SUN SYSTEMS

COMPREHENSIVE OPERATIONAL ANALYSIS

MILESTONE TWO REPORT

MAY 2023

TMD

VISION. PLAN. IMPLEMENT.

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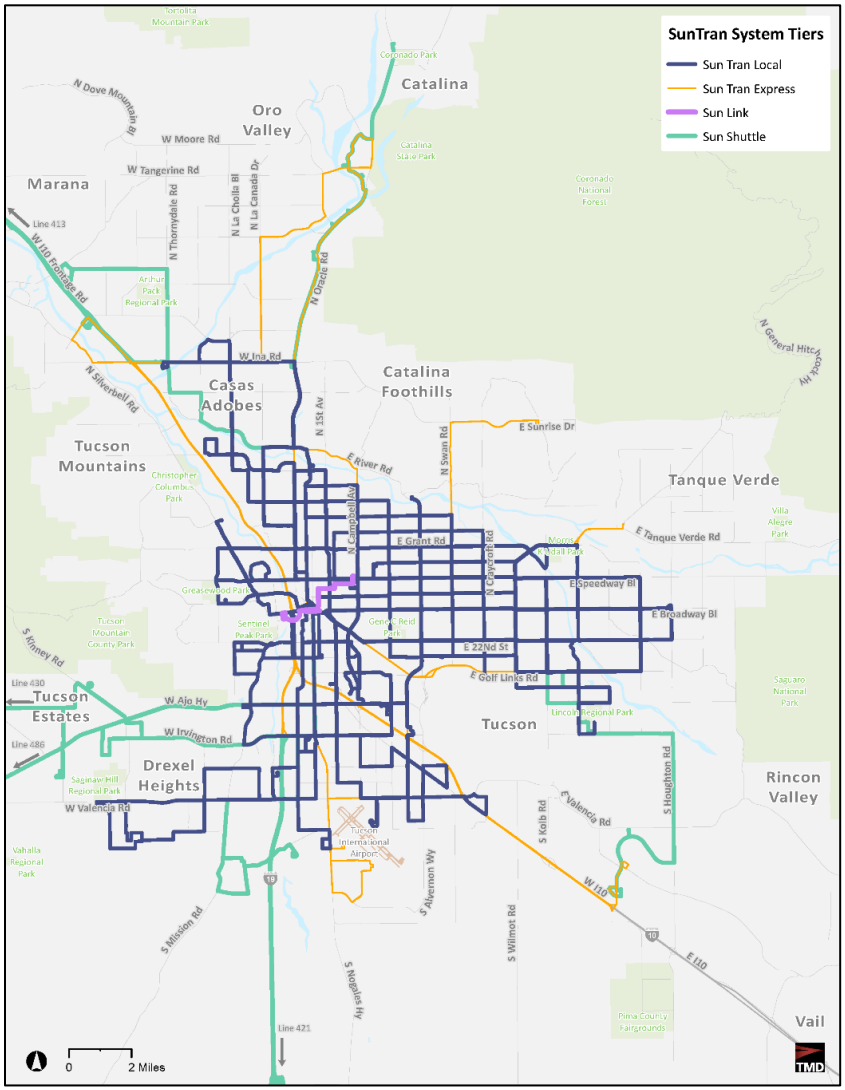
Introduction

The Sun Systems Comprehensive Operational Analysis (COA) is an opportunity to improve transit options in the Greater Tucson area to create a more equitable, effective, and efficient transit network. It will review and evaluate the Sun Tran, Sun Link, Sun Express, and Sun Shuttle services to determine potential improvements. Coming out of the COVID-19 pandemic, travel patterns have changed, and it is important for the transit network to respond to these changes to ensure it continues to meet the mobility needs of the local community. The COA is broken down into three steps, or Milestones. This report covers the items listed in Milestone Two.

- **Milestone One**
  - **System Background** – overview of the services, fare structures, and capital assets of the Sun Systems.
  - **Review of Relevant Planning Projects** – understanding of recent projects that may inform the COA.
  - **Market Analysis** – understanding of population, employment, and demographic patterns that may affect transit demand; understanding of regional travel patterns; analysis of the built environment and its impact on transit service.
- **Milestone Two**
  - **Access and Equity Analysis** – evaluation of the percent of different demographic groups with access to transit services; analysis of key destinations accessible by transit.
  - **Service Assessment** – understanding of the performance of current Sun Systems services; review of ridership trends, route-level performance, community transit access, and strengths and weaknesses of current service delivery.
- **Milestone Three**
  - **Public Involvement** – outreach to the public, riders, and stakeholders to solicit input on potential service changes and receive feedback on draft recommendations.
  - **Service Recommendations –** draft and final service plan developed based on findings from Milestone One and Two as well as input from the public involvement effort.

Data for this Milestone Two report primarily comes from Sun Tran's automatic passenger counter (APC) system for April and May 2022. Data was processed in TMD's in-house Service Analysis System (SAS) to create representative weekday, Saturday, and Sunday service days as the basis for route and network evaluation. Additional data came from the US Census American Community Survey.

Figure 1: Sun Systems Map



Access and Equity Analysis

This analysis assesses each demographic group's relative accessibility to Sun Systems services. Using American Community Survey data from 2020, it is possible to determine the percent of the population of the service area within a quarter-mile and half-mile walk of a bus stop. This report established a baseline, and the goal of the COA will be to increase access for equity populations such as youth and young adults, seniors, minority residents, low-income residents, and zero-vehicle households.

Currently, 60% of the population is within a half-mile walk of a transit stop. Most demographic groups exceed this average, with 71% of young adults, 67% of minorities, 77% of low-income households, and 82% of zero-vehicle households having access to transit. Youth are close to the system average at 59%. The largest gap is seniors, with only 52% within a half-mile walk of a transit stop. Seniors have less access compared to the overall population, and this gap will be more closely examined during the development of recommended service changes. This may be due to the fact that seniors, with higher lifelong career earnings, have purchased homes in desirable communities outside of the city center. As more seniors age in place, they remain dispersed from the urban core where transit service is more robust.

Figure 2: Percent of Population with Access to Transit

Demographic Group	Number within Quarter-Mile	Number within Half-Mile	Percent within Quarter-Mile	Percent within Half-Mile
Total Population	333,683	499,625	40%	60%
Total Jobs	176,371	240,659	52%	70%
Youth (under 18)	66,776	103,075	38%	59%
Young Adult (18-24)	55,978	77,687	51%	71%
Senior (65+)	49,898	77,889	34%	52%
Minority	192,495	287,880	44%	67%
Low-Income	75,894	107,619	54%	77%
Zero-Vehicle	17,933	23,718	62%	82%

Another important metric for measuring the quality of access to transit is to look at access to frequent service. While someone may be within a quarter mile of a bus stop, the quality of service at that stop impacts people's ability to conveniently rely on transit as their primary travel mode. Fifteen-minute service is the industry-wide standard for defining frequent service. At frequencies of 15 minutes or less, most riders will simply show up at a stop without consulting a timetable, since their average wait will be 7.5 minutes. At lower frequencies, even when service regularly operates every 20 minutes, riders will work to time their arrivals with the bus schedule to minimize their wait time. Since the percent of the population willing to plan out their trip is significantly smaller than the percent that wants to just show up and go, having frequent service of every 15 minutes or better greatly increases the potential market of transit riders.

Sun Tran defines their Frequent Transit Network as routes operating every 20 minutes or better throughout the day. Through the COA, the goal will be to increase this to 15 minutes to improve the customer experience. Currently, there are a handful of segments that operate every 15 minutes including portions of Route 4-Speedway, Route 8-Broadway, Route 11-Alvernon Way, Route 16-Oracle/Ina, Route 18-S 6th Ave, and the Sun Link streetcar.

Figure 3: Percent of Population with Access to Frequent Transit (15 minutes or better)

Demographic Group	Number within Quarter-Mile	Number within Half-Mile	Percent within Quarter-Mile	Percent within Half-Mile
Total Population	53,939	111,947	6%	13%
Total Jobs	72,505	99,882	21%	29%
Youth (under 18)	7,813	17,749	5%	10%
Young Adult (18-24)	14,115	25,888	13%	24%
Senior (65+)	7,306	15,948	5%	11%
Minority	27,891	58,689	6%	14%
Low-Income	14,529	29,667	10%	21%
Zero-Vehicle	4,458	8,705	15%	30%

A relatively small percentage of the population (13%) has access to truly frequent all-day service. Jobs are more heavily served (29%) given the concentration of jobs in Downtown Tucson. Young adults (18-24) are also more heavily represented (24%), due to the high frequency of Sun Link, which serves the University of Arizona. Zero-vehicle households are the most represented (30%) which is positive since these households more heavily rely on transit. Youth and seniors are the least represented (10% and 11% respectively), given that they tend to reside more in suburban, lower-density areas.

Population and Job Access by Route

In addition to evaluating access by demographic group, it is also interesting to look at access by route. Figure 4 shows the number of people and jobs within a half mile of each Sun Tran route. It also shows the population to jobs ratio. Routes are generally most successful when they include a mix of origins and destinations, so there are lots of opportunities for rider turnovers. Jobs are a good proxy for general destinations, since non-work trips to places like grocery stores, retail stores, and medical appointments are also employment centers. Routes with high population to jobs ratios are generally less successful because there are fewer places for riders to travel to along the route. However, it is also critical to note that high access is not directly correlated with route ridership and performance. A route could have high access numbers due to having a long trip length, or it could be in an area with demographic groups less likely to ride transit. This is only one indication of potential demand for transit service.

The top five and bottom five routes are highlighted in green and red respectively in Figure 4 below. Routes with the highest population and job access travel through the heart of the central Tucson grid, and many serve Downtown Tucson. Route 17 has the highest population access, but it is also one of the longest routes in the system, traveling through some of the densest parts of Tucson. The five routes with the lowest population access are the shortest routes in the system, and they are also located primarily west/south of I-10. Route 18 has incredibly high ridership, suggesting that much of its demand is derived from its role in the network as a north-south connector rather than from the destinations along the route. The routes with the lowest job access are all located in the southwest, where densities are lower and there are fewer destinations. These five routes also all have the lowest population to jobs ratios, which means that there are relatively few destinations for people to travel to, so there should generally be lower expectations for transit route performance.

Figure 4: Population and Jobs within Half Mile of a Sun Tran Route

Route	Population	Jobs	Percent of Population	Percent of Jobs	Population to Jobs Ratio
1	68,869	24,803	11%	14%	2.8
2	34,738	14,266	6%	8%	2.4
3	82,061	30,750	13%	18%	2.7
4	85,146	27,737	14%	16%	3.1
5	59,739	16,277	10%	10%	3.7
6	41,482	14,200	7%	8%	2.9
7	49,391	13,709	8%	8%	3.6
8	56,716	35,235	9%	21%	1.6
9	52,106	19,925	8%	12%	2.6
10	36,801	14,019	6%	8%	2.6
11	51,820	14,872	8%	9%	3.5
12	25,649	9,814	4%	6%	2.6
15	46,201	14,657	7%	9%	3.2
16	46,535	26,807	8%	16%	1.7
17	114,038	23,660	18%	14%	4.8
18	21,918	9,540	4%	6%	2.3
19	29,045	12,642	5%	7%	2.3

Route	Population	Jobs	Percent of Population	Percent of Jobs	Population to Jobs Ratio
21	19,231	12,445	3%	7%	1.5
22	13,646	8,438	2%	5%	1.6
23	41,688	9,876	7%	6%	4.2
24	21,980	1,487	4%	1%	14.8
25	36,294	11,844	6%	7%	3.1
26	43,643	3,193	7%	2%	13.7
27	34,336	4,210	6%	2%	8.2
29	40,910	6,781	7%	4%	6.0
34	61,637	29,755	10%	17%	2.1
37	33,849	7,751	5%	5%	4.4
50	19,663	1,926	3%	1%	10.2
61	33,105	18,531	5%	11%	1.8

Figure 5 shows similar information for the Sun Shuttle routes. These routes tend to have lower population and job access overall because they are shorter and also serve lower density areas outside the core urban area. For Sun Shuttle routes, ridership is much less correlated with population and job access since the routes are specifically designed to serve certain markets. They also operate at incredibly low headways (every 60 to 90 minutes) and often spend significant portions on, or along, freeways.

