter suggests that greater adherence to smart growth principles of compact, mixed-land use, buttressed by superior regional transit accessibility, may result in important reductions in average trip lengths and VMT demand on local and regional roads. While the Phoenix region, which was used as the test site for examining these relationships, does not exemplify compact, mixed-land use, it was still possible to find evidence of these relationships. In places like East Phoenix, the older southern portions of Scottsdale, and Tempe, the existence of higher densities, mix of development types, walkability, and good regional transit access may help to explain rates of vehicle ownership, average trip lengths, and household VMT generation that are considerably lower than those found in other parts of the region. Efforts to increase density in new plans and projects in a way that also emphasizes mix of uses, pedestrian friendly design, and transit serviceability could reduce VMT generation rates in new developments by up to 45 percent. If such designs permeate existing development patterns, then the likelihood emerges that the travel patterns of those areas may also be favorably affected. These findings buttress those of preceding tasks that concluded that properly designed developments, even if they entail significantly higher densities than currently exist, may be implemented without inordinate fears of crippling traffic congestion.

CHAPTER 6. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

OVERALL SUMMARY

This study was conducted to address a growing interest in the relationship between transportation needs, system performance and patterns of land use that are served. Certain development patterns are inherently more demanding of highway capacity than others in terms of vehicle trip generation rates, average trip lengths, and VMT. Moreover, the transportation system investments themselves subsequently influence the development patterns by providing increased accessibility to the areas served.

Coordination is often lacking in how decisions in these two important areas—land use and transportation—are made. Land use decisions have historically been very local in nature and tied to the rights of individual land owners to use their land as they see fit. In most urbanized regions, however, these decisions must conform to local planning and zoning codes that were created to ensure that these individual decisions do not depart unduly from locally defined norms of reasonableness, quality of construction, safety, and good taste. Concomitant with this established process, local communities with planning and zoning powers develop comprehensive and local master plans to clarify plans for orderly economic and residential development in future years.

In most areas of the United States, the local jurisdictions that have planning and zoning authority are considered sovereign in their right to plan their communities. However, what one community decides is an appropriate development plan may not be necessarily ideal for its neighbors or for the overall region in which it is located. Moreover, the planning aspirations may not fully account for the cost of supplying needed infrastructure, such as roads, schools, water/sewer service, and utilities. Since these services are usually the responsibility of county or state government, key development decisions may be made without full accounting for these infrastructure needs. Such decisions may be made as individual jurisdictions compete with each other for economic growth and investment and are encouraged to leverage these costs to the extent allowed by law; in other cases, they may simply lack the information, insights, or planning tools to fully understand the impacts associated with their decisions.

State and regional transportation and planning agencies are then faced with the difficult task of responding to these many individual land use decisions when planning for and finding sufficient funding to address the resulting needs. Funding is increasingly scarce while demands keep growing, and the transportation decision-makers must also consider numerous federal and state mandates and regulations, costs to maintain and operate the existing system, and a project prioritization process that has strong political undercurrents.

Examining trends captured in data from USDOT's National Personal (Household) Transportation Surveys and the FHWA's Highway Statistics database clearly demonstrate the magnitude of the growing gap between transportation demand and supply. These data (summarized in Chapter 2) show that while the nation's population grew by about 0.45 percent per year between 1976 and 2001, total VMT grew at a rate of 0.93 percent and household VMT—a subject of particular focus in land use planning—grew at a rate of 2.02 percent, reflecting a ratio of almost 5 to 1. Meanwhile, the rate at which new highway capacity has been provided since the end of the federal Interstate program in the early 1970s has only been at roughly the rate of population growth, which means that congestion levels have been steadily worsening. The reasons for this are both limitations related to funding, as the fixed cents-per-gallon federal gas tax has produced proportionately less revenue over time, as well as physical and environmental constraints that have limited the opportunities to build new or widen existing highways. Added to this financial burden is the fact that the majority of transportation dollars are being increasingly drawn to maintenance and replacement of heavily used and aging facilities, with less than 10 percent available for new capacity in most areas.

The State of Arizona and its MPOs are familiar with these trends and relationships, and the challenges they present. The original motivation for this study acknowledged the importance of land use decisions, but intended mainly to try to identify ways in which the state could be kept more informed and involved as these decisions were made. The initial concern was that it was particularly difficult to respond meaningfully to new transportation needs if advance information was not available to use in the state's planning and programming process. The scope was eventually broadened, however, to allow for the possibility that different types of land use, specifically higher-density compact, mixed-use development, might have important benefits in reducing traffic levels and growth.

ADOT recognized that to properly address this issue of compact land use and begin a dialogue among the many stakeholders in the planning and decision-making process, it would need to improve the base level of information and understanding on the topic. In particular, ADOT determined that it needed to address head-on a primary concern held by many that compact, mixed-use development implies high density, and that high density uniformly leads to increased traffic congestion. Before it could get behind the issue and ascertain what type of support, if any, was appropriate, ADOT realized that these characteristics and impacts needed to be more clearly understood and articulated.

These objectives led to the following scope elements:

- A thorough review of the literature to clarify the terms of the claimed relationship between land use and transportation, methods used in quantifying these impacts, and findings on the nature and magnitude of the impacts.
- A survey of knowledge and opinions regarding compact, mixed-use development among elected officials and practitioners across the state, and methods used to evaluate and mitigate land use impacts from new development.
- Identification of examples in the state where development-based traffic issues were deemed serious, followed by subsequent analysis of the relationship between the development and traffic.

- Recommendation of policies that may be more conducive to reducing traffic congestion.

In responding to these requirements, the research team made the following findings:

Literature Review

- **Prior Studies:** No earlier studies of the connection between land use and transportation in the State of Arizona or any of its metropolitan regions were uncovered, making this study the first such known effort.
- **Defining Land Use:** A growing number of research and empirical studies on land use and transportation relationships have been performed since the early 1990s. These efforts have come to define the essential properties of land use that affect travel behavior as the 4Ds of density, diversity, design, and destinations. This framework is important in clarifying that high density alone is not the essential ingredient in effective land use, but rather the characteristics of the mix and balance of uses (residential, employment, retail); design (how uses are presented to and accessible to nonauto travelers); and the ease with which opportunities (destinations) outside the community can be accessed by transit.
- **Travel Impacts:** Empirical studies suggest that households that reside in areas with compact, mixed land use own fewer vehicles, make fewer vehicle trips, have shorter trip lengths, and generate one-half to one-third the VMT of households of comparable size and income in conventional low-density, single-use environments. Similarly, well-designed land use at destinations (employment and commercial activity centers) not only reduce vehicle use when at those sites, but allow commuters or visitors to those sites freedom to consider other travel methods, such as transit, ridesharing, walking, or biking, since they are not auto-dependent once at the site.
- **Trip Purpose:** The biggest impact of compact, mixed-use development may be on nonwork travel, which accounts for more than 75 percent of household travel activity (commuting is down to about 20 percent) and has been steadily increasing as a share. Residents of compact, mixed-use areas tend to make a higher percentage of their trips for shopping, school and child-related activities, personal business, recreation, and entertainment to local opportunities by walking, biking, or short car trips.
- **Traffic Congestion vs. Accessibility:** Increasingly, planners are opting for measures other than local traffic congestion to gauge the performance of a plan or project. Limiting local development because of high adjacent traffic levels typically misses the benefits of the compact, mixed-use site, where increased density, better mix, and pedestrian friendliness contribute to greatly increased levels of overall accessibility within the activity area (more travel by walking or local transit) as well as encouraging more travel to the area by transit, ridesharing, and nonmotorized modes. In short, local traffic levels are being viewed as less important in judging the overall performance of a site. High local traffic levels are also frequently linked to through traffic and an inadequate local street (grid) network to accommodate and channel that traffic.

- **Planned vs. Free Market Environments:** Skeptics of smart growth or similar compact, mixed-use development approaches may decry what they regard as the loss of freedom that comes with government intervention into the free market and the preference of the American public. However, the research shows that the opportunities for first-time homebuyers are typically at the urban fringe, where the prices are lower because the product does not include the full costs of the development (roads, schools, utilities, public services) nor the private or public cost of transportation between the remote location and regional employment and commercial opportunities. Many of these first-time buyers were also lured by the offering of attractive unconventional financing, which has led to massive foreclosure rates and subsequent crashing of the mortgage and investment markets.

Survey of Officials

A comprehensive survey of elected officials, planning and zoning officials, planning professionals, and various state and regional officials across the state revealed the following key findings with regard to development options and traffic impacts:

- **Elected Official Circumspect:** Despite concerted outreach efforts, the participation of local elected officials in the survey was considerably less than for any of the other groups (20 percent vs. 33 percent to 35 percent).
- **Travel Impacts:** Most respondents believed that both transit use and nonmotorized travel would be much greater in the presence of compact, mixed-use development. However, their perceptions of what effect compact development would have on traffic congestion was equivocal: The largest single group felt it would produce less traffic, but overall, the majority felt it would either result in more traffic or were unsure. This result lent support to the principal concern of the study regarding the concerns about unfavorable traffic impacts.
- **Importance of Traffic Impacts in Development Decisions:** Impacts of a given development project on traffic were generally found to be in a secondary or moderate category of importance in determining the desirability of a project, being exceeded by such considerations as consistency with adopted plans, being an appropriate use for the given area, or whether there were negative impacts on the surrounding neighborhood or businesses. When traffic impacts were considered, they were most frequently evaluated at or adjacent to the site or the nearest intersection, and to a notably lesser extent on facilities outside the immediate site area, and seldom on facilities outside the jurisdiction. In the great majority of cases, the traffic impacts were gauged using traffic engineering guidelines and inputs from developers’ studies, and very seldom using models or input from sources other than the local jurisdiction.
- **Support for Compact, Mixed-Use Development:** The survey showed a surprisingly high level of support for compact, mixed-use development. The majority (77 percent to 83 percent) of respondents believed that their community would support compact, mixed-use development projects, and also the majority (62 percent to 81 percent) claimed to have encouraged such projects in their

jurisdiction. In terms of the most appropriate development for their own jurisdiction, the largest number of respondents indicated residential/retail mixed-use (79 percent to 94 percent), retail/office mixed-use (59 percent to 86 percent), and neighborhood retail (65 percent to 78 percent). Options that received the fewest votes included large shopping center/mall, big box retail, and high-rise office or residential. Elected officials were more likely than planning officials to support new development over infill or rehab, single-family over multifamily residential, and low-density over high-rise. In terms of the most appropriate development for the overall region, the highest levels of support were for mixed-use centers and corridors (68 percent to 81 percent), core area employment (58 percent to 77 percent), mixed-use communities (55 percent to 75 percent) and intensified employment in centers and corridors (56 percent to 83 percent). The least favored options were more housing or employment in either the inner or outer suburbs.

- **Need for Information:** When asked if they had sufficient knowledge at hand to make informed judgments about the impacts of mixed-use developments, elected officials answered almost unanimously yes (88 percent), while planning and zoning officials (64 percent) and professional planners (54 percent) were considerably less confident. When asked if they would use additional information were it made available, the elected officials also said yes (88 percent) while the planners were at about the same level of support (55 percent). However, planning and zoning officials appeared to be the most interested, with 86 percent thinking such information would be valuable.
- **Linking Congestion and Development:** Officials were asked to identify specific corridors that they believed had the worst traffic congestion problems. Of the corridors identified, the majority of respondents believed that the congestion was due to development outside their own jurisdiction. This result had several interpretations. One was that few associated problem traffic with immediately adjacent development in their communities, suggesting that local density from compact development was not the suspected culprit. The other interpretation is that the respondent did not wish to acknowledge (or could not perceive) that local development activity was responsible for the traffic. It was also interesting to discover that few problem corridors were identified in the most densely developed areas of the respective region.

Travel Behavior Analysis Results

Two types of analysis were undertaken to address the question of whether higher-density, compact, mixed-use development creates more traffic congestion. The first was to determine whether residents of Arizona—and specifically the Phoenix/MAG region, in which the project test sites were located—would exhibit differences in travel behavior related to land use characteristics as have been documented in national studies. The second was to explore the selected corridors to determine the nature of the link between development levels and traffic.

While Phoenix is an example of a modern U.S. city developed primarily under the shaping influence of the automobile in the post-World War II era, variations in key land use variables such as density, mix, pedestrian-friendly design, and transit service may still be found, albeit at more modest levels than in older U.S. cities that were shaped in the pre-war era. Such characteristics were seen in the older areas of Phoenix and Scottsdale, and in portions of Tempe in proximity to the university. Portions of these areas were selected for study, and compared against a control site represented by West Bell Road in the more-typically developed northwest portion of the metro area.

The three example sites—North Central Avenue in Phoenix, Scottsdale Road through the Old Town section of Scottsdale, and the Mill Avenue/Apache Boulevard corridor of Tempe—share some distinctive features that make them somewhat unique in the Phoenix region:

- **Density:** First, they are all higher-density areas, with residential densities in the 4.9 to 5.2 households-per- acre range vs. 2.6 in the Bell Road corridor, and employment densities of between 7.4 to 28.5 jobs per acre compared to only 1.3 in the Bell Road example[5]. The percentage of housing units that were multifamily vs. single-family detached ranged from 49 percent to 67 percent in the three study areas compared to 30 percent for Bell Road.
- **Jobs/Housing Balance:** Central Avenue, Scottsdale Road, and Mill/Apache are also major job centers, with between 34,000 and 66,000 jobs per location (21,500 to 47,500 of which were retail service), providing a balance of jobs-to-households of between 1.4 to 5.6 vs. only 0.5 for Bell Road.
- **Retail/Service Opportunities:** Each of the three areas also had a fairly high ratio of retail jobs per household, ranging from 0.56 to 0.65, which is a good measure of proximity of local services. In contrast, Bell Road's ratio was 0.31. Within a one-quarter mile radius of the average household were 20 to 21 retail/service opportunities in Scottsdale and Tempe, and 72 in the Central Avenue corridor, compared to 9 in the Bell Road area.
- **Design:** The three example areas share the characteristics of a gridded street network of small block size (generally one-eighth mile), good sidewalk coverage, and frequent, safe pedestrian crossings. Most commercial buildings face the street, with parking located either behind (ideal) or to the side (less preferred). In contrast, Bell Road is the typical suburban arterial corridor with all commercial activity sited along Bell Road, all designed to favor auto access with large parking lots and limited pedestrian facilities. Off the main Bell Road corridor, there is little adjacent road capacity, with few parallel roads and poor connectivity due to curvilinear subdivision street patterns.
- **Transit Accessibility:** The three example areas are all reasonably well served by transit. Residents of the three areas have access to between 34,000 and 165,000 regional jobs by transit, compared with only about 6,000 in the Bell Road area.

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[5] These are simple gross densities that measure activity per gross land area and not net densities that only consider land that is specifically zoned for that type use. Net densities are generally much higher.

Despite ranking higher than average on these 4Ds land use characteristics, the three compact, mixed-use examples also differ in important ways from each other as well as with Bell Road:

- **Composition:** Central Avenue is heavily oriented toward employment, while Scottsdale is more residentially oriented, and Tempe's composition is undoubtedly influenced by the university. Bell Road is primarily residential, with most of the employment being associated retail and commercial services.
- **Transit Orientation:** Central Avenue and Tempe are strong transit centers, based on their significant employment and student characters, sufficiently so that they are joined by the region's first rail transit system. Scottsdale is well-served by local transit, but not particularly well by regional transit. In the Bell Road corridor, virtually all transit use requires auto access to a park-and-ride facility.

Associated with these differences in land use and composition, the following important differences in travel behavior characteristics were observed:

- **Auto Ownership:** Households in the highest density areas owned the fewest vehicles, ranging from 1.4 vehicles per household along Central Avenue to 1.47 in Scottsdale vs. 1.7 along Bell Road. Tempe was surprisingly high at 1.63.
- **Average Trip Lengths:** Trip lengths were considerably shorter for residents of the three compact, mixed-use areas, with home-to-work distances ranging from 9.3 to 10.1 miles vs. 21.8 miles in the Bell Road corridor, and nonwork distances ranging from 3.8 to 9.1 miles vs. 26.5 miles in the Bell Road corridor.
- **Auto Use:** Average VMT for the three land use sites was considerably lower, with 17.0 daily vehicle miles per household along Central Avenue, 19.5 in Scottsdale, 24.2 in Tempe, and 31.8 along Bell Road.
- **Transit Use:** Transit share of all trips made by residents from the selected areas ranged from 10 percent in Tempe to 6.5 percent along Central Avenue and 5.5 percent in Scottsdale, compared to 0.8 percent along Bell Road. Trips by transit to the areas ranged from 6.7 percent along Central Avenue to 3 percent in Scottsdale, vs. 0.4 percent along Bell Road.
- **Internal Trip Capture:** A critical measure of the effectiveness of mixed land use is seen in the percentage of trips made by residents that stay "internal" to the community. Work trips are typically not well retained, given the transient nature of residential and employment locations, though in the study examples, between 18 percent and 21 percent of all resident work trips remained internal vs. only 13 percent in the Bell Road corridor. More telling is the rate of capture of nonwork trips, reflecting the variety and proximity of local services. In this case, Scottsdale and Tempe retain 41.8 percent and 39.8 percent of these trips, while Central Avenue's rate is only 21.7 percent, owing to its imbalance of employment to residential development. A surprisingly high percentage of nonwork trips in the Bell Road corridor (41.8 percent) are also retained, though this may simply be because all other opportunities are so far away.

To further isolate these land use relationships, researchers performed a 4Ds modeling exercise using data obtained from MAG's 2001 regional household travel survey. These data linking household characteristics with travel activity were supplemented with data on land use characteristics developed using GIS system tools and programming. Each household's location was accompanied by a description of density, mix of uses, walkability, number and type of opportunities, and regional transit service and accessibility to jobs. Regression models were estimated linking household vehicle ownership and daily household VMT for work and nonwork purposes to a collection of explanatory variables including the sociodemographic profile of the household (size, workers, students, income, autos); local land use (density, diversity, and design); and transportation system accessibility (regional transit accessibility to jobs). This framework was virtually identical to that used by researchers such as Kara Kockelman and Robert Cervero in Berkeley, and the author in Baltimore and Los Angeles. The following results were observed:

- **Vehicle Ownership** was determined to be positively related to household size, number of workers, and income, and *negatively* related to residential density, land use mix, and walk opportunities within ¼ mile – in other words, fewer vehicles are owned as density, mix and walking to local opportunities increases. Interestingly, auto ownership was not found sensitive to regional transit accessibility, as it was in the other modeling studies.
- **Daily Household Home-Based Work VMT** was found to be positively related to household workers, income, and vehicles, and negatively related to household size, regional transit accessibility to jobs, and land use mix. Because most jobs are located outside of walking range of the household, regional transit accessibility proved to be more relevant as an explanatory factor than local density or walk opportunities to services. It is important to note the role of auto ownership in this relationship, however, where improvements in local land use are tied to fewer vehicles owned, which then has the effect of reducing VMT in this model.
- **Daily Household Nonwork VMT** was found to be positively related to number of household students, vehicles, and income, and negatively associated with household size, residential density, and transit accessibility to retail/service jobs. Surprisingly, in relation to model research in other locations, land use mix and walk opportunities were not significant in this model, although their effect is represented indirectly through auto ownership.

The models were then applied to the MAG region to study differences across the region as represented by 17 different subareas, each with characteristically different values of the 4Ds variables as well as household sociodemographics themselves. These areas included Apache Junction; Chandler; Gilbert; Glendale; Mesa; Peoria; North, South, East and West Phoenix; North and South Scottsdale; Tempe/Guadalupe; Sun City (east and west); Northwest (El Mirage, Surprise, Wickenburg, Youngstown); Southwest (Avondale, Buckeye, Gila Bend, Goodyear, Litchfield Park, Tolleson); and the remaining unincorporated portions of Maricopa County. Comparing model predictions with the number of vehicles and actual VMT derived from the 2001 survey showed a high degree of correspondence when accounting for differences related to land use. The analysis confirmed the lowest rates of auto ownership and daily VMT in such locations as South Scottsdale and East Phoenix and the highest rates in locations such as Gilbert, Glendale, North Scottsdale, and Northwest. Sensitivity tests were performed to project the types of VMT reduction that might be achieved in each area based on incremental improvements in the land use variables.

Traffic Analysis Results

Finally, in relation to the key question of the study—does higher density cause traffic congestion—a strategic analysis was performed for each of the four case study areas. MAG's regional travel forecasting model was used to furnish information on the shape and capacity of the respective transportation networks in each location, and then estimates of the traffic volumes that are carried on those facilities during AM peak, midday, and PM peak conditions. By comparing the volumes with the design capacity of the facilities, the resulting V/C ratio is a commonly used measure of congestion levels on roadways. Levels of service are often linked to the magnitude of the V/C ratio, with levels A through C (up to V/C values of about 0.75) generally considered as unrestricted flow, Level D (0.75 to 0.85) as being moderately congested, Level E (0.85 to 1.0) as congested, and Level F (>1.0) as failing.

What this analysis revealed was that the selected roadways in the three highest density mixed-use sites had surprisingly good performance characteristics in both peak and off-peak periods, with V/C levels in the D or E range during the worst flow periods (usually PM peak period), while the conditions on Bell Road, the low-density development example, were significantly worse, exhibiting heavy traffic congestion at all periods, but with V/C ratios reaching 1.5 or greater on some segments in the PM peak period. Several factors were examined in an attempt to explain these differences:

- **Predicted vs. Actual Traffic Volumes:** Most planners understand that the volumes predicted by travel forecasting models, however sophisticated, are often not a perfect match with recorded counts. One reason for this is that regional models are often not as accurate when predicting down at the individual street level, as they tend to be calibrated and validated at the regional screenline and major facility level. The other reason is that there is a high degree of daily variability in count volumes on individual facilities. With this understanding, the MAG model link volume estimates were compared with MAG count data for a comparable period, and found to vary with no obvious systematic relationship with regard to type of facility, location, direction, or time of day. Overall, the MAG model was observed to overpredict volumes on the key facilities of interest (particularly those in the higher-density sample) by about 23 percent, implying that the actual conditions were perhaps better than those predicted by the model. In contrast, on Bell Road, the MAG model forecasts tended to underestimate the measured volumes.
- **Through Traffic:** A major consideration in evaluating traffic congestion in relation to local development is in how much of the traffic is actually related to local activity vs. simply passing through. In Scottsdale, the analysis found

that only about 23 percent to 28 percent of PM peak period volumes were composed of through traffic, which helps explain its moderate congestion levels. On Bell Road, almost half (46 percent) of all traffic in the PM peak period is through traffic, which helps account for the high traffic levels; however, even without this through traffic segment, Bell Road would likely still have failing level of service based purely on its local traffic. In contrast, the Central Avenue corridor, which has among the highest residential and employment densities in the region has an even higher percentage of through traffic (49 percent) and yet has V/C ratios that fall below 1.0 in the PM peak period.

