FRAMING THE QUESTIONS
APRIL 16, 2015

Pima Association of Governments

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1. Introduction

The **Regional Transit Visioning Project** seeks to facilitate a robust and focused discussion about the Tucson region's transit needs and choices. This project is conducted as part of Pima Association of Government (PAG)'s long range transportation plan development, and is intended to provide guidance on a regional transit vision to guide the 2045 RTP and future regional planning processes.

Framing the Questions is the first element of this process. It presents the known facts about the region, its economy, and its transportation demand, and describes many of the fundamental tradeoffs inherent to transit planning.

The last chapter of this report synthesizes that material to present a series of questions that Tucson citizens and elected officials must think about in deciding their own transit future, centered around three key questions:

- How should the Tucson region balance the competing goals of generating maximum ridership and providing maximum coverage?

- What total quantity of transit service is right for the Tucson region?

- What types of transit technologies are most cost-effective and may maximize transit's usefulness?

This report does not seek to provide answers to these questions. Only the community's citizens and elected officials can decide which paths are right given their priorities and values.

Instead, this report will be used to inform the process of stakeholder and public outreach to determine the answers to these questions.

2. Regional & City Context

2. Regional and City Context

In this section, we survey an array of demographic data available on the Tucson region, in order to provide a summary of existing context within which questions about transit will be asked, and decisions about transit must be made.

Transit ridership, and thus transit viability, is overwhelmingly determined by a city's pattern of development. For this reason, we review that relationship first, and then explore how Tucson's various types of development will tend to support public transit service.

Ridership-Supportive Land Use Conditions

While transit can be used to achieve a wide variety of outcomes, every transit agency must pay at least some attention to generating ridership. Ridership is not the only goal of transit, but it is almost always an important one, so it is important to understand the geometric facts about how transit becomes useful to large numbers of people, so that they logically choose to use it.

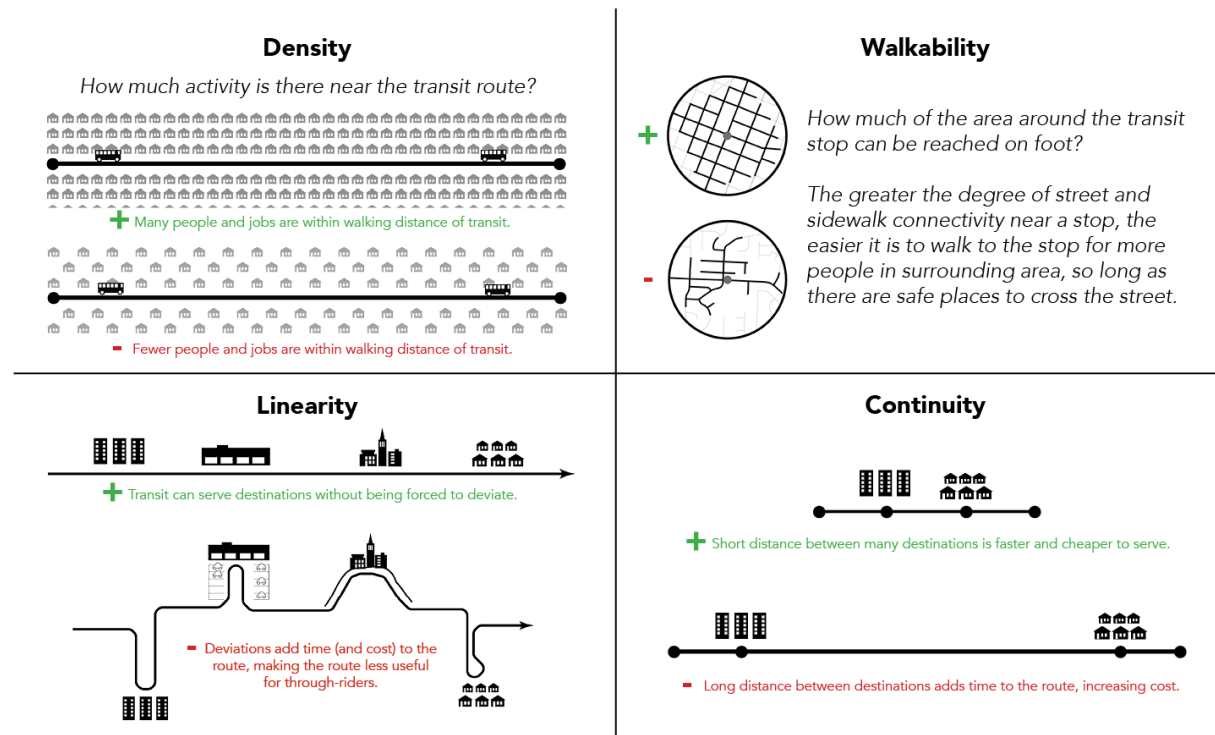The Four Geographic Indicators of High Ridership Potential

Density
How much activity is there near the transit route?

+ Many people and jobs are within walking distance of transit.

- Fewer people and jobs are within walking distance of transit.

Walkability
How much of the area around the transit stop can be reached on foot?

The greater the degree of street and sidewalk connectivity near a stop, the easier it is to walk to the stop for more people in surrounding area, so long as there are safe places to cross the street.

Linearity

+ Transit can serve destinations without being forced to deviate.

- Deviations add time (and cost) to the route, making the route less useful for through-riders.

Continuity

+ Short distance between many destinations is faster and cheaper to serve.

- Long distance between destinations adds time to the route, increasing cost.

Figure 1: Geographic Indictors of High Ridership Potential

A good way to visualize the impact of a place's urban form on ridership and costs is to ask: "How far do we have to run a transit vehicle to reach 100 people or jobs?" The lower this distance is, the higher the ridership potential of an area, and the lower the cost.

There are four major aspects of the built environment that determine an area's ridership potential:

- **Density**. How many people, jobs, and activities are near each transit stop? In denser areas, there are simply more people and activities near any given transit stop, so transit's market is potentially bigger.

2. Regional and City Context

Note that what matters here is the density right around potential transit stops, not the aggregate density of a whole city or region.

- **Walkability**. How many of the people near the transit stop can easily walk to the transit stop? If the street network is well connected and safe, more people near the stop can walk to it than if it is circuitous, discon-nected, or dangerous.
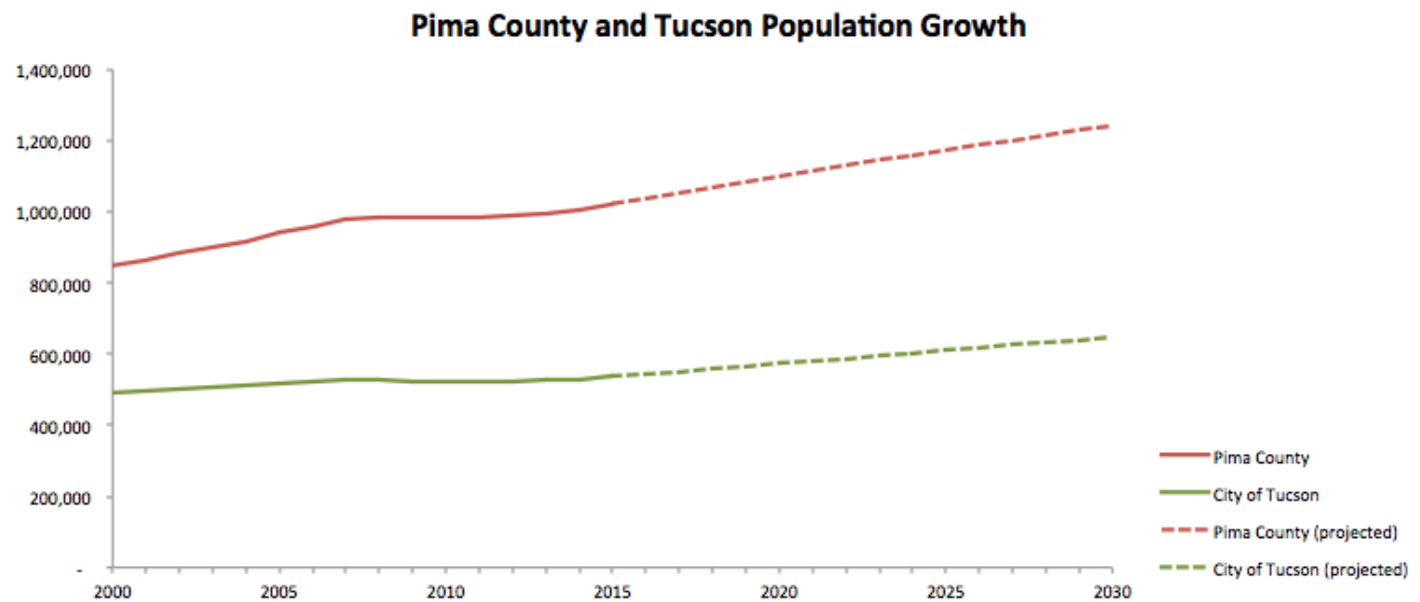
Pima County and Tucson Population Growth

Figure 2: Pima County and City of Tucson Population Growth

- **Linearity**. How many people and jobs can transit reach by traveling straight, direct paths? It costs more money (to a transit agency) and time (to passengers) for a transit agency to deviate to reach stops.

- **Continuity**. Does transit have to traverse long, low-demand gaps to reach people and jobs? The further transit has to drive to reach the same number of people, the longer those passengers' trips must

be, and the higher the cost to the transit agency to reach them.

Obviously, these elements are largely outside of the control of the transit agency; a place's urban form arises from a complex interaction of policy from all levels of government, residential and commercial real estate market trends, and individual aesthetic decisions. However, if a transit agency is expected to pursue a ridership goal, it will logi-cally focus its best service on areas where the four conditions listed above

are favorable, because this means that transit can be useful to the greatest possible number of people at a given level of cost.

Growth

Over the past decade, Tucson and Pima County have both grown slowly according to Arizona Department of Administration's employment and popu-lation statistics. The City of Tucson has around 4% more people than in 2004,

2. Regional and City Context

while Pima has 10% more people. Slow, steady growth is forecast to continue in Pima County into the future.

Density

Density is the single most powerful indicator of where transit is likely to succeed at generating high ridership, because it measures how many people or destinations are within walking distance of any transit stop.

Obviously, residential and employment densities are not the only measure of the intensity of travel demand. Retail, for example, has far more visitors than employees. For this reason, when we look at employment density, we consider not only jobs but also errands, services, schooling, social activities, and all of the transportation demands that they generate.

When looking at maps of density, it's important to remember that density around potential stops is what matters to transit. This means that patterns of high density along obvious lines have much higher transit potential than isolated clusters of activity.

Population Density

Figure 3 on page 9 shows population density by census block group. Population density is generally focused inside the boundaries of the City of Tucson. The highest-density block groups typically contain multifamily apartment buildings, like the ones near the University of Arizona campus.

Employment Density

The map of employment density shown in Figure 4 on page 10 tells us a few things everybody knows – downtown and the University of Arizona, as well as many of the region's shopping centers, are places where many people work in close proximity. However, we can also observe a smaller, but still significant level of concentration along the major commercial corridors, such as Broadway, Speedway, 6th, and Oracle. These are corridors which support many different types of trips to the various employers located along their extents.

It is important to note that in some cases, the large size of block groups in outlying areas may conceal some small pockets of density within their

geographic extent. This is especially true for employment density, since the boundaries of census block groups are not drawn to enclose particular numbers of jobs, as they are with population.

Activity Density

Transit responds to density of any kind; the more people there are near a stop, for whatever purpose, the larger transit's potential market is. One way of quickly getting a sense of that overall market size is to look at population and employment density in combination.

Figure 5 on page 11 shows population and employment density together; where zones are darker blue, a higher density of employment is present. Where they are more intensely pink, population density is higher. High density mixed-use block groups are dark purple, showing the combination of land uses through the mixing of blue and pink. The highest-density mixed-use block groups are colored yellow.

This map can help us examine features of the employment and population density maps in combination. The

2. Regional and City Context

greatest single activity center is the area between downtown and the University. However, other significant concentrations of population and jobs exist that are worthy of attention.

The Williams Center shopping area is clearly a major concentration of employment, but the adjoining block groups to the immediate northwest are also significant, with a slightly lower level of employment density and a moderately high level of population density.

2. Regional and City Context

Population Density

People/square mile
by Census Block Group

- 0-3500
- 3500-8000
- 8000-13000
- 13000-17392

Data Source :
American Community Survey, 2009-2013
5-year estimates
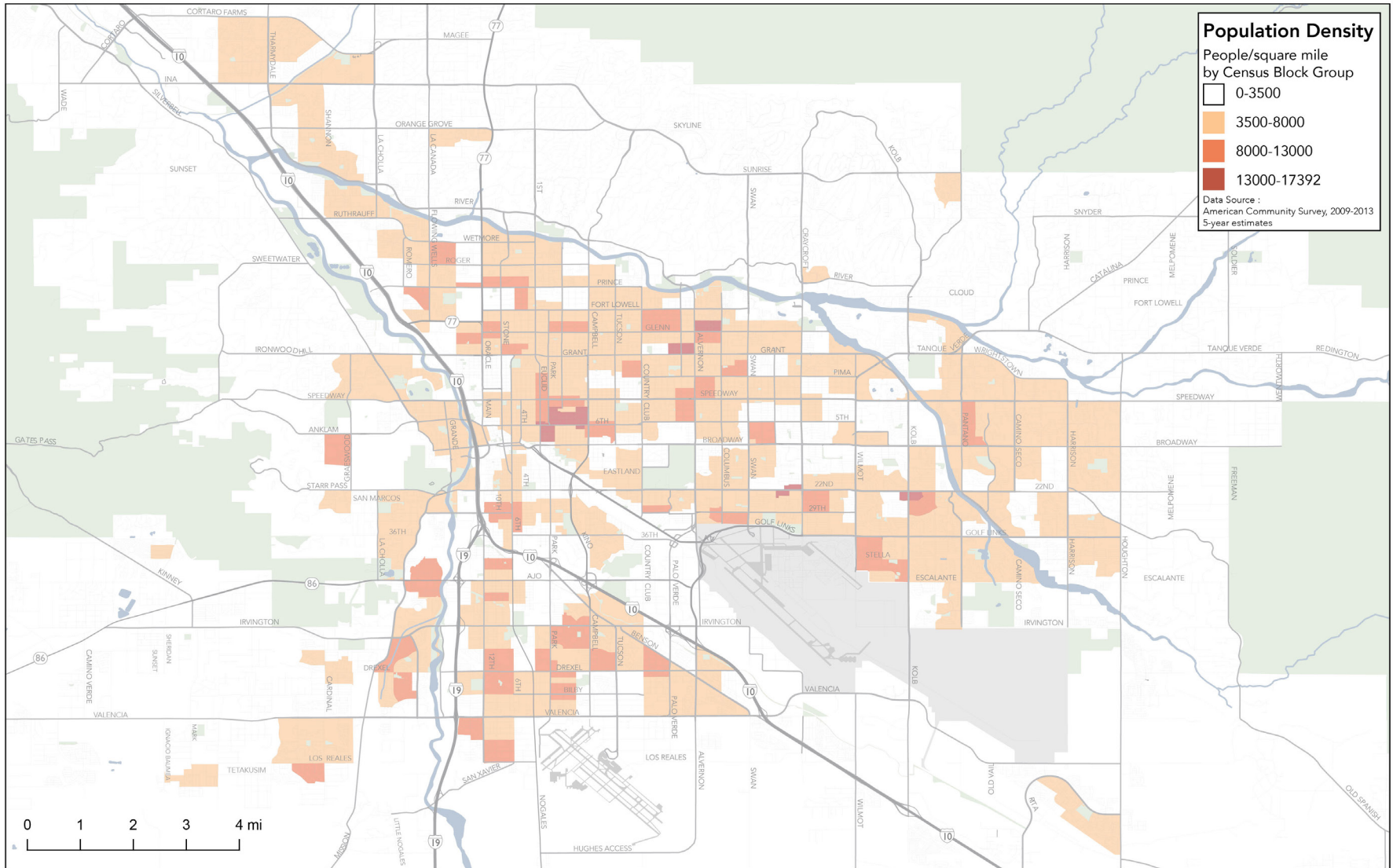
Figure 3: Population Density