Figure 5: Population and Jobs within Half Mile of a Sun Shuttle Route

Route	Population	Jobs	Percent of Population	Percent of Jobs	Population to Jobs Ratio
401	9,495	5,709	2%	3%	1.66
412	33,683	9,883	5%	6%	3.41
413	4,402	4,306	1%	3%	1.02
421	14,484	6,806	2%	4%	2.13
430	16,347	1,140	3%	1%	14.34
440	13,617	2,519	2%	1%	5.41
450	29,256	3,225	5%	2%	9.07

Sun Express is not included in this analysis because these routes are designed to serve very specific markets at specific times. They have limited stops and are catered towards serving certain destinations.

Service Assessment

The Service Assessment seeks to understand how riders use the Sun Systems network and how the various routes perform compared to one another. The goal is to understand the strengths of the current operation as well as identify opportunities for improvement – both in elevating the customer experience and in increasing the efficiency and effectiveness of service delivery.

The Sun Systems network is primarily a grid system. Tucson's major arterials form a one-mile grid network with smaller roads on the half-mile. With transit routes on most major roads, residents are at most a half-mile away from a transit route in any direction, which is convenient for transit access. Grids are an optimal setup for transit since any destination is accessible with one transfer. However, a successful grid system requires high frequency of service to minimize the transfer penalty. Encouraging riders to make use of the full network rather than just individual routes requires that riders can quickly and conveniently transfer between services.

Outside of the central part of the city, the system no longer follows a grid and provides a series of routes to varied destinations. There are few opportunities for transferring between routes, and network coverage is limited to a few major streets. In these areas, it is more difficult to use transit frequently, since fewer destinations are accessible via transit.

While many transfers just take place on-street where routes intersect, Sun Tran does have three major transfer centers: Tohono T'adai Transit Center (TTC), Ronstadt Transit Center (RTC), and Laos Transit Center (LTC). These are off-street facilities where the vehicles can layover and riders can conveniently transfer or wait for their bus.

Figure 6: Pictures of Bus and Bus Bays at Roy Laos Transit Center

How Riders Use the Network

This section analyzes how riders use the network – travel patterns by time of day, day of week, route, and stop – to understand where demand is most prevalent.

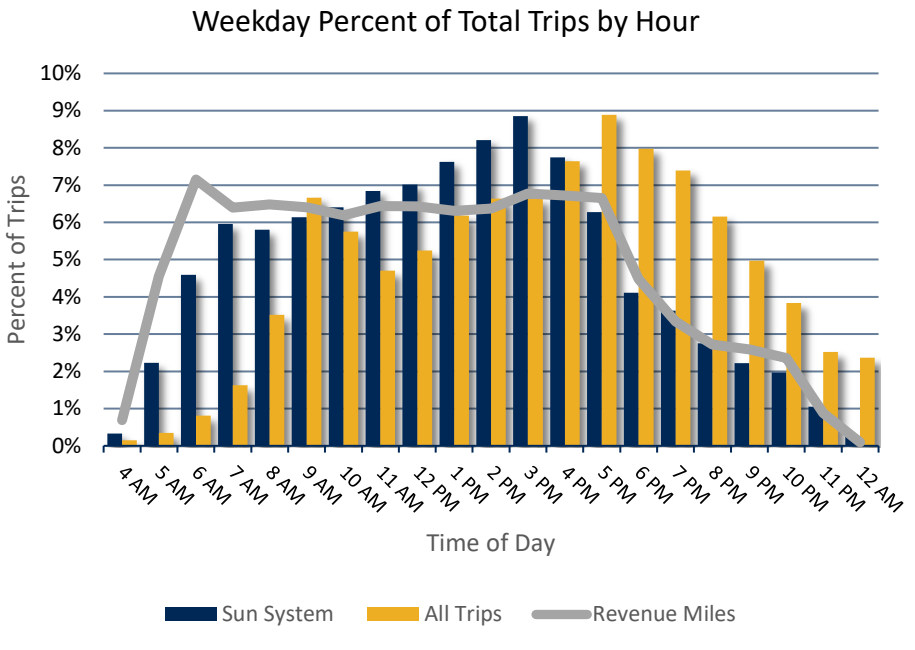
Ridership by Time of Day

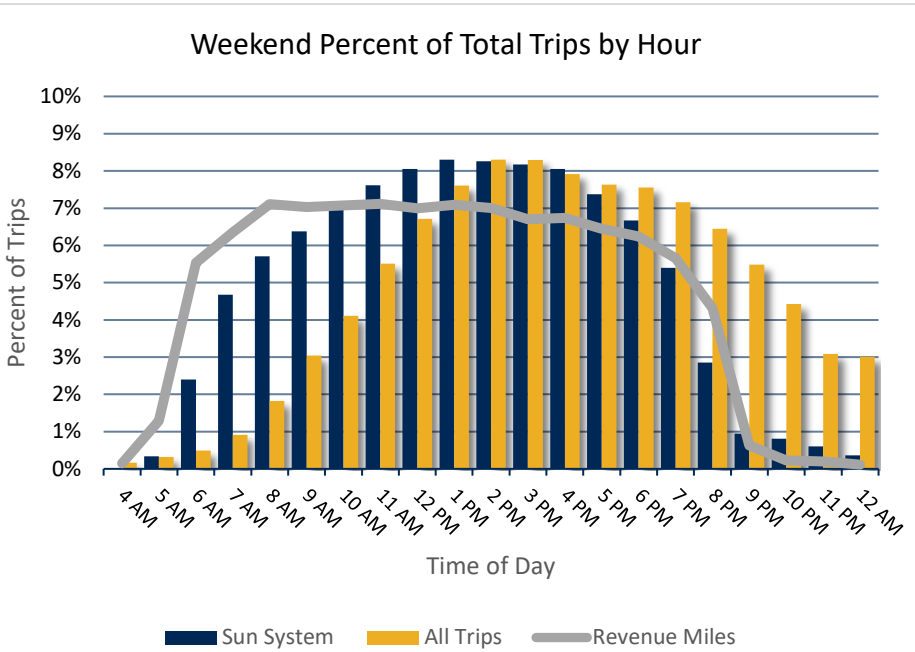
Ridership by hour can indicate how riders use the system and can give insight into how to efficiently allocate resources. As seen in Figure 7, service levels are flat throughout the day, which is different from many other systems that provide higher peak period frequencies during traditional commute times (6:00-9:00 am and 3:00-6:00 pm). Ridership follows a similar pattern, steadily increasing throughout the day, peaking at 3:00 pm, and then rapidly decreasing into the evening. Ridership does exceed service delivery in the afternoon, indicating that this is when service performance is the strongest. Both ridership and revenue miles decline significantly after 5:00 pm.

On the other hand, "All Trips," which comes from regional travel pattern data from the *Replica* software platform, indicates a much different pattern. This represents all trips happening in the region across all modes and shows that activity is the highest after 5:00 pm when people are off work and making trips like running errands, going out to dinner, or attending after-school activities. There is a slight peak in the morning around 9 am and then a dip during the day while people are at school and work. This discrepancy could be due to differing trip purposes between Sun System riders and trips made in private vehicles. There may be an opportunity to increase ridership by expanding evening service to capture more of these trips.

The pattern is similar on weekends. Service levels are constant from 7:00 am to 7:00 pm at which point they drop off significantly, with very little service after 9:00 pm. Ridership follows a straight bell curve throughout the day, peaking around noon. General travel also follows a bell curve but shifted later in the day, peaking around 3:00 pm. Travel at 11:00 am is as great as travel at 9:00 pm. The large difference between all trips and ridership/service levels after 9:00 pm indicates the presence of a demand for later evening bus service. This is also consistent with findings from on-board surveys and general stakeholder outreach.

Figure 7: Ridership, All Trips, and Revenue Miles by Hour of the Day





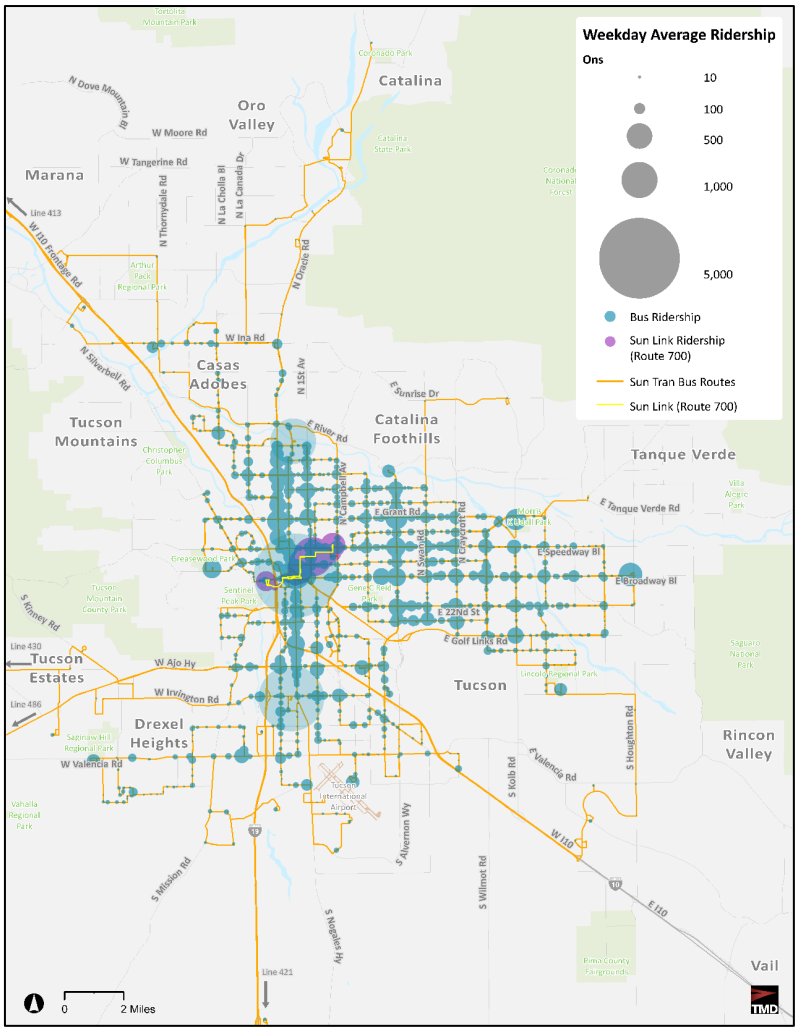
Ridership by Location

Sun Systems has a total of 1,505 bus stops. Ridership is heavily concentrated on a small percentage of the overall stops – 50% of systemwide weekday ridership takes place at just 75 stops. The top 20 boarding locations, excluding Sun Link stops, are shown in Figure 9. The three major transit centers account for almost 20% of all daily boardings – playing a very strong role in the overall network. Outside of the transit centers, most of the top locations are transfer points between major routes – 11-Alvernon, 4-Speedway, 8-Broadway. Other major ridership generators include Walmart, Fry's, shopping malls, dollar stores, and Pima Community College campuses.