- **Greater Efficiency:** One reason why these compact, mixed-use areas may have less traffic is greater multimodal accessibility based on their design: Not only do residents make fewer vehicle trips and walk and take transit more, but visitors to the site are also more likely to arrive by transit and walk to reach additional needs once in the area.
- **Transportation System Design:** The compact, mixed-use areas have a much richer variety of transportation options, including transit, and walkable streets to relevant nearby destinations. However a major component to this design is a comprehensive and fine-grained local street network. This grid not only provides safe and efficient internal walk circulation, but helps manage traffic flow by distributing traffic across more link options and allowing for alternative routes around blockages. In the Bell Road corridor there is little functional supporting capacity to the main highway in terms of parallel routes or connectors. In contrast, in Scottsdale, through traffic can easily pick a route around the most densely developed areas of town and, in fact, those routes (such as Goldwater Drive) are designed and function as intercept and diversion facilities.

These findings would seem to contradict the conventional wisdom that higher-intensity development is a leading contributor to localized traffic congestion. Clearly, there are many factors that contribute to local traffic congestion mixed use, such as through traffic, adequate street grid, and design characteristics that offer nonmotorized and transit alternatives for both residents and visitors.

CONCLUSIONS

The primary conclusions that appear to be supported by this analysis are as follows:

- Fears about compact, mixed-use development leading to intolerable traffic congestion do not appear to be substantiated by what is seen in practice. While increasing development activity of any type will generate additional traffic, the nature and design of that development and the design and adequacy of the supporting infrastructure are critical variables in determining the severity of the resulting traffic.
- Arterial corridors in the most densely developed portions of the MAG region show surprisingly good traffic flow, despite obvious higher density. Central Avenue; north of downtown Phoenix; Scottsdale Road through the heart of

Scottsdale; and Rural Road, McClintock Road, Apache Boulevard, and Broadway Road in Tempe all serve densely developed areas and yet maintain V/C ratios that are in very acceptable ranges.

- Intensified, more urban types of land use are distinguished not only by higher density, but by a balanced mix of uses—particularly retail mixed in with residential or employment—and design that encourages walking, bicycling, and transit use. Scottsdale is an excellent (though not perfect) example of compact, mixed-use with good internal access, while Central Avenue has the intensity and design, but lacks the appropriate mix and balance.
- Even if traffic congestion does occur on arterials that support higher-density mixed use, that congestion need not be seen as a negative outcome. In the examples of Mill Avenue in Tempe and Scottsdale Road in Scottsdale, design of those facilities is such as to discourage large volumes of through traffic. Street parking, turning restrictions, medians, street landscaping, and the presence of activity signals that these facilities are urban streets and not regional thoroughfares. On Scottsdale Road, this design results in fewer vehicles and reasonable traffic levels. On Mill Avenue, it is also accompanied by congestion, but it does not appear to diminish its use by travelers who wish to access the area. In the example of Central Avenue, it also results in higher transit use.
- Areas with compact, mixed-use design are much more effectively served by transit, resulting in higher use rates. Transit is even more effective when many such compact, mixed-use areas are interconnected with service.
- Residents of and visitors to compact, mixed-use areas are much more likely to “internalize” their travel needs by using the opportunities designed into their environments. Shorter distances allow them to walk or bike to necessary activities, or even to drive there in short vehicle trips. Average trip lengths are much shorter for residents of areas like Scottsdale, Tempe, and Central Avenue—particularly for nonwork travel—meaning that much less vehicle travel demand is imposed on the region’s highways. It also means that residents of such areas are likely to experience much less traffic delay and receive some immunity from rising future regional congestion levels.
- Design of a compact, mixed-use area is very important. For people to leave their cars, or to never get in them to start with, an area has to be inviting for travel on foot or by bicycle. There must be activities worth walking to (relevant and attractive destinations); they must be clustered in a way that makes them conveniently co-located (lessening the need to return to the car); and they should face the street with limited setbacks, with parking either along the street or in peripheral lots, not in large lots in front of the buildings. Walking should be made attractive and safe by a continuous sidewalk network, short blocks, frequent crossings, and buffering from traffic by trees or other barriers.
- Street grids appear to be a very effective way of managing traffic in higher-density activity areas. Short blocks between streets are not only important for encouraging walking, but provide a mechanism for vehicle traffic to circulate and dissipate more efficiently. Much of Phoenix and Tucson is made up of one mile arterial grids. While this may serve the purpose of regional vehicle movement, it is the opposite of what is needed to accommodate pedestrian and vehicle traffic in

mixed-use activity areas. When development is more concentrated, the street network must be similarly articulated to maximize circulation and access to specific destinations, with parallel streets being no more than one-quarter mile apart. The central facilities, like Central Avenue, Mill Avenue, or Scottsdale Road, are not typically designed or intended for conveying large volumes of through traffic, so some level of congestion is expected. The grids can be designed to accommodate a hierarchy of needs, however, so that through traffic can bypass the most intensely developed part of the center. This is the role played by Goldwater Boulevard in Scottsdale, and Rural and McClintock roads in Tempe. Central Avenue has no reliever road per se, but the existence of several closely spaced major parallel streets—most notably 7^{th} Avenue and 7^{th} Street—provide a number of alternative routes for north-south traffic. A corridor like Bell Road is so heavily congested because not only is its development completely auto-oriented, but it supports substantial through traffic without any parallel facilities to lessen the load.

RECOMMENDATIONS

The results of this study lend support to the benefits and viability of compact, mixed-use development. Support for this concept, frequently under the heading of smart growth, TOD, or livable communities, has been growing nationally since the late 1990s. Motivations have ranged from traffic mitigation to management of sprawl, land and habitat conservation, environmental impacts of growth on sensitive areas and water bodies (such as the Chesapeake Bay), air pollution, and climate change. There are also major fiscal and equity motives. Governments are finding that it is increasingly difficult to support the cost of accommodating new growth while also having to maintain facilities and services in older existing areas. These same trends also tend to leave less affluent members of society with fewer options for affordable housing, jobs, and essential services.

While compact, mixed-use development is not new for Arizona, with examples of such projects being visible across the state, the concept of compact land use does not appear to have reached the level of acceptance and application as it has in many other areas of the nation. Ideally, the results of this study will provide ADOT, the state's MPOs, transit agencies, and local jurisdictions with the foundations to further understand the nature and benefits of the concept, and to promote dialogue on planning and program options at a new level.

In that regard, the following recommendations are offered to help move the concept forward:

- **Education:** Building awareness of the characteristics and benefits of compact, mixed-use development is probably the first and most important step to gaining acceptance. The types of relationships articulated in this study can provide the basis for these efforts. It is fairly clear that the average citizen fears density as the enemy, linking it to a variety of ills including traffic congestion, influx of new and possibly different demographics, noise, crime, and loss of safety and security.

These concerns are clearly passed on to elected officials, who are keenly tuned to the public's sensitivities about change, and these trepidations are passed on to planners and administrators resulting in conservative plans, codes, and procedures. Reversing this stigma will not be easy and will only be achieved by demonstrating the inherent benefits of the alternative approach and giving assurances through example that many of the concerns are unwarranted.

- **Marketing:** Skeptics and detractors of neotraditional development often decry it as social engineering and forcing a product on the public that it does not want. The facts tell a quite different story. Real estate experts estimate that the industry has been able to meet only a fraction of the market demand for compact, mixed-use residential options due mainly to local zoning restrictions, and the limited supply has driven up prices to where it appears that only the well-off can afford to partake of this product. Rather than allow the concept to be marketed as what planners want and that government is trying to interfere with free choice, it would be astute to offer it as means to broadening rather than reducing the set of choices to serve an increasingly diversified market (singles, married without children, retirees) in an otherwise monolithic marketplace.
- **Improved Planning Tools:** The tools that are used for transportation planning in most metropolitan areas—certainly not just in Arizona—are poorly suited to account for the effects of different land uses. The effects of compact, mixed-use development are expressed at a much finer level of geographic detail than the TAZs that form the basis of the conventional four-step travel forecasting models. The relevant geography is the area within walking distance—roughly one-quarter to one-half mile—of a travel origin or destination. As a result, not only are important variations in local land use (density, mix, walk access to transit) not considered when estimating household vehicle ownership or trip generation, but shorter trips—the very type that are the objective of more compact land use designs—are lost within the aggregate "noise" of the TAZ. Few models actually estimate walk or bike trips, and those that do simply estimate the percentage of all trips generated by the households that are likely to be bike or walk. However, nothing further is done with these trips in the remaining steps of the transportation planning process (trip distribution, mode choice, and traffic assignment). Even short car trips, should they be made to attractions within the same TAZ, are lost to the analysis and, hence, in the enumeration of benefits. Most planning agencies are well aware of these deficiencies and are taking steps to improve their tools. However, short of a shift in the current modeling paradigm toward an activity-based approach that overcomes the restriction of TAZs, most of these efforts will have modest impacts toward quantifying the effects of smart growth. An attractive alternative in the short run may exist in the form of GIS-based sketch planning models, such as Envision, IPLACE3S, INDEX, or CommunityViz, that use parcel or grid-cell level resolution in a highly visual environment to detail and calculate the effects of alternative land use arrangements. Another set of tools recommended for further consideration are traffic microsimulation models, such as TransModeler or VISSUM, which are much more suited to analyzing the complex patterns and impacts of traffic flows in a local grid system. The benefits of such a tool are the ability to directly examine traffic impacts associated with

different development plans; and to experiment with alternative measures to better manage the traffic including parking policies, turning lanes, signal synchronization, one-way street systems, etc.

- **Visioning and Scenario Planning:** One opportunity for the application of improved planning tools is through visioning and scenario planning, which is also an excellent medium for education. Innovative planning ideas may fail to gain support from the public or decision-makers because their workings and impacts are not intuitive. Like most MPOs, MAG and PAG engage in visioning exercises to involve the public and key stakeholders as part of their long-range planning processes. These exercises provide a great opportunity to give additional visibility to and gain airing of these issues. If MAG and PAG are not already doing so, they should consider developing enhancements to their existing analysis tools to better reflect the effects of land use. One strong step in that direction would be to investigate adaptation of one of the new class of GIS-based land use planning tools such as Envision on IPLACE3S, as discussed above.
- **Improved Coordination with Local Planning:** Because the most important decisions regarding land use are made locally, it is vital that local jurisdictions be involved in the process of learning about and planning for compact, mixed-use development. Most of this will be of a voluntary nature, given the strongly held prerogative of local land use decision-making authority, so the most immediate mechanisms to improve participation are through education, coordination, and technical assistance. The state and the MPOs can offer workshops and training sessions on smart growth and can offer planning materials and aids to help with structuring codes, performing impact analyses, and suggesting performance criteria for plans and projects. Strong smart growth states like Maryland have modified certain planning provisions regarding annexations, determination of adequacy of public facilities, and transfer of development rights to try to encourage more accountability in local plans, although the important rights still remain with the local jurisdiction. The state's primary instrument for encouraging participation is the capital program, wherein it can adjust priority on requested projects based on support of broader state goals and objectives. However, many local jurisdictions lack the level of planning resources and tools found at the MPO level and, hence, many plans and decisions are based on judgment and simple analytic protocols. A much higher level of dialogue as well as the exchange of information and skill will assist localities in making difficult, frequently counterintuitive decisions. Introduction of highly visual planning tools, such as those described in the previous bullet, could be a major aid in this process.
- **Incentives:** Few strategies encourage a change in long-held behavior and practices as do incentives. In Maryland's Smart Growth program, the major incentive for change was the state's announcement that it would not provide funding for public infrastructure for new development located outside predefined growth areas, known as Priority Funding Areas (PFAs). The counties and local jurisdictions were allowed to specify the growth boundaries, after which funding for roads, water, schools, and other public facilities were limited to the PFAs. The general theme proved effective in directing attention to the needs of existing communities. With early leadership at the federal level, new sustainability

initiatives in many states, including Maryland, Missouri, Texas, and Oregon, are attempting to strengthen this incentive by using performance criteria to prioritize projects in the state budget. While this approach has resulted in some resistance, the movement to sharpen investment decisions to deliver the largest and most sustainable benefits is becoming a strong theme in an era of continuing revenue shortfalls. Many other less sweeping incentives can and have been used to encourage higher-intensity, well-designed development. These include:

- Planning grants to encourage study of smart growth developments.
- Tax credits to encourage location of projects or relocation of existing activities to desired areas.
- Green tape programs to streamline the arduous process of gaining zoning variances and approvals for mixed-use projects.
- Reduced parking requirements or other density bonuses for projects locating in mixed-use areas and meeting specified design goals.
- Reduced rate mortgages for households locating in mixed-use, transit-served areas.
- Financing or support of local sidewalk, trail, and local street networks.

- **Continuing Study:** The analysis and findings presented in this study are meaningful, but it should be recognized that the research was limited in various ways by the type of data available, limitations of the existing forecasting tools for purposes such they were used, and resources. It is recommended that new or existing mixed-use projects be monitored and studied to continue to build a database and deepen understanding. Such information would include traffic counts, trip generation and mode choice studies, internal capture, trip lengths, and even attitudinal surveys of travelers and stakeholders (residents, businesses, officials). The Valley Metro light rail line in Phoenix offers an opportunity to study changes in development and travel behavior under the first-time availability of a major new transportation system element.

There are many sources available to assist the State of Arizona, its MPOs, or local jurisdictions in advancing smart growth type objectives. The EPA operates a smart growth program that provides technical assistance and project grants to advance compact, mixed-use projects. The EPA has also teamed with the USDOT and U.S. Housing and Urban Development in a Sustainable Communities program designed to encourage broad national adoption of smart growth communities. Numerous leadership groups such as Smart Growth America and the Smart Growth Leadership Institute also provide outreach expertise in helping improve the level of understanding and flow of information on these issues. Finally, the TRB, through its various research programs, has sponsored many research and review studies, conferences and reports on smart growth, TOD, sustainability, and related topics.

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APPENDIX A: SUMMARY OF OPEN-ENDED QUESTION RESPONSES FROM SURVEY OF OFFICIALS

Other roles played in or tools to influence planning process as relates to land use & development decisions:

Elected officials: (Qu. 2)

No response

Planning and zoning officials: (Qu. 2)

- Planning and zoning officials advise the Board of Supervisors.
- Biological Conservation Plan.
- Design guidelines, hillside protection ordinance, public participation requirements.
- Advisory only to City Council.
- Neighborhood Preservation Zone.

Local planners: (Qu. 2)

- Design and construct roads.
- State planning efforts and smart growth.
- Review building, site, and civil construction plans for compliance, issue permits, inspection construction and issue a certificate of completion or occupancy.
- Negotiate Development Agreements for City.
- Evaluate all development proposals.
- Civil Plan Review, review construction plans for water, sewer, paving, grading; SWPPP, etc.
- Evaluate/update the City's Circulation System due to land development.
- Master plan for community development (HUDO).
- Participate in discussions related to growth, transit corridors, housing development.
- Integrate land use, community development, and transportation planning and policy.
- Participate in regional, sub-regional and corridor level transportation studies.
- Member of Transportation Commission. Review transportation planning issues and, as part of Commission, recommend policy to City Council.
- Plan Review.
- Review Improvement plans during the Final Design phase. Periodically involved in the review of plans during the preliminary stage.
- Transportation Commissioner.
- Look at short-term requirements (10 yr.) vs 20 yr. vs build-out for both large developers and CIP (TIP).
- Land Use and Design Review.
- Annexations, historic preservation.
- Issue engineering permits.

- Current planning (rezones, planning, special uses).
- Manage street projects (CIP).
- General management and administration of PAG participation at management committee and attendance at regional council meetings.
- Participate in public involvement process relating to the transportation aspects of some development decisions.
- Review rezoning requests and development plans and subdivision plans.
- Implement transit improvements.
- Rezoning.
- Review development proposals/submittals.
- Review plats, development plans, specific plans, etc.

State and regional transportation officials (Qu. 2)

- All local development must go through approval process by Planning Commission and Town Council.
- Approve Projects/Planning.
- Stipulate roadway dedication/improvements through development process.
- Member of Pima Association of Governments.
- Coordinate Regional Transportation Authority.

Other factors of importance when reviewing a development proposal:

Elected officials: (Qu. 3)

No response.

Planning and zoning officials: (Qu. 3)

- Impact on Biological Resources.
- Impact on environment, urban island effect, and global warming; air quality.
- Distance from city center, Sonoran desert protection plan.
- Long term energy impact.

Local planners: (Qu. 3)

- Opportunities for workforce housing development in conjunction with transit plan; incorporate County design standards, including visitability; incorporate green building concepts.
- Accessibility to recreation/open space areas. Balanced mix of housing and employment.
- Growth potential.
- Open Space and enhancements with newly developing areas.
- Transportation linkages and accessibility by various transportation modes.
- Multi-mode connectivity.
- Will the project be a walkable community?
- Will the project be taking into consideration its environmental impacts?
- Long-term impact—cost, congestion, infrastructure needed over time.

State and regional transportation officials: (Qu. 3)

No response.

Other ways asked to participate in the land use decision-making process:

Elected officials: (Qu. 4)

- Depends on personal knowledge.
- Staff does the analysis when asked.
- As issue comes before the council.
- As traffic studies are provided.

Planning and zoning officials: (Qu. 4)

No open-ended responses.

Local planners: (Qu. 4)

- Ensure transportation planning and policy decisions support local land use and community character.
- Review as part of transportation commission and recommend policy to City Council.
- Village Planning Committee.
- Impact fee.
- Issue permit to work on the land.
- Respond to city staff recommendations.
- Regional planning at macro level.
- Evaluate related transportation modifications and participate in the public involvement process.

State and regional transportation officials: (Qu. 4)

- We are asked by neighboring jurisdictions to comment on major General Plan Amendments and rezoning cases on our borders and in the Town's planning area.

Other ways to evaluate transportation needs or impacts associated with development proposals:

Elected officials:

Not asked.

Planning and zoning officials: (Qu. 5)

- Multi-use pedestrian and bike possibilities.
- Depends on size/impact/location of project (could be all of these, or just one).
- Usually only related to freeway intersections or planned freeway extensions.
- City-wide.
- Is there funding for improvements.
- Planning relies on MCDOT review comments.

Local planners: (Qu. 5)

- Large residential developments, small to large commercial projects, schools, industrial developments, large office developments.
- On and immediately adjacent to site for Commercial Development and Planned Community Development.
- Nearby intersections for Planned Community Development.
- This dept. does not conduct formal transportation evaluation.
- I am not asked to do this. This assessment is typically left up to MCDOT.
- The site determines how far out we look.
- All on various types and sizes of projects impact, immediate and surrounding areas. Larger projects and specific types of projects may have wider impact.

State and regional transportation officials

Not asked.

Other information on tools, practices or procedures for evaluation of transportation impacts of development projects or land use decisions:

Elected officials:

Not directly asked—see response to question 8 below, which asks about guiding studies, reports or policies concerning transportation impacts of development.

Planning and zoning officials: (Qu. 6)

- Depends on size of project and location.
- Generally done for Master Planned Communities or major cores with high rises.
- Usually done by applicant who has tools.

Local planners: (Qu. 6)

- We use AzDOT's Traffic Impact Analysis for Proposed Development as our standard for traffic impact reports. Our relationship with the AzDOT Tucson District Engineer and Regional Traffic Engineer is excellent. We use them as a resource. Many times we hire traffic engineering consultants to assist us with all of [our] traffic engineering issues.
- Answers are related to YOU not this agency.
- Follow MAG and AASHTO Standards.
- Don't actually do the work, just review it.
- Transportation Department.

State and regional transportation officials: (Qu. 4)

- Route design and infrastructure via email in ref to "Supply technical information or expert opinion to decision-makers" question above.
- Contact County Administrator Chuck Huckleberry at 520-740-8751.
- TOD guidelines and TOD zoning Overlay District.

Types of data obtained or studied on traffic effects of development projects:

Elected officials:

Not asked.

Planning and zoning officials: (Qu. 7)

- Call our Transportation Division.
- Depending on size, traffic studies are very important.
- If requested as condition for submission. Gilbert Planning Dept (if applicable).
- Contact Pima County P&Z staff.
- See City of Tucson DOT.
- TIMA guidelines on city website.
- Pima DOT I presume, or try Maggie Saaw.
- Contact Alan Sandasam, City of Mesa Transportation Department.
- Contact City of Tempe.
- Major streets and routes plan, regional transportation plan, Pima Association of Governments Information.
- Town Hall.
- Call PC Planning (520) 740-6800.
- General plan.
- Transportation staff and transportation committee.
- See Planning and Zoning Personnel.
- Town of Marana 2025 Transportation Plan, RTA 2030 Transportation Plan.

Local planners: (Qu. 7)

- Developers are required to perform traffic analysis impact studies.
- Speed studies, traffic signal warrants, traffic counts, turning movement counts, traffic signal phasing and timing analysis.
- We use this information for posting appropriate speed limits, justifying traffic signal installations or not, planning capacity improvements, adjusting signal phasing, timing and cycling and adjusting pavement marking and signage.
- Use for historical purposes to establish parking and verify parking studies. Do not retain information.
- We do annual traffic counts but these do not show trip origins.
- Traffic counts, mostly ignored, cannot recommend source.
- Use consultants.
- Occasionally, traffic volume data is collected and compared to before data.
- Traffic counts.
- Constant assessment using local data, APA (PAS) data, ULI reports, etc. All commonly available.

- We don’t conduct formal “after” evaluations, but traffic conditions are constantly monitored citywide and reports are received about traffic conditions adjacent to new developments on an informal basis.
- I’ve reviewed reports of traffic levels and of transit use in reports from City staff. They could report in more detail the specifics of studies.
- Visually observe conditions in the field.
- As a member of the Transportation Commission, I have seen data, but do not create data.
- See attached TIA procedures/requirements.
- ITS data to justify cost of installation of ITS.
- Require overall build-out model then require phasing model that includes previous development.
- Refer to traffic section of public works transportation division.
- Traffic court, accident records.
- Traffic studies, MAG studies.
- Obtained through city transportation staff.
- We require traffic impact studies from developers.
- Speed studies, signal warrants and turning movement counts.
- Models and forecasts.
- Traffic Engineer requires TIS or other studies.
- Traffic counts; direct observation of traffic conditions.
- Traffic projections and potential activity.
- Traffic counts on an as-needed basis. If we have what you are looking for (in reference to above question).
- The number of daily trips generated is estimated for every rezoning case. This information is provided by Pima Association of Governments and placed on our website.

State and regional transportation officials: (Qu. 5)

- Data requested but not typically provided.
- Local developments require a traffic impact study. Any recommendations regarding traffic improvements are usually implemented.
- Contact Deputy County Admin. John Bernal at 520-740-8751.
- Traffic engineers perform studies. They are available at City Engineering (Goodyear).
- AzDOT.
- Traffic counts on an as-needed basis.
- Traffic counts, Travel Reduction Program Employee Survey.
- Traffic Impact Reports, Corridor Studies, Road Studies; Call Town Engineer.
- City Departments (Streets or DSD).
- We require new development to provide a traffic study showing post-development impacts. These are localized studies, but as development and rezoning occurs, data is fed to regional models (analysis by others).
- We obtain traffic engineering studies for new projects as warranted by circumstances of project.