2. Regional and City Context

Employment Density

People/square mile
by Census Block Group

☐	0-3000
◼	3000-8000
◼	8000-16000
◼	16000+

Data Source :
Pima Association of Governments, 2013

0 1 2 3 4 mi

JARRETT
WALKER
+ ASSOCIATES
Let's think about transit
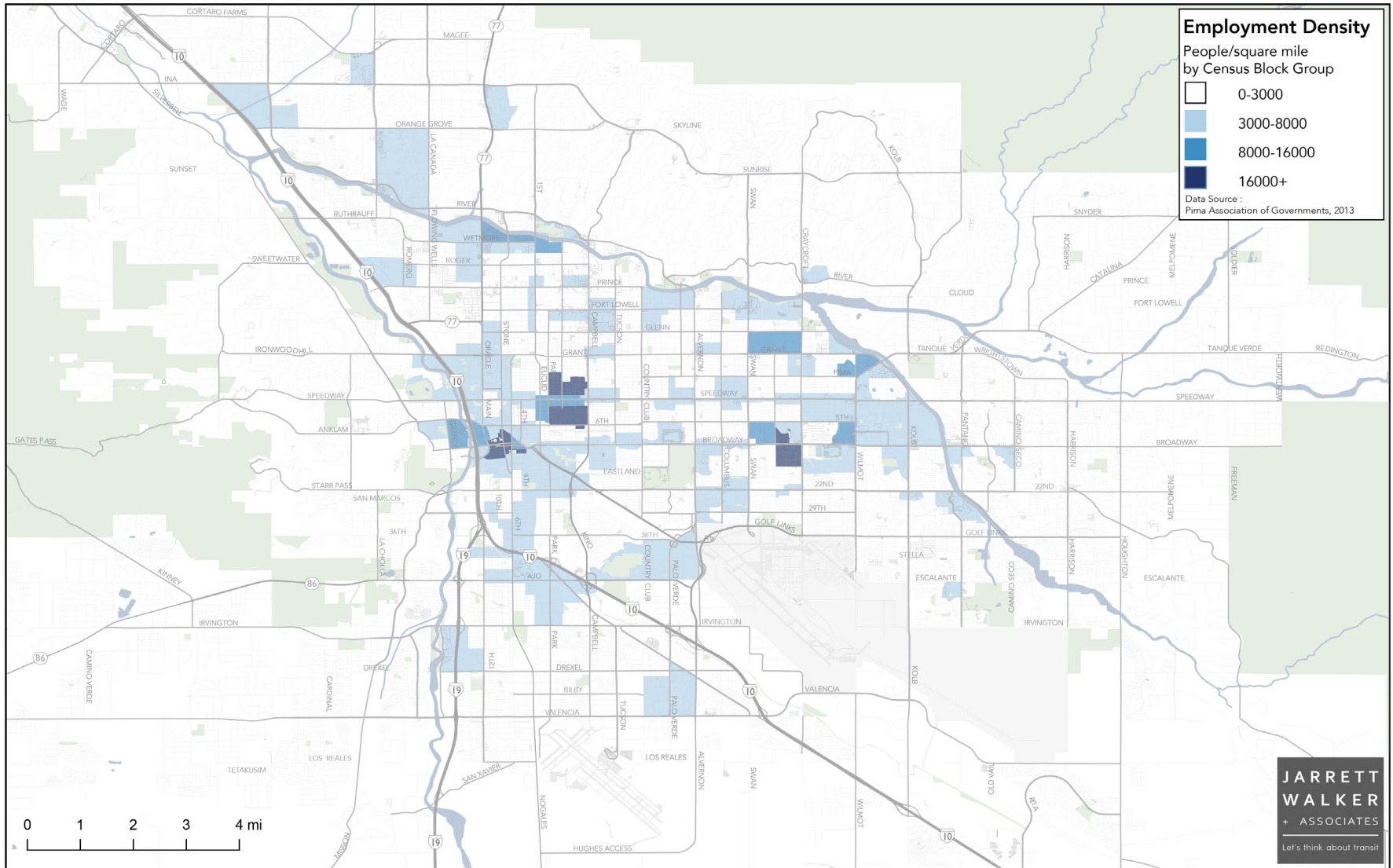
03/12/15

Figure 4: Employment Density
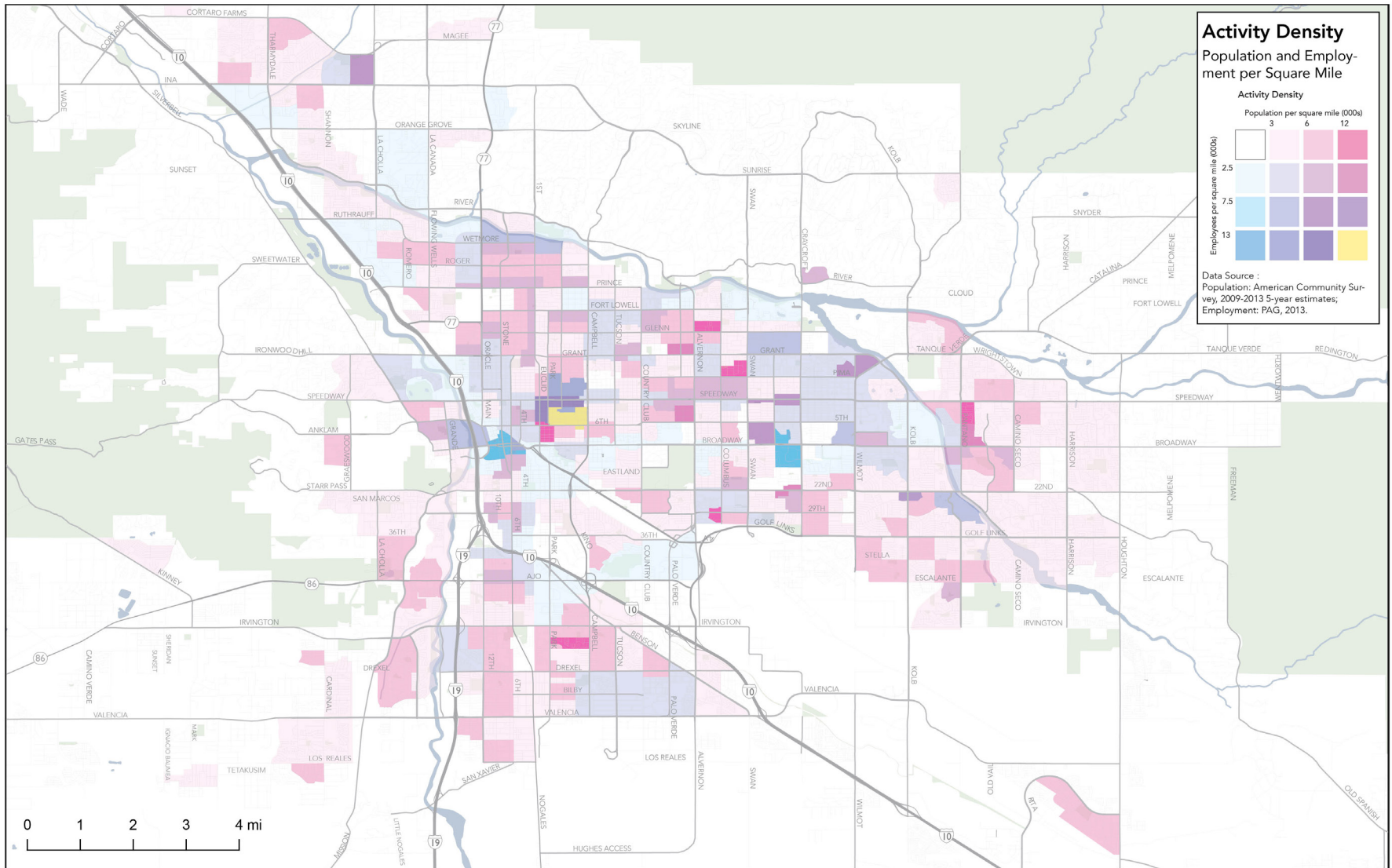
2. Regional and City Context

Figure 5: Activity Density

2. Regional and City Context

Travel Modes

People get around the Tucson region in many different ways: on foot or bicycle, or by personal vehicle, public transit, or taxi, to name just a few. These various options for getting around are called "modes."

According to the 2009-2013 American Community Survey, 86.4% of workers in the Tucson metropolitan area primarily drive or carpool to work. 2.5% take transit, and 4.2% cycle or walk to work. These broad numbers do little more than tell us that the personal automobile is dominant in Tucson, as it is in most places in the United States. However, about one in seven commuters usually make a different choice, and there are areas of the metro region where other modes are substantially more relevant.

When considering census travel mode data, it is important to note that the journey to work is not the only kind of travel or even the predominant one. It is merely the one that the Census asks about. As a result, these data do not offer a full picture of peoples' mobility needs and choices, but are the best

data available. They do offer some useful insight into how mode choices are made.

Transit Rate

While across the entire Tucson metro area, only 2.5% of commuters regularly travel to work using transit, in limited areas (those with higher density, walkability, and transit service), this rate is much higher. Transit is only a relevant mode where it exists at all, and more so where service levels are higher. Where transit is nonexistent, or only provides service very infrequently, it is unlikely to be useful for many people, so that area's rate of transit use will be correspondingly low.

Figure 7 on page 13 is a dot density map of people using transit to get to work. One dot on the map represents one person who regularly uses transit to get to work, according to the 2009-2013 American Community Survey. This

Mode	%
Car, truck, or van:	86.4%
Worked at home	4.9%
Public transportation (excluding taxicab):	2.5%
Walked	2.5%
Taxicab, motorcycle, or other means	2.1%
Bicycle	1.7%

Data Source: ACS 2009-2013 5-Year Estimates

Figure 6: Tucson Metropolitan Area Commute Mode Share

Dot Density A mapping technique where dots representing the total count of a quantity are randomly distributed across an area (like a block group or census tract) containing the count. Where more dots are present, more of whatever is being measured is present within the area. This is done to avoid a common problem when rates or counts are mapped using color shading - a high rate of occurence within a small population tends to be over-emphasized. However, it is important to remember that if dots are distributed across a large area, but whatever is being displayed is concentrated in a small section, the overall impression can be misleading- thus, the technique is most reliable for small areas.

2. Regional and City Context

Transit Commuting

● Each dot represents one person who uses transit for their daily journey to work.

Data Source :
American Community Survey, 2009-2013
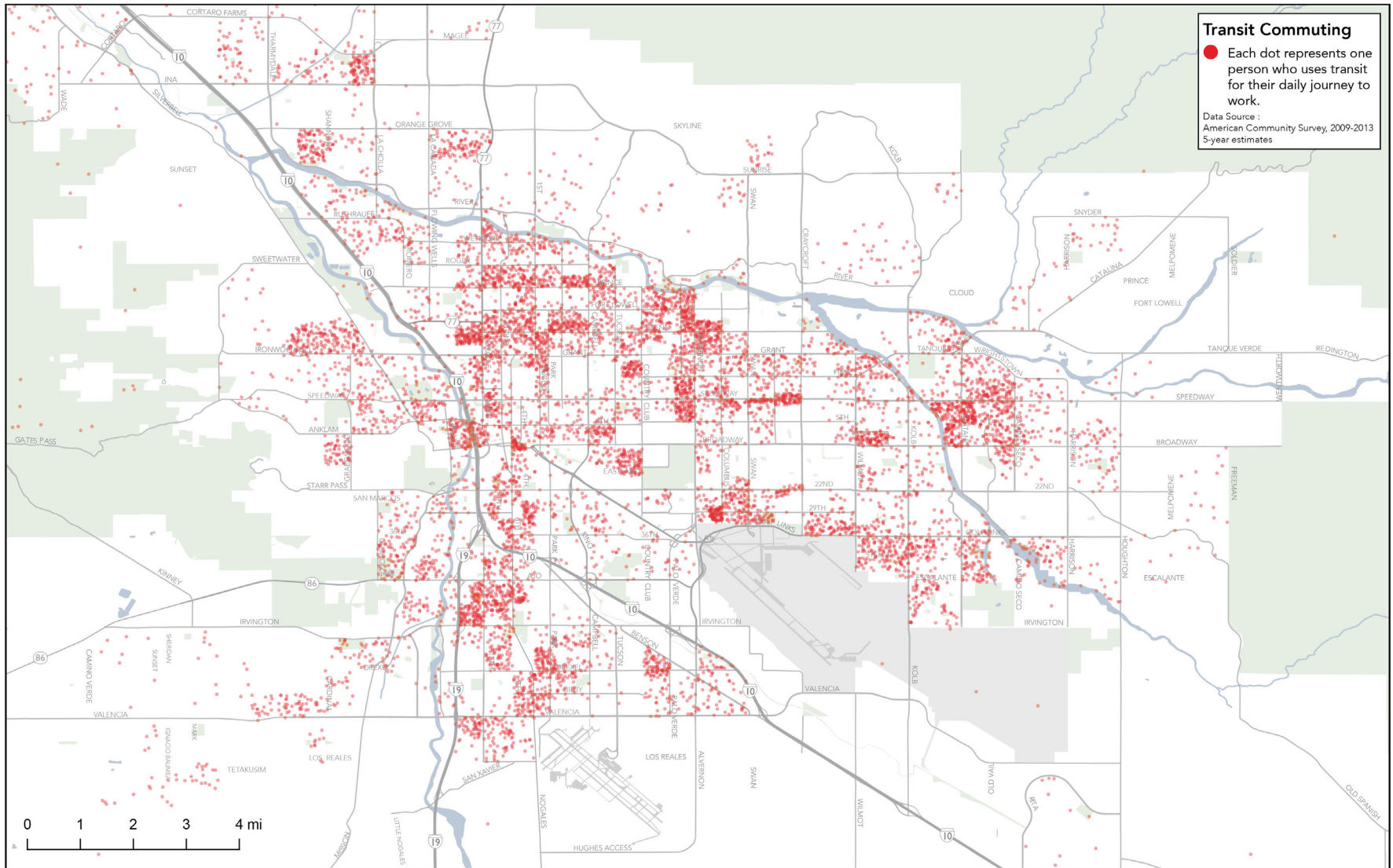5-year estimates

Figure 7: Journey to Work - Transit

2. Regional and City Context

technique can help to identify places where more people are using transit, without overemphasizing high usage rates among small populations.

This map shows us that in the part of the region where transit service is plentiful and convenient, a substantial number of people are already choosing to ride transit for their daily commute, though this is a small number in the context of the metropolitan area as a whole.