Figure 9: Top 20 Boarding Locations, Excluding Sun Link

Stop/Intersection	Riders	Percent of Ridership	Ridership Generators
Ronstadt Transit Center	6,124	11.2%	Major transfer hub
Laos Transit Center	3,284	6.0%	Major transfer hub
Tohono Transit Center	1,629	3.0%	Major transfer hub
Alvernon/Grant	648	1.2%	Walmart, Northgate Shopping Mall
Oracle/Grant	588	1.1%	McGary's Discount Groceries and Other Shopping
Speedway/Alvernon	526	1.0%	CVS Pharmacy, Lucky Strike Bowling, dining destinations
Broadway/Alvernon	512	0.9%	Walmart, El Con Center Shopping Mall
Broadway/Houghton Park & Ride	426	0.8%	Transfer hub, park & ride
Alvernon/22nd St	411	0.8%	Fry's, Police Department, Walgreen's, Goodwill
Stone/Speedway	362	0.7%	PCC Downtown
1st Av/Grant	350	0.6%	Fry's, Dollar Tree, 98 Cents Store
Sabino Canyon/Tanque Verde	332	0.6%	Udall Senior Center, Park, and Recreation Center
1st Av/Ft Lowell	327	0.6%	Walmart
Broadway/Wilmot	320	0.6%	Park Place Shopping Mall, Wilmot Plaza
Broadway/Craycroft	318	0.6%	Park Place Shopping Mall, Williams Center
Speedway/Craycroft	315	0.6%	Walgreens, Circle K, and other stores
22nd St/Craycroft	303	0.6%	Dollar Tree
Craycroft/29th St	295	0.5%	Moan's Oriental Market, QuikTrip
Pima Community College West Campus	283	0.5%	PCC West Campus
6th Av/39th St	268	0.5%	Fiesta Mercado and Food City Supermarket

Figure 8: Map of Average Weekday Boardings by Stop



There are 275 stops (18%) that have five or fewer boardings on an average weekday, representing just 2% of Sun Systems daily ridership. **Given the cost of bus stop maintenance, and the fact that each stop factors into a route's overall running time, there are opportunities to reduce costs by consolidating low usage bus stops.**

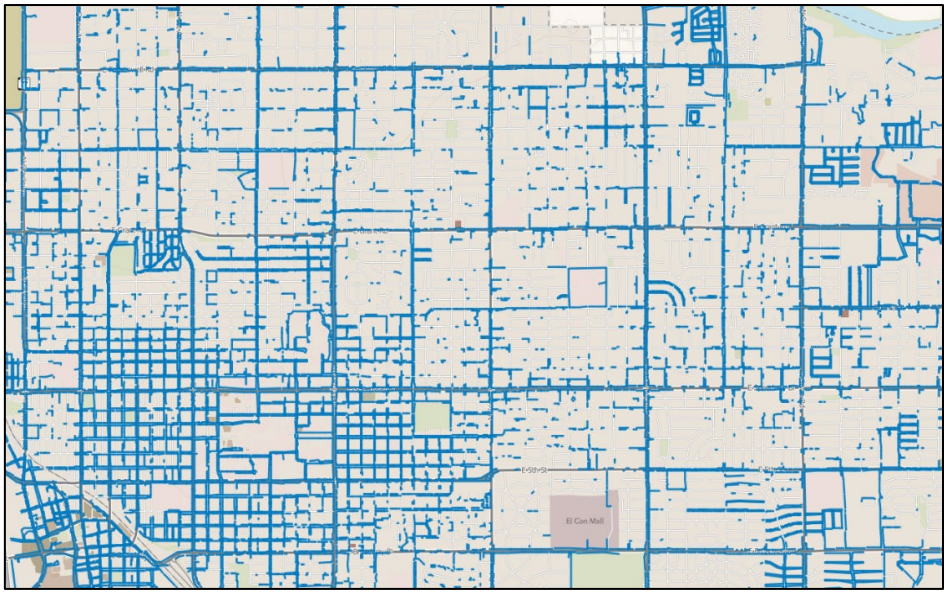
Stop Spacing

Achieving the right stop spacing requires balancing the needs of riders both on and off the bus. Riders off the bus prefer closer stop spacing, so they have a shorter walk to the bus. Riders on the bus prefer wider stop spacing, so the bus stops less often, and they have a faster trip. Targeted average stop spacing in urban environments that best achieves this balance is between 0.25 and 0.33 miles. Quarter mile stop spacing means that riders in between stops are at most a 3-minute walk away from the next stop. Route context must be considered; however, some parts of the route may have closer spacing if serving key destinations while some parts may have wider spacing if serving lower-density areas without destinations. In Tucson, most of the network operates on the one-mile grid with major intersections every half mile. This environment lends itself to quarter-mile stop spacing so stops can be evenly spaced with stops at all the major intersections. As predicted, the core Sun Tran routes have an average stop spacing of .28 miles. No route has an average stop spacing of 0.20 miles or less, suggesting that the service properly balances speed with access.

The quality of the walk experience plays a role in the overall customer experience as well. Walking to the stop is part of a transit journey, and riders should feel safe and enjoy the experience of getting to-and-from the bus stop. A few factors contribute to a high-quality pedestrian environment. Sidewalks are, of course, very important and should be wide, in good repair, and free of obstructions. Protected crossings are also important so that riders feel they can safely cross the street to access a bus stop. Narrow streets can improve the pedestrian environment, as cars generally move slower, and street crossings are shorter.

Tucson is not especially pedestrian friendly. Streets are typically very wide, with fast moving traffic. Many streets, especially outside of downtown and the University of Arizona campus, do not have sidewalks, which diminishes the appeal of walking to a bus stop. For some, an absence of sidewalks creates a complete barrier to access their closest bus stop. Even more challenging for riders is the lack of pedestrian crossings. The grid pattern of the street network in Tucson creates large blocks approximately a half-mile by a half-mile. While these blocks have their own interior street pattern that connects with the major throughfares that define them, there are not always pedestrian crossings mid-block. For a rider going to a destination mid-block, they may have to walk more than a quarter mile to the nearest crossing to access a stop for their return journey or jaywalk to the opposite side of the street. For this reason, most ridership activity is concentrated at the half-mile intervals, and especially at intersections where riders can transfer to another route. Additionally, the lack of street lighting may deter evening ridership. Tucson has certain light restrictions due to the nearby observatory that limits the amount of street lighting. Despite the regulations in place, the streets at night are incredibly dark, and riders may not feel safe waiting long periods of time at a bus stop.

Figure 10: Sidewalks in Central Tucson (Tucson Open Data tucsonaz.gov)



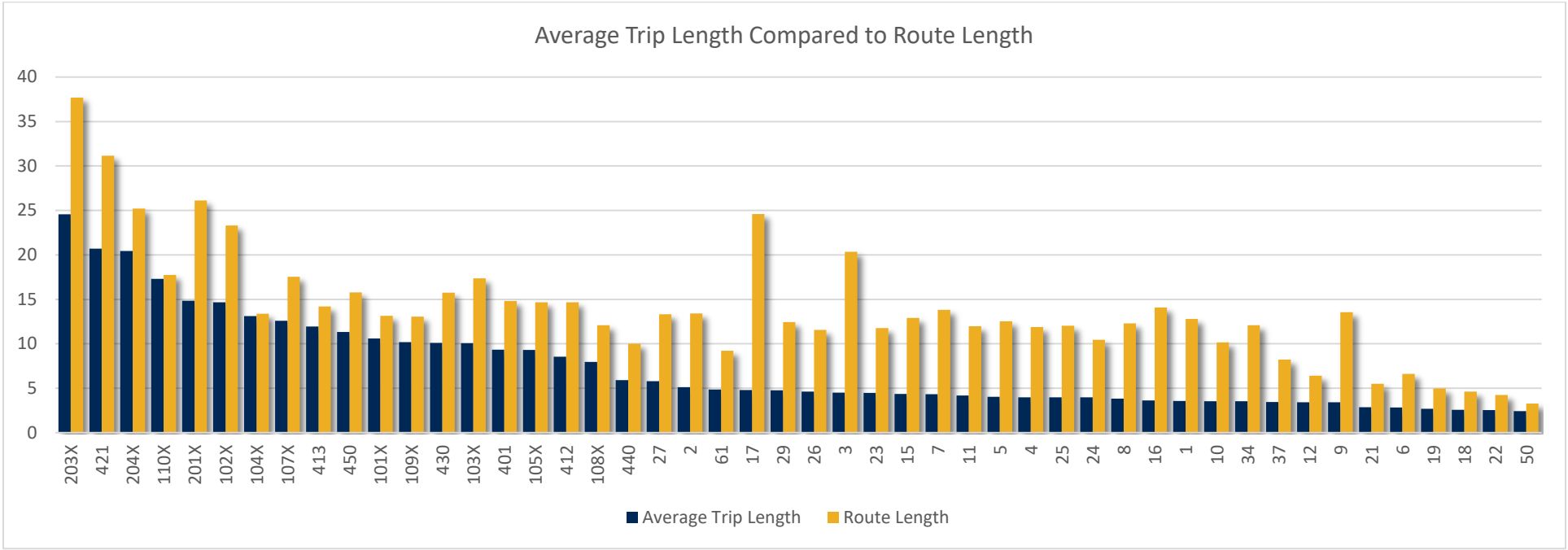
Trip Lengths

Average trip length is an important part of understanding how riders use the network, indicating whether riders use routes for local trips or to commute long distances. Knowing how riders use various routes helps determine if long routes need to be kept as a single service or if they can be broken up into smaller pieces that better reflect travel patterns. **Trip length also affects capacity; when riders travel longer distances, buses are fuller and have less seat turnover. On routes that have short average trip lengths, a single seat can be used by multiple riders as riders board and get off the bus.**

The average trip length across all Sun System routes is 3.67 miles, meaning most trips are relatively short. It is important to note, however, that this is a measurement of the trip length on a single bus; it does not account for transfers. The longest average trip length in the Sun System is on Route 203x (24.6 miles), unsurprising given that this is the longest route in the system. The shortest average trip lengths are on the shortest-distance routes like 50 and 22 and routes like 18 and 19 that serve dense urban areas where destinations are concentrated close together. Short trip lengths tie back to the importance of frequencies. Riders traveling shorter distances will have a lower tolerance for longer out of vehicle wait times. It is less desirable to wait 20 minutes for a 5-minute trip than to wait 5 minutes for a 20-minute trip. Figure 11 shows average trip length by route compared to total route length.

It is also important to review trip length compared to route length. For example, Route 17 has a relatively long route length (almost 25 miles), but an average trip length of 4.8 miles. This route twists and turns throughout Central Tucson, and there may be opportunities to realign portions of the route to better match up origin-destination patterns. It may make more sense to split up the route since few people are traveling the full length, in order to improve service efficiency.

Figure 11: Average Trip Length by Route



Transfer Patterns

The on-board survey conducted in 2022 collected information on rider itineraries and transfer patterns. According to that data, **26% of all riders transfer at least once, and 2.5% transfer two or three times**. In a grid network, it is expected that most riders will transfer once, one route taking them north/south and the other east/west. The transfer ratio is a little lower than expected for a true grid, but there are many routes that do not follow the grid pattern.

Transfer quality is affected by multiple factors, the first of which is frequency. Since riders cannot time their arrival at a transfer location, they have no control over the length of the wait at the stop. It is nearly impossible to time transfer connections for on-street transfers, so having higher frequency ensures that wait times will be minimal with random arrivals. Since most transfers take place on the street, having high-quality amenities, signage, and wayfinding is important for riders.

The top transfer pairs are listed in Figure 9 below. Route 18 is involved in 21% of all transfers, Route 16 in 16%, Routes 8 and 11 in 14%, and Route 4 in 11%. Transfers between 16 and 18 at RTC are by far the most popular transfer pair. In a grid, transfers are expected between north/south and east/west routes, but both 16 and 18 are north/south routes. This suggests high demand for direct connections north and south of Downtown, strengthening the case for a High-Capacity Transit corridor as outlined in the Norte-Sur project. Many of the major transfer pairs connect routes in southern communities with Route 18 at Laos Transit Center, where riders can then access destinations along S 6th Ave, Downtown Tucson, and transfer to more routes at Ronstadt Transit Center.