- Crash data—Police (local) and AzDOT; ADT—AzDOT; Road Inventory—Tohono Olodham Nation.

Aware of recent discussions, ordinances, studies, procedural or policy requirements in your jurisdiction that address issue of including transportation impacts in land use or development decisions:

Elected officials: (Qu. 8)

- MAG, County, and Avondale's transportation plans.
- Prop. 400 and how it affects our General Plan. Making the Council and Staff aware of Valley Metro plans as well.
- Surprise Transportation Plan that is part of the General Plan.
- The General Plan for the development of 1275 acres of State Land recently annexed required a transportation plan which we developed. The land has subsequently been sold to the Ellman Companies.
- Comprehensive plans for Pima and Pinal counties; General plans—Transportation forums.
- Our park-and-ride lot—99th and Glendale Ave.
- Too numerous to name.
- Transportation issue regarding new state trust land annexation and future development (1275 acres).
- We have a lot of new development in our city.
- Light rail studies.
- Transit Oriented Development (TOD) zoning along our light rail route (implemented); Density bonus along light rail line (study); Our general plan 2020 (policy-voter approved).
- Large employers, large retail projects, new residential, freeway openings.
- Economic Positioning Study and Special Planning Area Reports.

Extent of Coordination—Other:

Elected officials: (Qu. 6)

No open-end responses.

Planning and zoning officials: (Qu. 4)

No open-end responses.

Local planners:

Not asked.

State and regional transportation officials: (Qu. 6)

- Other local jurisdictions.
- Local districts, Bureau of Indian Affairs, Local Utility Authorities.

Other factors influencing effects of mixed-use development on traffic congestion:

Elected officials: (Qu. 12)

- Same traffic impact/resident but more localized to specific areas (concentrations).
- Other factors include availability of public transit, and other means (bike, walk).
- If on light rail route—less traffic. Otherwise, about the same.

Planning and zoning officials: (Qu. 12)

- Land use mix—employment, commercial, office, residential all have different impacts (especially peak)
- Depends on where the mixed use development is located.
- The mix of uses proposed.
- Location, access to arterials and freeways, internal transport plan, density, use, neighboring uses, types of mixed uses, percentage of each type.
- The mix of uses and the features that might generate trips into the area from outside (e.g., arenas, stadiums).
- Traffic patterns and trip generation will be based in large part on if people work in area they live. This will in large part be determined on the quality of jobs provided in the mixed-use area.
- The commercial/industrial must be compatible with the housing choice—if residents can work in their neighborhood then traffic would be less impacted outside community.

Local planners: (Qu 11)

- It really depends on what types of uses are involved and where the development is located. It has been very hard to convince the people of this town of the positive aspects of mixed-use development. Our General Plan calls for complimentary use developments. No MUD just CUD!
- Depends on the uses.
- Obviously depends on mix and relative density of office vs. residential vs. retail to “conventional project” at same site.
- It depends on many other factors such as size of development and location.
- We would expect less trip generation but not dramatically so. If situated in appropriate transportation corridors, traffic congestion to residential areas would be minimized.
- Depends upon mixture of uses, densities (high, medium, low, very low, etc.), development scale/area (size), connections to existing or proposed transportation routes.
- Depends on mix and density.
- If destinations like Kierland Commons, more traffic. Otherwise same or less.
- Many new mixed-use projects are going into areas that encourage public transit.

- Each site is different. Each will generate trips at its own rate.
- Transit facilities, pedestrian-friendly environment, signal light timing.
- Depends on the type of mixed use.
- Percent of each use.
- Location, transit, amount residential, road fatalities.
- Type of mixed use; availability of transit/transportation alternatives; location; density; site.
- Projects would have high density and would require traffic movements until transit was available.
- The types of uses available and the amount of residential provided; also depends upon the availability and proximity of transit facilities.
- Should include access to public transportation.

State and regional transportation officials: (Qu. 9)

- Design and use—may start with less traffic but move to about the same over time.
- Traffic flow would be critical.
- These developments may increase congestion outside their borders while lowering it within the development.

Other factors influencing effects of mixed-use development on transit use:

Elected officials: (Qu. 13)

- Depends on quality and types of services available.

Planning and zoning officials: (Qu. 13)

- What type of mixed use in what part of town?
- If mixed-use leads to lower auto parking need (i.e., ability to live, work and shop in small area) I'd expect transit use to increase.
- Depends on availability and frequency of transit service, as well as phasing of development.
- Need better transit (trains)—urban streetcars and safer bicycling and pedestrian conditions.
- Availability of transit, sidewalks to get to transit, hours of operation of transit.
- The mix of uses proposed.
- Proximity to transit; if a TOD project, would lead to greater transit use.

Local planners: (Qu 12)

- Depends on the available transit routes in the Valley area.
- It would lead to greater transit use if it were available. We are working on this through the RTA. We plan to build a park and ride facility, then extend Sun Tran to our commercial and industrial areas.
- Depends on whether transit is already in place.
- Obviously depends on mix—and proximity to transit alternatives, and connections to and from.
- Yes, if development is balanced with various uses/densities, employee/employer commutes that are reasonably with a 1/2 hour drive or less.
- Quality of transit integration and quality of service.
- Depends on proximity and choice of transit nearby.
- Peoria not a lot of transit possibilities.
- Depends on where employment is.
- Quality of transit (schedule, cleanliness, cost, etc.).
- Location and type of market—those projects geared to 2nd homes won't be as conducive to transit.
- Type of mixed use; availability/cost of parking; location; site-etc.; type of transit options; incentives.
- Transit generally is not available.
- What specific mixed uses and price range?
- If on existing transit route.

State and regional transportation officials: (Qu. 10)

- Design and uses.
- Location and whether routes exist.
- I think the specific developments and regional conditions would have a tremendous effect on this answer.

Other factors influencing effects of mixed-use development on pedestrian & bicycle travel:

Elected officials: (Qu. 14)

- None.

Planning and zoning officials: (Qu. 14)

- Depends on nature, type, and scope of project.
- Should increase, but depends on context of development within overall development patterns in area.
- Location to light rail, time of year (lower in summer), matrix of tenants.
- Availability of safe bike routes, sidewalks, street amenities such as trees for shade.
- The mix of uses proposed.

Local planners: (Qu 13)

- Depends on other nearby development.
- It does lead to greater bike and pedestrian travel. We have an aggressive plan to provide for the opportunity for folks to ride bikes or walk to wherever they want to go in town. Our typical arterial street cross section has bike lanes, multiuse path and a sidewalk. We are in the process of constructing a linear park up the CDO and BIG Washes which connect to our street system and major commercial uses.
- We wish that AzDOT would do the same on Oracle Road. Please help us convince them that it is the right thing to do. Clear zones are their issue.
- The proximity of distance from home to work and weather conditions.
- Obviously depends on mix—and location (existing pedestrian/bike environment) and connections to and from vs. "conventional project" at same site.
- Bike and pedestrian use will increase, but much depends on the relationship to other regional and community trip attractors.
- Quality of integration with community is critical.
- User-friendly environment.
- Depends upon facilities available and the type of uses and proximity to other sources.

State and regional transportation officials: (Qu. 11)

- More with proper design.
- If sidewalk or walkpaths, maybe more pedestrian usage.

Other factors influencing whether "my community" would support these types of developments:

Elected officials: (Qu. 15)

- The development would have to be within all regulations and guidelines and be creatively attractive; location would also very definitely be a factor.

Planning and zoning officials: (Qu. 12)

- Depends on layout, scale, intensity of development.
- As new director, I hope that I would be able to work with community on this. Very anti-mixed-use currently.
- Federal funding to help defray cost of transportation improvements.
- Immediate neighborhood response differs.
- Location, scale of development relative to surrounding uses.
- The relationship to existing land uses and neighborhoods; the value, cost, and availability of the residential uses.

Local planners: (Qu 14)

- If you would call them complementary use not multiuse developments they could support it.
- Fitting new development into an existing fabric may not work well with transportation networks. Rural communities tend to be less likely for this while more dense development could be considered. Proximity to services and recreational facilities improves quality of life and livability.
- Density, context.
- Consistent with plans; types of uses/neighborhood support.
- It would depend upon the surrounding neighborhoods and associated impacts and the site the development was to located.

State and regional transportation officials: (Qu. 12)

- Depends on the specific types and quantity of developments. Commuters from the urban fringe would see the most benefit in terms of quality of life, but would the projects be economically viable?
- The Tohono Oldham Nation in an isolated area; so we don't get much support, other than ourselves.

Do you have sufficient information on impacts of mixed-use development on traffic congestion to make informed decisions—Other:

Elected officials: (Qu. 16)

No open-end responses.

Planning and zoning officials: (Qu. 16)

- Often, projections are contingent on factors that are in place at the time. Multiple ongoing developments in the same vicinity are difficult to project.

Local planners: (Qu 15)

- The more information that I have the better. Please supply me with all that you can.
- Yes.
- Sometimes yes, sometimes no. Bigger projects are easier, smaller ones tend to be much more guesswork.
- Depends on the project and the information available.
- Applicant must provide traffic studies which are reviewed by traffic engineering staff.
- Depends on location and adjacent uses.

State and regional transportation officials: (Qu. 13)

- Large developments require a traffic study.
- Yes: Urban Land/Institute (Study on Phoenix LR and corridor); American Planning Association; Congress for the New Urbanism.

If such information were available, would it be used?—Other:

Elected officials: (Qu. 17)

No open-end responses.

Planning and zoning officials: (Qu. 17)

- Recommend its direct inclusion/use during planning and decision process.
- May use if appropriately defined and "logical."

Local planners: (Qu 16)

- I will use it.
- Will refer others to use it as well.
- In most cases, each option would/could be applicable; however, in some cases, it may not make a difference depending upon the geography, community dynamics or other environmental factors.
- I trust this info would first go to our City Transit planning.

State and regional transportation officials: (Qu. 14)

- Uncertain plans exist today that are unutilized.

Most appropriate types of development for "my community" in future—Other:

Elected officials: (Qu. 18)

- Flexible light industrial; smart buildings.
- Designated arts and crafts, boutiques, restaurants, book stores, etc., small retail specialty area.
- Retail/commercial redevelopment.

Planning and zoning officials: (Qu. 12)

- Redevelopment.
- Community recreation.
- Downtown redevelopment.
- Lodging.
- More parks.

Local planners: (Qu 17)

- Industrial: in specific regions of Phoenix.
- Other: Residential and commercial remodels. Adaptive reuse of commercial and historical structures, converting residential structures to business use and revitalizing neighborhoods & retail centers.
- There are good reasons and places for all of these types of projects in our community....
- My Community is too large to specify just one or two.
- Our city is growing and needs a fully-diversified land use/economic base. All development types are appropriate and desirable.
- Sports Entertainment uses.
- R & D, Healthcare, International.
- Tucson is a city of 230 square miles; all of these activities are taking place.
- Parks.
- Educational institutions, hospitals, technology centers.

State and regional transportation officials:

Not asked.

Most appropriate types of development for the region—Other:

Elected officials: (Qu. 19)

- Same traffic impact/resident but more localized to specific areas (concentrations).

Planning and zoning officials: (Qu. 19)

- Need to define growth boundaries before embarking on any more growth; also need to assess infrastructure needs and costs for the region and identify funding sources.
- Balanced live, work, shop to avoid commuting in all regions of the city.

Local planners: (Qu. 18)

- There are good reasons and places for all of these types of projects in our region ... .
- Problem of affordable housing rather than just MORE housing, as affordability has been pushed out into suburbs and unincorporated areas where public transportation is minimal. At best, workforce housing has to be a focus for future commercial development employment in core areas needs to provide a livable wage. Proverbial question—what comes first, retail or residential?
- None of these are inherently good or bad. In my view, we need a balance of many of these, giving residents more choices.
- The price of fuel and its availability will determine the type and distribution of new uses, not to mention availability of water.

State and regional transportation officials: (Qu. 16)

- We are presently updating the general plan and strategic plan for economic development, which will guide future growth (and influence).

Qu. 17: Types of development that will most likely occur in the region:

- Mixed-use neighborhoods and communities.
- Entertainment corridors.
- Mixed-use neighborhoods and communities.
- Mixed use may become a reality, but needs to be viewed positively by both the development community (i.e., will it make a profit) and general public (many of whom are not used to this form of development). As long as development standards are not compromised, this should have broad support in the planning/professional community.

APPENDIX B: CONGESTED CORRIDORS AS IDENTIFIED BY SURVEY OF OFFICIALS

Most Congested Corridors in Region (Qu. 18)

Elected officials—First choice

I-10 from Loop 101 west to Dysart Rd	Retail, auto mall, hospitals, medical offices
Elliott Road from Arizona Avenue east into Gilbert	Moving residents from Loop 101 to their homes
Bell Road between Grand and Sun Valley Parkway	Residential and commercial
Shea Boulevard	Major arterial—major shopping center
Oracle Road	Oro Valley and N-S commute
Northern Ave.	In and out of Glendale
101 Pima at 202 Stack	East Valley/Scottsdale
Alma School N/S	
Saguaro Blvd.	Commercial and multiple residential
59th Ave.	Glendale Community College
Bell Rd.	Retail and business
US-60 (Broadway Curve-101)	Downtown Phx (pass thru traffic)
Arizona Ave.	Downtown Area/Central City
I-10	Everything
Val Vista at Baseline	Hotel
Bell Road	All of the city
I-17 New River to SR 101	Phoenix

Elected officials—Second choice

Dysart Rd north and south of I-10	Retail, hospital, community college, residential
Warner Road from Arizona Avenue east into Gilbert	Same as Corridor 1
303 between I10 to Grand	Commercial Truck route and main N-S corridor
Saguaro Blvd.	In-town arterial, multi-residential area, several shopping/business areas
La Canada	North/South commute
51st Ave.	
US-60 Fwy (Superstition)	East Valley/Mesa Gilbert
Chandler Rd.	Center of town E/W
Shea Blvd.	Shopping Center
Olive Ave.	
Loop 101	Destination - Residential
I-10 (143/Airport)	Downtown Phx (pass thru traffic)
Alma School Rd.	Central City
Litchfield Rd.	Luke, LP, Goodyear
Warner & Gilbert	
303	Connection to interstate

Planning and zoning officials—First choice

Southern	Fiesta Mall
Bell Road	Bell Road Commercial Corridor
101 North	all of Scottsdale
Southern Ave. (48th St. to Price Rd.)	Several business, city pass-through
Black canyon freeway	downtown to north phoenix
SR 202/Gilbert Rd	Commercial, education, retail, residential
Price and Chandler	
101 and Union Hills	Wal-Mart
Broadway Blvd. from Downtown to Craycroft	Central
Scottsdale Rd./Frank Lloyd Wright to Loop 101	
Country Club	Main to US-60
Grant and Swan	Crossroads Festival/TMC
Scottsdale Rd. - entire length	Variety of uses - including regional commercial developments
NW Side (but I don’t go up that way if I can help it so I don't know specifics)	
Scottsdale Rd. - Thunderbird to Thompson Pearl	See above
Power Rd./Southern Ave.	Superstition Springs Mall
Union Hills/101 to 83rd Ave.	Peoria/Glendale
Interstate 10 and N/W Tucson area	Downtown/UA/Tucson Mall
Country Club/Arizona Ave.	North Chandler/SW Mesa industrial area
Oracle/Tangerine Rd. - Ina	
I-10 and US-60 interchange	SE and S. Valley
22nd St.	Downtown, east side, west side, south side
Oracle Rd.	Downtown, UAZ, malls, Oro Valley-Tucson corridor
Speedway	University of Arizona
Cortaro Rd. (East and West of I-10)	Pavilion Business Center and Cont. Ranch
Grant Rd.	Lots of them
East Camelback Rd.	Camelback core
Chaparral Road	Mid-Scottsdale
Airpark Corridor (Scottsdale Rd. to 101 FLW to Cactus)	Airpark Commercial, industrial, residential
Oracle Rd. - Miracle Mile to 1st Ave.	Oro Valley
Oracle Rd., River to Ft. Lowell	Northside Comercial
83rd Ave. and Thunderbird	
Ina Rd.: Silverbell to Camino De la Tierra	Commercial/RTL corridor
I-10 between 7th and 43rd Sts.	Surprise, Peoria, Goodyear, Avondale, Buckeye, Glendale
24th Street at Camelback	Esplanade, Biltmore Fashion

Planning and zoning officials—Second choice

Hwy 60	Superstition Springs
59th Avenue	Various public facilities: City Hall, Glendale Community College, Thunderbird Road Medical Corridor, Thunderbird Graduate School, Bell Road Commercial Corridor, Midwestern University
Scottsdale Road	All of Scottsdale
Rural Rd. (202 to US60)	None
Route 51	Downtown/other freeways to northeast Phoenix

Higley/Elliot	Residential
Ray and Alma School	
101 and Bell Rd.	Arrowhead Shopping Center
Ira Rd. from I-10 to Craycroft	NW
Hayden Rd./Hayden Rd. and Frank Lloyd Wright Area Loop 101	Retail Centers
Grant and Campbell	
Pima - entire length	Commercial and residential development
Somewhere else on NW side	
101 Pkwy (60/202) to 51	
Southern/Dobson	Mesa Community College
Bell Rd./67th to 99th Ave.	Glendale/Peoria
Tongus, Verde Rd. and Salino Canyon	East Side Tucson and Salino Canyon Recreation area
US-60 - Superstition Freeway	Entire East Valley
Oracle/Magee	
101 at 202 exchange	SE and S. Valley
I-10	Metro Tucson
Grant Rd.	No major ones directly - primary E-W corridor for developments outside city limits
Oracle Rd.	NW residence
Ina Road (East and West of I-10)	Business district
I-10	All
Scottsdale Rd.	Entire City
N. Scottsdale/N. Pima Rds.	North Scottsdale
Broadway Blvd. - I-10 to Prudance	Downtown Tucson
Campbell Ave., Broadway to River Rd.	North center commercial
83rd and Bell Rd.	Arrowhead
Thornydale Rd.: Orange Glove to Ina Rd.	Costco, Home Depot and other major retail centers
I-10 between 105 and Avondale	Avondale, Surprise, Buckeye
7th Street at McDowell	Multiple

Local planners—First choice

Chandler Boulevard near the Loop 101	Chandler Fashion Center
Loop 101- Shea to Loop 202	Scottsdale Airpark
Oracle Road	Cuts through the Town and provides a link between Pinal County and the City of Tucson.
Oracle Road	Tucson to Globe
Bell & 7th Street	
I-17/ I-10 Bell Road	Phoenix
University Drive	
Bell Road, 83rd Avenue	Mall
Milton Road from I-17 to Downtown	All of West Flagstaff
Bell Road	Regional commuter access to SR 101L, Arrowhead Towne Center
Bell Road	
Swan and Grant	Residential, commercial and gateway to foothills
Broadway/Rural	None, through traffic
Shea Boulevard	Four Peaks Plaza
Shea Blvd	Retail/Hospital
I-10 / Broadway Curve	Downtown Phoenix
Bell Road/ Sun Valley Parkway to Agua Fria	Downtown Surprise Arizona

River	
Central Ave/7th St/7th Ave from downtown to Dunlap Ave (approx. 8 mi)	Downtown, Midtown
Scottsdale Road	Downtown Scottsdale, Airpark, commercial centers
16th Street/US Highway 95	Yuma, AZ
Scottsdale Road and Frank Lloyd Wright Boulevard	Airpark
I-10/Broadway Curve	Downtown Phx to East Valley
Country Club Drive	US 60/ Downtown Mesa/ L202 Red Mountain/ North to Fountain Hills and Payson/ South to Gilbert Chandler
I-10 west bound	Down Town Phoenix
Bell Rd. 75th west to City limits	Mall, shopping, restaurants, freeway
Bell Rd.	No other East/West route to and from except corridor 2
Downtown Tempe/ASU Tempe Campus	Same as above
101 highway	Regional thruway, one of only 4 N/W corridors through city
Bell Rd.	Arrowhead/Auto dealers
University: Priest to Price	ASU, Freeway ties
Beeline Hwy	Payson
Cortaro Road east of I-10	Retail east/west of I-10
Bell Rd.	Arrowhead Mall/Strip Commercial
Bell Rd. and Loop 101	Restaurants, Mall, Autoplex
Van Buren St.	Canyon Trails MPC
Bullard Ave. between McDonald and Yuma Rd.	Office development employment corridor
Bell Rd./Loop 101 to West city limit	Auto dealers, Retail, Residential
Oracle Rd. - Calle Concordiea - Tangerine	Commercial/other/retail/thru traffic
Grant and Swan	Shopping
Bell Rd.	Neighboring Jurisdictions
Broadway	Park Place/U of A
Frank Lloyd Wright, SR101 - Scottsdale	Airpark
Power Rd.	Pinal County to US-60 and E. Valley
Bell Rd.	Retail and businesses, community
Camelback Rd.	Regional Retail/Office
I-10 Prince to 29th (now under construction)	Downtown
Country Club - Baseline to Southern	US-60
SR 101 (Pima) Freeway	City of Scottsdale
Lake Pleasant Rd.	Lake Pleasant
Oracle Rd. - Between Grant and River	Tucson Mall/Auto Mall
Shea Blvd. - Scottsdale Rd. to 96th St.	Scottsdale Commercial, hospital, freeway
I-10 @ Broadway	Regional
Ina Road from I-10 to easternmost town boundary	Retail centers, fast food, etc.

Local planners—Second choice

Ray Road near I-10	Shopping Center
Indian School Road - Loop 101 to Scottsdale Road	Downtown
La Canada	Cuts through the Town and provides a link between Pinal County and the City of Tucson
La Canada Drive	Tucson to Oro Valley
7th Street and Indian School	
I-10/Chandler Blvd to 7th Avenue	Phoenix/ East Valley

Rural Road	
Route 66	East Flagstaff
Grand Avenue (to SR 101L)	Downtown Phoenix
Speedway and Campbell	University of Arizona, residential commercial, medical
Southern/Rural	None, through traffic
Saguaro Boulevard	Downtown
Scottsdale Rd	Airpark
US-60	Downtown Phoenix
Grand Avenue/ Wickenburg to Agua Fria River	Emerging Surprise, Downtown Surprise, El Mirage Arizona
Indian School Rd/Camelback Rd, Central Ave to east City Limits	Midtown, Camelback East Village Core (i.e., area around 24th St/Camelback Rd)
Shea Boulevard	Commercial Centers, access to Fountain Hills, residential communities
4th Avenue/Highway 80/32nd Street	Yuma, AZ
L-101	EV Cities, Downtown Tempe, Scottsdale
Southern Avenue	Desert Banner/ Fiesta Mall/ MCC/ Superstition Springs/ Banner Baywood/ US 60
I-17 South Bound	Central Phoenix
Thunderbird Rd. 83rd west to City limits	Shopping/office
Grand Ave. (US-60)	Same as Corridor 1
Airpark	Airpark
Union Hills	L-101
Mill Ave.: Rio Salado to 10th	Downtown retail; ASU
260	Payson
Ina Rd./east of I-10	Commercial
McDowell Rd.	Palm Valley MPC
McDowell Rd.	Commercial/office
Thunderbird Rd./67th Ave. to 94th Ave.	Retail, Medical, Residential
La Cholla - Lambert to Ina	Residential/commercial/retail
Speedway and Campbell	University of Arizona
Thunderbird Rd.	Loop 101 and Commercial
Oracle Rd.	Tucson Mall
Indian School Rd.	Downtown
Gilbert Rd.	US-60 to downtown
Thunderbird Rd.	Commuting and retail
Central Avenue	Downtown/Midtown
Oracle Rd.	Tucson Mall/Strip development
Power - Baseline to Southern	Superstition Springs Mall/US-60
Scottsdale Rd.	Scottsdale Downtown
Bell Rd/	Corridor cross-town
Kolb Rd.	Davis Monthan, Retail centers
Scottsdale Rd. - Frank Lloyd Wright to Thompson Park	Commercial, Auto dealers, retail, freeway
US 60	Regional
Thornydale Road from Ina Road to southernmost town boundary	Retail centers, fast food, etc.