Most of the block groups where dots are most densely clustered are along the major frequent corridors like Speedway, Broadway, and Alvernon.

Walkability

Most transit trips start out as walking trips. While some people will ride transit from park-and-ride lots or are dropped off at a stop, for most people, the trip begins when they leave their home and walk to a transit stop. For transit, walk-ability is an important issue because every transit rider is also a pedestrian, at one end of the trip or both.

Density is one indicator of strong transit potential, but another is the walkability of an area. While walkability really lies in the nature of the built environment, one crude measure is simply how much walking happens now. Cycling is also of interest, as areas that are favorable for walking tend also to be more favorable for cycling.

High use of the active modes, walking and cycling, often indicate that exist-ing development patterns are favorably combining walkability with density, especially where the development includes both residences and jobs in close proximity, as near the University of Arizona. Poverty can also increase use of the active modes because individuals may be unable to afford other means of travel.

Across the city and region as a whole, only a small portion of workers bike or walk to work. Small areas can be iden-tified, however, where these modes are much more relevant. Figure 8 on page 15 maps workers traveling to work using cycling or walking, via the dot density technique discussed previously.

Around the university itself, more than 25% of workers walk or bike to work. In general, the closer a block group is to the university, the greater is the number of people using active modes of travel to work.

Smaller areas with a large number of active mode commuters are also found at many of the intersections of major arterials – for instance, near Alvernon and 5th/Speedway, or near Pantano and Broadway. It's worth noting that these nodes are mixed-use – places with both moderate density of employment and population.

Where densities are very low, residences and job locations are likely to be far apart, requiring lengthy commutes not suited to walking or cycling. However, in central Tucson, higher densities and a greater mixture of uses generate a higher rate of use of active modes for commuting.

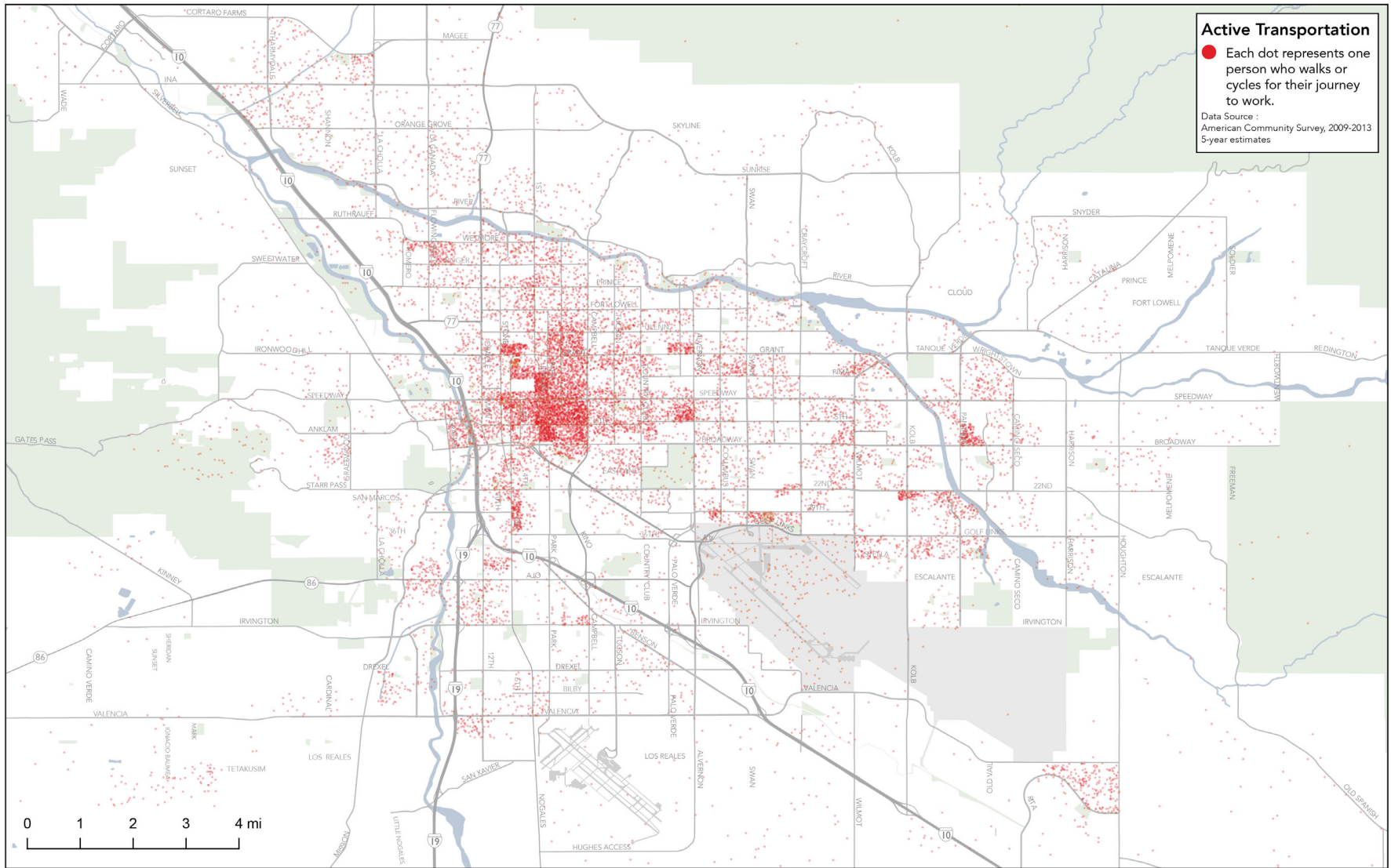# 2. Regional and City Context

Active Transportation

● Each dot represents one person who walks or cycles for their journey to work.

Data Source :
American Community Survey, 2009-2013
5-year estimates

Figure 8: Journey to Work - Walking and Cycling

2. Regional and City Context

Zero-Car Households

Zero-car households are important to transit because people who do not have a car (whether by necessity or choice) are more likely to use transit for a range of purposes. According to a 2011 Brookings Institution analysis[2] of US Census data, zero-car households are both more likely to be low-income and more likely to commute via public transit than other households. Note, however, that not all zero-car households are low income; some people are zero-car by choice, and others due to disability or an inability to drive.

According to 2009-2013 ACS estimates, 8.5% of households in the Tucson MSA have no vehicle available. This is slightly below the national number of 9.1%. In small parts of the urban area, this rate is substantially higher.

Figure 9 on page 17 maps zero-vehicle households in the Tucson region using the dot density technique.

From this map, we can observe the following areas where many households without private cars are concentrated:

- Around the University of Arizona

- Near the intersection of Alvernon and Speedway, as well as along Alvernon near Glenn and Grant

- South of Irvington between Campbell and Park

- Northeast of Pima and Wilmot

This is not an exhaustive list of every area of the city where a concentration of zero-vehicle households can be seen on the map. Typically, where there are more people in total, there are likely to be more people who do not own private automobiles.

In combination with supportive residential densities, zero-car households can be a sign that an area is worth consideration for frequent transit service designed to generate high ridership. Again, places with higher densities have larger potential markets for transit ridership, since there are simply more people near each stop who may choose to use the service. If many of those people's mobility choices are informed by a lack of private automobile, transit may be a more viable alternative for them.

2 Robert Puentes and Adie Tomer. "Transit Access and Zero-Vehicle Households". Brookings Institution, 2011.

2. Regional and City Context

Zero-Car Households

● Each dot represents one household with no access to a private automobile . Dots are distributed randomly across the area within each block group.

Data Source :
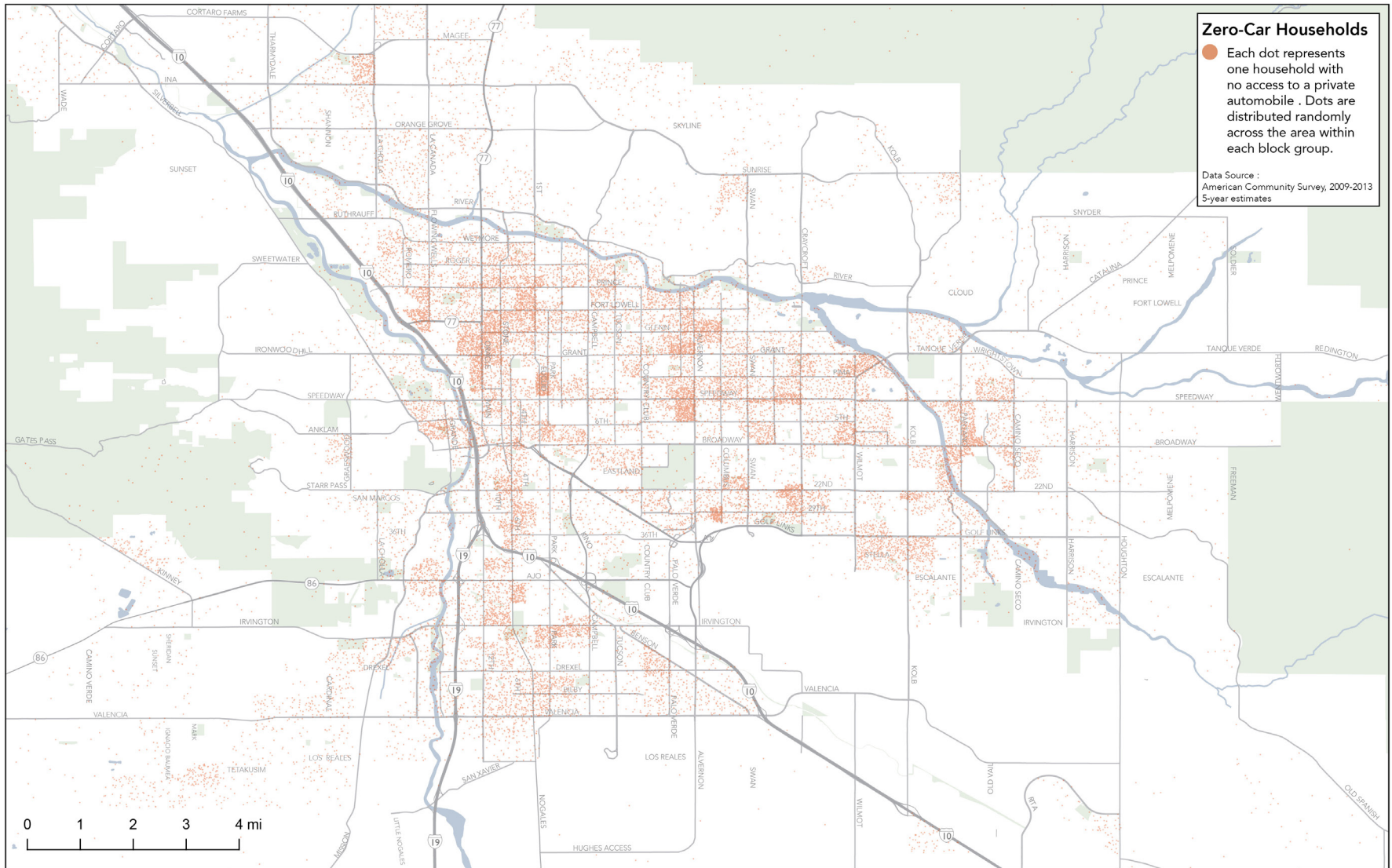American Community Survey, 2009-2013 5-year estimates

Figure 9: Zero-Car Households

2. Regional and City Context

Poverty

In 2013, the most recent year for which data is available, 19% of the population of the Tucson MSA was living below the poverty line, according to ACS 5-year estimates.

The map shown in Figure 10 on page 19 shows the density of people in poverty for the Tucson region using the dot density technique.

Census block groups containing very high densities of people in poverty are located throughout the urbanized area roughly coextensive with the bound-aries of the City of Tucson. Particular concentrations of these areas are found in Tucson south of Irvington Road; near the University of Arizona; west of Greasewood Road between Speedway and Starr Pass; and along Alvernon between Speedway and Fort Lowell.

This information is important because transit is sometimes asked to focus some degree of its resources towards enhancing mobility for low-income people. Mapping poverty in this way lets us generally identify the areas where people are located, so that

service can be effectively designed to meet their needs if desired.

2. Regional and City Context

People in Poverty

Dot Density

● Each dot represents one person living below the poverty line. Dots are distributed randomly within each block group.

Data Source :
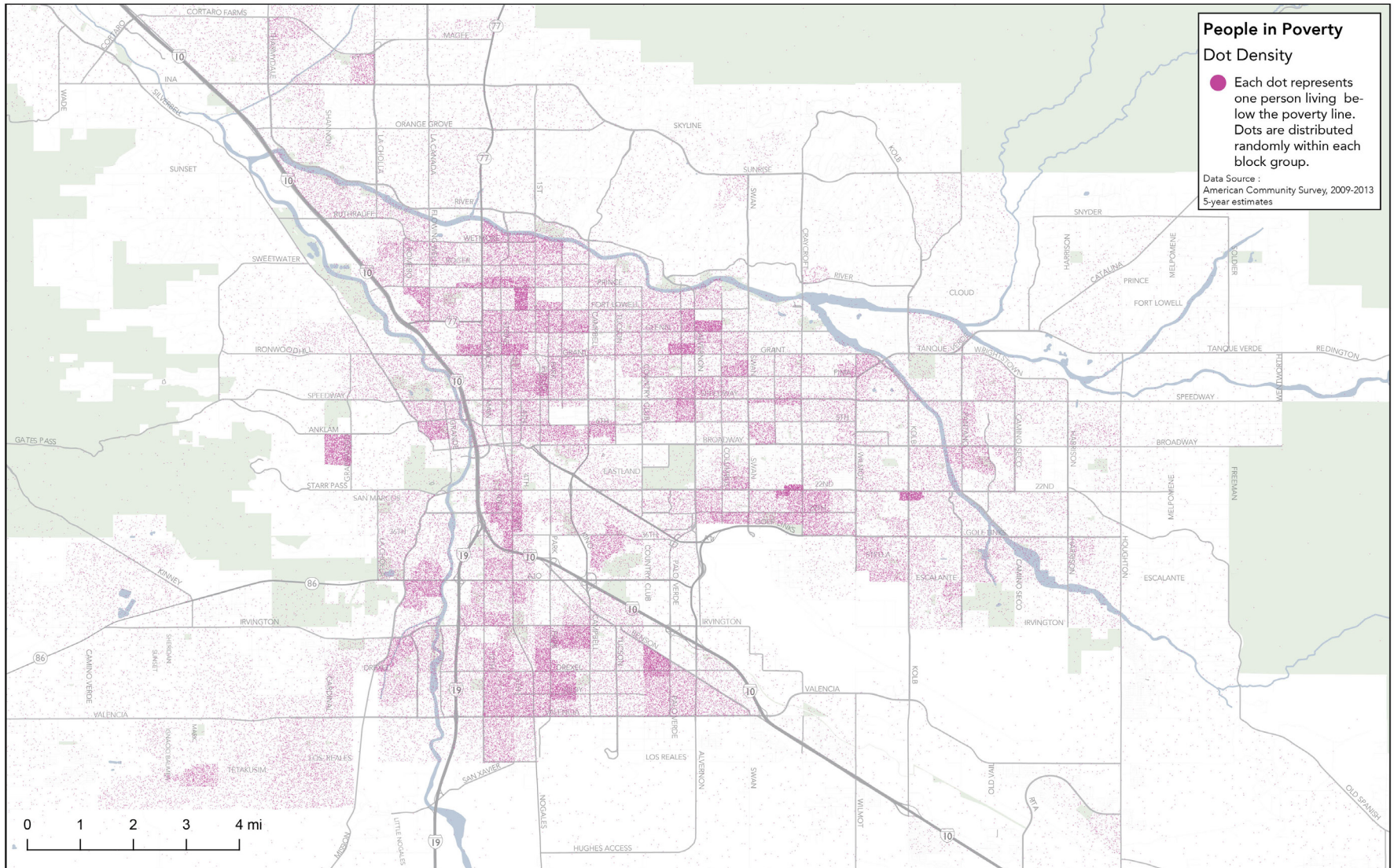American Community Survey, 2009-2013
5-year estimates

Figure 10: Poverty Density

2. Regional and City Context

Racial Categories

Race is not a strong predictor of transit usage, so this information does not guide transit planning as firmly as other factors explored in this chapter. However, Federal Title VI regulations, part of the Civil Rights Act of 1965, do require transit agencies to ensure that their plans do not create a dispropor-tionately negative impact on a particular racial group.