Figure 12: Top Transfer Pairs

First Route	Second Route	Daily Unlinked Trips	Percent of Daily Transfers	Location of Transfer
16 – Oracle/Ina	18 – S 6th Ave	526	2.5%	RTC
18 – S 6th Ave	29 - Valencia	438	2.1%	LTC
8 - Broadway	18 – S 6th Ave	415	2.0%	RTC
8 - Broadway	11 – Alvernon Way	410	2.0%	On-Street
4 - Speedway	11 – Alvernon Way	339	1.6%	On-Street
16 – Oracle/Ina	17 – Country Club/29th St	323	1.6%	On-Street
18 – S 6th Ave	24 – S 12th Ave	318	1.5%	LTC
7 – 22nd St	11 – Alvernon Way	315	1.5%	On-Street
18 – S 6th Ave	27 – Midvale Park	302	1.5%	LTC
18 – S 6th Ave	26 – Benson Highway	292	1.4%	LTC

Many of these top transfers take place at Laos Transit Center. This facility and intersections are designed such that buses cannot make a left turn to exit the transit center, requiring buses to make a 1.3-mile loop around residential streets. This adds significant running time to multiple routes and may actually require adding an entire extra vehicle to a route for higher frequency services, in addition to the time penalty incurred for passengers. Under existing service, all routes that serve LTC terminate there. However, under the draft plan, in an effort to create more crosstown service to link up origin-destination patterns, there may be recommendations to thru-route services through LTC. In this case, the significant out-of-direction movement needed to make a left turn may become prohibitive, resulting in too high of a cost to make the plan feasible. Serious consideration should be given to reconfiguring the access/egress in and out of LTC, both to reduce costs and improve the passenger experience.

Productivity by Route Segment

One of the most common metrics for measuring performance is productivity, which measures the number of passengers carried per hour of service. Since routes all have different lengths and different service levels, normalizing ridership generated by the number of hours allocated to the route allows for direct route-to-route comparisons. On average, Sun System routes carry 24.6 passengers per hour with the respective productivities by tier: Sun Tran – 24.5. Sun Link – 60.1, Sun Express – 7.8, and Sun Shuttle – 3.7. As shown in Figure 13, productivity is highest amongst the routes and segments connecting the transit centers and in Central Tucson. The ends of the route segments are generally less productive than the segments where ridership is higher. Productivity is also driven by the amount of resources allocated to a route. Routes that are circuitous and travel longer pathways will require more resources to operate at the same frequency than routes that are straight and direct. Route performance is also stronger on the one-mile grid, while routes on the half-mile tend to have lower performance. As seen in Figure 14, productivity varies by time period and day type with the highest average productivities during the afternoon peak period. Performance is lowest in the early morning, especially on weekends. It is higher in the evenings than in the AM Peak, and given the sharp decline in service levels, this could indicate the presence of latent demand for more service.

Figure 14: Chart of Productivity by Day Type and Time Period

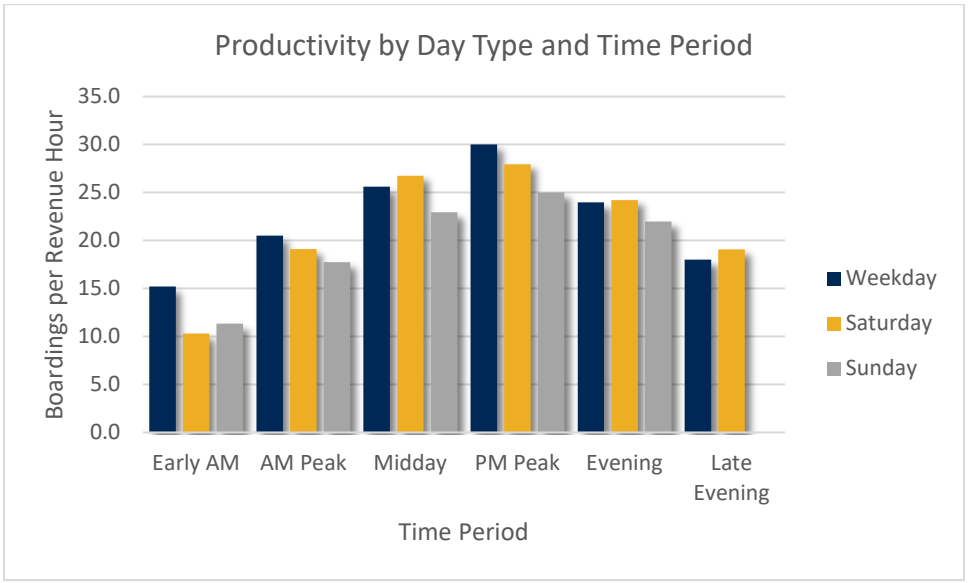
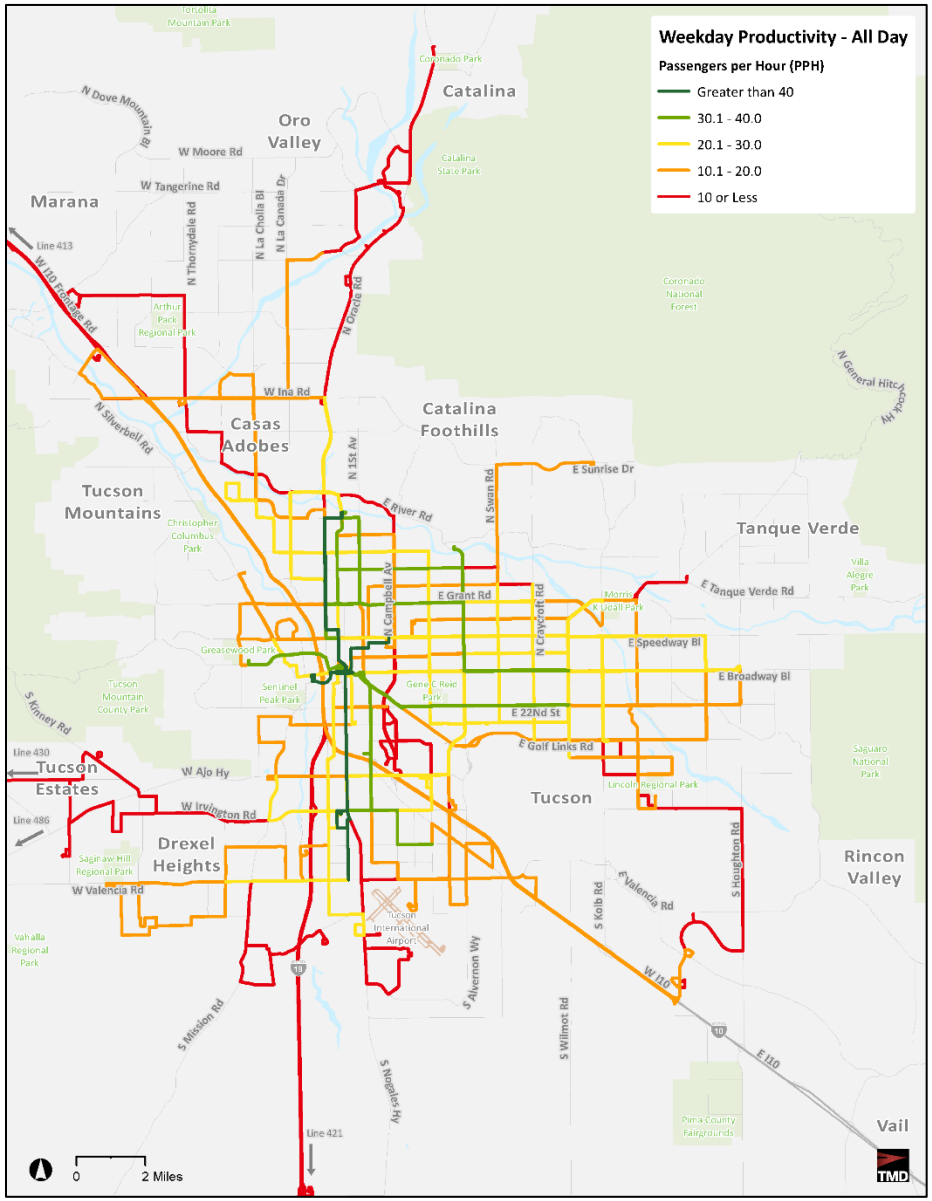


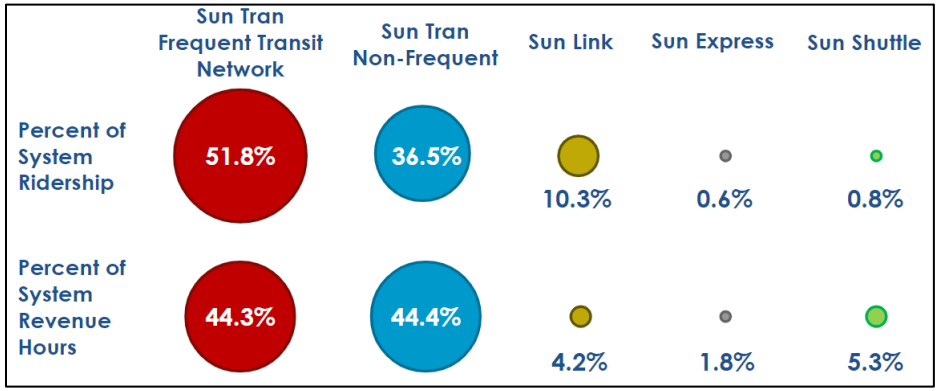
Figure 13: Map of Weekday Productivity by Route Segment



Route Contribution

This section evaluates the performance of the individual routes within the Sun Systems to assess each route's individual contribution. Figure 16 shows each route's weekday boardings, revenue hours, productivity (boardings/hour), and operating cost as well as each route's percentage of the overall system. As shown in Figure 15, together, the Sun Tran Frequent Transit Network (FTN) and Sun Link have a positive return on investment – they carry a higher share of ridership than they use in resources. The non-frequent Sun Tran routes, Sun Express, and Sun Shuttle, have a negative return on investment, carrying a higher cost per passenger.

Figure 15: Return on Resource Investment by Service Type



Ridership

Overall, Sun System carries close to 55,000 boardings each weekday. **The top five routes (16, 8, 4, 11, and 18) carry 33% of systemwide ridership and use only 28% of the resources.** Ridership is well-distributed among top-performing routes – no single route or set of routes dominates the network in terms of overall ridership. This suggests there are many key corridors, and all must function cohesively as a network to provide a seamless riding experience for customers.

Figure 16: Route Contribution Table

Route	Service Type	Weekday Boardings	Weekday Revenue Hours	Weekday Boardings/ Hour	Weekday Operating Cost	Operating Cost per Boarding	% System Boardings	% System Revenue Hours	% System Operating Cost
700	Sun Link	5,637	94	60.1	$15,922.78	$2.82	10.3%	4.2%	6.9%
16	Sun Tran – FTN	3,829	114	33.6	$11,351.44	$2.96	7.0%	5.1%	4.9%
8	Sun Tran – FTN	3,783	126	30.0	$12,756.32	$3.37	6.9%	5.7%	5.5%
4	Sun Tran – FTN	3,725	147	25.4	$14,730.05	$3.95	6.8%	6.6%	6.4%
11	Sun Tran – FTN	3,538	137	25.9	$14,201.85	$4.01	6.5%	6.2%	6.1%
18	Sun Tran – FTN	3,355	65	51.9	$6,208.98	$1.85	6.1%	2.9%	2.7%
17	Sun Tran	2,722	117	23.2	$12,585.99	$4.62	5.0%	5.3%	5.4%
34	Sun Tran – FTN	2,359	95	24.9	$9,656.27	$4.09	4.3%	4.3%	4.2%
9	Sun Tran – FTN	2,255	94	24.1	$9,971.01	$4.42	4.1%	4.2%	4.3%
7	Sun Tran – FTN	2,175	83	26.2	$8,952.97	$4.12	4.0%	3.7%	3.9%
3	Sun Tran	2,041	101	20.3	$10,493.21	$5.14	3.7%	4.5%	4.5%
6	Sun Tran – FTN	1,924	76	25.3	$7,041.61	$3.66	3.5%	3.4%	3.0%
25	Sun Tran	1,649	67	24.7	$6,840.39	$4.15	3.0%	3.0%	3.0%
1	Sun Tran	1,442	69	21.1	$6,750.16	$4.68	2.6%	3.1%	2.9%
12	Sun Tran - FTN	1,386	49	28.2	$5,081.48	$3.67	2.5%	2.2%	2.2%
10	Sun Tran	1,272	47	27.1	$4,781.48	$3.76	2.3%	2.1%	2.1%