State and regional transportation officials—First choice

Broadway Blvd.	Downtown, Malls, strip centers and east side
I-10 Broadway Curve	Sky Harbor Airport/Downtown Phoenix
Broadway - Wilmot to downtown	Park Place, Williams Center - Downtown
Lincoln Drive/Tatum Boulevard	None
Bell Rd. 67th to 94th Ave.	
Tegner St. Hwy 89-93	Town center
Scottsdale Rd. Frank Lloyd Wright to Tempe	
Oracle Rd.	North/South mobility corridor, mostly retail activity along corridor
I-10	
I-17	
Country Club, Baseline to Southern	US-60
Oracle Rd.	Mix - medical, apt. housing, retail
I-10	
Oracle Rd.	Northwest Pima
I-10	Downtown Phoenix
Interstate 17	Anthem, employment centers
Tatum/101	Desert Ridge Market Mayo Hospital American Express
Ellsworth Road	Downtown/Regional traffic
West I-10 - Loop 101 West	Region/nation
I-10	all
Entire Route of Hwy. 86	Entire Tohono O'odham Nation

State and regional transportation officials—Second choice

Oracle Road	Downtown, Malls and strip centers, north side
I-17 Anthem to Durango Curve	Downtown Phoenix
Oracle - River to Downtown	Tucson Mall, Downtown
Lincoln Drive/Mockingbird Lane	None
Thunderbird Rd. 67th to 94th Ave.	
Wickenburg Way - Hwy 60	Westside Commerce center, post office, schools
Loop 101	
Valencia Rd.	DM Air Force Base/Raytheon/Tucson Airport
SR 69	
Power Rd., Baseline to Southern	US-60
Grant Rd.	Mixed use from I-10 to Harrison
I-17	
I-10	Tucson/Phoenix
I-17	Downtown Phoenix
I-10 East	Ahwatukee, AZ Mills Mall, Casinos
I-17/Carefree	Housing
Power Road	Power Ranch, Marketplace projects
I-10 East of Queen Creek	Region/nation
EW and NS Corridors	
Federal Route 15	North portion of Tohono O'odham Nation

APPENDIX C: SELECTION OF STUDY CORRIDORS

PURPOSE

Under Task 4 of the study work plan, the objective was to identify a sample of transportation corridors in the Phoenix and Tucson metropolitan areas where there is evidence of both higher-intensity development and traffic congestion. The relationship between land use patterns and traffic levels will then be analyzed to try to ascertain the impact of higher-density development on traffic generation and congestion. The purpose of subtask 4A has been to present the study team's initial recommendations for the sample of corridors to the TAC for consideration and selection.

Task 4 provides the opportunity to examine the issue of whether higher-density development is associated with increased traffic congestion in a practical context. By picking an array of settings in the Tucson and Phoenix areas with different roadway systems, development patterns, and composition, it will be possible to apply some of the new analytic frameworks along with existing planning tools and data to improve our understanding of how traffic is affected, and if there are ways that either land use or the transportation system can be modified or managed to produce better results.

PROCESS FOR SELECTING CORRIDORS

An initial set of criteria to guide the selection of corridors was established in the proposal and repeated in the work plan. These were primarily aimed at identifying activity centers that would be served by the respective corridors, having the following characteristics:

- Different overall levels of development intensity.
- Different degrees of mix and function, ranging from single-purpose employment, commercial or residential activity to heavily diversified.
- Different degrees of pedestrian friendliness, as defined by sidewalks, block lengths, safe crossings, and level of auto access.
- Location at the end of vs. along a major corridor.
- With and without good transit service.
- With and without restricted/priced parking.
- Places where development/traffic related issues are currently under study, or where major new development or transportation projects (e.g., transit) are being planned.

Several steps were then taken to identify candidate corridors. The first was to solicit help from respondents to the Survey of Officials conducted in Task 3. Each respondent was asked to identify up to two highway corridors—preferably in their jurisdiction—where congestion was an issue and where the character of land use was probably involved. Respondents were asked to qualify their response in terms of:

- The segment of the facility most exhibiting the condition.
- The time(s) of day/week when the congestion was most evident.
- The likely contributing causes of the congestion.

- The extent to which the congestion was due to development inside vs. outside the respondent's district.

These recommendations are contained in Appendix B. The most frequent responses are listed below, and a summary of the key characteristics of all corridors recommended by the survey (including the number of times each was mentioned) are in Tables 32 and 33.

Phoenix area

- Bell Road: Traffic associated with adjacent commercial activity.
- Interstate 10: Primarily associated with travel to downtown Phoenix.
- Interstate 17: Also associated with travel to downtown Phoenix.
- Scottsdale Road: Relating to the City of Scottsdale and the Airpark.
- Highway 101: Primarily associated with commercial activity at Union Hills.
- Shea Blvd.: Linked to commercial activity, a major hospital, and the nearby freeway.
- Thunderbird Road: Due to shopping and commercial activity.
- US 60: Combining through traffic with traffic to downtown Phoenix.

Tucson area

- Oracle Road: Particularly in relation to the Tucson Mall as well as regional through traffic.
- Grant Road: For reasons of both adjacent commercial development and through traffic.
- Interstate 10: Primarily associated with travel to downtown Tucson.
- Broadway Boulevard: Associated with activity in downtown Tucson and associated malls and strip commercial centers.
- Speedway Boulevard: For reasons of both adjacent commercial development and through traffic and University of Arizona.

All of the corridors mentioned in the survey were plotted on maps of the respective metropolitan area. Because many of these corridors are very long, their composition and character changes from jurisdiction to jurisdiction. Hence, a corridor may have been mentioned by several respondents, but depending upon their affiliation, they may have seen and reported on a different segment and potentially different set of contributing causes. This dilemma of which corridor segment to look at was further complicated by an uneven distribution in the sample of survey respondents. Of 134 total respondents, a small number of jurisdictions—Peoria, Scottsdale, Tempe, and the City of Tucson—composed 51 percent of the total. This introduces the possibility that the group of identified facilities may have a sampling bias toward these respondents.

To address this concern and to begin to align the recommendations more closely with the criteria, the following additional steps were taken: First, planning staff and officials at both MPOs, MAG, and PAG were engaged in the process. Per the proposal, the two MPOs were apprised of the study purpose and goals, the desire to identify and analyze corridors, and the need to access and use existing data sources and their regional travel model capabilities. MAG and PAG demonstrated high interest in and support for the study, including the offer of later performing the necessary analyses. They furnished us with requested information needed for the corridor identification process, including transportation network maps; various GIS data including land use, historical traffic volume, and congestion data; and maps of historic, current, and projected population and employment density.

Upon mapping the suggested corridors and overlaying them with the traffic congestion and land use data, researchers found it difficult to identify situations that would satisfy the initial criteria for corridors. Unlike conditions found commonly in the northeastern United States, regional development patterns and transportation networks are not composed of nodes and spokes, where major corridors are either radial or circumferential. Hence, the expectation of finding various examples of high-density activity centers lying at the ends of or immediately adjacent to major transportation corridors had to be revisited in light of the much more uniform low-density/large-grid patterns that are common in both Tucson and Phoenix. This caused a reassessment of the criteria for major regional activity centers with significant employment activity as well as the desire to find examples of mixed-use, higher-density, and walkable residential areas. We shared these concerns with transportation staff at MAG and PAG, tapping their knowledge to try to sharpen the search for examples that would meet our criteria.

In our discussion with the MPOs, we attempted to draw a distinction between the following types of sites:

- Destinations that are primarily employment-oriented, but where the land uses permit a contrast between more “urban” types of sites with higher density, some mix of uses, walkability, limited parking, and transit service vs. more typical suburban sites that are totally auto-oriented with abundant free parking, no local services, no transit, and no ability to walk to other locations from the work site.
- Destinations that are primarily commercial, offering shopping, services, and perhaps entertainment for either residents (households or employees) or visitors/customers from outside the community. For this travel market, the desire is to identify contrasting examples between traditional retail that can be reached by walking, transit, or short car trip (or permitting the ability to abandon the car once at the destination, which could include shopping malls) vs. more conventional, auto-oriented commercial districts where destinations are distributed along arterial highways or single-purpose supermarket/big box shopping requiring individual vehicle trips.

The intention in both trip markets is to “disassemble” the traffic stream in the respective corridors and identify where the travelers are coming from/going to (at a selected reference point), their travel purpose, and mode of travel. This will then allow us to compare the travelers who have actual destinations in the selected areas with those in the contrasting areas, and to compare both with the portion of the travel stream that is made up of through travelers. We will do this analysis through a combination of “select link” analysis with the respective travel models and possibly with the help of geocoded trip diary information from the respective regional household travel surveys.

From this revised perspective, and with input from the MPOs, we then examined supporting information to refine our search. The primary aids for this investigation were:

- Traffic volume and congestion maps (current and historic).
- Land use type and density maps (current and projections).
- Transit system route maps and, for Phoenix, alignment for the new light rail line.

From this multiple set of procedures, the following set of corridors is offered for consideration for the two metro areas.

PHOENIX

Expressways

Beginning with the interstate/freeway system, researchers recommend the following situations, in declining order of priority:

- **I-10** as it enters downtown Phoenix from the west, following its junction with I-17. Heavy traffic from this point to the intersection with SR 51. It would be expected that travelers on this route would be headed to primarily employment in downtown Phoenix. Express transit on both I-17 and I-10 may help provide some efficiency for travelers destined to the downtown.
- **I-17** between Thunderbird Road and Northern Avenue. There appears to be significant adjacent development along I-17 through this segment, and particularly at Northern Avenue—both residential and employment—and traffic levels are moderately high.

Other possibilities include the following, but would seem of lesser interest:

- **Loop 101** on the northeast between 7th Street and SR 51, and on the southeast from Chandler Blvd. to Red Mountain Freeway (202), and on the east between Chaparral and Shea Blvds. near Scottsdale. These all show only medium to high levels of traffic, and it is difficult to see a connection with adjacent development.
- **I-10** south of Phoenix through the "Broadway Curve." Traffic levels appear high, but this section of highway also appears to be a regional mixing bowl, melding through traffic with activity from the Hohokam Expressway, Broadway Blvd. through Tempe, and the Superstition Freeway (US 60).
- **US 60 (Superstition Freeway)** from I-10 to Mesa. Significant traffic, but propose to study on a more localized basis.

Arterials

Arterial highways are perhaps more interesting in that they are more likely to serve a mixture of local and through traffic, and hence may bear a closer association with development. The following situations are proposed:

- **Bell Road** is at the top of everyone's list, though it is perhaps one of the most remote facilities in the system. Looking at its daily traffic loadings, it is clear that the western segment between Grand Avenue and Loop 101 has some of the highest traffic totals among arterials in the region. This segment is proposed for study, even though it does not appear to be particularly densely developed, to ascertain the nature (residential or commercial) of the traffic. The eastern end of Bell Road, between 7th Street and Scottsdale Road, would make an interesting comparison study since it appears to have more density but much lower traffic levels.

- **Scottsdale Road** from Chaparral north to Thunderbird Road and the Airpark has a surprisingly high degree of traffic in relation to adjacent development, and should be studied. At the same time, the section from Chaparral south to Thomas Road is the most urban portion of Scottsdale Road and runs through the business district of the downtown. Comparing the northern and southern segments as specified would seem to provide a good contrast in development styles and traffic impacts.
- **Central Avenue** may not be mentioned on a list of traffic problems nor show up particularly strongly on a regional traffic congestion map, but it is the main arterial corridor into the downtown from the north and is surrounded by much of the area's high-rise development. Again, researchers see two different behaviors along the corridor that may be worth contrasting. To cover the core of the downtown, they suggest examining the segment of Central and N 1st Avenue (one-way couplet) between Van Buren and Jefferson. They also suggest looking at the segment from Van Buren north to Camelback, largely because this also coincides with the alignment of the new light rail line.
- **Mill Avenue/Apache Blvd** is interesting because it connects downtown Phoenix with Tempe and the main ASU campus, which is also the route for the new light rail line. The university must be one of the region's major trip generators, sufficient to justify building transit in this corridor. Researchers suggest studying flows in this corridor, including Broadway and University, to evaluate the impact of the university on the region, the local road network, and the potential effects of somewhat more urban land use and existing transit use in the corridor.
- **West McDowell Road** is a potentially interesting study in that it runs through some of the highest concentrations of residential land use in the region (from N. 91st Avenue to N. 35th Avenue, and from McDowell north to Grand Avenue and W. Glendale Avenue. McDowell does not appear to be particularly congested over this stretch, although it does run parallel to I-10, which becomes more congested as it approaches downtown. It would be interesting to determine both the nature of trips generated in this combined corridor and how the arterial and freeway work together to meet local vs. long distance travel needs.
- **Alma School Road** and **Country Club Road** at the intersection with US 60 and Baseline Road. This quadrant appears to carry significant traffic even though the immediately adjacent land uses do not appear to be high density. However, south of Baseline is substantial residential development and north of US 60 is substantial retail (Fiesta Mall and Retail Center) and perhaps other commercial activity. Data do not suggest high employment concentrations in this area, however.

- **E. Shea Blvd. and E Camelback Road** west of Scottsdale Road are both mentioned by numerous survey respondents as having development-related congestion. In this case the congestion appears to be associated with extensive commercial development—from 68th Street to Scottsdale on Camelback and from SR 51 to Scottsdale on Shea.

TUCSON

Expressways

Researchers recommend looking at the **I-10** approaches to downtown Tucson from both the north and the south. If other travel relationships (i.e., unexpectedly high traffic volume segments) are revealed elsewhere along its length through the region, consideration will be given to examining those sections as well.

Arterials

Comparing responses from the survey with input from PAG staff and then examining traffic volumes along with corresponding land uses led to the following recommendations for arterial corridors to be studied in Tucson:

- **Oracle Road** was far and away the most frequently mentioned arterial by survey respondents and PAG staff. Examining a map of traffic volumes corroborates this perception. Looking at the association between high-traffic segments and development patterns, researchers recommend focusing attention on the northern segment between Ina Road and Magee Road, and a midsection at West Prince Road. Oracle Road does not continue directly into the Tucson central business district, so researchers do not see an urban element to include in the assessment.
- **Broadway Boulevard** will provide both an urban and suburban section for comparison. For the urban section researchers recommend Broadway and its one-way pair Congress in the Tucson downtown area, between South 6th Avenue and South Stone Avenue. In talking with PAG staff, Broadway also supports one of the most successful bus routes. For the suburban component, researchers recommend the segment of Broadway between Swan Road and Craycroft Road. There appears to be a spike in traffic along that segment, and there is also notable development intensity there, with a mix of commercial, office and residential activity.
- **Speedway Boulevard** carries high traffic volumes through most of its length, extending from 1st Avenue to Swan Road. The major activity along Speedway is strip commercial development, so it will make a good study between the intensity of this type of development and congestion. Researchers suggest focusing on the section between North Country Club Road and North Alvernon Way.
- **Kolb Road** has a surprisingly congested segment between Broadway and Speedway, based on the intensity of development visible on a map (i.e., it does not appear that intense). It may be enlightening to uncover the contributions to this traffic.

Table 32. Characteristics of Phoenix Corridors.

NAME	No.OF TIMES MENTIONED IN SURVEY	DIRECTION	FROM (E/S)	TYPICAL FUNCLASS	REGIONAL CORRIDOR	RESIDENTIAL	COMMERCIAL TRUCK ROUTE	RETAIL	AUTO MALLS	COMMUTER ROUTE	COMMERCIAL CORRIDOR	UNIVERSITY/COLLEGE	AIRPORT ACCESS	DOWNTOWN TRAFFIC	THROUGH TRAFFIC	MAJOR SPORTS VENUES	MILITARY BASE	CASINOS	MAJOR SHOPPING	INDUSTRIAL	MEDICAL/PROFESSIONAL OFFICES	HOSPITALS	HIGHWAY/INTERSTATE ACCESS	SMART CORRIDOR	AVG DELAY	MAJOR SPEED DECREASE 1993-2003
BELL RD	21	EW	SCOTTSDALE RD to L303	ARTERIAL	X	X		X	X	X	X			X		X			X		X	X	X	X	7	X
INTERSTATE 10	19	EW	PECOS RD to LITCHFIELD RD	FREEWAY		X	X	X	X	X		X	X	X	X	X		X	X		X	X	X			
SCOTTSDALE RD	14	NS	L202 EAST to SR-74	ARTERIAL		X		X	X	X	X			X					X	X	X	X	X	X	6	X
LOOP 101	13	NS/EW	CHANDLER BLVD to I-10 WEST	HIGHWAY	X	X	X	X	X	X				X	X	X			X		X	X				
INTERSTATE 17	10	NS	16TH ST to SR-74	FREEWAY		X	X	X	X	X		X		X	X				X		X	X	X			
SHEA BLVD	7	EW	SR-87 to SR-51	ARTERIAL		X		X			X			X				X	X		X	X	X	X	9	X
COUNTRY CLUB DR-ARIZONA AVE	6	NS	OCOTILLO RD to MCDOWELL RD	ARTERIAL		X		X	X	X				X						X			X	X	8	X
SOUTHERN AVE	6	EW	48TH ST to ELLSWORTH RD	ARTERIAL	X	X		X		X				X	X				X		X	X	X		6	X
THUNDERBIRD RD	6	EW	7TH ST to L101 WEST	ARTERIAL		X		X		X											X	X	X	X	8	
POWER RD	5	NS	OCOTILLO RD to L202 NORTH	ARTERIAL	X	X				X									X				X	X	3	X
US-60 EAST	5	EW	SR-88 to I-10 TI	HIGHWAY	X	X	X			X		X		X					X			X	X			
CAMELBACK RD	4	EW	HAYDEN RD to CENTRAL AVE	ARTERIAL		X		X	X	X	X								X		X		X	X	8	X
INDIAN SCHOOL RD	4	EW	L101 EAST to L101 WEST	ARTERIAL										X										X	8	X
RURAL RD	4	NS	CHANDLER BLVD to L202 NORTH	ARTERIAL											X									X	8	
7TH ST	3	NS	BROADWAY RD to L101 NORTH	ARTERIAL																				X	7	X
83RD AVE	3	NS	SR-85 to DEER VALLEY RD	ARTERIAL		X		X		X	X					X			X				X		6	
ALMA SCHOOL RD	3	NS	PECOS RD to MCDOWELL RD	ARTERIAL										X					X						9	X
CHANDLER BLVD	3	EW	AZ AVENUE to I-10	ARTERIAL										X					X					X	4	X
FRANK LLOYD WRIGHT BLVD	3	EW	SHEA BLVD TO SCOTTSDALE RD	ARTERIAL		X		X												X					4	
GRAND AVE (US-60)	3	SE-NW	7TH AVE to WICKENBURG	ARTERIAL	X	X	X	X		X	X			X	X					X	X	X		X	7	X
MCDOWELL RD	3	EW	SR-87 to L101 WEST	ARTERIAL	X	X		X						X	X						X	X	X	X	7	
SAGUARO BLVD	3	NS	SHEA BLVD to FOUNTAIN HILLS BLVD	ARTERIAL		X		X		X				X					X		X				3	
UNION HILLS DR	3	EW	TATUM BLVD to 91ST AVE	ARTERIAL		X		X		X					X						X	X	X		3	X
UNIVERSITY DR	3	EW	ELLSWORTH RD to SR-143	ARTERIAL				X		X		X		X							X		X	X	7	X
59TH AVE	2	NS	SR-85 to L101 NORTH	ARTERIAL								X												X	9	
BEELINE HIGHWAY (SR-87)	2	SW-NE	L202 to PAYSON	HIGHWAY	X		X			X								X					X	X	2	
CENTRAL AVE	2	NS	ADAMS ST to DUNLAP AVE	ARTERIAL				X						X		X					X				3	X
ELLIOT RD	2	EW	POWER RD to L101 EAST	ARTERIAL		X																	X		8	X
GILBERT RD	2	NS	RAY RD to L202 NORTH	ARTERIAL		X		X		X		X											X	X	6	
LINCOLN DR	2	NS	SCOTTSDALE RD to SR-51	ARTERIAL		X		X		X													X		2	
LOOP 303	2	NS	I-10 to I-17	HIGHWAY	X		X			X													X			
PIMA RD	2	NS	MCKELLIPS RD to SHEA BLVD	ARTERIAL																					5	
RAY RD	2	EW	I-10 to POWER RD	ARTERIAL															X						5	
US-60 (Broadway Curve-101)	2	EW	L101 EAST to I-10/BROADWAY	HIGHWAY										X												
WARNER RD	2	EW	POWER RD to SR-87	ARTERIAL																					8	X
51ST AVE	1	NS	SR-85 to L101 NORTH	ARTERIAL																					8	
7TH AVE	1	NS	ADAMS ST to DUNLAP AVE	ARTERIAL																					5	X
BROADWAY RD	1	EW	POWER RD to 7TH ST	ARTERIAL																				X	8	X
BULLARD AVE	1	NS	SR-85 to MCDOWELL RD	ARTERIAL																	X				1	
CHAPARRAL RD	1	EW	L101 EAST to SCOTTSDALE RD	ARTERIAL		X		X															X		1	
DOBSON RD	1	NS	US-60 EAST to BROADWAY RD	ARTERIAL																					7	
DYSART RD	1	NS	SR-85 to INDIAN SCHOOL RD	ARTERIAL		X		X				X										X		X	3	
ELLSWORTH RD	1	NS	HUNT HWY to BROWN RD	ARTERIAL	X	X		X		X				X	X								X	X	8	X
HAYDEN RD	1	NS	REDFIELD RD to FLW BLVD	ARTERIAL																				X	8	
HIGLEY RD	1	NS	HUNT HWY to L202 NORTH	ARTERIAL																				X	5	
LAKE PLEASANT RD	1	NS	BEARSDLEY RD to I-17 NORTH	ARTERIAL	X	X				X															2	
LITCHFIELD RD	1	NS	SR-85 to BELL RD	ARTERIAL													X							X	4	
MILL AVE	1	NS	UNIVERSITY DR to L202 NORTH	ARTERIAL		X		X	X	X		X		X					X		X	X	X		5	
NORTHERN AVE	1	EW	I-17 to L101 WEST	ARTERIAL		X				X													X		7	
OLIVE AVE (DUNLAP)	1	EW	I-17 to LITCHFIELD RD	ARTERIAL																				X	8	
SR-51	1	NS	I-10 to L101 NORTH	HIGHWAY																						
TATUM BLVD	1	NS	MCDONALD DR to L101 NORTH	ARTERIAL		X		X		X									X				X	X	6	
VAN BUREN ST	1	EW	PRIEST DR to 35TH AVE	ARTERIAL	X			X		X				X						X				X	7	X

Table 33. Characteristics of Tucson Corridors.