Figure 12 on page 21 is a map pro-duced by the Weldon Cooper Center for Public Service at the University of Virginia, showing the population of Tucson by race and ethnicity. This map uses the dot-density technique for 2010 US Census Blocks. Where many dots are very close together, the overall density of people is higher. Where dots of a single color are predominant, people of a particular race or ethnicity make up most of the area's population.

Tucson MSA Race and Ethnicity (2013)

Hispanic or Latino (of any race)	**345,072**	**35%**
Not Hispanic or Latino	**641,819**	**65%**
White alone	539,713	55%
Black or African American alone	32,322	3%
American Indian and Alaska Native alone	24,067	2%
Asian alone	25,505	3%
Native Hawaiian and Other Pacific Islander alone	1,184	0%
Some other race alone	1,459	0%
Two or more races	17,569	2%
Total	**986,891**	**100%**

Data source: ACS 2009-2013 5-year Estimates

Figure 11: Tucson MSA Race and Ethnicity (2013)
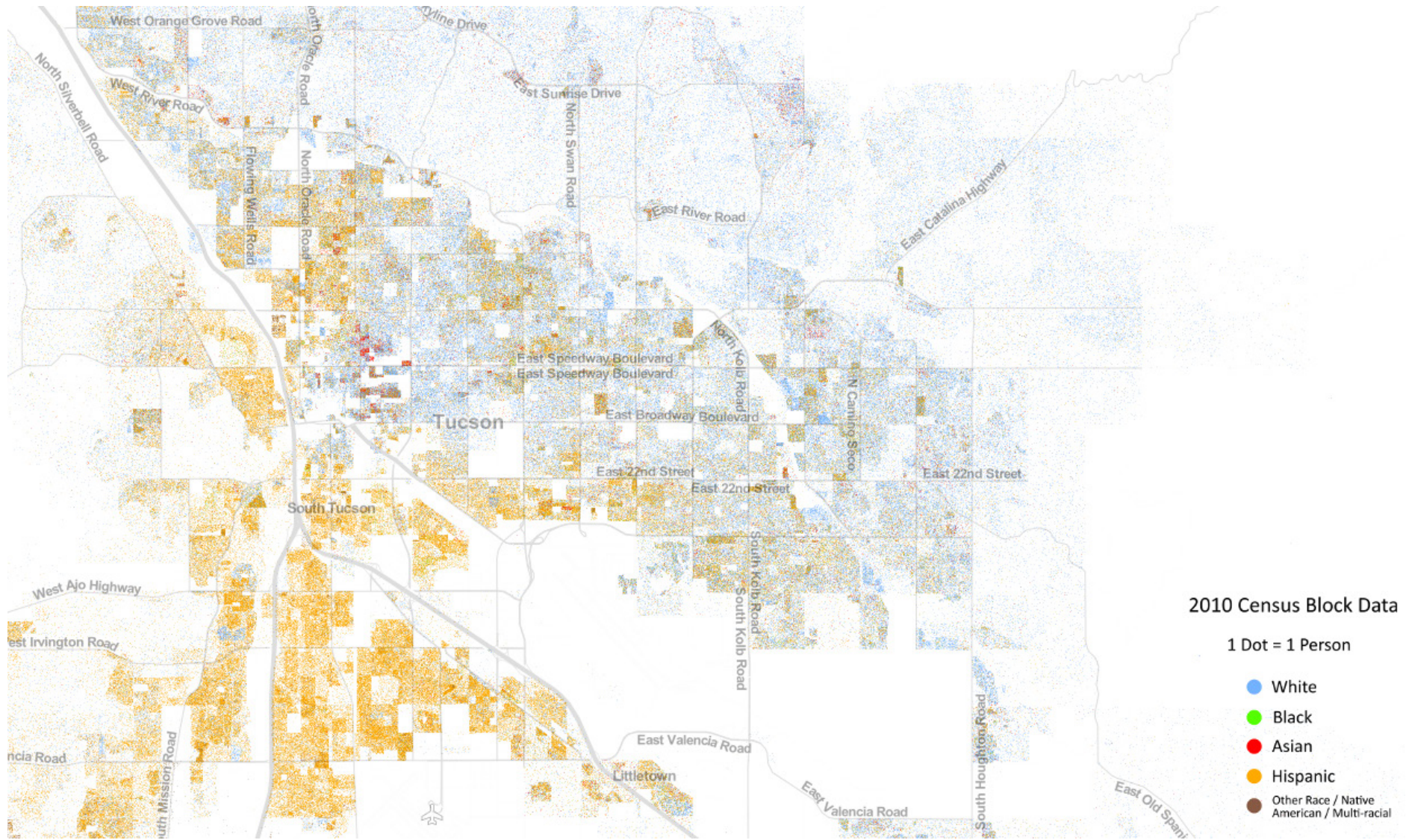
2. Regional and City Context

Figure 12: Tucson Racial Dot Density Map (Courtesy of Weldon Cooper Center for Public Service at the University of Virginia)

3. Existing System

3. Existing System

This section surveys available data on Sun Tran's current network and performance. While our intention is to provide a snapshot of the network, it largely does not reflect the most recent service changes, which had not been in place long enough to generate sufficient data for analysis at the time of writing.

Fixed-route transit service in the Tucson area is provided by Sun Tran, a department of the City of Tucson in operation since 1969. As of the most recent service change (February 2015), Sun Tran operates 30 local routes and ten peak-hour express routes. Additionally, there are ten shuttle routes throughout the region's Sun Shuttle service, providing service to the outlying jurisdictions and connections to Sun Tran's system.

In July 2014, the Sun Link streetcar was opened between the University of Arizona and the Mercado west of downtown. This service provides a direct frequent link between these destinations throughout the day.

While there may be inefficiencies that would turn up on closer inspection, the Sun Tran network is, in its basic structure, relatively efficient. Obvious signs
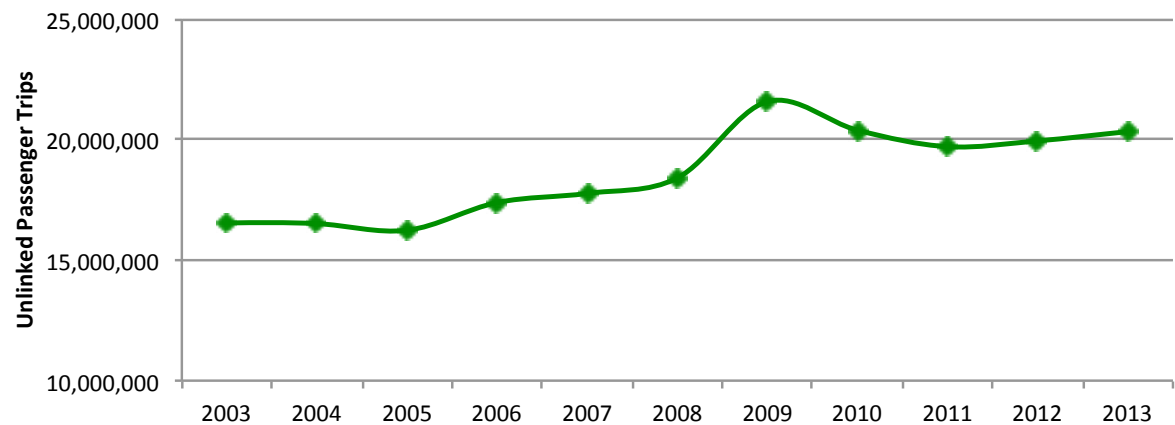
Sun Tran Annual Ridership

Figure 13: Sun Tran Annual Ridership

of inefficiency include many routes running on top of each other on the same street, or parallel routes so close together that they are competing for the same customers. Where transit networks have been restructured to achieve massive increases in service at no increase in operating cost (as in the recent Houston Transit System Reimagining[2]), it was because the existing system showed many examples of these kinds of inefficiency.

In Tucson's network, by contrast, strong duplication appears only with the express services that run alongside local lines, and while there may be some inefficiency in this category, these services represent a very small share of the budget. In short, a dramatically expanded transit system for Tucson will require an increase in operating cost, because the existing network structure does not show the usual signs that signal large amounts of waste in the current design.

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2 More information on this major redesign of the city's transit system can be found at Houston METRO's website, ridemetro.org.

3. Existing System

#	Name	Weekday Frequency (min)				Weekday Span (hrs)	Saturday Frequency		Saturday Span (hrs)	Sunday Frequency		Sunday Span (hrs)
		AM	Mid	PM	Eve	(hrs)	Day	Eve	(hrs)	Day	Eve	(hrs)
1	Glenn/Swan	30	30	30	60	16:55	60	60	14:55	60	60	12:55
2	Pueblo Gardens	30	30	30	60	18:05	60	60	13:51	60	60	13:51
3	6th St./Wilmot	30	30	30	60	18:50	60	60	16:55	60	60	13:28
4	**Speedway**	**15**	**15**	**10**	**30**	**19:18**	**30**	**30**	**15:45**	**30**	**30**	**13:45**
5	Pima/West Speedway	30	30	30	60	13:41	60	60	13:46	60	60	12:42
6	Euclid/N. 1st Ave.	15	30	15	60	19:14	30	30	14:35	60	60	13:32
7	**22nd St.**	**20**	**15**	**20**	**60**	**17:25**	**60**	**60**	**14:55**	**60**	**60**	**12:55**
8	**Broadway**	**10**	**10**	**10**	**30**	**19:10**	**15**	**30**	**15:42**	**20**	**30**	**14:49**
9	**E. Grant Road**	**30**	**15**	**30**	**60**	**19:13**	**60**	**60**	**14:55**	**60**	**60**	**13:41**
10	Flowing Wells	30	30	30	40	18:06	60	60	15:00	60	60	13:36
11	**Alvernon Way**	**15**	**15**	**15**	**60**	**17:50**	**30**	**30**	**15:15**	**30**	**30**	**13:46**
12	**10th/12th Ave**	**15**	**15**	**15**	**15**	**19:27**	**30**	**30**	**15:57**	**30**	**30**	**14:57**
15	Campbell Ave.	20	20	20	60	18:07	60	60	14:38	60	60	12:43
16	**Oracle/Ina**	**15**	**10**	**7**	**30**	**18:54**	**15**	**30**	**15:25**	**20**	**30**	**14:51**
17	Country Club/29th St.	30	30	30	60	18:00	60	60	15:52	60	60	13:51
18	**S. 6th Ave.**	**10**	**7**	**7**	**30**	**19:59**	**15**	**30**	**16:16**	**20**	**20**	**14:26**
19	Stone Ave.	30	30	30	60	17:21	30	60	14:47	60	60	13:55
20	West Grant Road	30	30	30	60	11:54	60	60	12:49	60	60	12:19
21	Congress/Silverbell	30	30	30	60	17:14	30	60	14:53	30	60	13:23
22	Grande	30	30	30	60	17:51	60	60	15:18	60	60	13:36
23	Mission Road	30	30	30	60	18:11	60	60	14:30	60	60	12:36
24	S. 12th Ave.	30	30	30	60	17:00	60	60	15:17	60	60	12:35
25	S. Park Ave	20	30	20	60	19:40	30	30	15:26	60	60	14:26
26	Benson Highway	30	30	30	60	18:23	60	60	14:27	60	60	13:00
27	Midvale Park	15	30	15	40	17:31	60	60	14:41	60	60	13:41
29	Valencia	30	30	30	40	17:36	60	60	15:35	60	60	13:41
34	Craycroft/Ft. Lowell	30	30	30	60	17:23	60	60	15:05	60	60	13:00
37	Pantano	30	30	30	30	14:14	60	60	14:00	60	60	13:00
50	Ajo Way	30	30	30	60	16:11	60	60	13:33	60	60	10:11
61	La Cholla	30	30	30	40	14:20	60	60	12:53	60	60	12:53

*Frequent Network Route (weekday midday frequency 15 minutes or less)

Figure 14: Sun Tran Route Spans and Previailing Frequency by Period

Historic Ridership

Over the past decade, Sun Tran ridership has steadily grown by an average rate of 2.8% per year. Ridership peaked in 2009 at 21.5 million annual boardings before falling off in 2010 and 2011. Ridership began to grow again in 2012 and 2013.

Frequency & Span

The aspect of transit planning that tends to attract the most public interest is geographical coverage: how much of the area of a city or region does the transit service touch? However, this measure does not indicate how useful a transit service is, and thus, what sorts of ridership outcomes can be expected.

Frequency and span are the major determining factors in how useful a transit service can be. Frequency tells us how often a bus comes, and thus, how convenient it is for people. Span tells us whether service exists at all during the times when people need it.