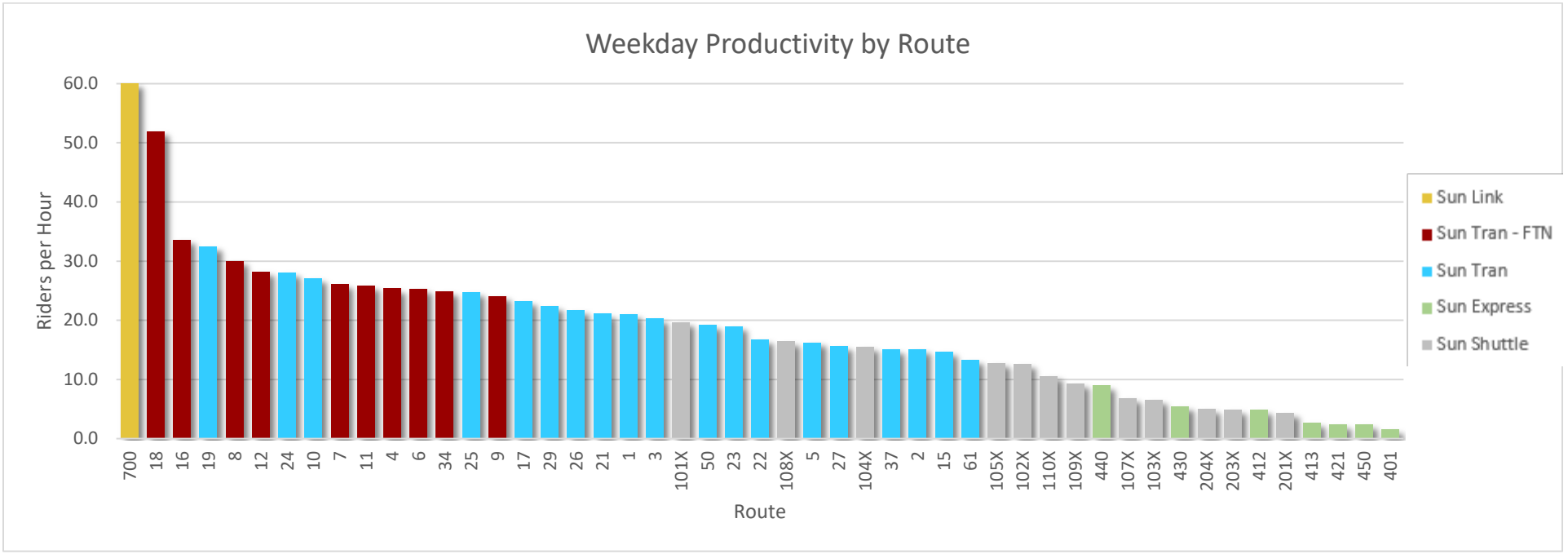
Route	Service Type	Weekday Boardings	Weekday Revenue Hours	Weekday Boardings/ Hour	Weekday Operating Cost	Operating Cost per Boarding	% System Boardings	% System Revenue Hours	% System Operating Cost
29	Sun Tran	1,249	56	22.4	$6,009.70	$4.81	2.3%	2.5%	2.6%
23	Sun Tran	1,233	65	19.0	$6,631.83	$5.38	2.3%	2.9%	2.9%
2	Sun Tran	1,000	66	15.1	$6,889.46	$6.89	1.8%	3.0%	3.0%
19	Sun Tran	977	30	32.4	$2,946.78	$3.02	1.8%	1.4%	1.3%
15	Sun Tran	910	62	14.7	$6,527.72	$7.17	1.7%	2.8%	2.8%
26	Sun Tran	892	41	21.7	$4,674.83	$5.24	1.6%	1.8%	2.0%
5	Sun Tran	854	52	16.3	$5,468.94	$6.40	1.6%	2.4%	2.4%
27	Sun Tran	813	52	15.7	$5,620.14	$6.91	1.5%	2.3%	2.4%
24	Sun Tran	614	22	28.0	$2,394.17	$3.90	1.1%	1.0%	1.0%
21	Sun Tran	601	28	21.1	$2,872.53	$4.78	1.1%	1.3%	1.2%
37	Sun Tran	592	39	15.1	$4,016.05	$6.78	1.1%	1.8%	1.7%
61	Sun Tran	452	34	13.3	$3,613.50	$7.99	0.8%	1.5%	1.6%
50	Sun Tran	398	21	19.2	$2,072.16	$5.21	0.7%	0.9%	0.9%
22	Sun Tran	296	18	16.8	$1,818.71	$6.14	0.5%	0.8%	0.8%
440	Sun Shuttle	131	15	9.0	$934.40	$7.13	0.2%	0.7%	0.4%
430	Sun Shuttle	72	13	5.5	$836.27	$11.61	0.1%	0.6%	0.4%
421	Sun Shuttle	66	27	2.4	$1,742.93	$26.41	0.1%	1.2%	0.8%
412	Sun Shuttle	65	13	4.8	$860.80	$13.24	0.1%	0.6%	0.4%
101X	Sun Express	44	2	19.7	$298.71	$6.79	0.1%	0.1%	0.1%
204X	Sun Express	42	8	5.0	$1,031.35	$24.56	0.1%	0.4%	0.4%
401	Sun Shuttle	36	23	1.5	$1,495.47	$41.54	0.1%	1.1%	0.6%
413	Sun Shuttle	34	13	2.7	$808.53	$23.78	0.1%	0.6%	0.3%
203X	Sun Express	32	7	4.8	$877.21	$27.41	0.1%	0.3%	0.4%
450	Sun Shuttle	31	13	2.4	$819.20	$26.43	0.1%	0.6%	0.4%
107X	Sun Express	27	4	6.9	$468.60	$17.36	0.0%	0.2%	0.2%
201X	Sun Express	26	6	4.4	$709.48	$27.29	0.0%	0.3%	0.3%
102X	Sun Express	25	2	12.6	$265.35	$10.61	0.0%	0.1%	0.1%
110X	Sun Express	23	2	10.6	$346.24	$15.05	0.0%	0.1%	0.1%
105X	Sun Express	20	2	12.8	$188.45	$9.42	0.0%	0.1%	0.1%
108X	Sun Express	20	1	16.4	$151.57	$7.58	0.0%	0.1%	0.1%
103X	Sun Express	19	3	6.6	$299.64	$15.77	0.0%	0.1%	0.1%
104X	Sun Express	16	1	15.5	$151.60	$9.47	0.0%	0.0%	0.1%
109X	Sun Express	12	1	9.4	$159.09	$13.26	0.0%	0.1%	0.1%

Productivity

As mentioned earlier, productivity normalizes ridership generation against the investment in resources. A route can generate a lot of ridership, but if it requires an inordinate amount of resources such that the cost to operate the service is incredibly high, it does not present good value for Sun Systems. "Good" productivity is defined differently for every transit system, but 20 passengers per hour is generally a target threshold for agencies to follow when evaluating fixed-route services. When productivities drop to less than 10 passengers per hour, the cost per passenger tends to increase significantly.

On the whole, Sun Tran routes average 24.5 pph. Despite running higher frequency levels, the routes in the Frequent Transit Network tend to have higher productivity than non-frequent routes, suggesting the frequency is well-matched to demand. Route 18 is by far the most productive Sun Tran route, carrying over twice the service tier average. It is a short, direct route with no deviations that carries high ridership and serves a role as a major transfer line for riders traveling to Downtown Tucson from the south and southwest. Route 18's incredibly high productivity may be an indication that it warrants additional frequency. Route 16 is another direct, linear route with the second highest productivity, and the average is brought down by the extension north of Tohono T'adai Transit Center. South of the transit center, Route 16 carries 42 passengers per hour. Even though Route 19 is not a frequent route, it is a third direct and linear route, paralleling Route 16. In terms of low-performing routes, both Routes 2 and 15 serve the Tucson Marketplace area and have significant out-of-direction deviations. Route 2 is also incredibly circuitous. Route 37, as detailed in a later section, has a high recovery ratio, so its hours are inflated by having extra time at the end of the line, and this decreases productivity. Route 61's low performance may be due to a combination of low ridership (3rd lowest overall) and high recovery (34%).

Figure 17: Weekday Productivity by Route



Sun Express and Sun Shuttle performance is incredibly low, averaging 7.8 and 3.7 passengers per hour respectively. As detailed in the Sun Express section below, this measurement of productivity does not reflect the full cost of operating Sun Express routes since these routes have an incredibly high revenue to deadhead/pull

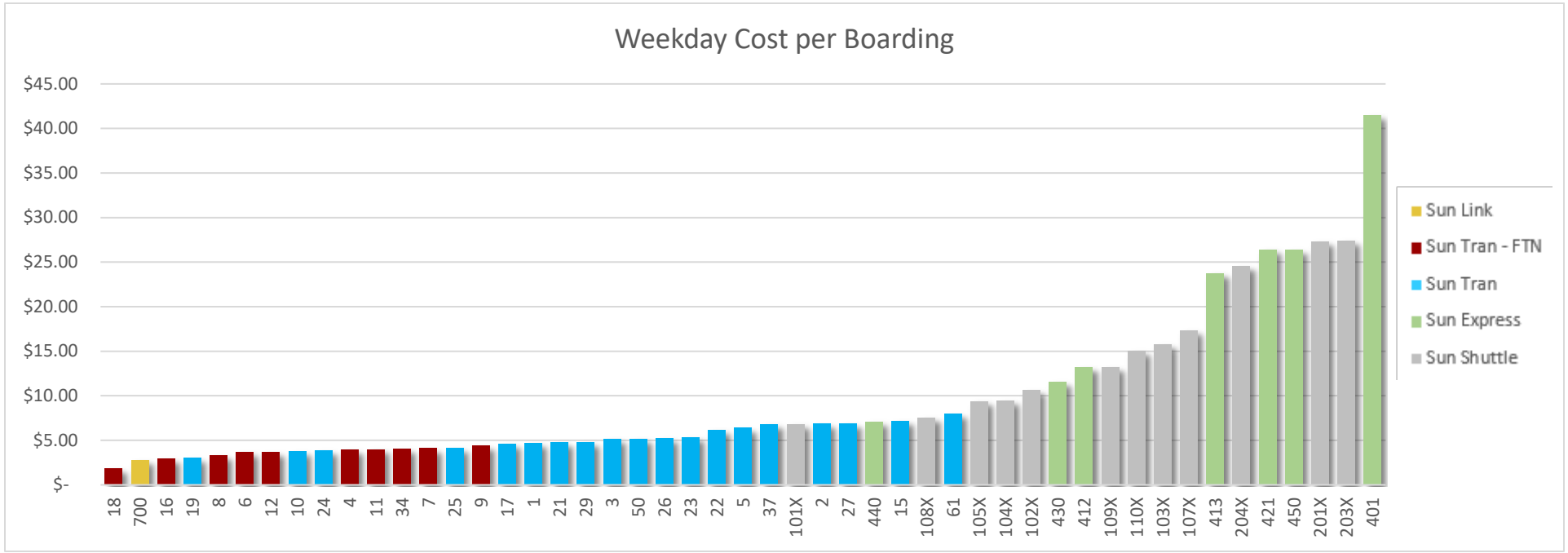
time ratio. Sun Shuttle routes carry an average of 3.7 passengers per hour. These tend to serve lower density areas with low frequencies and subsequently have low ridership which contributes to the low productivity. Since on demand services can generally carry 2-3 passengers per hour, some Sun Shuttle routes may be candidates for replacement by on demand services. However, many routes travel far distances (which contributes to lower productivity), and these types of routes are more difficult to serve efficiently using the on demand model.

Cost per Boarding

Cost per boarding is another way to measure a route's relative performance. The cost is driven by both hourly and mileage-based costs. Total operating cost is equal to (revenue hours x cost per hour) + (revenue miles x cost per mile). This means that two routes with the same number of hours will have different costs if they operate at different speeds, covering a different number of miles per hour with varying fuel and maintenance costs.