NAME	No.OF TIMES MENTIONED IN SURVEY	DIRECTION	FROM/TO	MPO	SELECTED BY SURVEY RE	FACILITY TYPE	RESIDENTIAL	REGIONAL CORRIDOR	COMMERCIAL TRUCK ROU	SPECIAL EVENT ACCESS	DOWNTOWN TRAFFIC	UNIVERSITY/COLLEGE	RETAIL	AIRPORT ACCESS	MAJOR SHOPPING	MIXED USE	MILITARY BASE	COMMERCIAL CORRIDOR	HOSPITALS	MEDICAL/PROFESSIONAL	THROUGH TRAFFIC	COMMUTER ROUTE	LOCAL COMMERCIAL	INDUSTRIAL	OFFICE	HIGHWAY ACCESS	AVG DELAY	MAJOR SPEED DECREASE 1993-2003
ORACLE RD (SR-77)	18	NS	GRANT RD to SR-79	PAG	Y	ARTERIAL	X	X			X		X		X			X		X	X	X	X			X	7	X
GRANT RD	7	EW	KOLB RD to SILVERBELL RD	PAG	Y	ARTERIAL				X			X		X	X						X	X			X		
INTERSTATE 10	7	EW	SE CITY LIMITS to NW CITY LIMITS	PAG	Y	FREEWAY		X	X		X				X							X					6	X
BROADWAY BLVD	6	EW	WENTWORTH RD to MAIN AVE	PAG	Y	ARTERIAL					X	X			X						X		X					
INA RD	5	EW	1ST AVE to WADE RD	PAG	Y	ARTERIAL							X					X					X			X		
CAMPBELL AVE	4	NS	BROADWAY BLVD to RIVER RD	PAG	Y	ARTERIAL	X					X	X					X	X	X			X				9	X
LA CANADA DR	3	NS	RIVER RD to MOORE RD	PAG	Y	ARTERIAL																X					8	X
SPEEDWAY BLVD	3	EW	WENTWORTH RD to GREASWOOD RD	PAG	Y	ARTERIAL	X					X	X						X	X			X			X	6	X
SWAN RD	3	NS	22NDST to SUNRISE DR	PAG	Y	ARTERIAL	X			X			X		X								X				8	
CORTARO (FARMS) RD	2	EW	SHANNON RD to INA RD	PAG	Y	ARTERIAL							X		X								X				3	X
THORNYDALE RD	2	NS	ORANGE GROVE RD to MOORE RD	PAG	Y	ARTERIAL							X										X					
22ND ST	1	EW	HOUGHTON RD to I-10	PAG	Y	ARTERIAL																X				X	8	X
AJO WAY (SR-86)	1	EW	ALVERNON WAY to MISSION RD	PAG	Y	ARTERIAL		X														X				X	8	X
KOLB RD	1	NS	I-10 to GRANT RD	PAG	Y	ARTERIAL							X										X				8	
LA CHOLLA BLBV	1	NS	AJO HWY to STAR PASS BLVD (22ND ST)	PAG	Y	ARTERIAL	X						X										X				7	X
SABINO CANYON RD	1	NS	TANQUE VERDE RD to SUNRISE DR	PAG	Y	ARTERIAL																					6	
TANQUE VERDE RD	1	EW	WENTWORTH RD to KOLB RD	PAG	Y	ARTERIAL																					9	X
VALENCIA RD	1	EW	SR-86 to HOUGHTON RD	PAG	Y	ARTERIAL								X			X			X							4	X

APPENDIX D: TRAFFIC COUNTS FROM 2006/2007 MAG REGIONAL TRAFFIC VOLUME STUDY

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	12:00:00 AM	36	34
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	12:15:00 AM	42	31
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	12:30:00 AM	54	27
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	12:45:00 AM	52	29
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	1:00:00 AM	43	21
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	1:15:00 AM	39	12
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	1:30:00 AM	35	19
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	1:45:00 AM	35	6
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	2:00:00 AM	33	9
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	2:15:00 AM	50	12
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	2:30:00 AM	30	21
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	2:45:00 AM	24	9
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	3:00:00 AM	14	13
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	3:15:00 AM	7	9
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	3:30:00 AM	8	11
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	3:45:00 AM	11	6
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	4:00:00 AM	10	7
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	4:15:00 AM	15	9
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	4:30:00 AM	16	15
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	4:45:00 AM	14	21
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	5:00:00 AM	25	22
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	5:15:00 AM	39	45
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	5:30:00 AM	50	78
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	5:45:00 AM	63	78
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	6:00:00 AM	46	61
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	6:15:00 AM	85	70
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	6:30:00 AM	73	84
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	6:45:00 AM	131	97
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	7:00:00 AM	142	98
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	7:15:00 AM	156	148
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	7:30:00 AM	151	170
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	7:45:00 AM	173	178
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	8:00:00 AM	141	183
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	8:15:00 AM	160	195
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	8:30:00 AM	149	151
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	8:45:00 AM	153	174
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	9:00:00 AM	142	157
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	9:15:00 AM	159	177
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	9:30:00 AM	153	172
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	9:45:00 AM	163	144
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	10:00:00 AM	146	153
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	10:15:00 AM	173	174
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	10:30:00 AM	154	183
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	10:45:00 AM	163	187
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	11:00:00 AM	180	176
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	11:15:00 AM	164	177
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	11:30:00 AM	180	171
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	11:45:00 AM	205	188

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	12:00:00 PM	206	189
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	12:15:00 PM	214	192
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	12:30:00 PM	227	174
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	12:45:00 PM	209	202
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	1:00:00 PM	213	163
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	1:15:00 PM	214	206
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	1:30:00 PM	218	198
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	1:45:00 PM	179	181
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	2:00:00 PM	207	177
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	2:15:00 PM	198	178
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	2:30:00 PM	201	187
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	2:45:00 PM	201	170
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	3:00:00 PM	207	168
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	3:15:00 PM	212	183
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	3:30:00 PM	229	166
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	3:45:00 PM	223	186
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	4:00:00 PM	219	183
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	4:15:00 PM	224	189
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	4:30:00 PM	220	168
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	4:45:00 PM	199	197
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	5:00:00 PM	194	174
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	5:15:00 PM	142	201
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	5:30:00 PM	217	193
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	5:45:00 PM	227	206
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	6:00:00 PM	208	172
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	6:15:00 PM	221	197
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	6:30:00 PM	187	188
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	6:45:00 PM	193	180
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	7:00:00 PM	172	164
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	7:15:00 PM	168	148
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	7:30:00 PM	178	140
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	7:45:00 PM	133	111
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	8:00:00 PM	156	113
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	8:15:00 PM	174	102
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	8:30:00 PM	140	115
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	8:45:00 PM	173	99
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	9:00:00 PM	161	119
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	9:15:00 PM	143	89
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	9:30:00 PM	139	103
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	9:45:00 PM	114	78
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	10:00:00 PM	142	68
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	10:15:00 PM	89	68
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	10:30:00 PM	67	71
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	10:45:00 PM	85	53
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	11:00:00 PM	53	58
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	11:15:00 PM	69	47
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	11:30:00 PM	68	37
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	11:45:00 PM	59	40
710	SCOTTSDALE RD	CAMELBACK RD	CHAPARRAL RD	12:00:00 AM	42	32

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	12:00:00 AM	48	31
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	12:15:00 AM	42	36
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	12:30:00 AM	47	29
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	12:45:00 AM	55	23
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	1:00:00 AM	22	18
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	1:15:00 AM	32	18
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	1:30:00 AM	30	12
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	1:45:00 AM	32	14
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	2:00:00 AM	41	16
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	2:15:00 AM	45	21
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	2:30:00 AM	28	11
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	2:45:00 AM	27	15
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	3:00:00 AM	24	22
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	3:15:00 AM	24	18
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	3:30:00 AM	32	24
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	3:45:00 AM	26	22
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	4:00:00 AM	18	21
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	4:15:00 AM	18	13
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	4:30:00 AM	27	34
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	4:45:00 AM	37	52
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	5:00:00 AM	23	47
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	5:15:00 AM	48	88
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	5:30:00 AM	67	138
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	5:45:00 AM	74	188
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	6:00:00 AM	84	189
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	6:15:00 AM	108	190
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	6:30:00 AM	151	255
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	6:45:00 AM	176	294
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	7:00:00 AM	177	309
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	7:15:00 AM	200	295
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	7:30:00 AM	246	350
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	7:45:00 AM	256	369
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	8:00:00 AM	293	426
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	8:15:00 AM	277	374
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	8:30:00 AM	249	362
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	8:45:00 AM	240	397
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	9:00:00 AM	226	333
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	9:15:00 AM	260	327
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	9:30:00 AM	256	297
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	9:45:00 AM	280	355
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	10:00:00 AM	274	343
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	10:15:00 AM	287	246
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	10:30:00 AM	314	292
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	10:45:00 AM	280	228
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	11:00:00 AM	325	237
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	11:15:00 AM	332	233
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	11:30:00 AM	359	242
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	11:45:00 AM	325	241

709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	39021.5	338	296
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	12:15:00 PM	336	267
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	12:30:00 PM	315	293
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	12:45:00 PM	352	291
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	1:00:00 PM	367	281
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	1:15:00 PM	292	272
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	1:30:00 PM	323	293
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	1:45:00 PM	319	254
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	2:00:00 PM	335	304
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	2:15:00 PM	355	243
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	2:30:00 PM	439	318
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	2:45:00 PM	391	297
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	3:00:00 PM	447	276
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	3:15:00 PM	415	214
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	3:30:00 PM	451	254
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	3:45:00 PM	474	236
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	4:00:00 PM	463	255
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	4:15:00 PM	452	232
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	4:30:00 PM	453	205
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	4:45:00 PM	491	248
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	5:00:00 PM	467	200
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	5:15:00 PM	458	218
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	5:30:00 PM	430	254
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	5:45:00 PM	436	260
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	6:00:00 PM	426	232
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	6:15:00 PM	388	256
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	6:30:00 PM	298	248
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	6:45:00 PM	274	211
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	7:00:00 PM	227	171
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	7:15:00 PM	226	187
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	7:30:00 PM	186	164
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	7:45:00 PM	205	157
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	8:00:00 PM	184	153
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	8:15:00 PM	163	156
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	8:30:00 PM	168	163
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	8:45:00 PM	172	145
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	9:00:00 PM	170	131
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	9:15:00 PM	195	165
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	9:30:00 PM	187	153
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	9:45:00 PM	160	127
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	10:00:00 PM	152	153
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	10:15:00 PM	109	125
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	10:30:00 PM	123	120
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	10:45:00 PM	91	109
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	11:00:00 PM	101	89
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	11:15:00 PM	63	79
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	11:30:00 PM	79	83
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	11:45:00 PM	61	77
709	INDIAN SCHOOL RD	SCOTTSDALE RD	HAYDEN RD	12:00:00 AM	69	58

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
137	CAMELBACK RD	64TH ST	68TH ST	12:00:00 AM	42	62
137	CAMELBACK RD	64TH ST	68TH ST	12:15:00 AM	43	50
137	CAMELBACK RD	64TH ST	68TH ST	12:30:00 AM	39	39
137	CAMELBACK RD	64TH ST	68TH ST	12:45:00 AM	31	27
137	CAMELBACK RD	64TH ST	68TH ST	1:00:00 AM	29	22
137	CAMELBACK RD	64TH ST	68TH ST	1:15:00 AM	33	16
137	CAMELBACK RD	64TH ST	68TH ST	1:30:00 AM	35	21
137	CAMELBACK RD	64TH ST	68TH ST	1:45:00 AM	21	10
137	CAMELBACK RD	64TH ST	68TH ST	2:00:00 AM	33	15
137	CAMELBACK RD	64TH ST	68TH ST	2:15:00 AM	36	18
137	CAMELBACK RD	64TH ST	68TH ST	2:30:00 AM	32	11
137	CAMELBACK RD	64TH ST	68TH ST	2:45:00 AM	11	10
137	CAMELBACK RD	64TH ST	68TH ST	3:00:00 AM	16	18
137	CAMELBACK RD	64TH ST	68TH ST	3:15:00 AM	10	11
137	CAMELBACK RD	64TH ST	68TH ST	3:30:00 AM	11	15
137	CAMELBACK RD	64TH ST	68TH ST	3:45:00 AM	10	21
137	CAMELBACK RD	64TH ST	68TH ST	4:00:00 AM	11	8
137	CAMELBACK RD	64TH ST	68TH ST	4:15:00 AM	12	13
137	CAMELBACK RD	64TH ST	68TH ST	4:30:00 AM	12	29
137	CAMELBACK RD	64TH ST	68TH ST	4:45:00 AM	24	42
137	CAMELBACK RD	64TH ST	68TH ST	5:00:00 AM	17	27
137	CAMELBACK RD	64TH ST	68TH ST	5:15:00 AM	44	38
137	CAMELBACK RD	64TH ST	68TH ST	5:30:00 AM	32	78
137	CAMELBACK RD	64TH ST	68TH ST	5:45:00 AM	54	117
137	CAMELBACK RD	64TH ST	68TH ST	6:00:00 AM	69	86
137	CAMELBACK RD	64TH ST	68TH ST	6:15:00 AM	72	123
137	CAMELBACK RD	64TH ST	68TH ST	6:30:00 AM	80	180
137	CAMELBACK RD	64TH ST	68TH ST	6:45:00 AM	140	217
137	CAMELBACK RD	64TH ST	68TH ST	7:00:00 AM	192	181
137	CAMELBACK RD	64TH ST	68TH ST	7:15:00 AM	217	223
137	CAMELBACK RD	64TH ST	68TH ST	7:30:00 AM	242	257
137	CAMELBACK RD	64TH ST	68TH ST	7:45:00 AM	260	285
137	CAMELBACK RD	64TH ST	68TH ST	8:00:00 AM	263	283
137	CAMELBACK RD	64TH ST	68TH ST	8:15:00 AM	236	238
137	CAMELBACK RD	64TH ST	68TH ST	8:30:00 AM	196	240
137	CAMELBACK RD	64TH ST	68TH ST	8:45:00 AM	197	286
137	CAMELBACK RD	64TH ST	68TH ST	9:00:00 AM	177	232
137	CAMELBACK RD	64TH ST	68TH ST	9:15:00 AM	170	200
137	CAMELBACK RD	64TH ST	68TH ST	9:30:00 AM	135	193
137	CAMELBACK RD	64TH ST	68TH ST	9:45:00 AM	159	228
137	CAMELBACK RD	64TH ST	68TH ST	10:00:00 AM	175	223
137	CAMELBACK RD	64TH ST	68TH ST	10:15:00 AM	150	192
137	CAMELBACK RD	64TH ST	68TH ST	10:30:00 AM	196	188
137	CAMELBACK RD	64TH ST	68TH ST	10:45:00 AM	171	232
137	CAMELBACK RD	64TH ST	68TH ST	11:00:00 AM	170	221
137	CAMELBACK RD	64TH ST	68TH ST	11:15:00 AM	195	213
137	CAMELBACK RD	64TH ST	68TH ST	11:30:00 AM	194	219
137	CAMELBACK RD	64TH ST	68TH ST	11:45:00 AM	201	261

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
137	CAMELBACK RD	64TH ST	68TH ST	12:00:00 PM	214	202
137	CAMELBACK RD	64TH ST	68TH ST	12:15:00 PM	203	212
137	CAMELBACK RD	64TH ST	68TH ST	12:30:00 PM	201	205
137	CAMELBACK RD	64TH ST	68TH ST	12:45:00 PM	238	209
137	CAMELBACK RD	64TH ST	68TH ST	1:00:00 PM	244	228
137	CAMELBACK RD	64TH ST	68TH ST	1:15:00 PM	233	177
137	CAMELBACK RD	64TH ST	68TH ST	1:30:00 PM	187	202
137	CAMELBACK RD	64TH ST	68TH ST	1:45:00 PM	208	228
137	CAMELBACK RD	64TH ST	68TH ST	2:00:00 PM	238	222
137	CAMELBACK RD	64TH ST	68TH ST	2:15:00 PM	263	218
137	CAMELBACK RD	64TH ST	68TH ST	2:30:00 PM	328	231
137	CAMELBACK RD	64TH ST	68TH ST	2:45:00 PM	268	227
137	CAMELBACK RD	64TH ST	68TH ST	3:00:00 PM	296	260
137	CAMELBACK RD	64TH ST	68TH ST	3:15:00 PM	260	250
137	CAMELBACK RD	64TH ST	68TH ST	3:30:00 PM	288	258
137	CAMELBACK RD	64TH ST	68TH ST	3:45:00 PM	277	250
137	CAMELBACK RD	64TH ST	68TH ST	4:00:00 PM	288	302
137	CAMELBACK RD	64TH ST	68TH ST	4:15:00 PM	274	277
137	CAMELBACK RD	64TH ST	68TH ST	4:30:00 PM	247	305
137	CAMELBACK RD	64TH ST	68TH ST	4:45:00 PM	267	326
137	CAMELBACK RD	64TH ST	68TH ST	5:00:00 PM	338	369
137	CAMELBACK RD	64TH ST	68TH ST	5:15:00 PM	344	381
137	CAMELBACK RD	64TH ST	68TH ST	5:30:00 PM	293	390
137	CAMELBACK RD	64TH ST	68TH ST	5:45:00 PM	262	412
137	CAMELBACK RD	64TH ST	68TH ST	6:00:00 PM	248	359
137	CAMELBACK RD	64TH ST	68TH ST	6:15:00 PM	223	286
137	CAMELBACK RD	64TH ST	68TH ST	6:30:00 PM	179	204
137	CAMELBACK RD	64TH ST	68TH ST	6:45:00 PM	177	189
137	CAMELBACK RD	64TH ST	68TH ST	7:00:00 PM	165	164
137	CAMELBACK RD	64TH ST	68TH ST	7:15:00 PM	142	143
137	CAMELBACK RD	64TH ST	68TH ST	7:30:00 PM	129	140
137	CAMELBACK RD	64TH ST	68TH ST	7:45:00 PM	129	102
137	CAMELBACK RD	64TH ST	68TH ST	8:00:00 PM	142	98
137	CAMELBACK RD	64TH ST	68TH ST	8:15:00 PM	101	101
137	CAMELBACK RD	64TH ST	68TH ST	8:30:00 PM	115	87
137	CAMELBACK RD	64TH ST	68TH ST	8:45:00 PM	112	79
137	CAMELBACK RD	64TH ST	68TH ST	9:00:00 PM	121	76
137	CAMELBACK RD	64TH ST	68TH ST	9:15:00 PM	130	67
137	CAMELBACK RD	64TH ST	68TH ST	9:30:00 PM	95	65
137	CAMELBACK RD	64TH ST	68TH ST	9:45:00 PM	92	80
137	CAMELBACK RD	64TH ST	68TH ST	10:00:00 PM	98	76
137	CAMELBACK RD	64TH ST	68TH ST	10:15:00 PM	72	50
137	CAMELBACK RD	64TH ST	68TH ST	10:30:00 PM	69	37
137	CAMELBACK RD	64TH ST	68TH ST	10:45:00 PM	56	41
137	CAMELBACK RD	64TH ST	68TH ST	11:00:00 PM	71	40
137	CAMELBACK RD	64TH ST	68TH ST	11:15:00 PM	53	19
137	CAMELBACK RD	64TH ST	68TH ST	11:30:00 PM	40	28
137	CAMELBACK RD	64TH ST	68TH ST	11:45:00 PM	23	23
137	CAMELBACK RD	64TH ST	68TH ST	12:00:00 AM	38	25

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
237	APACHE BLVD	MILL AVE	RURAL RD	12:00:00 AM	37	19
237	APACHE BLVD	MILL AVE	RURAL RD	12:15:00 AM	33	26
237	APACHE BLVD	MILL AVE	RURAL RD	12:30:00 AM	27	24
237	APACHE BLVD	MILL AVE	RURAL RD	12:45:00 AM	26	22
237	APACHE BLVD	MILL AVE	RURAL RD	1:00:00 AM	13	21
237	APACHE BLVD	MILL AVE	RURAL RD	1:15:00 AM	26	14
237	APACHE BLVD	MILL AVE	RURAL RD	1:30:00 AM	15	15
237	APACHE BLVD	MILL AVE	RURAL RD	1:45:00 AM	25	15
237	APACHE BLVD	MILL AVE	RURAL RD	2:00:00 AM	20	14
237	APACHE BLVD	MILL AVE	RURAL RD	2:15:00 AM	19	12
237	APACHE BLVD	MILL AVE	RURAL RD	2:30:00 AM	12	7
237	APACHE BLVD	MILL AVE	RURAL RD	2:45:00 AM	13	13
237	APACHE BLVD	MILL AVE	RURAL RD	3:00:00 AM	6	4
237	APACHE BLVD	MILL AVE	RURAL RD	3:15:00 AM	6	8
237	APACHE BLVD	MILL AVE	RURAL RD	3:30:00 AM	8	8
237	APACHE BLVD	MILL AVE	RURAL RD	3:45:00 AM	8	8
237	APACHE BLVD	MILL AVE	RURAL RD	4:00:00 AM	3	3
237	APACHE BLVD	MILL AVE	RURAL RD	4:15:00 AM	9	9
237	APACHE BLVD	MILL AVE	RURAL RD	4:30:00 AM	10	8
237	APACHE BLVD	MILL AVE	RURAL RD	4:45:00 AM	5	12
237	APACHE BLVD	MILL AVE	RURAL RD	5:00:00 AM	9	15
237	APACHE BLVD	MILL AVE	RURAL RD	5:15:00 AM	20	25
237	APACHE BLVD	MILL AVE	RURAL RD	5:30:00 AM	19	30
237	APACHE BLVD	MILL AVE	RURAL RD	5:45:00 AM	32	24
237	APACHE BLVD	MILL AVE	RURAL RD	6:00:00 AM	37	29
237	APACHE BLVD	MILL AVE	RURAL RD	6:15:00 AM	35	40
237	APACHE BLVD	MILL AVE	RURAL RD	6:30:00 AM	32	98
237	APACHE BLVD	MILL AVE	RURAL RD	6:45:00 AM	43	124
237	APACHE BLVD	MILL AVE	RURAL RD	7:00:00 AM	51	117
237	APACHE BLVD	MILL AVE	RURAL RD	7:15:00 AM	83	164
237	APACHE BLVD	MILL AVE	RURAL RD	7:30:00 AM	74	216
237	APACHE BLVD	MILL AVE	RURAL RD	7:45:00 AM	85	270
237	APACHE BLVD	MILL AVE	RURAL RD	8:00:00 AM	90	208
237	APACHE BLVD	MILL AVE	RURAL RD	8:15:00 AM	92	206
237	APACHE BLVD	MILL AVE	RURAL RD	8:30:00 AM	113	199
237	APACHE BLVD	MILL AVE	RURAL RD	8:45:00 AM	114	195
237	APACHE BLVD	MILL AVE	RURAL RD	9:00:00 AM	133	167
237	APACHE BLVD	MILL AVE	RURAL RD	9:15:00 AM	103	151
237	APACHE BLVD	MILL AVE	RURAL RD	9:30:00 AM	98	118
237	APACHE BLVD	MILL AVE	RURAL RD	9:45:00 AM	80	137
237	APACHE BLVD	MILL AVE	RURAL RD	10:00:00 AM	82	100
237	APACHE BLVD	MILL AVE	RURAL RD	10:15:00 AM	112	148
237	APACHE BLVD	MILL AVE	RURAL RD	10:30:00 AM	172	178
237	APACHE BLVD	MILL AVE	RURAL RD	10:45:00 AM	111	125
237	APACHE BLVD	MILL AVE	RURAL RD	11:00:00 AM	115	118
237	APACHE BLVD	MILL AVE	RURAL RD	11:15:00 AM	136	165
237	APACHE BLVD	MILL AVE	RURAL RD	11:30:00 AM	169	158
237	APACHE BLVD	MILL AVE	RURAL RD	11:45:00 AM	155	145