To call attention to the time-based dimension of transit, the map shown in Figure 15 on page 25 displays each
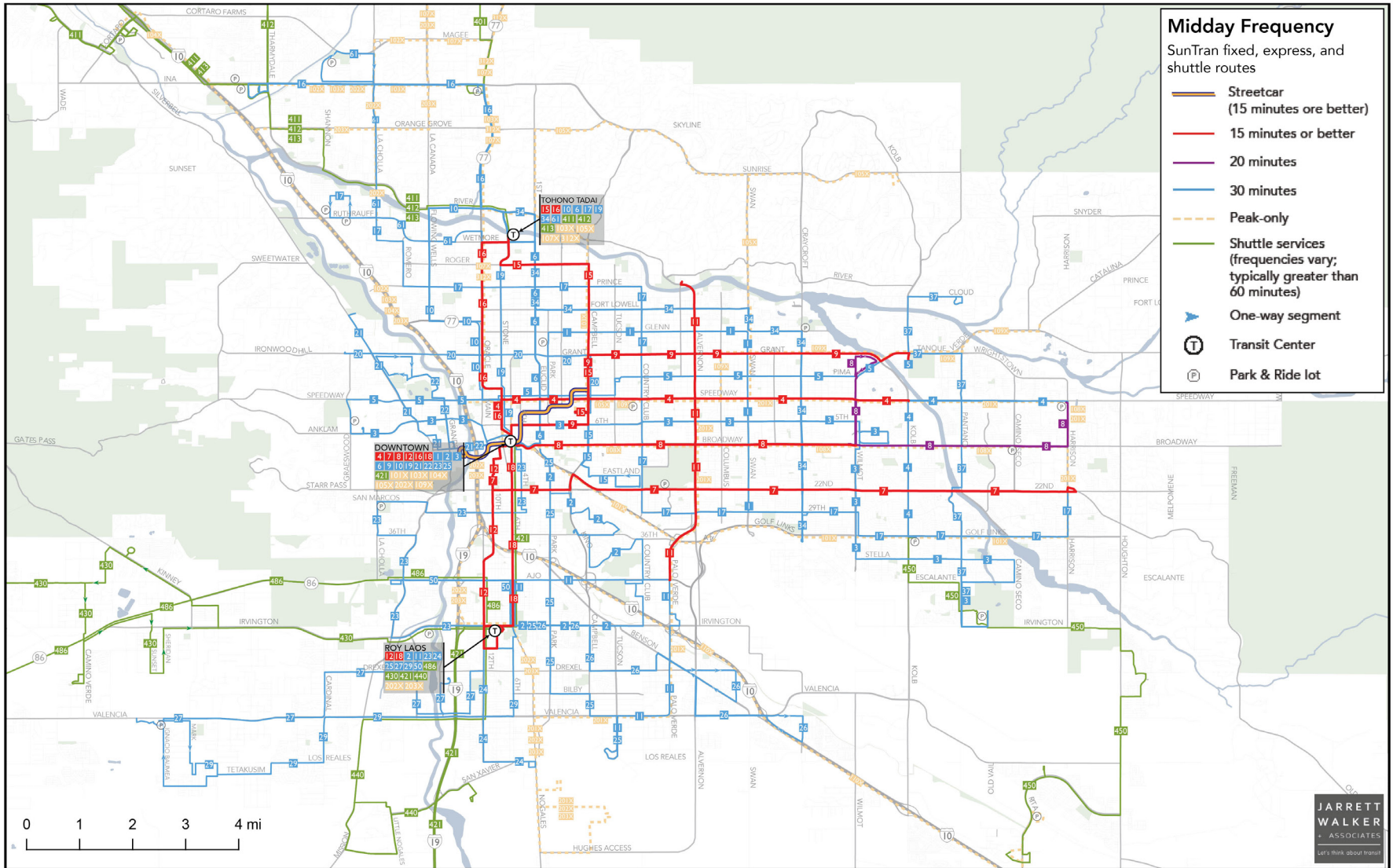
3. Existing System

Midday Frequency

SunTran fixed, express, and shuttle routes

- Streetcar (15 minutes ore better)
- 15 minutes or better
- 20 minutes
- 30 minutes
- Peak-only
- Shuttle services (frequencies vary; typically greater than 60 minutes)
- One-way segment
- (T) Transit Center
- (P) Park & Ride lot

Figure 15: Sun Tran and Sun Shuttle Midday Route Frequency

3. Existing System

of Sun Tran's routes color-coded by midday frequency. Frequency and span are also shown in detail for each route on the table in Figure 14.

Generally, 15-minute headways are the industry-standard threshold for frequent service. When a bus is coming every 15 minutes, an average wait is just 7.5 minutes, short enough that consulting a schedule is unnecessary. This expands the usefulness and convenience of transit for everyone, including people who might otherwise choose to drive. Peak-only routes, which are not available during the midday, are indicated in a dashed orange line.

In the current Sun Tran network, eight routes, plus the streetcar, operate at 15-minute or better headways. These routes serve relatively dense, high-activity corridors, connecting multiple important destinations. All other regular fixed routes run every 20 or 30 minutes, extending a moderate level of service to most of the urbanized area of the Tucson metropolitan area. Some infrequent routes operate at increased frequency during the AM and PM peak periods.

The ten express routes each make between two and six trips during both the AM and PM peak periods, directly linking downtown, the airport, and outer parts of Tucson. These routes are not available on weekends.

Sun Shuttle routes connect areas outside the main urban area to transfer points within the Sun Tran system throughout the day, operating at 60-minute or greater frequency. Some of the shuttle routes are available on Saturdays, but with a shorter span of service, usually terminating by late afternoon or early evening.

While frequency determines how useful transit is for riders, span determines whether that service exists at all when needed. During weekdays, all of Sun Tran's frequent routes run for at least 18 hours per day, from the early morning until late night, or in the case of the 12-10/12th Ave and 18-6th Ave, after midnight. These long spans mean that transit can still be a viable travel option for people whose work schedules require them to commute during these periods.

Sun Tran's less frequent fixed routes generally operate a shorter service day (14-18 hours), though some, like the 25-S. `Park Ave or 6-Euclid, have long spans serving the early morning and late night as well. Different spans between routes mean that trips requiring a transfer may not be possible at all times.

On the weekends, many routes' spans are substantially shorter. Most routes enter service at least an hour later, and all cease service by 10:00 PM with one exception – the streetcar, which runs until 2:00 AM on Saturdays. This means that Sun Tran is less useful for all sorts of trips made during weekend nights – for instance, people whose weekend shifts end after 10:00 PM, or people returning late in the evening from a night out. Spans decrease even further on Sundays.

Ridership

Ridership emerges from a combination of density, walkability, linear transit paths, and street connectivity, along with adequate transit service. Where is
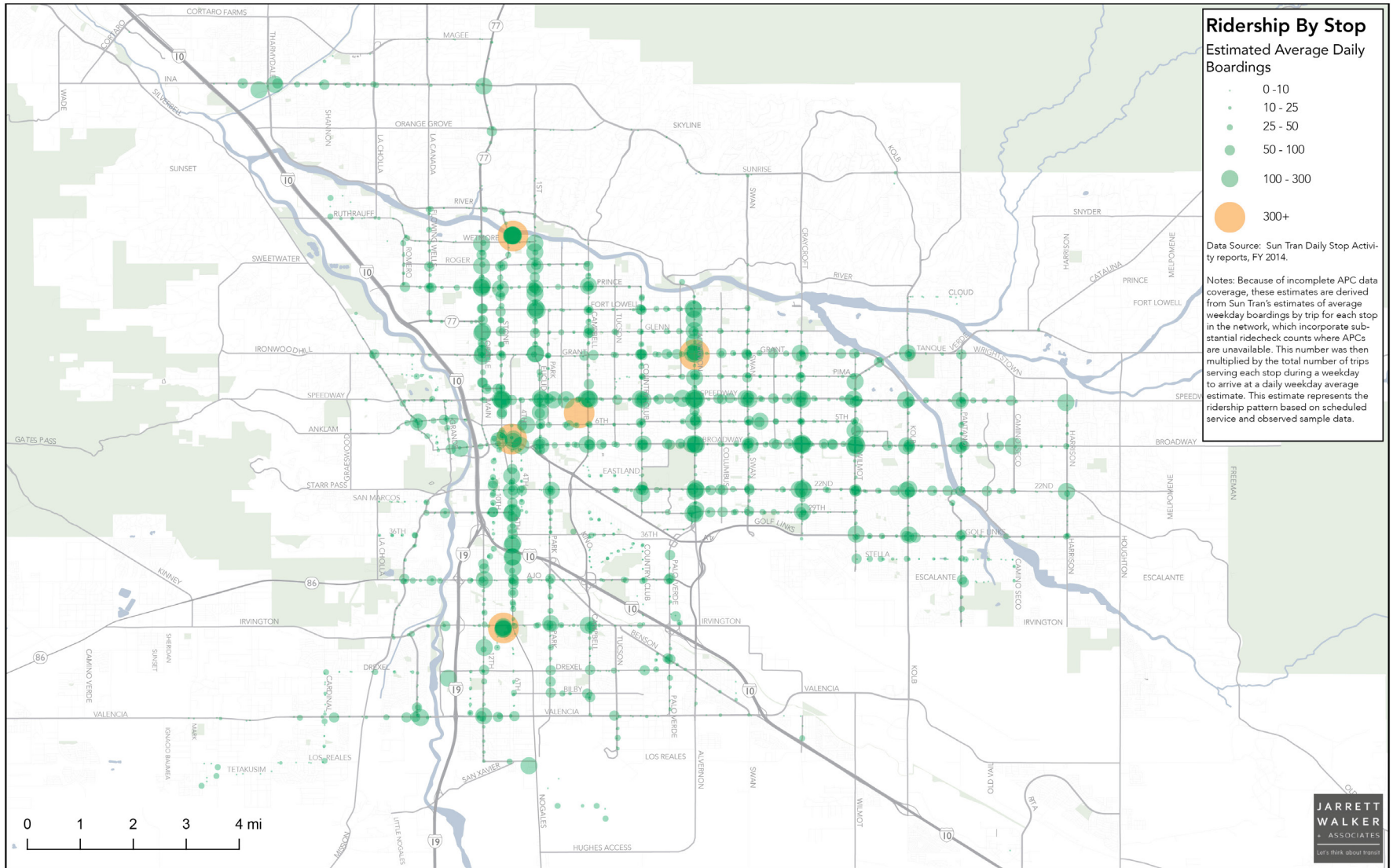
3. Existing System

Ridership By Stop
Estimated Average Daily Boardings

- 0 - 10
- 10 - 25
- 25 - 50
- 50 - 100
- 100 - 300
- 300+

Data Source: Sun Tran Daily Stop Activity reports, FY 2014.

Notes: Because of incomplete APC data coverage, these estimates are derived from Sun Tran's estimates of average weekday boardings by trip for each stop in the network, which incorporate substantial ridecheck counts where APCs are unavailable. This number was then multiplied by the total number of trips serving each stop during a weekday to arrive at a daily weekday average estimate. This estimate represents the ridership pattern based on scheduled service and observed sample data.

Figure 16: Sun Tran Ridership by Stop

3. Existing System

Sun Tran succeeding at generating high ridership today?

Figure 16 on page 27 displays the pattern of ridership by stop across the Sun Tran system for FY14 (prior to recent service changes, which split several through-routes in downtown Tucson, and adjusted frequencies on the 9-Grant, 16-Oracle/Ina, and 8-Broadway). Each stop circle is sized based on the number of people esti-mated[3] to board a bus there each day.

We can observe some key patterns in Sun Tran's ridership from this map.

The highest-ridership stops in the network tend to be clustered at major intersections (such as Grant and Alvernon or Broadway and Craycroft). In Tucson, as in many cities laid out with a large arterial grid, important destinations tend to cluster at major intersections. These include places like shopping malls and big-box

3 Because Sun Tran routes do not have total APC (Automatic Passenger Counter) coverage, the estimate of average daily boardings uses ridecheck numbers for the average boardings per trip at each stop in the network. The average boardings per trip by stop was then multi-plied by the total number of trips per weekday at each stop to arrive at an estimated average daily boardings by stop.

retail, as well as multifamily residential complexes.

Intersections like this often have adjoin-ing concentrations of population and employment, increasing the size of the overall market for transit. Since many of Sun Tran's routes operate on these arterials, a person located near an inter-section will have easier access to transit in multiple directions than somebody traveling from an intermediate segment.

These intersections are also of use for people transferring between routes, though without linked trip data, it is impossible to know the exact break-down between ridership generated by transfers and ridership generated by local origins.

We can also observe substantial rider-ship on corridors like Oracle and Euclid, which both pass through areas of dense, mixed-use development, and which serve important anchoring destinations like downtown, Tucson Mall, and the University of Arizona.

The Sun Link streetcar carries an average of 4019 passengers per weekday on its route between the

University of Arizona, Downtown and the Mercado. This level of rider-ship is comparable to routes like the 11-Alvernon and 6-Euclid. The streetcar provides high-frequency service to a very dense, mixed-use area and major destinations, and its strong ridership after less than a year in operation is another signal of how successful at gen-erating ridership this strategy can be in Tucson.

Where density is more limited, rider-ship tends to be more limited as well. This can be seen in the ridership of stops served by the 27-Midvale Park and 29-Valencia west of Drexel. This is a low-density, residential area, with a street network that offers more limited pedestrian connectivity than the grid of streets found in other parts of Tucson. As mentioned in the discussion of the ridership recipe, transit is capable of generating the most ridership when many people are within a short walk of a stop. Correspondingly, ridership on these segments is low.

Finally, ridership is clearly responding powerfully to frequency. The highest ridership corridors tend to be those

3. Existing System

Route	Weekday Ridership	Saturday Ridership	Sunday Ridership
1-Glenn/Swan	1848	841	607
2-Pueblo Gardens	1212	493	345
3-6th St./Wilmot	3152	1036	738
4-Speedway	5387	2681	1766
5-Pima/West Speedway	1134	374	312
6-Euclid/N. 1st Ave.	4079	2227	1259
7-22nd St.	2928	1156	821
8-Broadway	10074	5637	3664
9-E. Grant Road	2532	973	687
10-Flowing Wells	1321	766	516
11-Alvernon Way	4279	2283	1590
15-Campbell Ave.	1886	652	482
16-Oracle/Ina	6751	3250	2473
17-Country Club/29th St.	3197	1335	1023
19-Stone Ave.	1535	841	466
20-West Grant Road	418	188	141
21-Congress/Silverbell	768	475	345
22-Grande	754	267	173
23-Mission Road	1600	663	437
24-S. 12th Ave.	920	501	402
26-Benson Highway	1043	511	390
27-Midvale Park	1248	589	480
29-Valencia	1497	879	526
34-Craycroft/Ft. Lowell	2211	1148	839
37-Pantano	760	283	212
50-Ajo Way	615	206	128
61-La Cholla	622	272	257

Figure 17: Sun Tran Routes Weekday and Weekend Ridership

that run every 15 minutes or better all day (red lines and the streetcar in the network map of Figure 14.)

Weekends

In the discussion of frequency and span earlier, we observed that most Sun Tran routes operate at substantially lower frequencies and shorter spans on the weekends. Weekend ridership is much lower on all Sun Tran routes. While fewer people work on weekends, there are still many who must travel to their jobs. Furthermore, even people who are not at work have all sorts of other trips to make. At a lower level of service on weekends, transit is less useful for all these purposes, because lower frequencies mean longer waits and greater inconvenience.

3. Existing System

Geographic Structure

There are several basic structures that can underlie a transit network:

- One is the "radial" or "hub-and-spoke" structure in which all routes lead to and from downtown. Anyone wishing to travel from one non-central location to another must pass through downtown and transfer to another route there. A radial structure makes sense when one part of a city (typically the downtown) is a dominant destination all day – for work, for play, and for commerce. Often, routes are scheduled to converge at a set time (called a "pulse") to reduce transfer times between routes.

- Another structure is the "grid." In a grid, parallel east-west routes and parallel north-south routes intersect all across the city, not only downtown. A grid structure is most suited to a city with multiple activity centers and corridors scattered around the urban area, where many people are traveling to many different destinations, for

all sorts of purposes, all day long. Grid networks are only effective when intersecting routes operate at high frequencies, generally every 15 minutes or better, so that connections between routes do not require long, inconvenient waits.

Tucson is largely laid out as a grid, with most routes operating on grid arterial streets at one mile or one-half mile spacing from one another. However, while Sun Tran routes are physically arranged as a grid, only a few routes operate at high enough frequencies to

make transfer-based grid movements truly convenient. Sun Tran's current Frequent Network is largely oriented towards downtown.