Average costs per passengers are $4.20, $16.17, and $17.24 for Sun Tran, Sun Express, and Sun Shuttle, respectively. All of the Frequent Transit Network routes have costs below $5.00 per passenger, which is generally a good target when evaluating fixed-route performance. The Sun Link streetcar (Route 700), despite carrying 10% of systemwide riders, does not have the lowest cost per boarding because its operating cost per hour is nearly twice that of Sun Tran bus service. Sun Express and Sun Shuttle are considerably more expensive to operate on a per passenger basis, some costing over $25.00 per rider. Route 401 has by far the highest cost per boarding. It has the lowest ridership generated per hour but also has high speeds on N Oracle Rd, greatly increasing its mileage cost on a per hour basis.

Figure 18: Weekday Cost per Boarding



Sun Express

Sun Express operates 12 different routes that operate during peak commute periods on weekdays and transport riders from residential areas to major employment centers. These routes have limited stops as well as limited trip times. Most routes operate only one to two trips in each direction daily. The trip times are oriented earlier in the day, most morning trips arrive downtown around 7:30-7:50 AM, and afternoon trips leave downtown around 4:30-4:45 PM, well before a typical 5:00 PM workday end. With only one trip in each direction and no flexibility for daily schedule variances, it is incredibly hard for riders to be comfortable relying on these routes. If for some reason a rider is running late and misses their trip home, there are literally no other options other than calling an expensive taxi or Uber/Lyft.

Overall, the Express routes are under-performing, carrying a total of 306 riders across 12 routes, which is pretty much equivalent to the lowest-ridership fixed-route (Route 22). **While the Express routes are undoubtedly convenient for those who use them, they are incredibly costly to operate on a per boarding basis.** Express routes are more expensive to operate than traditional fixed-route service. For one, the faster speeds mean that each route covers more miles in a set amount of time than a local route, increasing the mileage cost (fuel, vehicle maintenance, etc.). The limited stops reduce opportunities for seat turnover and additional revenue generation (when a fare is being charged).

The express routes also significantly increase Sun Systems peak vehicle requirements. Because all of these buses are being deployed at the same time, Sun Systems has to have a dedicated fleet that is used a relatively small portion of the time. Its required spare ratio is calculated based on the vehicles in maximum service, so the required number of spares is increased. Additionally, because Sun Express buses are branded with their own livery, they cannot be substituted on to other Sun Tran routes.

Express Overlays

Sun Express operates 108X which is an overlay of Route 8-Broadway. It has one morning inbound trip at 7:02 AM (32 minutes) and one afternoon outbound trip at 4:41 PM (41 minutes). Route 8 has inbound trips at 6:37 AM and 7:07 AM that take 48 minutes and outbound trips at 4:30 PM and 5:00 PM that take 54 minutes. The 7:02 AM trip on 108X carries 13 passengers while the 4:41 PM trip carries 7. For comparison, the comparable trips on Route 8 carry 30 to 36 passengers.

For riders traveling between the limited stops on Route 108X at the specific trip times, the route offers a great benefit. Running times are roughly 25-33% faster than on Route 8, so riders have shorter travel times. However, the route is useful for only a handful of riders: riders traveling between two of the select stops on 108X at a particular time of day.

Given the relatively high cost of operating Route 108X ($7.58/passenger compared to Route 8 ($3.37/passenger), it may be more cost-effective to add extra Route 8 service during these times than running an entirely separate express overlay.

Sun On Demand

In November 2020, Sun Tran implemented two microtransit Sun On Demand zones, where riders can reserve a ride through an app and receive curb-to-curb service to destinations within the designated zone. Riders can choose to ride immediately or make a reservation for a trip up to seven days in advance. Service operates Monday-Friday between 6:00 AM and 8:00 PM, Saturday between 8:00 AM and 7:00 PM, and Sunday 9:00 AM to 5:00 PM. Detailed ridership data was received for the month of October 2022.

Sun On Demand – Zone 1

Zone 1 is located just west of Downtown Tucson, stretching from Grant Rd. in the north, Main Ave. in the east, Congress St. in the south, and Silverbell Rd. in the west. While multiple routes pass through the zone, Route 21 Congress/Silverbell and Route 22 El Rio/W. Speedway lie almost entirely within the zone.

In October 2022, Zone 1 carried 541 riders, with an average of 18.3 on weekdays and 15.6 on weekends. Highest ridership is on Tuesdays (23.8 riders) and lowest is on Wednesdays (12.3 riders). While those are the number of completed trips, there is also a high cancellation rate of 31%, spread across all day types. Assuming one vehicle is dedicated to the zone for the 14-hour timespan, the productivity of the zone is only 1.3 passengers per hour. A successful on-demand zone should be able to achieve 2.5-3.0 boardings per hour. In comparison, Route 22 which operates within the service area and has the lowest ridership of any fixed-route still achieves 16.7 boardings per hour. **There are limitations to how many on-demand trips can be completed per hour, but it does seem that the overlap of fixed-route and on-demand service in this zone is limiting the on-demand zone's ridership potential.**

Top destinations include the U.S. Post-Service Reentry Adjustment Center (37 trips), El Rio Library and Neighborhood Center (36 trips), Ronstadt Transit Center (25 trips), Safeway/St. Mary's Plaza (22 trips), Davita Dialysis (19 trips), and the Tucson Section 8 Housing Program (15 trips). Out of these locations, only the Section 8 Housing Program off N Commerce Park Loop is not accessible via fixed-route transit. It is beneficial to Sun Tran to have all trips that can be completed on fixed-routes to be completed as such, since there is not additional cost to providing service on a per passenger basis as those buses would be operating anyway. With on-demand service, any time a vehicle is pulled to do a trip, it is being pulled away from being able to complete another potential trip. The on-demand services should be limited only to trips that cannot be completed using the fixed-route network.

Figure 19: Monthly Microtransit Ridership Zone 1

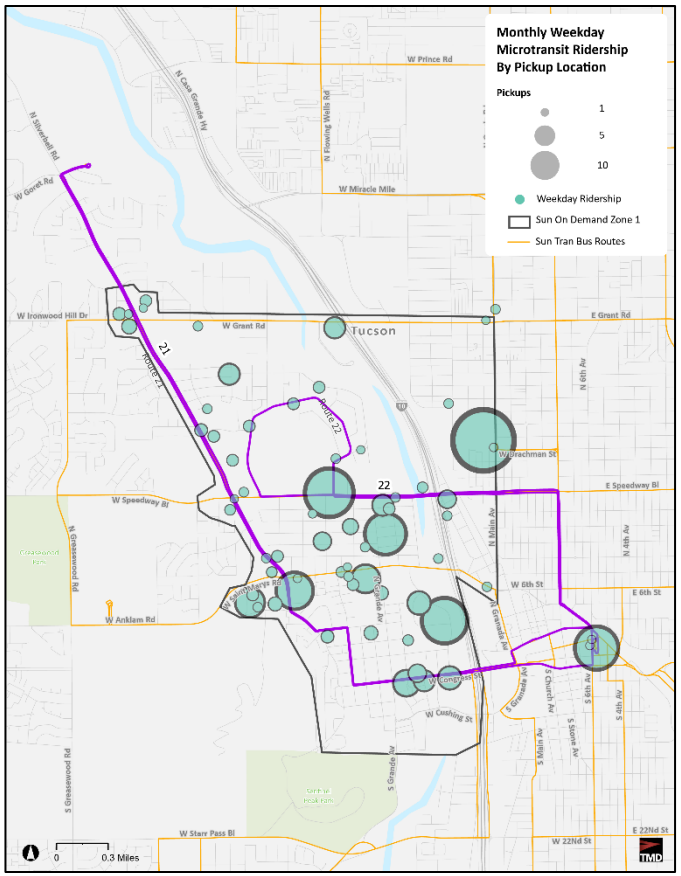
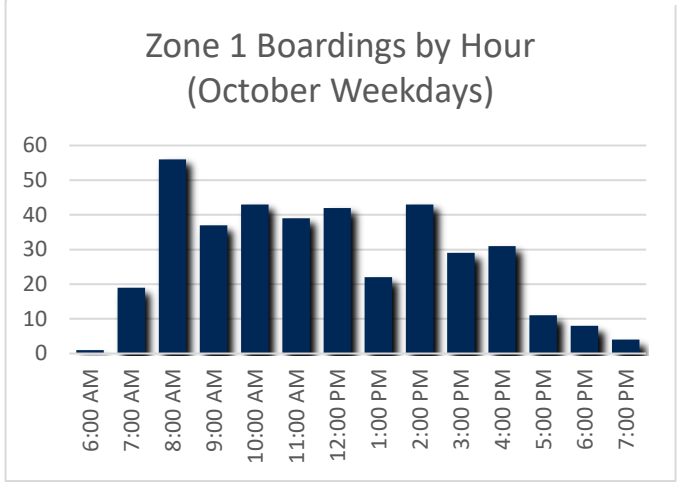


Figure 20: Boardings by Hour Zone 1



Sun On Demand – Zone 2

Zone 2 is in the Tucson Marketplace Area, just east of South Tucson, stretching from 8th St. in the north, Country Club Rd. in the east, Ajo Way in the south, and Park Av. on the west. While multiple routes pass through the zone on the major corridors, both Routes 2 and 15 provide considerable circulation within the zone, serving major local destinations.

In October 2022, Zone 2 carried 340 riders, with an average of 10.9 on weekdays and 11.3 on weekends. Highest ridership is on Fridays (14.5 riders) and lowest is on Tuesdays (7.5 riders). While those are the number of completed trips, there is also a high cancellation rate of 29%, spread across all day types. Assuming one vehicle is dedicated to the zone for the 14-hour timespan, the productivity of the zone is only 0.8 passengers per hour. As previously noted, a successful on-demand zone should be able to achieve 2.5-3.0 boardings per hour.

Forty percent of destinations are to just five locations – Walmart (36 trips) and Costco (11 trips) at Tucson Marketplace, Ronstadt Transit Center (17 trips) in Downtown Tucson, Banner University Medical Center (15 trips), and Safeway (11 trips). Some of the other large trip generators are individual residences where occupants make multiple trips per week.

Fixed-route service in this area is also low-performing. Route 2 between Kino & Cherrybell and BUMC falls entirely within this zone, and that segment carries only 8.7 passengers per hour, making it the second lowest-performing fixed-route segment in the entire Sun Tran network. It is joined by the Route 15 segment between BUMC and U of A which carries 8.8 passengers per hour and is the third lowest-performing segment in the network. Though the area around Tucson Marketplace and ML King Jr. Way are planned for significant development, the roadway network poses challenges for transit. Both Routes 2 and 15 spend significant time traveling out of direction to loop around and through Tucson Marketplace, and still cannot get riders closer than 1/3 of a mile from Walmart. Ideally, on-demand service or first-last mile mobility options would be able to close the gap between the destinations and fixed-route transit stops such that Sun Tran service could be streamlined onto South Kino Pkwy.