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
237	APACHE BLVD	MILL AVE	RURAL RD	12:00:00 PM	159	194
237	APACHE BLVD	MILL AVE	RURAL RD	12:15:00 PM	165	168
237	APACHE BLVD	MILL AVE	RURAL RD	12:30:00 PM	134	173
237	APACHE BLVD	MILL AVE	RURAL RD	12:45:00 PM	138	159
237	APACHE BLVD	MILL AVE	RURAL RD	1:00:00 PM	145	157
237	APACHE BLVD	MILL AVE	RURAL RD	1:15:00 PM	161	178
237	APACHE BLVD	MILL AVE	RURAL RD	1:30:00 PM	185	185
237	APACHE BLVD	MILL AVE	RURAL RD	1:45:00 PM	136	141
237	APACHE BLVD	MILL AVE	RURAL RD	2:00:00 PM	142	115
237	APACHE BLVD	MILL AVE	RURAL RD	2:15:00 PM	169	126
237	APACHE BLVD	MILL AVE	RURAL RD	2:30:00 PM	154	150
237	APACHE BLVD	MILL AVE	RURAL RD	2:45:00 PM	193	174
237	APACHE BLVD	MILL AVE	RURAL RD	3:00:00 PM	195	193
237	APACHE BLVD	MILL AVE	RURAL RD	3:15:00 PM	180	146
237	APACHE BLVD	MILL AVE	RURAL RD	3:30:00 PM	194	170
237	APACHE BLVD	MILL AVE	RURAL RD	3:45:00 PM	204	150
237	APACHE BLVD	MILL AVE	RURAL RD	4:00:00 PM	198	156
237	APACHE BLVD	MILL AVE	RURAL RD	4:15:00 PM	195	162
237	APACHE BLVD	MILL AVE	RURAL RD	4:30:00 PM	276	179
237	APACHE BLVD	MILL AVE	RURAL RD	4:45:00 PM	267	157
237	APACHE BLVD	MILL AVE	RURAL RD	5:00:00 PM	309	178
237	APACHE BLVD	MILL AVE	RURAL RD	5:15:00 PM	320	204
237	APACHE BLVD	MILL AVE	RURAL RD	5:30:00 PM	279	175
237	APACHE BLVD	MILL AVE	RURAL RD	5:45:00 PM	270	175
237	APACHE BLVD	MILL AVE	RURAL RD	6:00:00 PM	213	185
237	APACHE BLVD	MILL AVE	RURAL RD	6:15:00 PM	190	157
237	APACHE BLVD	MILL AVE	RURAL RD	6:30:00 PM	150	140
237	APACHE BLVD	MILL AVE	RURAL RD	6:45:00 PM	139	145
237	APACHE BLVD	MILL AVE	RURAL RD	7:00:00 PM	155	140
237	APACHE BLVD	MILL AVE	RURAL RD	7:15:00 PM	144	129
237	APACHE BLVD	MILL AVE	RURAL RD	7:30:00 PM	137	127
237	APACHE BLVD	MILL AVE	RURAL RD	7:45:00 PM	143	122
237	APACHE BLVD	MILL AVE	RURAL RD	8:00:00 PM	150	112
237	APACHE BLVD	MILL AVE	RURAL RD	8:15:00 PM	140	104
237	APACHE BLVD	MILL AVE	RURAL RD	8:30:00 PM	140	94
237	APACHE BLVD	MILL AVE	RURAL RD	8:45:00 PM	140	96
237	APACHE BLVD	MILL AVE	RURAL RD	9:00:00 PM	166	94
237	APACHE BLVD	MILL AVE	RURAL RD	9:15:00 PM	125	82
237	APACHE BLVD	MILL AVE	RURAL RD	9:30:00 PM	125	90
237	APACHE BLVD	MILL AVE	RURAL RD	9:45:00 PM	77	87
237	APACHE BLVD	MILL AVE	RURAL RD	10:00:00 PM	96	93
237	APACHE BLVD	MILL AVE	RURAL RD	10:15:00 PM	75	71
237	APACHE BLVD	MILL AVE	RURAL RD	10:30:00 PM	73	65
237	APACHE BLVD	MILL AVE	RURAL RD	10:45:00 PM	77	45
237	APACHE BLVD	MILL AVE	RURAL RD	11:00:00 PM	66	43
237	APACHE BLVD	MILL AVE	RURAL RD	11:15:00 PM	62	40
237	APACHE BLVD	MILL AVE	RURAL RD	11:30:00 PM	46	36
237	APACHE BLVD	MILL AVE	RURAL RD	11:45:00 PM	47	38
237	APACHE BLVD	MILL AVE	RURAL RD	12:00:00 AM	54	44

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
250	BROADWAY RD	MILL AVE	RURAL RD	12:00:00 AM	40	40
250	BROADWAY RD	MILL AVE	RURAL RD	12:15:00 AM	41	34
250	BROADWAY RD	MILL AVE	RURAL RD	12:30:00 AM	28	26
250	BROADWAY RD	MILL AVE	RURAL RD	12:45:00 AM	35	23
250	BROADWAY RD	MILL AVE	RURAL RD	1:00:00 AM	25	28
250	BROADWAY RD	MILL AVE	RURAL RD	1:15:00 AM	20	22
250	BROADWAY RD	MILL AVE	RURAL RD	1:30:00 AM	12	11
250	BROADWAY RD	MILL AVE	RURAL RD	1:45:00 AM	19	18
250	BROADWAY RD	MILL AVE	RURAL RD	2:00:00 AM	16	14
250	BROADWAY RD	MILL AVE	RURAL RD	2:15:00 AM	26	16
250	BROADWAY RD	MILL AVE	RURAL RD	2:30:00 AM	15	14
250	BROADWAY RD	MILL AVE	RURAL RD	2:45:00 AM	13	12
250	BROADWAY RD	MILL AVE	RURAL RD	3:00:00 AM	14	10
250	BROADWAY RD	MILL AVE	RURAL RD	3:15:00 AM	14	19
250	BROADWAY RD	MILL AVE	RURAL RD	3:30:00 AM	10	23
250	BROADWAY RD	MILL AVE	RURAL RD	3:45:00 AM	14	30
250	BROADWAY RD	MILL AVE	RURAL RD	4:00:00 AM	19	30
250	BROADWAY RD	MILL AVE	RURAL RD	4:15:00 AM	24	48
250	BROADWAY RD	MILL AVE	RURAL RD	4:30:00 AM	29	76
250	BROADWAY RD	MILL AVE	RURAL RD	4:45:00 AM	39	84
250	BROADWAY RD	MILL AVE	RURAL RD	5:00:00 AM	43	73
250	BROADWAY RD	MILL AVE	RURAL RD	5:15:00 AM	42	126
250	BROADWAY RD	MILL AVE	RURAL RD	5:30:00 AM	83	200
250	BROADWAY RD	MILL AVE	RURAL RD	5:45:00 AM	80	230
250	BROADWAY RD	MILL AVE	RURAL RD	6:00:00 AM	105	169
250	BROADWAY RD	MILL AVE	RURAL RD	6:15:00 AM	92	236
250	BROADWAY RD	MILL AVE	RURAL RD	6:30:00 AM	114	262
250	BROADWAY RD	MILL AVE	RURAL RD	6:45:00 AM	122	311
250	BROADWAY RD	MILL AVE	RURAL RD	7:00:00 AM	146	313
250	BROADWAY RD	MILL AVE	RURAL RD	7:15:00 AM	158	293
250	BROADWAY RD	MILL AVE	RURAL RD	7:30:00 AM	174	327
250	BROADWAY RD	MILL AVE	RURAL RD	7:45:00 AM	182	332
250	BROADWAY RD	MILL AVE	RURAL RD	8:00:00 AM	169	355
250	BROADWAY RD	MILL AVE	RURAL RD	8:15:00 AM	191	274
250	BROADWAY RD	MILL AVE	RURAL RD	8:30:00 AM	198	247
250	BROADWAY RD	MILL AVE	RURAL RD	8:45:00 AM	190	218
250	BROADWAY RD	MILL AVE	RURAL RD	9:00:00 AM	191	207
250	BROADWAY RD	MILL AVE	RURAL RD	9:15:00 AM	174	194
250	BROADWAY RD	MILL AVE	RURAL RD	9:30:00 AM	174	171
250	BROADWAY RD	MILL AVE	RURAL RD	9:45:00 AM	207	171
250	BROADWAY RD	MILL AVE	RURAL RD	10:00:00 AM	240	168
250	BROADWAY RD	MILL AVE	RURAL RD	10:15:00 AM	245	176
250	BROADWAY RD	MILL AVE	RURAL RD	10:30:00 AM	214	203
250	BROADWAY RD	MILL AVE	RURAL RD	10:45:00 AM	197	199
250	BROADWAY RD	MILL AVE	RURAL RD	11:00:00 AM	214	187
250	BROADWAY RD	MILL AVE	RURAL RD	11:15:00 AM	241	196
250	BROADWAY RD	MILL AVE	RURAL RD	11:30:00 AM	243	193
250	BROADWAY RD	MILL AVE	RURAL RD	11:45:00 AM	235	206

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
250	BROADWAY RD	MILL AVE	RURAL RD	12:00:00 PM	283	254
250	BROADWAY RD	MILL AVE	RURAL RD	12:15:00 PM	241	275
250	BROADWAY RD	MILL AVE	RURAL RD	12:30:00 PM	248	233
250	BROADWAY RD	MILL AVE	RURAL RD	12:45:00 PM	229	234
250	BROADWAY RD	MILL AVE	RURAL RD	1:00:00 PM	250	233
250	BROADWAY RD	MILL AVE	RURAL RD	1:15:00 PM	247	252
250	BROADWAY RD	MILL AVE	RURAL RD	1:30:00 PM	226	220
250	BROADWAY RD	MILL AVE	RURAL RD	1:45:00 PM	220	243
250	BROADWAY RD	MILL AVE	RURAL RD	2:00:00 PM	247	229
250	BROADWAY RD	MILL AVE	RURAL RD	2:15:00 PM	269	214
250	BROADWAY RD	MILL AVE	RURAL RD	2:30:00 PM	287	206
250	BROADWAY RD	MILL AVE	RURAL RD	2:45:00 PM	296	242
250	BROADWAY RD	MILL AVE	RURAL RD	3:00:00 PM	324	312
250	BROADWAY RD	MILL AVE	RURAL RD	3:15:00 PM	313	247
250	BROADWAY RD	MILL AVE	RURAL RD	3:30:00 PM	319	190
250	BROADWAY RD	MILL AVE	RURAL RD	3:45:00 PM	304	232
250	BROADWAY RD	MILL AVE	RURAL RD	4:00:00 PM	337	230
250	BROADWAY RD	MILL AVE	RURAL RD	4:15:00 PM	368	192
250	BROADWAY RD	MILL AVE	RURAL RD	4:30:00 PM	351	216
250	BROADWAY RD	MILL AVE	RURAL RD	4:45:00 PM	331	228
250	BROADWAY RD	MILL AVE	RURAL RD	5:00:00 PM	387	197
250	BROADWAY RD	MILL AVE	RURAL RD	5:15:00 PM	351	215
250	BROADWAY RD	MILL AVE	RURAL RD	5:30:00 PM	341	216
250	BROADWAY RD	MILL AVE	RURAL RD	5:45:00 PM	320	214
250	BROADWAY RD	MILL AVE	RURAL RD	6:00:00 PM	310	233
250	BROADWAY RD	MILL AVE	RURAL RD	6:15:00 PM	279	193
250	BROADWAY RD	MILL AVE	RURAL RD	6:30:00 PM	246	183
250	BROADWAY RD	MILL AVE	RURAL RD	6:45:00 PM	235	168
250	BROADWAY RD	MILL AVE	RURAL RD	7:00:00 PM	183	172
250	BROADWAY RD	MILL AVE	RURAL RD	7:15:00 PM	158	122
250	BROADWAY RD	MILL AVE	RURAL RD	7:30:00 PM	145	120
250	BROADWAY RD	MILL AVE	RURAL RD	7:45:00 PM	105	131
250	BROADWAY RD	MILL AVE	RURAL RD	8:00:00 PM	125	149
250	BROADWAY RD	MILL AVE	RURAL RD	8:15:00 PM	109	125
250	BROADWAY RD	MILL AVE	RURAL RD	8:30:00 PM	152	129
250	BROADWAY RD	MILL AVE	RURAL RD	8:45:00 PM	146	88
250	BROADWAY RD	MILL AVE	RURAL RD	9:00:00 PM	113	104
250	BROADWAY RD	MILL AVE	RURAL RD	9:15:00 PM	98	100
250	BROADWAY RD	MILL AVE	RURAL RD	9:30:00 PM	99	104
250	BROADWAY RD	MILL AVE	RURAL RD	9:45:00 PM	100	100
250	BROADWAY RD	MILL AVE	RURAL RD	10:00:00 PM	103	107
250	BROADWAY RD	MILL AVE	RURAL RD	10:15:00 PM	86	82
250	BROADWAY RD	MILL AVE	RURAL RD	10:30:00 PM	78	78
250	BROADWAY RD	MILL AVE	RURAL RD	10:45:00 PM	69	63
250	BROADWAY RD	MILL AVE	RURAL RD	11:00:00 PM	70	57
250	BROADWAY RD	MILL AVE	RURAL RD	11:15:00 PM	56	49
250	BROADWAY RD	MILL AVE	RURAL RD	11:30:00 PM	59	50
250	BROADWAY RD	MILL AVE	RURAL RD	11:45:00 PM	46	49
250	BROADWAY RD	MILL AVE	RURAL RD	12:00:00 AM	49	38

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	12:00:00 AM	44	64
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	12:15:00 AM	37	68
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	12:30:00 AM	27	53
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	12:45:00 AM	21	41
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	1:00:00 AM	15	39
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	1:15:00 AM	19	23
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	1:30:00 AM	18	22
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	1:45:00 AM	9	24
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	2:00:00 AM	12	42
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	2:15:00 AM	9	16
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	2:30:00 AM	8	12
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	2:45:00 AM	17	10
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	3:00:00 AM	2	13
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	3:15:00 AM	11	8
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	3:30:00 AM	13	14
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	3:45:00 AM	11	15
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	4:00:00 AM	14	11
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	4:15:00 AM	15	11
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	4:30:00 AM	29	17
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	4:45:00 AM	34	21
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	5:00:00 AM	27	25
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	5:15:00 AM	56	28
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	5:30:00 AM	69	31
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	5:45:00 AM	85	41
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	6:00:00 AM	67	45
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	6:15:00 AM	118	56
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	6:30:00 AM	189	74
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	6:45:00 AM	262	78
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	7:00:00 AM	220	90
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	7:15:00 AM	291	123
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	7:30:00 AM	358	120
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	7:45:00 AM	362	118
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	8:00:00 AM	360	133
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	8:15:00 AM	308	116
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	8:30:00 AM	302	122
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	8:45:00 AM	373	159
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	9:00:00 AM	393	152
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	9:15:00 AM	297	139
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	9:30:00 AM	209	139
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	9:45:00 AM	246	154
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	10:00:00 AM	219	163
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	10:15:00 AM	302	251
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	10:30:00 AM	304	250
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	10:45:00 AM	225	178
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	11:00:00 AM	179	177
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	11:15:00 AM	201	161
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	11:30:00 AM	235	237
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	11:45:00 AM	303	250

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	12:00:00 PM	299	318
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	12:15:00 PM	261	262
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	12:30:00 PM	212	230
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	12:45:00 PM	218	251
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	1:00:00 PM	239	251
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	1:15:00 PM	292	248
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	1:30:00 PM	300	341
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	1:45:00 PM	195	270
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	2:00:00 PM	183	239
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	2:15:00 PM	182	252
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	2:30:00 PM	218	284
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	2:45:00 PM	227	291
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	3:00:00 PM	239	421
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	3:15:00 PM	207	296
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	3:30:00 PM	184	295
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	3:45:00 PM	221	279
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	4:00:00 PM	198	344
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	4:15:00 PM	257	351
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	4:30:00 PM	282	440
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	4:45:00 PM	263	404
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	5:00:00 PM	214	439
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	5:15:00 PM	227	390
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	5:30:00 PM	245	354
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	5:45:00 PM	284	374
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	6:00:00 PM	241	357
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	6:15:00 PM	230	304
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	6:30:00 PM	243	288
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	6:45:00 PM	210	231
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	7:00:00 PM	176	309
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	7:15:00 PM	168	266
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	7:30:00 PM	194	240
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	7:45:00 PM	180	217
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	8:00:00 PM	156	281
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	8:15:00 PM	137	250
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	8:30:00 PM	164	254
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	8:45:00 PM	167	200
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	9:00:00 PM	145	224
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	9:15:00 PM	109	223
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	9:30:00 PM	133	182
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	9:45:00 PM	96	165
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	10:00:00 PM	98	154
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	10:15:00 PM	94	139
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	10:30:00 PM	72	146
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	10:45:00 PM	73	134
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	11:00:00 PM	66	92
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	11:15:00 PM	58	110
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	11:30:00 PM	51	99
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	11:45:00 PM	57	97
546	MILL AVE	APACHE BLVD	UNIVERSITY DR	12:00:00 AM	42	78

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	12:00:00 AM	68	88
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	12:15:00 AM	66	66
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	12:30:00 AM	67	57
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	12:45:00 AM	50	61
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	1:00:00 AM	54	59
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	1:15:00 AM	43	39
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	1:30:00 AM	43	46
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	1:45:00 AM	41	39
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	2:00:00 AM	33	40
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	2:15:00 AM	32	39
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	2:30:00 AM	17	24
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	2:45:00 AM	14	28
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	3:00:00 AM	15	13
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	3:15:00 AM	22	15
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	3:30:00 AM	16	13
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	3:45:00 AM	18	18
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	4:00:00 AM	25	16
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	4:15:00 AM	22	23
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	4:30:00 AM	31	40
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	4:45:00 AM	33	40
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	5:00:00 AM	54	23
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	5:15:00 AM	83	45
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	5:30:00 AM	93	68
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	5:45:00 AM	101	78
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	6:00:00 AM	90	66
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	6:15:00 AM	123	97
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	6:30:00 AM	172	80
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	6:45:00 AM	224	116
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	7:00:00 AM	271	98
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	7:15:00 AM	288	143
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	7:30:00 AM	261	180
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	7:45:00 AM	271	188
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	8:00:00 AM	251	150
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	8:15:00 AM	284	185
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	8:30:00 AM	280	163
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	8:45:00 AM	292	175
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	9:00:00 AM	294	203
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	9:15:00 AM	262	147
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	9:30:00 AM	209	146
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	9:45:00 AM	216	142
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	10:00:00 AM	223	129
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	10:15:00 AM	239	160
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	10:30:00 AM	205	160
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	10:45:00 AM	185	140
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	11:00:00 AM	195	146
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	11:15:00 AM	176	145
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	11:30:00 AM	219	165
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	11:45:00 AM	226	168

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	12:00:00 PM	263	158
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	12:15:00 PM	245	129
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	12:30:00 PM	208	162
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	12:45:00 PM	223	166
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	1:00:00 PM	219	175
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	1:15:00 PM	261	177
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	1:30:00 PM	242	182
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	1:45:00 PM	210	124
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	2:00:00 PM	223	192
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	2:15:00 PM	195	248
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	2:30:00 PM	206	212
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	2:45:00 PM	221	199
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	3:00:00 PM	250	103
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	3:15:00 PM	238	122
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	3:30:00 PM	238	163
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	3:45:00 PM	235	237
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	4:00:00 PM	247	239
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	4:15:00 PM	222	200
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	4:30:00 PM	227	153
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	4:45:00 PM	267	134
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	5:00:00 PM	240	124
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	5:15:00 PM	257	136
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	5:30:00 PM	230	123
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	5:45:00 PM	227	139
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	6:00:00 PM	235	132
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	6:15:00 PM	245	140
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	6:30:00 PM	210	143
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	6:45:00 PM	216	169
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	7:00:00 PM	214	191
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	7:15:00 PM	207	194
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	7:30:00 PM	204	185
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	7:45:00 PM	214	199
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	8:00:00 PM	205	173
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	8:15:00 PM	192	181
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	8:30:00 PM	168	174
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	8:45:00 PM	181	166
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	9:00:00 PM	150	152
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	9:15:00 PM	190	186
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	9:30:00 PM	154	183
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	9:45:00 PM	173	152
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	10:00:00 PM	165	156
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	10:15:00 PM	132	138
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	10:30:00 PM	130	130
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	10:45:00 PM	106	118
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	11:00:00 PM	114	120
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	11:15:00 PM	114	122
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	11:30:00 PM	80	94
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	11:45:00 PM	112	102
555	RURAL RD	APACHE BLVD	UNIVERSITY DR	12:00:00 AM	92	89