The only frequent line that does not go downtown is 11-Alvernon, but this is one of the most productive routes in the system, and is a good example of what a successful frequent grid element looks like. It offers 15-minute service throughout most of the day, and has consistently high ridership along its segments north of 29th. While it is impossible to know exactly how many
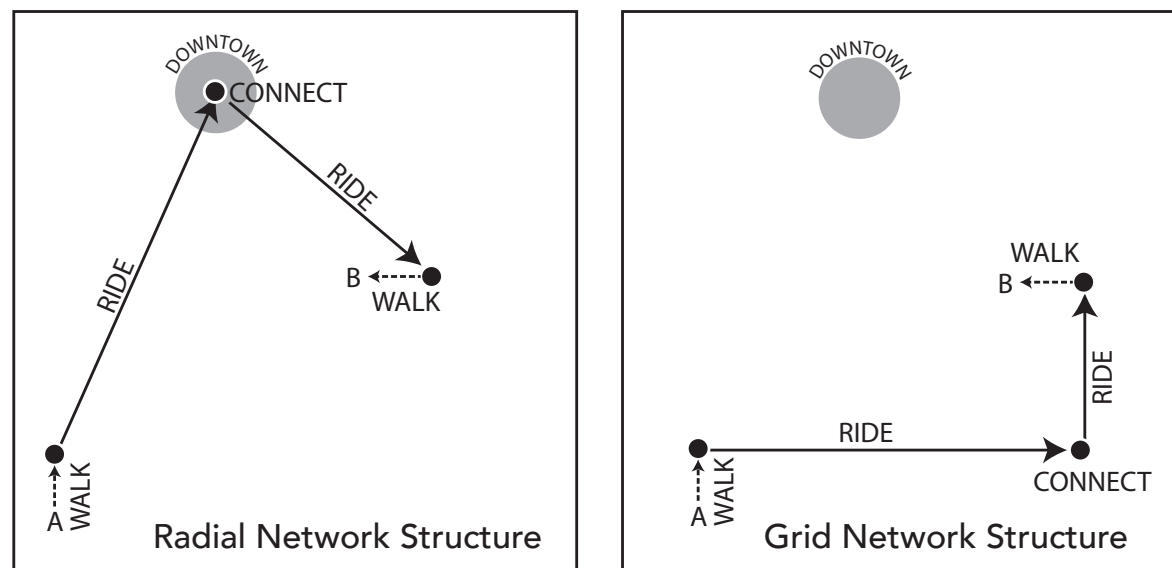

Radial Network Structure

Grid Network Structure

Figure 18: Radial and Grid Network Structure

3. Existing System

people are connecting routes without linked trip data, the intersections where the 11-Alvernon crosses the 7-22nd, 8-Broadway, and 4-Speedway all have very high ridership stops. This pattern shows how a crosstown line succeeds, by combining many local destinations with many connection opportunities. The result can be a more produc-tive service than one that goes into downtown. It is not unusual, in similar systems, for the most productive line to be a grid crosstown, not a radial into downtown.

Grid networks provide multidirectional transit mobility, but they work best at high frequency. The performance of the 11-Alvernon is a strong indicator of what might be possible if a grid of intersect-ing frequent routes were extended to more of the dense areas of central Tucson.

While the bulk of Sun Tran's service is arranged as a grid, the peak express routes are exclusively radial, because they serve a very specific purpose: the downtown peak commute market. These routes typically have their end-points in downtown and in suburban

park & ride lots, and stop at only the most important points between, since most riders are traveling to or from the downtown core.

3. Existing System

Productivity

While ridership is not the only goal of transit (as we will discuss in Chapter 4) it is normal to evaluate transit service in terms of ridership per unit of cost. A key way to measure this goal is **productivity** level – how much ridership is being generated per unit of cost?

To assess this, we examine the number of boardings per revenue hour of service each route in the Sun Tran system generates. The scatterplot in Figure 19 shows the productivity of each Sun Tran route on the y-axis, compared to the midday frequency of each route on the x-axis.

Note that this chart is based on data from 2014, and does not reflect changes instituted in the most recent February 2015 service change.

Revenue Hour A cost unit representing one bus operating in service for one hour. This cost depends on several factors: the length of the route; the operating speed of the bus; the frequency of the route (since higher frequency is supplied by more buses and drivers); and the span of service along the route.

Frequency is a fundamental aspect of transit. How often a vehicle serves a given stop is one of the most important factors in both the usefulness of the service for customers and the operating cost of the route for the transit agency.

A striking fact about frequency is that although higher frequency means more revenue hours, which should pull the productivity ratio down, high frequency often correlates with *high* productivity. This is because frequent service is dramatically more useful than infrequent service, since it allows people to use transit without having to consult a schedule or spend much time waiting at stops. When frequency is deployed serving dense,
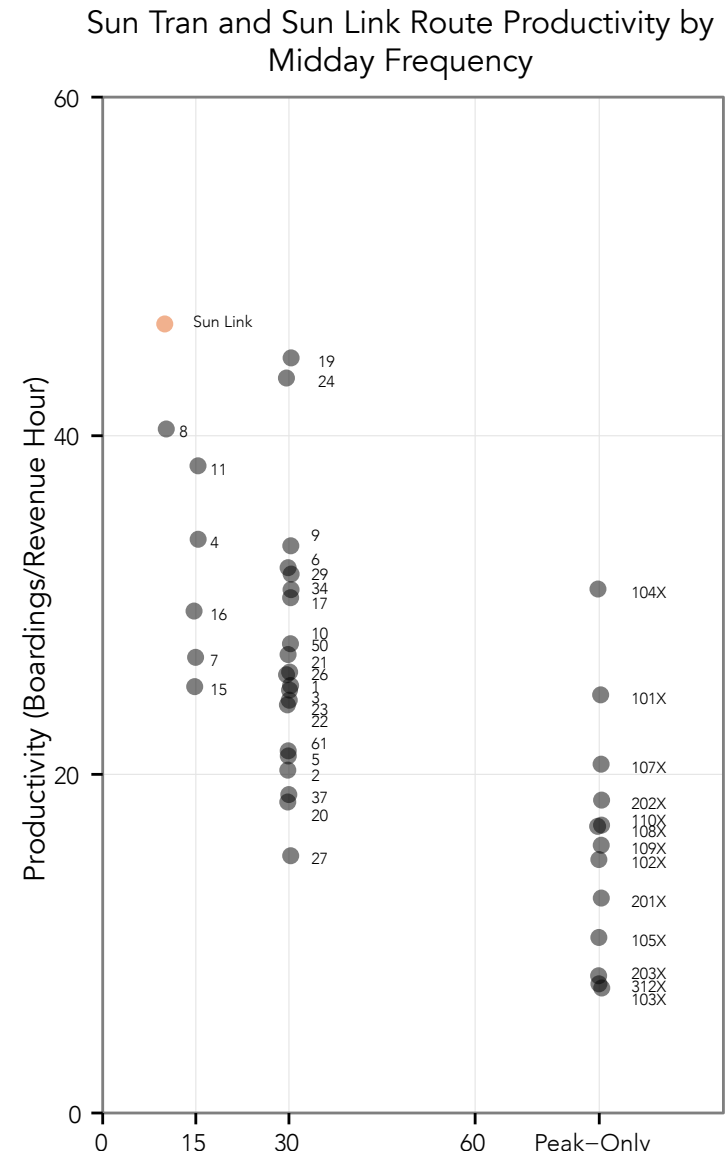

Figure 19: Sun Tran Route Productivity by Midday Frequency

3. Existing System

walkable places, where many people are available and able to use transit, the result can be a higher level of productivity than that of a less frequent service, since the service is now so much more useful for a wider range of purposes.

From Figure 19, we can observe a general correlation between the level of service (frequency) of Sun Tran routes and their productivity scores. Sun Tran's Frequent routes are on average more productive than its 30-minute and peak-only services. The most productive service is also one of the most frequent: the Sun Link streetcar.

On this chart, the outlier routes (those whose productivity is much lower or higher than other routes operating at the same frequency) are also worthy of attention. A very low-performing route suggests that the level of investment may be above what its market can productively support. A route whose productivity is much greater than others of its class may be serving a transit market that could prove even more productive with further investment.

Most striking on the chart of Sun Tran routes are the 19-Stone Ave and 24-S

12th Ave, both 30-minute routes boasting the highest productivity of any in the Sun Tran system (other than the streetcar). While these routes do not carry an extraordinarily large number of people (both are outside of the top ten routes in terms of total average daily boardings), they generate a moderate level of riderhip very efficiently.

The lowest productivity routes in the system are peak-only express routes, particularly those serving outlying areas like the 312X-Oro Valley-Tohono Express, 203X-Oro Valley-Aero Park, and 103X-Northwest-Downtown Express. Sun Tran's express routes serving the City of Tucson, such as the 104X-Marana and 101X-Golf Links, perform comparatively better.

It is important to keep in mind that measuring express routes in terms of revenue hours hides the added cost inherent in peak-direction service: the time required to drive empty buses to the start of the route, usually described as deadhead. Peak only service also requires a large fleet that is not used efficiently, and costs associated with short driver shifts. As a result, many

of these expresses are even less productive than they appear to be in this analysis. Nationally, the low performance of peak express service is not unusual in cities of Tucson's scale. This type of service is very narrowly specialized, and usually succeeds only if there is a major barrier to driving that the express service bypasses, such as routine severe congestion bypassed by bus lanes.

Weekends

Weekend ridership is lower on all routes, but so is the frequency and span. However, some routes, like the 6-Euclid or 7-22nd St, are more productive on Saturdays than on weekdays. A full table comparing weekday ridership and productivity to weekends is shown in Figure 20 on page 34

This means that on Saturdays, the 7-22nd St, 4-Speedway, and 11-Alvernon all outstrip the weekday productivity of the most productive route on weekdays, the 8-Broadway! This means that despite a much lower service level, which makes the service less useful and less convenient, many people still need

3. Existing System

Route	Weekday Productivity	Saturday Productivity	Sunday Productivity
1-Glenn/Swan	25.25	**26.58**	21.45
2-Pueblo Gardens	20.25	**20.34**	18.72
3-6th St./Wilmot	24.98	18.65	15.75
4-Speedway	33.89	**44.00**	**33.96**
5-Pima/West Speedway	21.09	14.44	14.18
6-Euclid/N. 1st Ave.	32.21	**34.26**	32.13
7-22nd St.	26.90	**41.02**	**33.79**
8-Broadway	40.41	37.66	34.83
9-E. Grant Road	33.49	33.12	26.19
10-Flowing Wells	27.71	**33.52**	23.97
11-Alvernon Way	38.22	**44.85**	30.74
15-Campbell Ave.	25.19	**27.05**	**25.53**
16-Oracle/Ina	29.64	**38.75**	**30.24**
17-Country Club/29th	30.43	29.07	25.74
19-Stone Ave.	44.60	29.87	33.41
20-West Grant Road	18.36	14.66	11.44
21-Congress/Silverbell	26.04	18.26	13.75
22-Grande	24.10	17.45	12.72
23-Mission Road	24.39	**30.81**	22.35
24-S. 12th Ave.	43.42	36.68	37.15
26-Benson Highway	25.89	28.58	25.21
27-Midvale Park	15.19	**26.98**	**23.45**
29-Valencia	31.82	**38.89**	26.99
34-Craycroft/Ft. Lowell	30.91	**34.75**	28.35
37-Pantano	18.80	13.95	11.28
50-Ajo Way	27.07	**27.84**	23.40
61-La Cholla	21.40	14.95	14.12

bold - greater than weekday

Figure 20: Weekday / Weekend Productivity (routes prior to Feb 15 service change)

to make trips and are choosing to use transit.

These frequent routes generate a lot of ridership on weekdays by providing convenient, useful frequent service to dense areas and destinations where many people live and work.

Particularly interesting is the Saturday performance of the 11-Alvernon. From the chart in Figure 19 on page 32, we know that on the weekdays, it is a high-performing crosstown route, serving dense land uses; previously, we've discussed its role as a major frequent crosstown in the network. Surprisingly, even at lower weekend frequencies (where the

route is presumably much less useful for transfers), it operates even more productively.

The high productivity of these routes at such low service levels suggests a strong weekend travel market that may be capable of generating a higher level of productive ridership at a higher service level.

Multi-City Productivity Chart

While outliers like routes 19 and 24 are present in most transit systems, the general correlation between frequency and productivity is very common, as reflected in data collected from numerous other transit agencies. Figure 21 compiles the same data for a group of 15 transit agencies, plus Sun Tran, around the United States. Sun Tran's routes are highlighted in red, and occupy the same positions in this chart as in Figure 19.

Many transit agencies do not publish this information at the route level, and the data shown here is by no means a complete picture of transit routes across the US. Nevertheless, through

3. Existing System

examination of this data for over 600 transit routes in 15 cities, we can observe that frequency and productivity are often correlated.

It is worth noting that many other variables play into ridership, and thus productivity, explaining the degree of variation across the frequency levels. These include:

• Quality of each route's transit market (density, walkability, linearity, connectivity)

• Level of investment relative to market quality – is the right frequency deployed in the right place?

Each broad class of frequencies contains a large range of productivity levels by individual routes, many of which excel beyond or lag behind their peers. For instance, the average productivity for all

routes operating at 15-minute or better headways is 38 boardings per revenue hour, but this is within a range of fewer than ten boardings per revenue hour to greater than 90. While frequency and productivity tend to be correlated, when deployed in the wrong place and without the land use and development indicators suggesting high ridership potential, even a frequent route can fail to generate productive ridership.
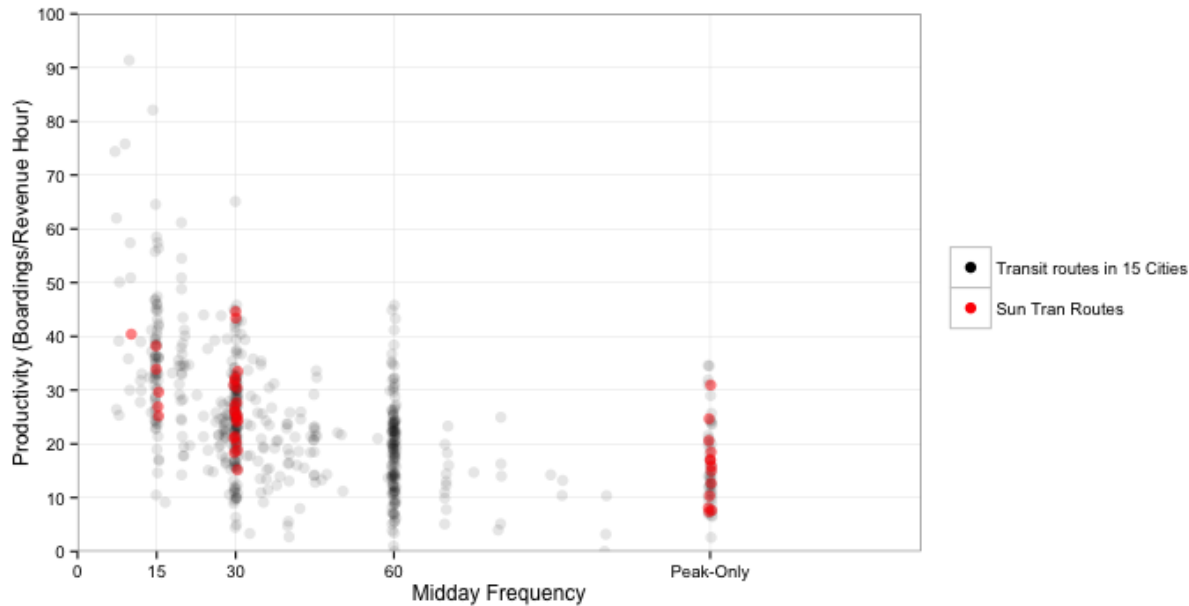
Figure 21: Transit Route Frequency and Productivity: Data from Sun Tran and 15 other US transit agencies

3. Existing System

Peer Review

This section reviews what some comparable cities are achieving with transit investments of various sizes. Comparable cities should not be taken as "peer pressure." Different cities have different values and are entitled to make different choices. However, the peer review can help to give a sense of the range of what is being achieved in similar cities in the US.