Figure 21: Monthly Microtransit Ridership Zone 2

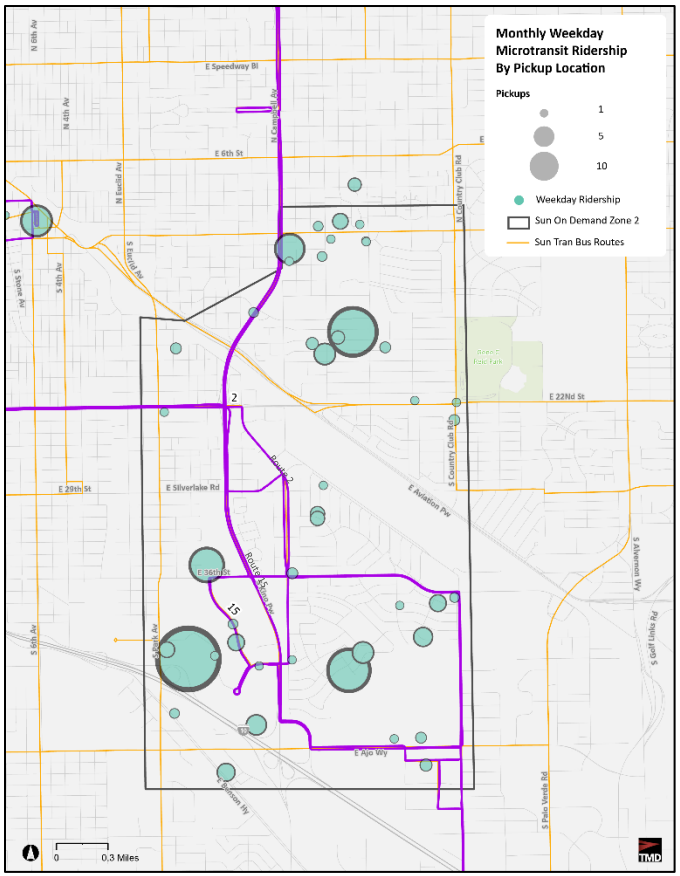
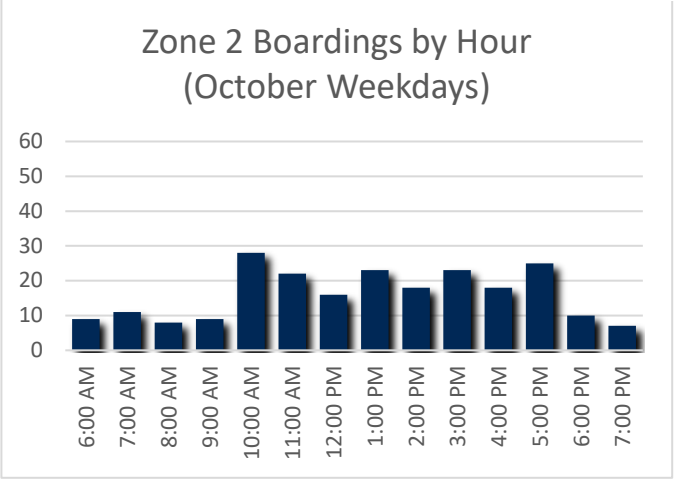


Figure 22: Boarding by Hour Zone 2



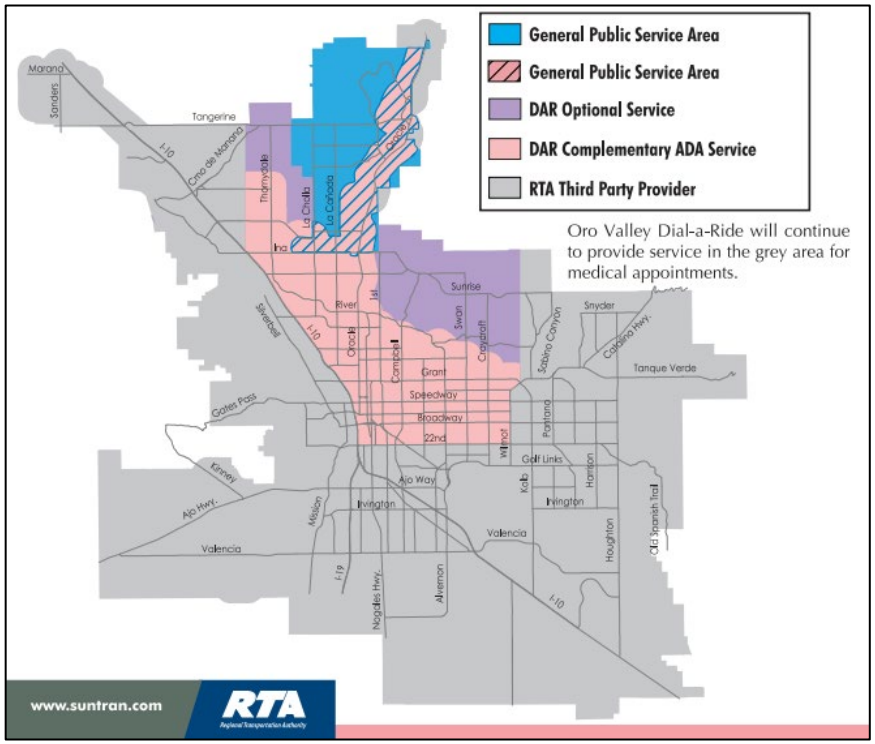
Sun Shuttle Dial-a-Ride

In addition to the 400-series fixed-route shuttles, Sun Shuttle also operates three general public Dial-a-Ride (DAR) zones. Within these zones, Sun Shuttle provides curb-to-curb service for trips within a designated service area. Reservations must be made one to seven days in advance, but some same-day service is available.

Oro Valley

Oro Valley is located approximately 10 miles due north of Downtown Tucson, and it is by far the most-used Sun Shuttle DAR zone. The General Public service operates between 6:00 AM and 8:00 PM on weekdays. Included in the zone are multiple transfer points to Sun Tran and Sun Express routes that provide connections into Tucson. Seniors over the age of 65 and ADA-qualified passengers are eligible to travel outside of the designated General Public Service Area as long as their roundtrip originates within that zone. This allows riders with direct access into Tucson east of I-10 as far south as 22nd St and as far east as Wilmot Rd. Riders can also go beyond these boundaries for medical appointments at major healthcare facilities. The ADA-service also operates on weekends between 9:00 AM and 6:00 PM.

Figure 23: Oro Valley Dar Zone



On average, there are 96 riders a day in the General Public zone, 150 in the ADA zone on weekdays, and 38 in the ADA zone on weekends. Overall, the ADA zone carries 2.4 passengers per hour while the General Public zone carries 1.6 passengers per hour. Given the large nature of the service area, there are no major trends in travel demand patterns. The largest ridership generators are individual homes going to varied places across the service area. It would seem that there would be a large amount of overlap with Sun Van services that complement Sun Tran fixed-routes. The zone extends significantly beyond Oro Valley, allowing passengers to travel to destinations within central Tucson. Given the overlap, there may be an opportunity for cost savings by streamlining operations between Sun Shuttle DAR and Sun Van services for ADA passengers.

Marana/Avra Valley

The Marana/Avra Valley zone launched in June 2022, replacing Sun Shuttle Route 410. The two cities are located roughly 25 miles northwest of Downtown Tucson. The zone provides internal circulation between destinations in those two cities. Service is operated in this zone on weekdays between 6:00 AM and 7:00 PM. Individual trip data for the Marana/Avra Valley zone was provided for September 1-October 31, 2022. Data was available for 25 weekdays, over which time the DAR carried 167 riders (an average of 6.7 rides per day on days where there was any rider activity). There were a total of 217 trips requested, but 33 were no-shows (15%), and 17 were cancellations (8%). The 167 rides were completed by 33 individuals, and 54% of all trips are completed by just 7 individuals.

The service is primarily used for riders to gain access to the Marana Main Health Center. Out of the 167 completed one-way trips, 43 end at the Marana Main Health Center, representing one-quarter of all trip ends, and roughly one-half of all roundtrip purposes. Additional destinations include Marana Middle School, Estes Elementary School, and Ora Mae Park; however, these locations only have about six to seven trips over the two-month period. The remaining trips are to individual residences, and the number of trips depends on how frequently that rider uses the service.

Green Valley/Sahuarita

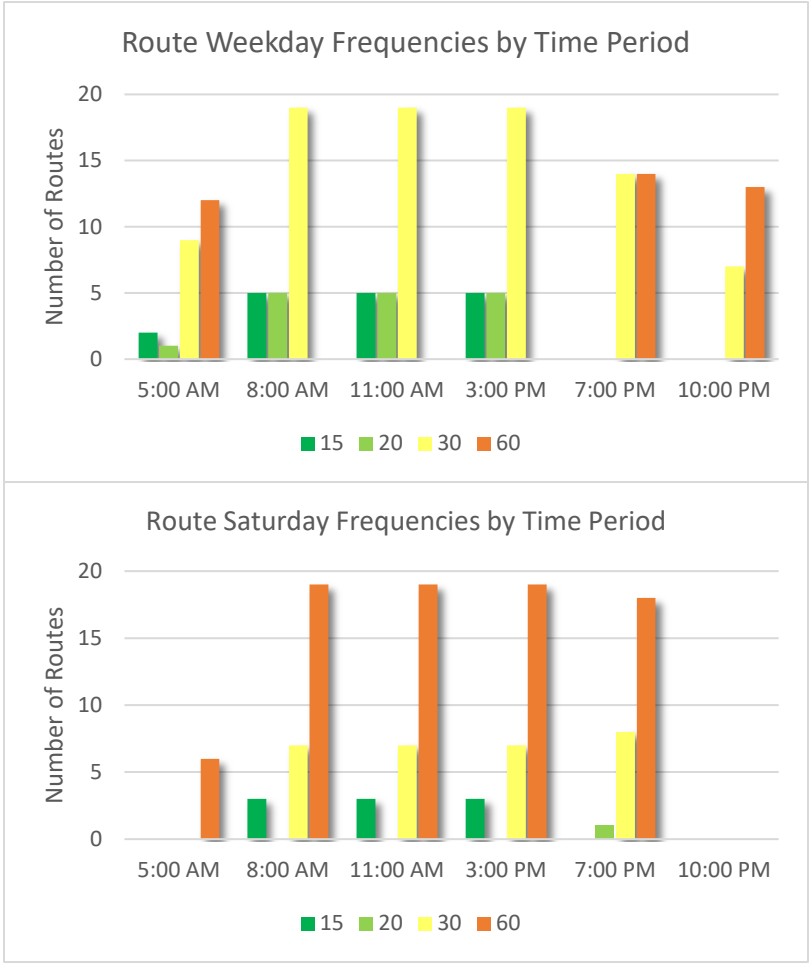
Green Valley and Sahuarita lie roughly 25 miles south of Downtown Tucson along I-19. The development is concentrated along the freeway, spanning only about a mile on either side of I-19, meaning that the freeway serves as the major arterial for most trips. The Green Valley/Sahuarita zone operates 6:00 AM to 7:00 PM weekdays and 9:00 AM to 3:00 PM on Saturdays. Between April 25-May 28, 2022, the zone carried 572 riders, an average of 21 trips on weekdays and 8 trips on Saturdays. A total of 682 trips were requested, with 72 no-shows (11%) and 38 cancellations (6%). The 572 rides were completed by 67 individuals (7 individuals scheduled trips but either cancelled or did not show up for any trip). Trip generation is broadly distributed among individuals. A total of nine riders used the service 20-29 times, 14 used it 10-19 times, 12 used it 5-9 times, and the remaining 32 used the service less than 5 times. In terms of trip purpose, 334 were for Leisure, 68 for Dialysis, 49 for Medical, and the remaining 231 for "Other."

The most common destination is La Posada Community services, which represents 82 out of 533 weekday trips (15%). The second most common destination is the shopping district off S Nogales Hwy with Walmart, Madera Market Place, Ross, Dollar Tree, Sprouts, T.J. Maxx, etc., carrying 73 trips. Additional common destinations include Dialysis Clinic, Inc. (32 trips), Safeway at Continental Shopping Plaza (10 trips), and Fry's at Rancho Sahuarita Market Place (9 trips). Most of the remaining trips are to individual residences.

Service Quality and the Customer Experience

Frequency and Span of Service

Figure 24: Route Frequencies by Time Period



Frequency of service, or how many trips a route operates per hour, is the number one factor that attracts riders to use the bus. Riders want to be able to show up at a stop without consulting a schedule and have a bus arrive within a few minutes. When service is infrequent (trips are more than 15 minutes apart), most riders will not spontaneously use transit, but rather will plan their arrivals around the timetable to minimize wait time. This requires them to organize their plans around the bus schedule, making transit much less attractive. Frequency becomes even more important in a grid system like Tucson's because of the heavy reliance on transfers to complete a trip. When transferring, riders do not have control over their arrival time at the stop, so they cannot choose to minimize how long they wait. Low frequency service with a transfer also greatly increases the length of someone's trip, since they have to factor in the wait time in between trips.

As shown in Figure 24, on weekdays, most Sun Tran routes operate at every 30 minutes or less. There are 10 Sun Tran Routes (4, 6, 7, 8, 9, 11, 12, 16, 18, 34) that are a part of the Frequent Transit Network along with the Sun Link streetcar. These routes operate every 20 minutes or better, Monday through Friday, 6 AM to 6 PM.