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	12:00:00 AM	15	9
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	12:15:00 AM	12	7
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	12:30:00 AM	15	2
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	12:45:00 AM	10	7
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	1:00:00 AM	6	4
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	1:15:00 AM	10	7
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	1:30:00 AM	7	4
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	1:45:00 AM	8	6
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	2:00:00 AM	5	2
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	2:15:00 AM	3	9
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	2:30:00 AM	2	3
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	2:45:00 AM	3	5
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	3:00:00 AM	0	6
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	3:15:00 AM	2	5
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	3:30:00 AM	7	3
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	3:45:00 AM	2	10
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	4:00:00 AM	2	10
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	4:15:00 AM	7	14
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	4:30:00 AM	3	18
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	4:45:00 AM	8	18
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	5:00:00 AM	4	18
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	5:15:00 AM	7	29
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	5:30:00 AM	11	57
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	5:45:00 AM	13	80
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	6:00:00 AM	22	100
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	6:15:00 AM	23	114
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	6:30:00 AM	44	169
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	6:45:00 AM	57	214
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	7:00:00 AM	73	227
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	7:15:00 AM	90	286
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	7:30:00 AM	112	326
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	7:45:00 AM	179	362
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	8:00:00 AM	136	299
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	8:15:00 AM	97	282
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	8:30:00 AM	86	223
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	8:45:00 AM	93	225
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	9:00:00 AM	81	164
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	9:15:00 AM	84	163
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	9:30:00 AM	87	154
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	9:45:00 AM	82	160
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	10:00:00 AM	87	143
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	10:15:00 AM	109	109
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	10:30:00 AM	105	138
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	10:45:00 AM	95	166
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	11:00:00 AM	119	151
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	11:15:00 AM	114	134
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	11:30:00 AM	113	184
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	11:45:00 AM	142	161

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	12:00:00 PM	154	141
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	12:15:00 PM	131	149
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	12:30:00 PM	178	153
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	12:45:00 PM	142	167
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	1:00:00 PM	133	139
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	1:15:00 PM	135	174
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	1:30:00 PM	138	129
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	1:45:00 PM	131	149
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	2:00:00 PM	152	137
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	2:15:00 PM	171	111
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	2:30:00 PM	163	120
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	2:45:00 PM	194	121
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	3:00:00 PM	262	161
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	3:15:00 PM	242	145
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	3:30:00 PM	216	153
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	3:45:00 PM	212	168
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	4:00:00 PM	245	152
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	4:15:00 PM	268	155
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	4:30:00 PM	260	158
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	4:45:00 PM	270	171
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	5:00:00 PM	325	159
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	5:15:00 PM	314	153
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	5:30:00 PM	267	144
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	5:45:00 PM	240	184
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	6:00:00 PM	242	159
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	6:15:00 PM	191	117
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	6:30:00 PM	150	127
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	6:45:00 PM	131	124
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	7:00:00 PM	159	88
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	7:15:00 PM	124	98
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	7:30:00 PM	95	90
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	7:45:00 PM	81	70
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	8:00:00 PM	111	55
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	8:15:00 PM	86	54
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	8:30:00 PM	67	40
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	8:45:00 PM	106	37
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	9:00:00 PM	53	58
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	9:15:00 PM	42	43
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	9:30:00 PM	33	49
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	9:45:00 PM	41	42
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	10:00:00 PM	32	32
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	10:15:00 PM	24	16
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	10:30:00 PM	34	20
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	10:45:00 PM	25	32
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	11:00:00 PM	22	9
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	11:15:00 PM	12	18
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	11:30:00 PM	21	13
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	11:45:00 PM	13	12
465	CENTRAL AVE	CAMELBACK RD	MISSOURI AVE	12:00:00 AM	11	5

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
713	THOMAS RD	7TH AVE	CENTRAL AVE	12:00:00 AM	20	29
713	THOMAS RD	7TH AVE	CENTRAL AVE	12:15:00 AM	19	20
713	THOMAS RD	7TH AVE	CENTRAL AVE	12:30:00 AM	27	13
713	THOMAS RD	7TH AVE	CENTRAL AVE	12:45:00 AM	16	27
713	THOMAS RD	7TH AVE	CENTRAL AVE	1:00:00 AM	14	14
713	THOMAS RD	7TH AVE	CENTRAL AVE	1:15:00 AM	11	20
713	THOMAS RD	7TH AVE	CENTRAL AVE	1:30:00 AM	7	23
713	THOMAS RD	7TH AVE	CENTRAL AVE	1:45:00 AM	9	13
713	THOMAS RD	7TH AVE	CENTRAL AVE	2:00:00 AM	16	17
713	THOMAS RD	7TH AVE	CENTRAL AVE	2:15:00 AM	12	10
713	THOMAS RD	7TH AVE	CENTRAL AVE	2:30:00 AM	16	12
713	THOMAS RD	7TH AVE	CENTRAL AVE	2:45:00 AM	17	8
713	THOMAS RD	7TH AVE	CENTRAL AVE	3:00:00 AM	13	12
713	THOMAS RD	7TH AVE	CENTRAL AVE	3:15:00 AM	9	9
713	THOMAS RD	7TH AVE	CENTRAL AVE	3:30:00 AM	20	24
713	THOMAS RD	7TH AVE	CENTRAL AVE	3:45:00 AM	25	9
713	THOMAS RD	7TH AVE	CENTRAL AVE	4:00:00 AM	19	11
713	THOMAS RD	7TH AVE	CENTRAL AVE	4:15:00 AM	25	18
713	THOMAS RD	7TH AVE	CENTRAL AVE	4:30:00 AM	35	32
713	THOMAS RD	7TH AVE	CENTRAL AVE	4:45:00 AM	69	46
713	THOMAS RD	7TH AVE	CENTRAL AVE	5:00:00 AM	63	44
713	THOMAS RD	7TH AVE	CENTRAL AVE	5:15:00 AM	101	39
713	THOMAS RD	7TH AVE	CENTRAL AVE	5:30:00 AM	153	78
713	THOMAS RD	7TH AVE	CENTRAL AVE	5:45:00 AM	200	111
713	THOMAS RD	7TH AVE	CENTRAL AVE	6:00:00 AM	244	107
713	THOMAS RD	7TH AVE	CENTRAL AVE	6:15:00 AM	297	151
713	THOMAS RD	7TH AVE	CENTRAL AVE	6:30:00 AM	396	175
713	THOMAS RD	7TH AVE	CENTRAL AVE	6:45:00 AM	436	210
713	THOMAS RD	7TH AVE	CENTRAL AVE	7:00:00 AM	433	203
713	THOMAS RD	7TH AVE	CENTRAL AVE	7:15:00 AM	444	250
713	THOMAS RD	7TH AVE	CENTRAL AVE	7:30:00 AM	494	249
713	THOMAS RD	7TH AVE	CENTRAL AVE	7:45:00 AM	508	269
713	THOMAS RD	7TH AVE	CENTRAL AVE	8:00:00 AM	470	280
713	THOMAS RD	7TH AVE	CENTRAL AVE	8:15:00 AM	494	256
713	THOMAS RD	7TH AVE	CENTRAL AVE	8:30:00 AM	394	240
713	THOMAS RD	7TH AVE	CENTRAL AVE	8:45:00 AM	454	294
713	THOMAS RD	7TH AVE	CENTRAL AVE	9:00:00 AM	450	237
713	THOMAS RD	7TH AVE	CENTRAL AVE	9:15:00 AM	424	229
713	THOMAS RD	7TH AVE	CENTRAL AVE	9:30:00 AM	313	284
713	THOMAS RD	7TH AVE	CENTRAL AVE	9:45:00 AM	340	273
713	THOMAS RD	7TH AVE	CENTRAL AVE	10:00:00 AM	312	235
713	THOMAS RD	7TH AVE	CENTRAL AVE	10:15:00 AM	290	230
713	THOMAS RD	7TH AVE	CENTRAL AVE	10:30:00 AM	300	275
713	THOMAS RD	7TH AVE	CENTRAL AVE	10:45:00 AM	312	262
713	THOMAS RD	7TH AVE	CENTRAL AVE	11:00:00 AM	343	270
713	THOMAS RD	7TH AVE	CENTRAL AVE	11:15:00 AM	350	302
713	THOMAS RD	7TH AVE	CENTRAL AVE	11:30:00 AM	368	342
713	THOMAS RD	7TH AVE	CENTRAL AVE	11:45:00 AM	333	343

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
713	THOMAS RD	7TH AVE	CENTRAL AVE	12:00:00 PM	349	340
713	THOMAS RD	7TH AVE	CENTRAL AVE	12:15:00 PM	381	360
713	THOMAS RD	7TH AVE	CENTRAL AVE	12:30:00 PM	343	337
713	THOMAS RD	7TH AVE	CENTRAL AVE	12:45:00 PM	401	348
713	THOMAS RD	7TH AVE	CENTRAL AVE	1:00:00 PM	341	366
713	THOMAS RD	7TH AVE	CENTRAL AVE	1:15:00 PM	344	335
713	THOMAS RD	7TH AVE	CENTRAL AVE	1:30:00 PM	319	338
713	THOMAS RD	7TH AVE	CENTRAL AVE	1:45:00 PM	343	317
713	THOMAS RD	7TH AVE	CENTRAL AVE	2:00:00 PM	309	360
713	THOMAS RD	7TH AVE	CENTRAL AVE	2:15:00 PM	313	371
713	THOMAS RD	7TH AVE	CENTRAL AVE	2:30:00 PM	326	353
713	THOMAS RD	7TH AVE	CENTRAL AVE	2:45:00 PM	359	399
713	THOMAS RD	7TH AVE	CENTRAL AVE	3:00:00 PM	283	416
713	THOMAS RD	7TH AVE	CENTRAL AVE	3:15:00 PM	286	399
713	THOMAS RD	7TH AVE	CENTRAL AVE	3:30:00 PM	311	548
713	THOMAS RD	7TH AVE	CENTRAL AVE	3:45:00 PM	308	463
713	THOMAS RD	7TH AVE	CENTRAL AVE	4:00:00 PM	313	575
713	THOMAS RD	7TH AVE	CENTRAL AVE	4:15:00 PM	322	577
713	THOMAS RD	7TH AVE	CENTRAL AVE	4:30:00 PM	317	565
713	THOMAS RD	7TH AVE	CENTRAL AVE	4:45:00 PM	329	593
713	THOMAS RD	7TH AVE	CENTRAL AVE	5:00:00 PM	308	577
713	THOMAS RD	7TH AVE	CENTRAL AVE	5:15:00 PM	289	576
713	THOMAS RD	7TH AVE	CENTRAL AVE	5:30:00 PM	333	550
713	THOMAS RD	7TH AVE	CENTRAL AVE	5:45:00 PM	292	455
713	THOMAS RD	7TH AVE	CENTRAL AVE	6:00:00 PM	226	462
713	THOMAS RD	7TH AVE	CENTRAL AVE	6:15:00 PM	235	383
713	THOMAS RD	7TH AVE	CENTRAL AVE	6:30:00 PM	240	320
713	THOMAS RD	7TH AVE	CENTRAL AVE	6:45:00 PM	182	274
713	THOMAS RD	7TH AVE	CENTRAL AVE	7:00:00 PM	190	244
713	THOMAS RD	7TH AVE	CENTRAL AVE	7:15:00 PM	168	205
713	THOMAS RD	7TH AVE	CENTRAL AVE	7:30:00 PM	163	184
713	THOMAS RD	7TH AVE	CENTRAL AVE	7:45:00 PM	160	147
713	THOMAS RD	7TH AVE	CENTRAL AVE	8:00:00 PM	145	166
713	THOMAS RD	7TH AVE	CENTRAL AVE	8:15:00 PM	134	132
713	THOMAS RD	7TH AVE	CENTRAL AVE	8:30:00 PM	159	136
713	THOMAS RD	7TH AVE	CENTRAL AVE	8:45:00 PM	110	106
713	THOMAS RD	7TH AVE	CENTRAL AVE	9:00:00 PM	132	138
713	THOMAS RD	7TH AVE	CENTRAL AVE	9:15:00 PM	105	116
713	THOMAS RD	7TH AVE	CENTRAL AVE	9:30:00 PM	127	88
713	THOMAS RD	7TH AVE	CENTRAL AVE	9:45:00 PM	97	58
713	THOMAS RD	7TH AVE	CENTRAL AVE	10:00:00 PM	101	106
713	THOMAS RD	7TH AVE	CENTRAL AVE	10:15:00 PM	82	59
713	THOMAS RD	7TH AVE	CENTRAL AVE	10:30:00 PM	45	52
713	THOMAS RD	7TH AVE	CENTRAL AVE	10:45:00 PM	55	48
713	THOMAS RD	7TH AVE	CENTRAL AVE	11:00:00 PM	39	49
713	THOMAS RD	7TH AVE	CENTRAL AVE	11:15:00 PM	29	30
713	THOMAS RD	7TH AVE	CENTRAL AVE	11:30:00 PM	30	43
713	THOMAS RD	7TH AVE	CENTRAL AVE	11:45:00 PM	18	37
713	THOMAS RD	7TH AVE	CENTRAL AVE	12:00:00 AM	16	34

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
453	7TH AVE	I10	MCDOWELL RD	12:00:00 AM	31	41
453	7TH AVE	I10	MCDOWELL RD	12:15:00 AM	29	32
453	7TH AVE	I10	MCDOWELL RD	12:30:00 AM	30	33
453	7TH AVE	I10	MCDOWELL RD	12:45:00 AM	19	31
453	7TH AVE	I10	MCDOWELL RD	1:00:00 AM	17	24
453	7TH AVE	I10	MCDOWELL RD	1:15:00 AM	18	38
453	7TH AVE	I10	MCDOWELL RD	1:30:00 AM	22	21
453	7TH AVE	I10	MCDOWELL RD	1:45:00 AM	14	28
453	7TH AVE	I10	MCDOWELL RD	2:00:00 AM	17	23
453	7TH AVE	I10	MCDOWELL RD	2:15:00 AM	14	17
453	7TH AVE	I10	MCDOWELL RD	2:30:00 AM	13	22
453	7TH AVE	I10	MCDOWELL RD	2:45:00 AM	14	18
453	7TH AVE	I10	MCDOWELL RD	3:00:00 AM	8	13
453	7TH AVE	I10	MCDOWELL RD	3:15:00 AM	12	22
453	7TH AVE	I10	MCDOWELL RD	3:30:00 AM	20	18
453	7TH AVE	I10	MCDOWELL RD	3:45:00 AM	16	26
453	7TH AVE	I10	MCDOWELL RD	4:00:00 AM	14	23
453	7TH AVE	I10	MCDOWELL RD	4:15:00 AM	24	34
453	7TH AVE	I10	MCDOWELL RD	4:30:00 AM	36	47
453	7TH AVE	I10	MCDOWELL RD	4:45:00 AM	48	59
453	7TH AVE	I10	MCDOWELL RD	5:00:00 AM	57	74
453	7TH AVE	I10	MCDOWELL RD	5:15:00 AM	75	103
453	7TH AVE	I10	MCDOWELL RD	5:30:00 AM	83	169
453	7TH AVE	I10	MCDOWELL RD	5:45:00 AM	141	167
453	7TH AVE	I10	MCDOWELL RD	6:00:00 AM	141	168
453	7TH AVE	I10	MCDOWELL RD	6:15:00 AM	179	197
453	7TH AVE	I10	MCDOWELL RD	6:30:00 AM	228	247
453	7TH AVE	I10	MCDOWELL RD	6:45:00 AM	237	236
453	7TH AVE	I10	MCDOWELL RD	7:00:00 AM	271	238
453	7TH AVE	I10	MCDOWELL RD	7:15:00 AM	279	258
453	7TH AVE	I10	MCDOWELL RD	7:30:00 AM	296	264
453	7TH AVE	I10	MCDOWELL RD	7:45:00 AM	292	265
453	7TH AVE	I10	MCDOWELL RD	8:00:00 AM	291	258
453	7TH AVE	I10	MCDOWELL RD	8:15:00 AM	279	247
453	7TH AVE	I10	MCDOWELL RD	8:30:00 AM	268	236
453	7TH AVE	I10	MCDOWELL RD	8:45:00 AM	297	231
453	7TH AVE	I10	MCDOWELL RD	9:00:00 AM	247	194
453	7TH AVE	I10	MCDOWELL RD	9:15:00 AM	223	183
453	7TH AVE	I10	MCDOWELL RD	9:30:00 AM	227	194
453	7TH AVE	I10	MCDOWELL RD	9:45:00 AM	256	210
453	7TH AVE	I10	MCDOWELL RD	10:00:00 AM	207	184
453	7TH AVE	I10	MCDOWELL RD	10:15:00 AM	208	173
453	7TH AVE	I10	MCDOWELL RD	10:30:00 AM	213	203
453	7TH AVE	I10	MCDOWELL RD	10:45:00 AM	244	193
453	7TH AVE	I10	MCDOWELL RD	11:00:00 AM	236	216
453	7TH AVE	I10	MCDOWELL RD	11:15:00 AM	225	204
453	7TH AVE	I10	MCDOWELL RD	11:30:00 AM	227	210
453	7TH AVE	I10	MCDOWELL RD	11:45:00 AM	217	222

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
453	7TH AVE	I10	MCDOWELL RD	12:00:00 PM	190	240
453	7TH AVE	I10	MCDOWELL RD	12:15:00 PM	209	224
453	7TH AVE	I10	MCDOWELL RD	12:30:00 PM	215	215
453	7TH AVE	I10	MCDOWELL RD	12:45:00 PM	234	228
453	7TH AVE	I10	MCDOWELL RD	1:00:00 PM	219	242
453	7TH AVE	I10	MCDOWELL RD	1:15:00 PM	202	233
453	7TH AVE	I10	MCDOWELL RD	1:30:00 PM	201	228
453	7TH AVE	I10	MCDOWELL RD	1:45:00 PM	193	212
453	7TH AVE	I10	MCDOWELL RD	2:00:00 PM	195	239
453	7TH AVE	I10	MCDOWELL RD	2:15:00 PM	166	241
453	7TH AVE	I10	MCDOWELL RD	2:30:00 PM	198	235
453	7TH AVE	I10	MCDOWELL RD	2:45:00 PM	193	230
453	7TH AVE	I10	MCDOWELL RD	3:00:00 PM	185	241
453	7TH AVE	I10	MCDOWELL RD	3:15:00 PM	187	232
453	7TH AVE	I10	MCDOWELL RD	3:30:00 PM	208	225
453	7TH AVE	I10	MCDOWELL RD	3:45:00 PM	199	227
453	7TH AVE	I10	MCDOWELL RD	4:00:00 PM	184	239
453	7TH AVE	I10	MCDOWELL RD	4:15:00 PM	192	220
453	7TH AVE	I10	MCDOWELL RD	4:30:00 PM	216	266
453	7TH AVE	I10	MCDOWELL RD	4:45:00 PM	215	185
453	7TH AVE	I10	MCDOWELL RD	5:00:00 PM	195	230
453	7TH AVE	I10	MCDOWELL RD	5:15:00 PM	231	161
453	7TH AVE	I10	MCDOWELL RD	5:30:00 PM	221	219
453	7TH AVE	I10	MCDOWELL RD	5:45:00 PM	211	237
453	7TH AVE	I10	MCDOWELL RD	6:00:00 PM	224	258
453	7TH AVE	I10	MCDOWELL RD	6:15:00 PM	238	233
453	7TH AVE	I10	MCDOWELL RD	6:30:00 PM	227	203
453	7TH AVE	I10	MCDOWELL RD	6:45:00 PM	217	205
453	7TH AVE	I10	MCDOWELL RD	7:00:00 PM	180	196
453	7TH AVE	I10	MCDOWELL RD	7:15:00 PM	137	146
453	7TH AVE	I10	MCDOWELL RD	7:30:00 PM	154	172
453	7TH AVE	I10	MCDOWELL RD	7:45:00 PM	143	170
453	7TH AVE	I10	MCDOWELL RD	8:00:00 PM	146	170
453	7TH AVE	I10	MCDOWELL RD	8:15:00 PM	116	165
453	7TH AVE	I10	MCDOWELL RD	8:30:00 PM	121	133
453	7TH AVE	I10	MCDOWELL RD	8:45:00 PM	118	130
453	7TH AVE	I10	MCDOWELL RD	9:00:00 PM	112	149
453	7TH AVE	I10	MCDOWELL RD	9:15:00 PM	123	131
453	7TH AVE	I10	MCDOWELL RD	9:30:00 PM	107	120
453	7TH AVE	I10	MCDOWELL RD	9:45:00 PM	110	109
453	7TH AVE	I10	MCDOWELL RD	10:00:00 PM	126	93
453	7TH AVE	I10	MCDOWELL RD	10:15:00 PM	129	90
453	7TH AVE	I10	MCDOWELL RD	10:30:00 PM	128	70
453	7TH AVE	I10	MCDOWELL RD	10:45:00 PM	96	61
453	7TH AVE	I10	MCDOWELL RD	11:00:00 PM	54	59
453	7TH AVE	I10	MCDOWELL RD	11:15:00 PM	65	43
453	7TH AVE	I10	MCDOWELL RD	11:30:00 PM	54	35
453	7TH AVE	I10	MCDOWELL RD	11:45:00 PM	52	46
453	7TH AVE	I10	MCDOWELL RD	12:00:00 AM	37	37

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
468	7TH ST	I10	MCDOWELL RD	12:00:00 AM	32	56
468	7TH ST	I10	MCDOWELL RD	12:15:00 AM	22	42
468	7TH ST	I10	MCDOWELL RD	12:30:00 AM	47	30
468	7TH ST	I10	MCDOWELL RD	12:45:00 AM	27	29
468	7TH ST	I10	MCDOWELL RD	1:00:00 AM	34	46
468	7TH ST	I10	MCDOWELL RD	1:15:00 AM	36	34
468	7TH ST	I10	MCDOWELL RD	1:30:00 AM	17	28
468	7TH ST	I10	MCDOWELL RD	1:45:00 AM	28	32
468	7TH ST	I10	MCDOWELL RD	2:00:00 AM	18	29
468	7TH ST	I10	MCDOWELL RD	2:15:00 AM	22	24
468	7TH ST	I10	MCDOWELL RD	2:30:00 AM	26	16
468	7TH ST	I10	MCDOWELL RD	2:45:00 AM	21	24
468	7TH ST	I10	MCDOWELL RD	3:00:00 AM	21	19
468	7TH ST	I10	MCDOWELL RD	3:15:00 AM	24	28
468	7TH ST	I10	MCDOWELL RD	3:30:00 AM	20	25
468	7TH ST	I10	MCDOWELL RD	3:45:00 AM	34	22
468	7TH ST	I10	MCDOWELL RD	4:00:00 AM	23	32
468	7TH ST	I10	MCDOWELL RD	4:15:00 AM	31	29
468	7TH ST	I10	MCDOWELL RD	4:30:00 AM	56	56
468	7TH ST	I10	MCDOWELL RD	4:45:00 AM	69	55
468	7TH ST	I10	MCDOWELL RD	5:00:00 AM	58	77
468	7TH ST	I10	MCDOWELL RD	5:15:00 AM	93	108
468	7TH ST	I10	MCDOWELL RD	5:30:00 AM	148	188
468	7TH ST	I10	MCDOWELL RD	5:45:00 AM	186	194
468	7TH ST	I10	MCDOWELL RD	6:00:00 AM	256	250
468	7TH ST	I10	MCDOWELL RD	6:15:00 AM	275	316
468	7TH ST	I10	MCDOWELL RD	6:30:00 AM	323	369
468	7TH ST	I10	MCDOWELL RD	6:45:00 AM	430	394
468	7TH ST	I10	MCDOWELL RD	7:00:00 AM	394	449
468	7TH ST	I10	MCDOWELL RD	7:15:00 AM	460	453
468	7TH ST	I10	MCDOWELL RD	7:30:00 AM	491	445
468	7TH ST	I10	MCDOWELL RD	7:45:00 AM	567	455
468	7TH ST	I10	MCDOWELL RD	8:00:00 AM	507	444
468	7TH ST	I10	MCDOWELL RD	8:15:00 AM	534	459
468	7TH ST	I10	MCDOWELL RD	8:30:00 AM	532	421
468	7TH ST	I10	MCDOWELL RD	8:45:00 AM	565	385
468	7TH ST	I10	MCDOWELL RD	9:00:00 AM	449	323
468	7TH ST	I10	MCDOWELL RD	9:15:00 AM	475	327
468	7TH ST	I10	MCDOWELL RD	9:30:00 AM	498	352
468	7TH ST	I10	MCDOWELL RD	9:45:00 AM	471	316
468	7TH ST	I10	MCDOWELL RD	10:00:00 AM	446	299
468	7TH ST	I10	MCDOWELL RD	10:15:00 AM	419	357
468	7TH ST	I10	MCDOWELL RD	10:30:00 AM	416	381
468	7TH ST	I10	MCDOWELL RD	10:45:00 AM	436	386
468	7TH ST	I10	MCDOWELL RD	11:00:00 AM	446	405
468	7TH ST	I10	MCDOWELL RD	11:15:00 AM	462	398
468	7TH ST	I10	MCDOWELL RD	11:30:00 AM	480	413
468	7TH ST	I10	MCDOWELL RD	11:45:00 AM	442	419