We surveyed comparable urbanized areas via the federal National Transit Database (NTD) for 2013, the most

recent year for which data were available for all peers. These areas were chosen based on their size, location, and economic similarities relevant to transit, such as the major university.

Among these cities are obvious regional peers in terms of metro size, competitive proximity, and the presence of a major university.

There is no one right level of transit investment or ridership. Cities and regions make choices to provide more or less transit service, and people make decisions to use it based upon

how relevant it is to their own mobility needs. This peer review is included in order to place Tucson in the context of other urban areas, between which there is substantial variation in transit choices and outcomes.

The transit systems serving this set of peers also vary widely in their costs to provide services. Cost per revenue hour ranges from $73.79 (Tulsa) to $138.69 (Sacramento). However, we found no meaningful correlation between unit costs and either of the other indicators considered here.

Peer reviews are an opportunity for the reader to think about what kind of metro area Tucson aspires to be. If Tucson would rather aspire to the outcomes of less transit-rich cities, it can choose to aim closer to that level of investment and outcome.

Transit Service Abundance

Service abundance refers to the sheer quantity of public transit available – the total number of annual revenue hours of service (excluding all paratransit and vanpool service) per person within the
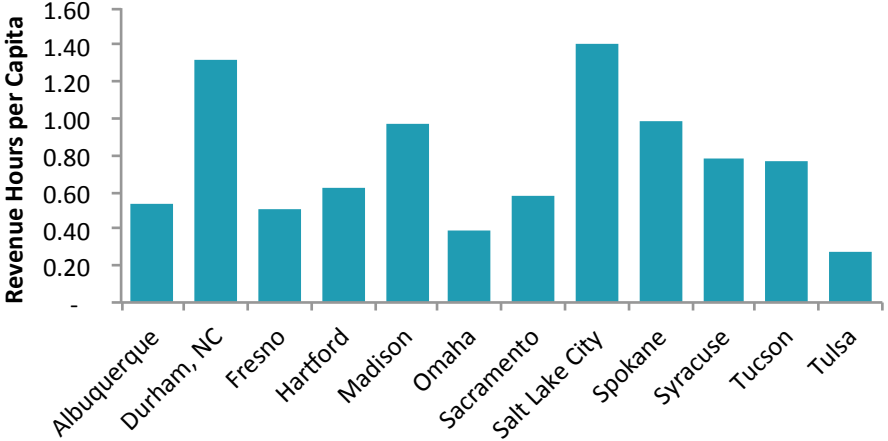
Transit Service Abundance

Figure 22: Transit Service Abundance

3. Existing System

area served. Figure 22 shows this information for the various peer cities, as well as Tucson.

This indicator is arrived at by dividing the total annual revenue hours of all transit agencies within an urbanized area by the total number of people living within that area. This number represents the level of investment in the transit system relative to the number of people in the urban area.

Tucson is in the middle of the pack in transit abundance among the peers surveyed. Regional peers like Omaha and Tulsa provide a much lower level of service than Tucson. Tucson's level of abundance is most similar to that of Syracuse and Hartford, other medium-sized cities with large universities.

Tucson's abundance level is substantially below those of Madison and Spokane, other cities in the same size class which boast big universities. These cities have chosen to provide a very high level of service, as has another, smaller city with some of the same features, Durham, North Carolina.

Transit Service Relevance
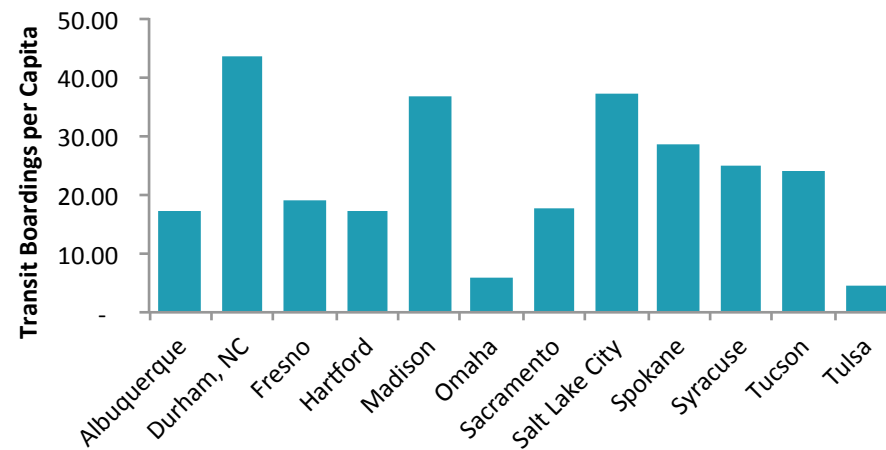
Figure 23: Transit Service Relevance

Transit Service Relevance

A high-level measure of the relevance of transit to the life and economy of a city is ridership divided by population.

The distribution of peers by this measure is very similar to the first chart showing abundance. In short, ridership correlates closely with the quantity of service provided. The cities with the highest level of relevance are Durham, Madison, and Salt Lake City, which are also those with the highest level of abundance.

Tucson's closest peers are also similar: Syracuse and Spokane, with Albuquerque, Fresno, and Hartford each a step down.

The cities that have chosen to invest in transit at a high level have generally seen a high return in terms of ridership per capita. When we examine the correlation between the two measures, we observe a very strong positive relationship[4] between the two.

_____

4 The correlation coefficient between the variables of service abundance and relevance is HERE=0.94. The correlation coefficient is a number between -1 (perfect negative correlation) and +1 (perfect positive correlation)

3. Existing System

Among the peers with a much lower level of investment (Tulsa and Omaha), transit appears to be of minimal relevance to the overall life and economy of the community, with both registering fewer than ten annual transit boardings per capita.

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describing the relationship of two variables; a positive correlation means that as one variable increases, the other examined variable increases as well.

4. Key Choices

4. Key Choices

In the task of transit planning, we deal with limits and possibilities dictated by geometry, geography, and the nature of transit's operating costs. Technical analysis can tell us what is possible under certain levels of funding and certain conditions. But a technical analysis cannot tell us what is right or best for a community, unless it is guided by a discussion about values and priorities.

The values-based part of transit planning deals with questions to which there is no universally correct answer, questions over which reasonable people can disagree. For example:

- Should a transit system be run like a social service, or like a business? Social services respond to small numbers of people with severe needs; businesses about how many people will use the service, not how badly they need it.

- Should the transit system be particularly interested in ridership from certain areas or demographic groups?

- What is the appropriate burden to place on taxpayers in order to provide an adequate level of service?

People will answer these questions differently, depending on their personal preferences and on their values, or on the values of the institutions or organizations whose customers or constituents they represent.

This chapter explores these and other questions in more detail.

Ridership or coverage?

The hardest choice around transit is the tradeoff between ridership goals, which are met by maximizing the number of riders, and coverage goals, which are met by maximizing the number of people to which service is *available*, regardless of whether they ride.

The trade-off arises unavoidably from the nature of the transit product.

No transit agency is at either extreme. But a position on the spectrum between these competing goals needs to be identified – for example, by specifying what percentage of the agency's resources will be devoted to each goal.

Only if there is a clear policy on this can services be measured according to their intended purpose.

Ridership Goal: Maximize Ridership

Do you want transit to be designed for maximum ridership within the budget? This goal serves several common intentions for transit, including:

- Low subsidy, because more of the revenue comes from fares.

- Environmental benefits of transit, including vehicle trip reduction and emissions benefits.

- Support for dense urban development, because a focus on ridership tends to serve these areas well.

Networks designed for ridership provide very attractive and useful service in the areas where the development pattern indicates high ridership potential. These tend to be inner city areas, but the full range of factors are outlined at the beginning of Chapter 2, in "Figure 1: Geographic Indictors of High Ridership Potential" on page 5. In short, high ridership tends

4. Key Choices

to arise from frequent service serving development patterns that are:

- Dense, so that there are many reasons to travel to and from the area around each stop.

- Walkable, so that it is easy to get to and from transit stops.

- Linear, so that transit can run in straight lines as it connects these places, and

- Proximate. Distances are relatively short, so that transit can serve many people without driving long distances.

The Ridership goal is often what is meant by "running transit like a business." Unlike government services, businesses are motivated by the goal of maximum profit. In the case of local transit, where the fare paid by each customer is reasonably constant, this would mean maximizing the number of customers at a given cost.

Government services have a more complex set of motives, but they do resemble businesses when they are trying to maximize the number of users.

It is important to understand both why transit sometimes runs like a business and why it sometimes, intentionally, does not.

Every private business chooses which markets it will enter based on where it believes it can realize the strongest return on investment. If Tucson wanted its transit to work in this way, this would mean deploying all of the service in places where the greatest number of people are the most likely to use it. That is the essence of the Ridership goal.

Coverage Goal: Access for Everyone

It's very common to hear that the goal of our transit services should be "access for everyone." This goal reflects desires such as:

- Service to every city and every area within the service area.

- Lifeline for people with severe mobility limitations, no matter where they live.

- Support for suburban and rural styles of development.

When you say "for all," you implicitly say "every last one, no matter how expensive it is to get to them." The resulting network would run less service in high-demand areas so that it can run more service in low-demand areas, to ensure that everyone has some access regardless of where they live. Service is spread out, which also means that it is spread thin. The resulting frequencies are low, and service may not run long hours. Because the service is not very useful, even in areas of high transit demand, ridership is typically poor.

But while the Coverage goal is not what would motivate a private business, it has played an important role in the shaping of every North American public transit system. Excluding so much of a service area tends to be politically unacceptable. Concerns about lifeline access – not high demand, but extreme needs experienced by small numbers of people – are also a reason to devote resources to the coverage goal.
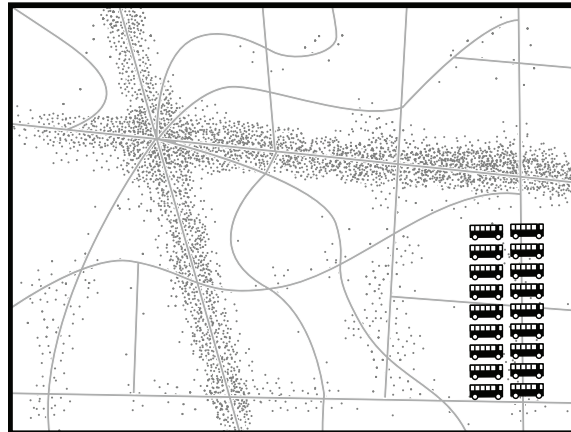
The Two Goals in Practice

Why does a Ridership goal cause service to be concentrated in the

4. Key Choices

highest-demand areas? Because, as we noted previously, frequency correlates with high productivity (ridership per unit of cost). High-frequency service, serving a favorably-built environment, consistently generates the highest "bang for buck," that is, ridership per unit of cost.
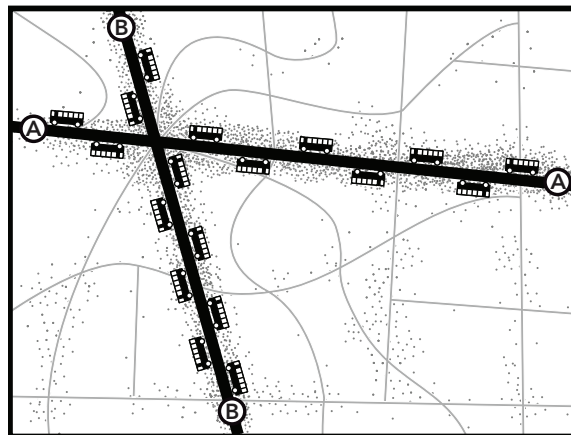
High-ridership planning therefore starts with high all-day frequency and extends it as far as it will go, focusing on the places where the most people will benefit from it. That, in turn, means dense and walkable places where many people are near the stops and can get to the stops. A transit line along an already-busy corridor can also stimulate some new growth along that corridor, encouraging new retail, employment activity, and residential growth.

Transit agencies are often falsely accused of failing at one goal because they are delivering on the opposite goal. For example, a low-ridership route in a low-density neighborhood may be providing an important social service in support of a coverage goal. The route is not necessarily failing to meet a high ridership goal, because it was never intended to attract high ridership.

Imagine you are the transit planner for this fictional town. The dots scattered around the map are people and jobs; the streets shown are ones on which transit can be operated. The 18 buses are the resources the town has to run transit.

Before you can plan transit routes, you must first decide what you want transit to do.

Ridership Goal
"Think like a business"

This transit network is designed to generate high ridership as efficiently as possible. The transit agency has thought like a business, investing its resources only into the best transit markets.
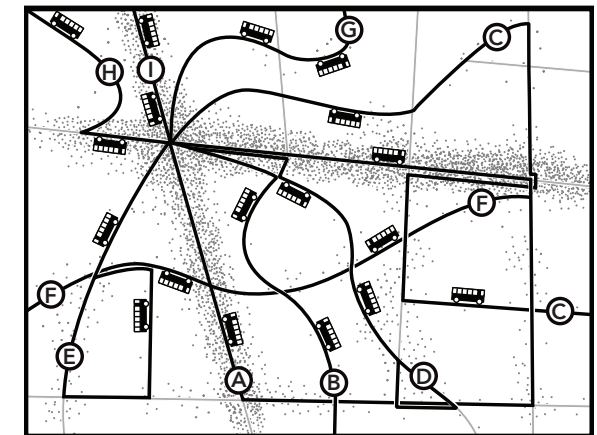
Figure 24: Ridership and Coverage Goals

Coverage Goal
"Access for all"

This network is designed to provide some access to the transit system for all people. The transit agency has divided its resources among many routes throughout the town, none very frequent.

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Side header

Because these two goals – ridership and coverage – are opposite possible uses of the same funding, it is important that Tucson have a conversation with the community about how to balance them.

So throughout this study, we will ask: What percentage of resources do you want to devote to the goal of Ridership, and what percentage to Coverage?

How much transit does the region need?

What if both the ridership and coverage goals are desirable? As we've established, within a fixed budget, it is never possible to fully fund each of them. So a fundamental question for any region, when it comes to transit, is how much is enough?

From our peer review, beginning on page 35, we learned that Tucson already has more transit per capita than many of its regional peers in size, like Tulsa or Oklahoma City, and is comparable to other midsize urban areas with large universities, like Spokane, Syracuse, or Fresno.

However, we also noted that there are cities that could be thought of as peers which have made the decision to invest at a much higher level than Tucson. Madison and Durham are two examples of this: medium-sized cities with big universities that provide a very high level of transit abundance.

The crux of the question around funding is *what do you want the transit agency to do that it is not currently doing?* Some answers to this might be things like "cover a larger geographic area with fixed route service," "build some sort of high capacity transit," or "provide more frequency in central Tucson." As it stands, Sun Tran could do any of these things, but not without making hard choices about the agency's priorities.