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
468	7TH ST	I10	MCDOWELL RD	12:00:00 PM	499	446
468	7TH ST	I10	MCDOWELL RD	12:15:00 PM	448	418
468	7TH ST	I10	MCDOWELL RD	12:30:00 PM	457	387
468	7TH ST	I10	MCDOWELL RD	12:45:00 PM	469	423
468	7TH ST	I10	MCDOWELL RD	1:00:00 PM	454	439
468	7TH ST	I10	MCDOWELL RD	1:15:00 PM	433	410
468	7TH ST	I10	MCDOWELL RD	1:30:00 PM	431	415
468	7TH ST	I10	MCDOWELL RD	1:45:00 PM	456	414
468	7TH ST	I10	MCDOWELL RD	2:00:00 PM	377	405
468	7TH ST	I10	MCDOWELL RD	2:15:00 PM	401	411
468	7TH ST	I10	MCDOWELL RD	2:30:00 PM	439	449
468	7TH ST	I10	MCDOWELL RD	2:45:00 PM	468	404
468	7TH ST	I10	MCDOWELL RD	3:00:00 PM	487	456
468	7TH ST	I10	MCDOWELL RD	3:15:00 PM	492	475
468	7TH ST	I10	MCDOWELL RD	3:30:00 PM	501	454
468	7TH ST	I10	MCDOWELL RD	3:45:00 PM	524	493
468	7TH ST	I10	MCDOWELL RD	4:00:00 PM	527	497
468	7TH ST	I10	MCDOWELL RD	4:15:00 PM	583	481
468	7TH ST	I10	MCDOWELL RD	4:30:00 PM	525	462
468	7TH ST	I10	MCDOWELL RD	4:45:00 PM	612	433
468	7TH ST	I10	MCDOWELL RD	5:00:00 PM	608	466
468	7TH ST	I10	MCDOWELL RD	5:15:00 PM	558	445
468	7TH ST	I10	MCDOWELL RD	5:30:00 PM	569	417
468	7TH ST	I10	MCDOWELL RD	5:45:00 PM	542	416
468	7TH ST	I10	MCDOWELL RD	6:00:00 PM	450	381
468	7TH ST	I10	MCDOWELL RD	6:15:00 PM	413	360
468	7TH ST	I10	MCDOWELL RD	6:30:00 PM	329	345
468	7TH ST	I10	MCDOWELL RD	6:45:00 PM	287	320
468	7TH ST	I10	MCDOWELL RD	7:00:00 PM	263	309
468	7TH ST	I10	MCDOWELL RD	7:15:00 PM	235	287
468	7TH ST	I10	MCDOWELL RD	7:30:00 PM	222	318
468	7TH ST	I10	MCDOWELL RD	7:45:00 PM	196	252
468	7TH ST	I10	MCDOWELL RD	8:00:00 PM	202	256
468	7TH ST	I10	MCDOWELL RD	8:15:00 PM	225	226
468	7TH ST	I10	MCDOWELL RD	8:30:00 PM	193	219
468	7TH ST	I10	MCDOWELL RD	8:45:00 PM	164	222
468	7TH ST	I10	MCDOWELL RD	9:00:00 PM	151	220
468	7TH ST	I10	MCDOWELL RD	9:15:00 PM	135	167
468	7TH ST	I10	MCDOWELL RD	9:30:00 PM	170	144
468	7TH ST	I10	MCDOWELL RD	9:45:00 PM	125	131
468	7TH ST	I10	MCDOWELL RD	10:00:00 PM	126	135
468	7TH ST	I10	MCDOWELL RD	10:15:00 PM	108	137
468	7TH ST	I10	MCDOWELL RD	10:30:00 PM	102	101
468	7TH ST	I10	MCDOWELL RD	10:45:00 PM	89	94
468	7TH ST	I10	MCDOWELL RD	11:00:00 PM	76	90
468	7TH ST	I10	MCDOWELL RD	11:15:00 PM	64	69
468	7TH ST	I10	MCDOWELL RD	11:30:00 PM	73	86
468	7TH ST	I10	MCDOWELL RD	11:45:00 PM	53	74
468	7TH ST	I10	MCDOWELL RD	12:00:00 AM	48	65

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	12:00:00 AM	51	25
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	12:15:00 AM	28	34
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	12:30:00 AM	29	20
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	12:45:00 AM	29	24
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	1:00:00 AM	20	28
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	1:15:00 AM	23	25
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	1:30:00 AM	19	16
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	1:45:00 AM	25	15
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	2:00:00 AM	18	21
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	2:15:00 AM	25	21
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	2:30:00 AM	8	15
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	2:45:00 AM	13	16
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	3:00:00 AM	20	21
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	3:15:00 AM	17	13
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	3:30:00 AM	10	15
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	3:45:00 AM	18	14
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	4:00:00 AM	11	21
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	4:15:00 AM	15	41
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	4:30:00 AM	18	41
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	4:45:00 AM	31	52
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	5:00:00 AM	43	68
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	5:15:00 AM	44	89
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	5:30:00 AM	44	167
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	5:45:00 AM	62	202
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	6:00:00 AM	104	242
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	6:15:00 AM	168	351
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	6:30:00 AM	247	520
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	6:45:00 AM	317	588
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	7:00:00 AM	324	622
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	7:15:00 AM	387	677
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	7:30:00 AM	408	652
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	7:45:00 AM	456	747
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	8:00:00 AM	415	710
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	8:15:00 AM	376	655
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	8:30:00 AM	280	566
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	8:45:00 AM	280	528
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	9:00:00 AM	228	382
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	9:15:00 AM	218	341
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	9:30:00 AM	217	284
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	9:45:00 AM	270	308
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	10:00:00 AM	235	282
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	10:15:00 AM	259	330
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	10:30:00 AM	244	328
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	10:45:00 AM	305	353
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	11:00:00 AM	308	342
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	11:15:00 AM	346	387
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	11:30:00 AM	338	367
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	11:45:00 AM	369	322

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	12:00:00 PM	385	284
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	12:15:00 PM	347	341
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	12:30:00 PM	319	360
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	12:45:00 PM	330	348
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	1:00:00 PM	312	363
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	1:15:00 PM	343	333
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	1:30:00 PM	280	282
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	1:45:00 PM	331	320
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	2:00:00 PM	348	320
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	2:15:00 PM	342	313
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	2:30:00 PM	392	254
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	2:45:00 PM	470	291
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	3:00:00 PM	450	322
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	3:15:00 PM	431	308
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	3:30:00 PM	516	305
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	3:45:00 PM	555	294
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	4:00:00 PM	631	306
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	4:15:00 PM	627	385
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	4:30:00 PM	619	355
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	4:45:00 PM	655	356
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	5:00:00 PM	676	410
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	5:15:00 PM	704	380
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	5:30:00 PM	617	345
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	5:45:00 PM	551	310
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	6:00:00 PM	482	257
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	6:15:00 PM	391	209
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	6:30:00 PM	322	210
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	6:45:00 PM	275	204
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	7:00:00 PM	233	218
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	7:15:00 PM	202	164
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	7:30:00 PM	195	179
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	7:45:00 PM	182	119
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	8:00:00 PM	194	148
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	8:15:00 PM	172	129
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	8:30:00 PM	182	114
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	8:45:00 PM	156	107
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	9:00:00 PM	182	109
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	9:15:00 PM	167	95
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	9:30:00 PM	187	101
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	9:45:00 PM	192	105
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	10:00:00 PM	197	86
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	10:15:00 PM	168	83
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	10:30:00 PM	129	68
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	10:45:00 PM	68	49
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	11:00:00 PM	59	36
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	11:15:00 PM	71	49
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	11:30:00 PM	66	47
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	11:45:00 PM	57	38
470	7TH ST	INDIAN SCHOOL RD	CAMELBACK RD	12:00:00 AM	49	40

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
151	INDIAN SCHOOL RD	3RD ST	7TH ST	12:00:00 AM	41	50
151	INDIAN SCHOOL RD	3RD ST	7TH ST	12:15:00 AM	39	48
151	INDIAN SCHOOL RD	3RD ST	7TH ST	12:30:00 AM	33	36
151	INDIAN SCHOOL RD	3RD ST	7TH ST	12:45:00 AM	21	28
151	INDIAN SCHOOL RD	3RD ST	7TH ST	1:00:00 AM	20	21
151	INDIAN SCHOOL RD	3RD ST	7TH ST	1:15:00 AM	19	25
151	INDIAN SCHOOL RD	3RD ST	7TH ST	1:30:00 AM	14	26
151	INDIAN SCHOOL RD	3RD ST	7TH ST	1:45:00 AM	24	27
151	INDIAN SCHOOL RD	3RD ST	7TH ST	2:00:00 AM	26	23
151	INDIAN SCHOOL RD	3RD ST	7TH ST	2:15:00 AM	24	30
151	INDIAN SCHOOL RD	3RD ST	7TH ST	2:30:00 AM	17	20
151	INDIAN SCHOOL RD	3RD ST	7TH ST	2:45:00 AM	16	23
151	INDIAN SCHOOL RD	3RD ST	7TH ST	3:00:00 AM	18	15
151	INDIAN SCHOOL RD	3RD ST	7TH ST	3:15:00 AM	11	18
151	INDIAN SCHOOL RD	3RD ST	7TH ST	3:30:00 AM	14	15
151	INDIAN SCHOOL RD	3RD ST	7TH ST	3:45:00 AM	25	15
151	INDIAN SCHOOL RD	3RD ST	7TH ST	4:00:00 AM	25	16
151	INDIAN SCHOOL RD	3RD ST	7TH ST	4:15:00 AM	31	21
151	INDIAN SCHOOL RD	3RD ST	7TH ST	4:30:00 AM	39	31
151	INDIAN SCHOOL RD	3RD ST	7TH ST	4:45:00 AM	50	37
151	INDIAN SCHOOL RD	3RD ST	7TH ST	5:00:00 AM	54	64
151	INDIAN SCHOOL RD	3RD ST	7TH ST	5:15:00 AM	72	69
151	INDIAN SCHOOL RD	3RD ST	7TH ST	5:30:00 AM	99	101
151	INDIAN SCHOOL RD	3RD ST	7TH ST	5:45:00 AM	116	120
151	INDIAN SCHOOL RD	3RD ST	7TH ST	6:00:00 AM	143	129
151	INDIAN SCHOOL RD	3RD ST	7TH ST	6:15:00 AM	162	157
151	INDIAN SCHOOL RD	3RD ST	7TH ST	6:30:00 AM	171	204
151	INDIAN SCHOOL RD	3RD ST	7TH ST	6:45:00 AM	178	234
151	INDIAN SCHOOL RD	3RD ST	7TH ST	7:00:00 AM	150	242
151	INDIAN SCHOOL RD	3RD ST	7TH ST	7:15:00 AM	169	236
151	INDIAN SCHOOL RD	3RD ST	7TH ST	7:30:00 AM	143	278
151	INDIAN SCHOOL RD	3RD ST	7TH ST	7:45:00 AM	164	280
151	INDIAN SCHOOL RD	3RD ST	7TH ST	8:00:00 AM	183	260
151	INDIAN SCHOOL RD	3RD ST	7TH ST	8:15:00 AM	167	255
151	INDIAN SCHOOL RD	3RD ST	7TH ST	8:30:00 AM	183	234
151	INDIAN SCHOOL RD	3RD ST	7TH ST	8:45:00 AM	198	236
151	INDIAN SCHOOL RD	3RD ST	7TH ST	9:00:00 AM	148	232
151	INDIAN SCHOOL RD	3RD ST	7TH ST	9:15:00 AM	184	226
151	INDIAN SCHOOL RD	3RD ST	7TH ST	9:30:00 AM	171	232
151	INDIAN SCHOOL RD	3RD ST	7TH ST	9:45:00 AM	174	230
151	INDIAN SCHOOL RD	3RD ST	7TH ST	10:00:00 AM	176	210
151	INDIAN SCHOOL RD	3RD ST	7TH ST	10:15:00 AM	184	215
151	INDIAN SCHOOL RD	3RD ST	7TH ST	10:30:00 AM	192	215
151	INDIAN SCHOOL RD	3RD ST	7TH ST	10:45:00 AM	209	204
151	INDIAN SCHOOL RD	3RD ST	7TH ST	11:00:00 AM	219	200
151	INDIAN SCHOOL RD	3RD ST	7TH ST	11:15:00 AM	220	210
151	INDIAN SCHOOL RD	3RD ST	7TH ST	11:30:00 AM	232	220
151	INDIAN SCHOOL RD	3RD ST	7TH ST	11:45:00 AM	223	228

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
151	INDIAN SCHOOL RD	3RD ST	7TH ST	12:00:00 PM	244	201
151	INDIAN SCHOOL RD	3RD ST	7TH ST	12:15:00 PM	215	226
151	INDIAN SCHOOL RD	3RD ST	7TH ST	12:30:00 PM	218	239
151	INDIAN SCHOOL RD	3RD ST	7TH ST	12:45:00 PM	223	227
151	INDIAN SCHOOL RD	3RD ST	7TH ST	1:00:00 PM	204	229
151	INDIAN SCHOOL RD	3RD ST	7TH ST	1:15:00 PM	202	223
151	INDIAN SCHOOL RD	3RD ST	7TH ST	1:30:00 PM	211	239
151	INDIAN SCHOOL RD	3RD ST	7TH ST	1:45:00 PM	203	232
151	INDIAN SCHOOL RD	3RD ST	7TH ST	2:00:00 PM	212	218
151	INDIAN SCHOOL RD	3RD ST	7TH ST	2:15:00 PM	227	238
151	INDIAN SCHOOL RD	3RD ST	7TH ST	2:30:00 PM	228	211
151	INDIAN SCHOOL RD	3RD ST	7TH ST	2:45:00 PM	205	222
151	INDIAN SCHOOL RD	3RD ST	7TH ST	3:00:00 PM	234	203
151	INDIAN SCHOOL RD	3RD ST	7TH ST	3:15:00 PM	216	210
151	INDIAN SCHOOL RD	3RD ST	7TH ST	3:30:00 PM	250	211
151	INDIAN SCHOOL RD	3RD ST	7TH ST	3:45:00 PM	268	214
151	INDIAN SCHOOL RD	3RD ST	7TH ST	4:00:00 PM	288	227
151	INDIAN SCHOOL RD	3RD ST	7TH ST	4:15:00 PM	294	217
151	INDIAN SCHOOL RD	3RD ST	7TH ST	4:30:00 PM	286	197
151	INDIAN SCHOOL RD	3RD ST	7TH ST	4:45:00 PM	257	217
151	INDIAN SCHOOL RD	3RD ST	7TH ST	5:00:00 PM	300	220
151	INDIAN SCHOOL RD	3RD ST	7TH ST	5:15:00 PM	293	217
151	INDIAN SCHOOL RD	3RD ST	7TH ST	5:30:00 PM	261	220
151	INDIAN SCHOOL RD	3RD ST	7TH ST	5:45:00 PM	264	178
151	INDIAN SCHOOL RD	3RD ST	7TH ST	6:00:00 PM	276	219
151	INDIAN SCHOOL RD	3RD ST	7TH ST	6:15:00 PM	244	216
151	INDIAN SCHOOL RD	3RD ST	7TH ST	6:30:00 PM	217	202
151	INDIAN SCHOOL RD	3RD ST	7TH ST	6:45:00 PM	209	204
151	INDIAN SCHOOL RD	3RD ST	7TH ST	7:00:00 PM	179	155
151	INDIAN SCHOOL RD	3RD ST	7TH ST	7:15:00 PM	157	140
151	INDIAN SCHOOL RD	3RD ST	7TH ST	7:30:00 PM	154	152
151	INDIAN SCHOOL RD	3RD ST	7TH ST	7:45:00 PM	151	132
151	INDIAN SCHOOL RD	3RD ST	7TH ST	8:00:00 PM	165	159
151	INDIAN SCHOOL RD	3RD ST	7TH ST	8:15:00 PM	153	149
151	INDIAN SCHOOL RD	3RD ST	7TH ST	8:30:00 PM	132	111
151	INDIAN SCHOOL RD	3RD ST	7TH ST	8:45:00 PM	151	118
151	INDIAN SCHOOL RD	3RD ST	7TH ST	9:00:00 PM	123	133
151	INDIAN SCHOOL RD	3RD ST	7TH ST	9:15:00 PM	111	129
151	INDIAN SCHOOL RD	3RD ST	7TH ST	9:30:00 PM	100	109
151	INDIAN SCHOOL RD	3RD ST	7TH ST	9:45:00 PM	103	116
151	INDIAN SCHOOL RD	3RD ST	7TH ST	10:00:00 PM	118	103
151	INDIAN SCHOOL RD	3RD ST	7TH ST	10:15:00 PM	106	106
151	INDIAN SCHOOL RD	3RD ST	7TH ST	10:30:00 PM	86	88
151	INDIAN SCHOOL RD	3RD ST	7TH ST	10:45:00 PM	73	93
151	INDIAN SCHOOL RD	3RD ST	7TH ST	11:00:00 PM	64	76
151	INDIAN SCHOOL RD	3RD ST	7TH ST	11:15:00 PM	67	83
151	INDIAN SCHOOL RD	3RD ST	7TH ST	11:30:00 PM	57	62
151	INDIAN SCHOOL RD	3RD ST	7TH ST	11:45:00 PM	57	57
151	INDIAN SCHOOL RD	3RD ST	7TH ST	12:00:00 AM	44	57

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	12:00:00 AM	30	55
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	12:15:00 AM	23	59
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	12:30:00 AM	31	43
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	12:45:00 AM	20	32
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	1:00:00 AM	28	26
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	1:15:00 AM	18	33
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	1:30:00 AM	15	22
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	1:45:00 AM	12	19
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	2:00:00 AM	12	37
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	2:15:00 AM	23	30
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	2:30:00 AM	7	26
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	2:45:00 AM	19	28
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	3:00:00 AM	23	14
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	3:15:00 AM	20	13
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	3:30:00 AM	42	19
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	3:45:00 AM	45	20
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	4:00:00 AM	61	20
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	4:15:00 AM	70	33
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	4:30:00 AM	124	36
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	4:45:00 AM	127	52
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	5:00:00 AM	208	53
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	5:15:00 AM	298	77
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	5:30:00 AM	363	104
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	5:45:00 AM	342	141
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	6:00:00 AM	432	179
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	6:15:00 AM	535	217
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	6:30:00 AM	634	297
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	6:45:00 AM	683	350
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	7:00:00 AM	583	331
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	7:15:00 AM	637	333
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	7:30:00 AM	615	359
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	7:45:00 AM	661	407
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	8:00:00 AM	564	359
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	8:15:00 AM	553	371
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	8:30:00 AM	574	342
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	8:45:00 AM	506	367
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	9:00:00 AM	500	401
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	9:15:00 AM	506	346
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	9:30:00 AM	574	396
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	9:45:00 AM	604	374
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	10:00:00 AM	513	392
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	10:15:00 AM	541	378
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	10:30:00 AM	494	422
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	10:45:00 AM	559	396
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	11:00:00 AM	583	397
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	11:15:00 AM	531	420
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	11:30:00 AM	527	459
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	11:45:00 AM	512	405

ID	Street	Start Point	End Point	Time	NB/EB	SB/WB
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	12:00:00 PM	448	428
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	12:15:00 PM	529	450
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	12:30:00 PM	509	465
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	12:45:00 PM	538	465
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	1:00:00 PM	480	479
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	1:15:00 PM	544	424
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	1:30:00 PM	466	465
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	1:45:00 PM	511	447
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	2:00:00 PM	490	475
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	2:15:00 PM	548	463
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	2:30:00 PM	459	482
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	2:45:00 PM	464	422
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	3:00:00 PM	487	502
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	3:15:00 PM	518	456
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	3:30:00 PM	476	528
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	3:45:00 PM	485	470
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	4:00:00 PM	467	539
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	4:15:00 PM	461	460
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	4:30:00 PM	438	523
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	4:45:00 PM	465	457
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	5:00:00 PM	496	519
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	5:15:00 PM	488	480
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	5:30:00 PM	420	493
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	5:45:00 PM	379	500
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	6:00:00 PM	296	526
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	6:15:00 PM	319	357
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	6:30:00 PM	287	481
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	6:45:00 PM	227	486
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	7:00:00 PM	174	309
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	7:15:00 PM	212	331
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	7:30:00 PM	158	358
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	7:45:00 PM	188	269
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	8:00:00 PM	161	304
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	8:15:00 PM	176	245
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	8:30:00 PM	147	291
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	8:45:00 PM	126	254
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	9:00:00 PM	136	269
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	9:15:00 PM	129	267
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	9:30:00 PM	104	219
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	9:45:00 PM	83	189
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	10:00:00 PM	81	197
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	10:15:00 PM	68	161
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	10:30:00 PM	67	135
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	10:45:00 PM	59	138
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	11:00:00 PM	44	87
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	11:15:00 PM	31	74
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	11:30:00 PM	44	87
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	11:45:00 PM	32	75
31	BELL RD	R H JOHNSON BLVD	EL MIRAGE RD	12:00:00 AM	25	73