For instance, Sun Tran could increase frequencies on all of its inner Tucson grid routes. But at the current level of resources, this would require cutting service in other places, like rush hour express routes or shuttles. This would be a shift from the Coverage goal toward the Ridership goal.

On the other hand, if you want to add service without deleting other service,

a greater level of resources would be required.

Contemplating a higher overall quantity of service is also a question about a community's goals and identity. A city like Durham, one of the surveyed peers, has decided that it wants to make transit a realistic, convenient travel option for everyone. This may not feel like a valuable investment to the people of Tulsa.

How to balance service spending with infrastructure spending?

Transit's ability to offer attractive service can benefit from a range of infrastructure, including rail lines, busways, transfer facilities, and simpler things like stops and shelters.

But transit infrastructure is useless without transit operations, and the actual benefits that transit provides to people arise from transit being operated, not just being built.

This is a key difference between transit and common kinds of public infrastructure, such as roads and buildings. Once

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you've built them, a road or a building can be used. But a transit facility has to be operated, and in transit, operating cost is dominant.

So while a road budget might be mostly about building roads, a transit budget has to be carefully balanced between infrastructure and operations.

Obviously, there is no point in building infrastructure that you can't afford to operate, but this trade-off is bigger than that. Buses, the dominant form of transit service, don't require much infrastructure, but are still a very efficient way to provide a high quantity of useful transit. For this reason, they are found in almost every urban area in the world.

So the tradeoff is this: the more a plan spends on major infrastructure, the less abundant and extensive its bus service can be. Major infrastructure often ends up competing with sheer abundance of bus service, when it comes to dividing up the funding provided by any new local source.

Technology Choices

Which type, if any, of major infrastructure investment is right for a city will depend on a number of factors: the big-picture transit priorities (ridership or coverage), future funding, ridership levels and capacity concerns, reliability issues, real estate aspirations, and the state of local feeling about exclusive transit right-of-way.

Tucson has already made one substantial investment in transit infrastructure: the Sun Link streetcar.

This section discusses several types of transit infrastructure investments relevant to a city of Tucson's size, density and development pattern.

INCREMENTAL IMPROVEMENTS

The simplest, lowest-cost alternative is to continually improve the existing bus system through many small projects and service design changes. These can include fixed infrastructure investments like transit signal priority and queue jump lanes, operational practices meant to improve speed and reliability, or service types approximating some of the features of Bus Rapid Transit.

Such improvements can be a method of addressing specific concerns at a low cost; for instance, a particular intersection causing an inordinate amount of delay might be a candidate for transit signal priority.

Where capacity is an important consideration, the cheapest type of improvement is to simply increase frequency levels on the necessary corridors. This can be effective up to the point at which it becomes more effective or efficient to operate a different, higher-capacity vehicle type, rather than simply adding more service.

Service branding is another method of improving the effectiveness of conventional bus service. Increasingly, many transit agencies are choosing to focus their customer information on highlighting the various service levels offered by a network, with a particular emphasis on the most convenient, most useful services: the Frequent Network.

RAPID BUS

Often, larger vehicles are introduced as part of a "Rapid Bus" or "BRT-lite" effort, featuring distinctive branding

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and other improvements (wider stop spacing, off-board fare collection, sometimes signal priority) meant to improve speed and reliability without taking an exclusive lane.

Using a larger vehicle to solve problems related to overcrowding is a technological solution that is well-suited to corridors where there is overcrowding, but where the case for exclusive lanes or rail is weak because of lower demand, political opposition, or right-of-way or funding constraints.

The Rapid Bus does everything to increase capacity that can be done, without an exclusive right-of-way, grade separation, or rails in the ground. Naturally, the effectiveness of the Rapid Bus is limited by existing patterns of auto traffic in a corridor, as well as the vehicle size at which it becomes unfeasible to run a bus in traffic.
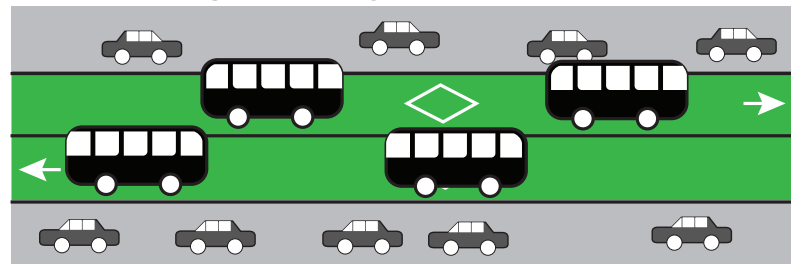
BUS RAPID TRANSIT

Where there is a need for greater capacity and support for exclusive right-of-way, buses can be used as a high-capacity technology. Buses run on dedicated bus-only roads, or exclusive

Transit in mixed traffic
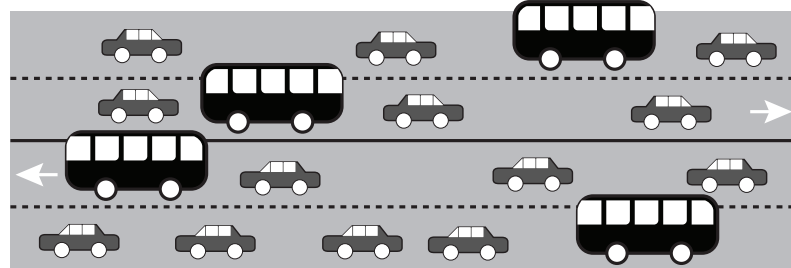
In mixed traffic, transit is exposed to the various movements of all other road users - crashes, turns, lane changes, etc.

Exclusive Right-of-Way

In an exclusive right-of-way, transit is protected from personal auto traffic, and can move without interruption. Transit in exclusive right-of-way can be operated with any type of vehicle. The most important thing is that it be separate from personal auto traffic.
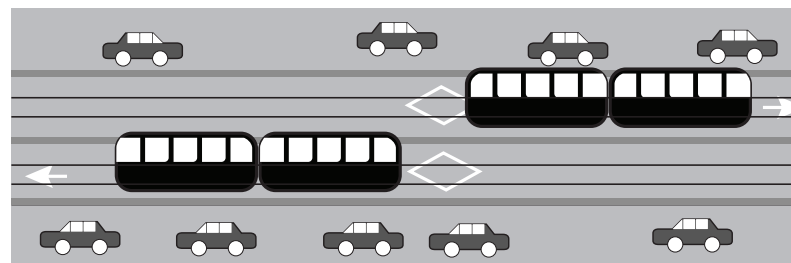

Figure 25: Exclusive Right-of-Way

curbside or median lanes on arterial streets. In some cases, a form of BRT may share HOV/HOT lanes with private auto traffic. Street-running BRT usually

features some sort of charismatic articulated vehicle.

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This technology is differentiated from the Rapid Bus by its exclusive right-of-way, but in reality, there is a spectrum of improved bus technologies. Many BRT products in North America feature exclusive lanes for a portion of their routes, while running in mixed traffic in other sections. Bus-only lanes in areas of high congestion can effect meaningful improvements to speed and reliability. However, even if bus lanes are present in one segment of the route, their absence in other congested locations can produce significant limitations.

A distinction can be drawn between two types of arterial BRT: open and closed. In open BRT, the exclusive lane is not physically separated from auto traffic, and local buses can interline with the BRT system where routes overlap. Closed BRT systems have lanes which are physically separated from traffic, and frequently use a special vehicle designed to interact with a unique station design. Both open and closed BRT can greatly increase the capacity of the BRT corridor, and can provide a substantial increase in capacity, reliability, and speed. However, open BRT, if designed in a way that anticipates interaction with underlying local services, can provide these same benefits to all routes during the section running in the BRT corridor.

STREETCAR

Obviously familiar to anyone in Tucson, streetcars are a high-capacity technology using an electric rail vehicle. While inspired by European streetcars that are often in exclusive lanes, most North American streetcars run in mixed traffic. They are best suited for short corridors where speed and reliability are not primary issues of concern, serving important destinations and dense land uses that can take advantage of the added capacity of each vehicle.

While streetcars can carry more passengers per vehicle than most buses, because they run in mixed traffic, they are vulnerable to the same issues of reliability created by many vehicles traveling in close proximity in the limited space available on surface streets. In mixed traffic situations they are inferior to buses in one key respect affecting speed and reliability: when a disruption arises in the lane in front of a transit vehicle, a bus can often go around this disruption while the streetcar is trapped behind it.

Streetcars are often the technology of choice when there is strong political support for rail, but insufficient need for capacity, speed, or reliability to support a technology which escapes mixed traffic. Streetcar may be a preferred technology due to other reasons unrelated to capacity needs, such as perception of comfort, durability, value, or the expectation of real estate, redevelopment and appreciation outcomes. In recent years, several North American cities have built new streetcar lines using modern vehicles, while others continue to operate historic systems established decades before.

LIGHT RAIL

Light Rail Transit (LRT) is often used where exclusive right-of-way has support, and where high vehicle capacity is needed, but where the volume of transit ridership does not justify fully grade-separated technologies such as heavy rail or driverless rapid transit. LRT is defined by having its own lane or grade; otherwise, the more appropriate term is streetcar. LRT usually runs on

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arterial streets, but sometimes takes advantage of preexisting rail corridors. In some cases, LRT may include short mixed traffic segments, as when the rail lane is used as a turn lane for auto traffic, but these must be limited and signal timing must be designed so that the cars do not block the rail vehicle in normal operations.

LRT almost always has exclusive lanes on its on-street segments, but because it lacks full grade separation, it cannot deliver the highest levels of speed, reliability, and capacity. LRT is vulnerable to disruptions from traffic due to congestion at intersections (though signal priority can largely alleviate this), or from collisions with auto traffic. Additionally, at-grade LRT systems' top speeds are limited by the presence of pedestrians.

Benefits of Major Infrastructure

Some infrastructure improvements save operating cost. They do this in two ways:

- By saving time, which is money for transit. Most transit operating cost lies in the driver's time. Anything that helps transit run faster (rails, busways, bus lanes, signal priority, and so on) saves operating cost. Faster fare-collection systems that speed up boarding are another example.

- By increasing capacity, so that you need fewer drivers to carry the same number of people. One of the main selling points of rail, once demand is high enough, is the much higher capacity in terms of passengers per driver. This means that at high frequencies, one train (and driver) replace several buses (and drivers). This is also why some transit agencies invest in large buses. Faster service is also intrinsically higher-capacity service, because available vehicles and drivers cycle the line more quickly.

Major infrastructure delivers many other benefits, of course:

- It can create a safer and more pleasant environment for customers. Rail in particular also provides a consistently better ride quality.

- In many cases, it may be the only way to deliver a high level of speed and reliability in an important corridor.

- It tends to increase the legibility of transit services, often because the built environment (rail, for example, or a prominent busway) makes the route obvious.

- It is a signal of permanence, since significant public funds have been invested.

- Partly because of its obvious permanence and quality, it sends signals to the real estate market that helps trigger urban development. This last point has become a major argument for rail transit investments, in particular, in the US, and Federal funding criteria now consider these outcomes. Many other kinds of expensive and durable infrastructure have similar "city-shaping" effects to various degrees, including sufficiently high-quality bus infrastructure.

- It has important aesthetic values in its role in the cityscape, which can

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also be relevant to redevelopment outcomes.

- The Federal government can provide large-scale assistance with funding major infrastructure, so these projects attract funding to the region.

Benefits of Low-Infrastructure Operations

While the benefits of transit infrastructure may be evident, there is also a benefit to operations that do not require such major infrastructure spending. Transit that doesn't need infrastructure can spend more on operations, which often means service to more places, more frequently, making for a more useful service.

This principle is why the bus is such a universal tool in transit agencies all over the world. While it too benefits from major infrastructure such as busways, it can function without it and therefore is a very cost-effective way of providing large quantities of transit.

The same principle explains why commuter and intercity rail is often relatively affordable to develop where rail lines already exist. These services use existing rails, and while they often need to add some rails and stations, the cost is often lower than the cost of building a rail line from scratch.

Low-infrastructure operations are also intrinsically incremental. A service pattern can be created without waiting for the infrastructure. It is possible to create service patterns, see how well they perform, and then revise them over time. Successful bus lines do become permanent, but less successful ones (based not just on ridership but on the community's preferred ridership-coverage balance) can be revised.

Summing Up the Trade-off

A major question for a region considering its transit future, then, will be how much of the local revenues to set aside for the "match" needed to attract major infrastructure.

Making this investment requires:

- Valuing the benefits of major infrastructure, listed previously, above

larger quantities of low-infrastructure service.

- A preference for long-term over short-term outcomes. Major infrastructure takes years to get funded, environmentally cleared, and built. For example, the most optimistic estimate for a light rail line is that it could be running eight years after the plan is approved by voters.

- Accepting the risk of not succeeding in competition for the Federal funds, leaving the major infrastructure unfunded.

Appendix : Glossary of Transit Terms

Activity density	Activity density is a combination of residential density and employment density; it measures the combined number of people and jobs per square mile.
American Community Survey (ACS)	The American Community Survey, or ACS, is a product of the United States Census Bureau comprising national data on population, housing, transportation, income, poverty, demographics, and many other topics.
Boardings	A boarding is the event of a person getting onto a transit vehicle. A trip that involves connections between routes will therefore involve more than one boarding.
Connection	A connection takes place when a person uses two transit vehicles to make a trip. It can also be called a transfer.
Coverage	Coverage can refer to the amount of geographic space, the proportion of people or the proportion of jobs that are within a certain distance of transit service. A "coverage ratio" can be calculated for an entire transit system, or for certain types of transit (e.g. frequent transit). An assumption about how far people will walk to a given transit service - often ranging from 1/4 to 1/2 mile - must be made in order to calculate a coverage ratio.
Fixed route transit	Fixed route transit describes any transit service that is operated on the same predictable route. In contrast, paratransit and demand-responsive service may always or often follow different routes for each vehicle trip, as they serve different customers and their trips.
Frequency	Frequency is often expressed in minutes, i.e. a service that comes every 15 minutes has "15 minute frequency." A more technical term for frequency is headway.
Headway	Headway is a technical transit term for frequency. A service that comes every 15 minutes can be said to have a "15 minute headway."

Appendix : Glossary

Land use	Land use describes the way a parcel of land is being used, for example as commercial, industrial or multi-family residential. Land use descriptions can be general or very specific. Land use is distinct from zoning, as land may be rezoned under existing uses and buildings long before changes to its use take place.
NTD	NTD stands for National Transit Database, a federal clearinghouse of general information about transit in the U.S. and information specific to each transit agency. Agencies of a certain size are required to submit financial and performance data to the NTD each year. http://www.ntdprogram.gov/ntdprogram/
Peak	In some places, two peaks of travel (and transit) demand take place each day: in the morning and afternoon, as people travel to and from work and school. However, in many places travel demand peaks only once, in the midday or afternoon, as service shifts change and students leave school.
Peak-only	A transit service that is peak-only operates only during the morning and afternoon travel peaks.
Productivity	The word productivity is often used in transit to describe the number of people served per unit of cost. Productivity can be expressed for an entire transit system, a subset of the system, individual lines or even for segments of lines.
Revenue hours	The time a transit vehicle and its operator spend out in public, available to passengers and (potentially) collecting revenue.
Ridership	Ridership refers informally to the number of boardings or trips taken on a transit system or a particular transit service.
Span	The span of a transit service is the number of hours it operates during the day, e.g. a service may have a 17.5 hour span, running from 6:00 am to 11:30 pm.