Service levels drop significantly on weekends, falling to 54% and 43% of weekday levels on Saturdays and Sundays, respectively. **Additional weekend service was the number one most requested service improvement from riders in the 2022 on-board survey**. All Sun Tran routes operate seven days a week, but their frequency levels drop from 29 routes that operate every 30 minutes or better during the week to just 10 routes on Saturdays, and 7 routes on Sundays, with most routes halving their weekday headways. Only three routes, the 8, 16, and 18, maintain the 15-minute frequency on Saturdays. Consequently, ridership drops on weekends as well, carrying 57% of weekday ridership levels on Saturdays and only 39% on Sundays. **Carrying high frequencies over to the weekends is an important part of maintaining ridership**. Trips on weekends tend to be more discretionary (less work and appointment-based), and riders want to be able to make these trips spontaneously without having to plan them in advance. Transferring also becomes a lot more difficult since wait times between routes doubles where they are not timed to connect.

Along with a decrease in frequency, the service span is also shortened on Saturdays and Sundays. On weekdays 24 out of 29 Sun Tran routes begin service at 5:00 AM, and 20 out of 29 operate until 11:00 PM. On Saturdays, the span shortens to 6 out of 29 routes beginning at 5:00 AM and most routes ending by 9:00 PM. Routes 4, 12, and 29 are the only routes with departing trips at 9:00 PM on Saturdays. On Sundays, the trend continues with 11 being the only route which begins at 5:00 AM. Additionally, only 9 out of 29 Sun Tran routes operate until 9:00 PM on Sundays. **The Sun System COA survey and community outreach found that the need for later service hours on weekends was overwhelmingly the most desired time period for additional service among current riders.** Having a robust

service span is important because it provides flexibility in trip making and allows riders to use transit for a wider variety of trips. The travel demand data shown earlier in Figure 7 shows that weekend travel demand at 9:00 PM is just as great as it is at 11:00 AM. If Sun Tran wants to be the primary mobility mode for its riders, it must offer high-quality service when people want to travel.

Figure 26: Map of Weekday Midday Frequency by Route Segment

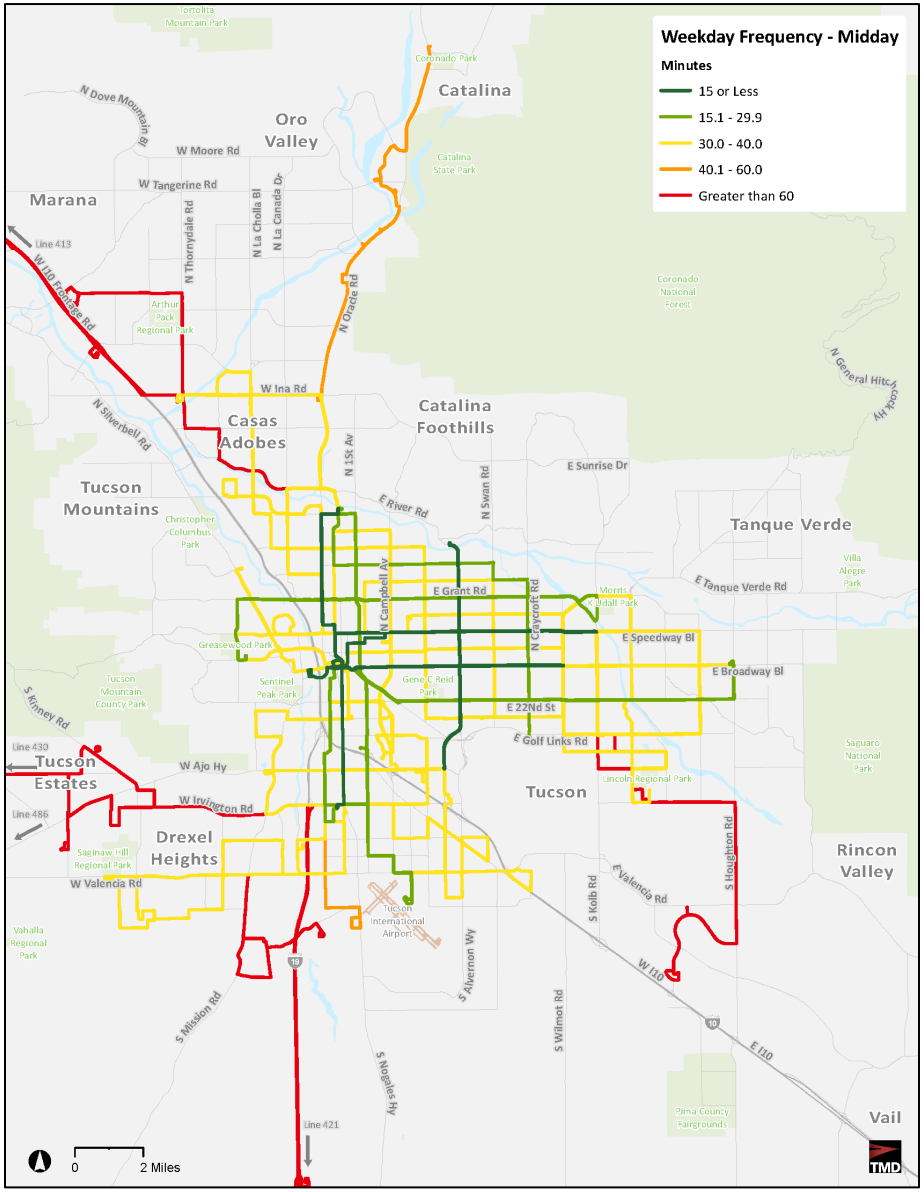
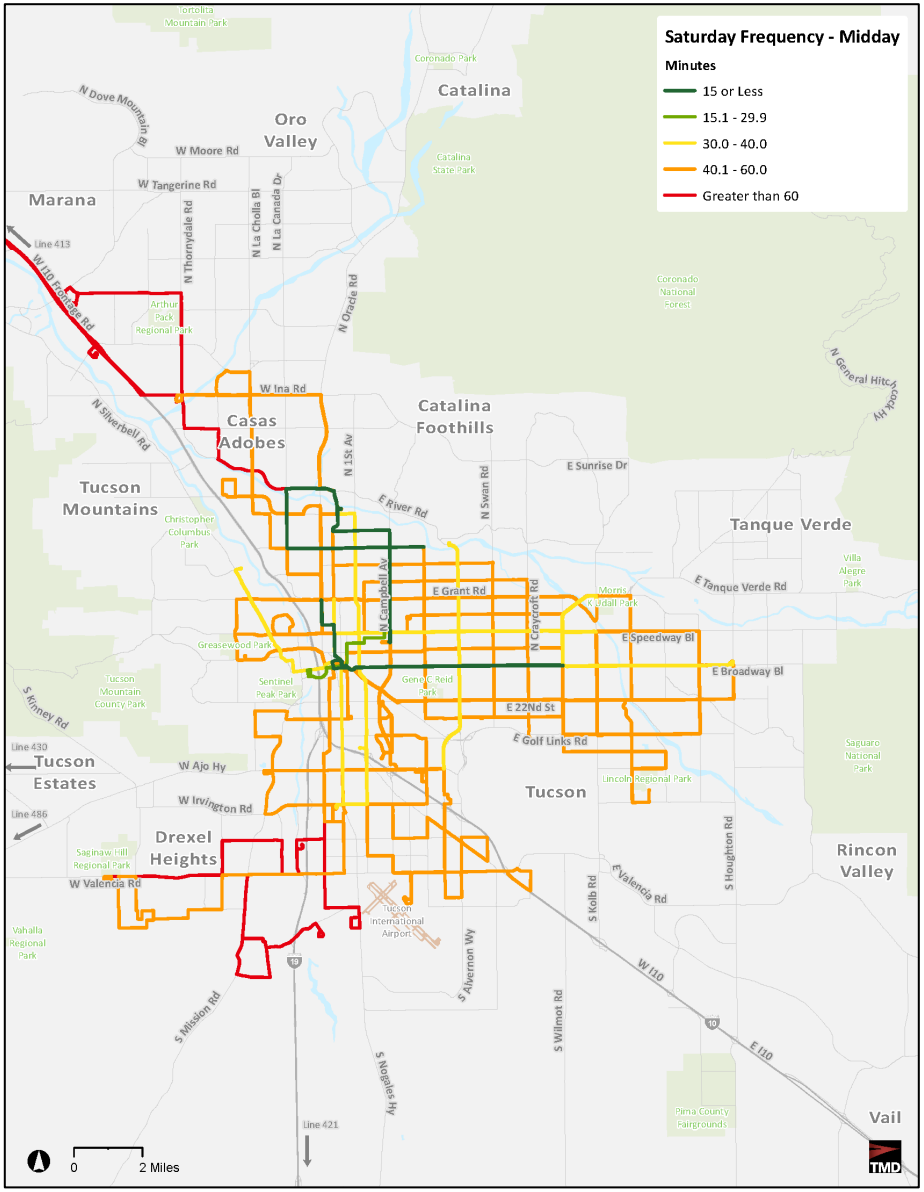


Figure 25: Map of Saturday Midday Frequency by Route Segment



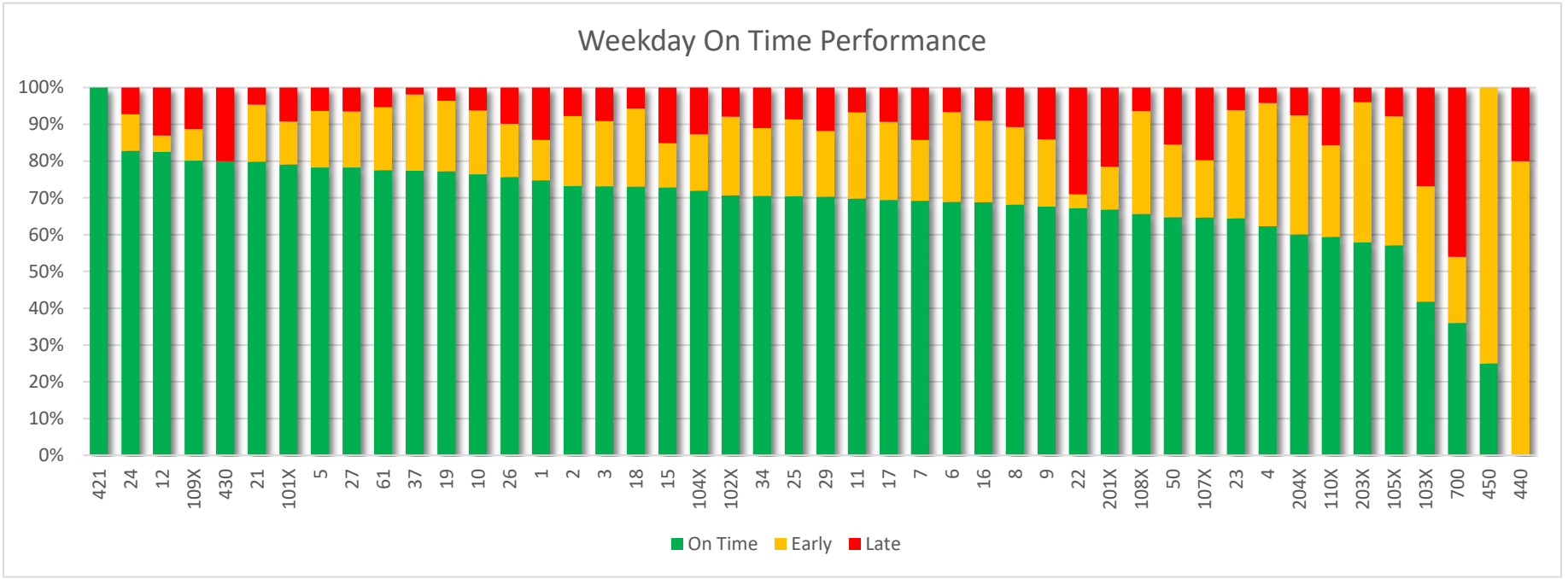
On-Time Performance

Service reliability is the number one factor that retains ridership. Riders must be able to rely on the bus consistently to get them where they need to go. Sun Tran defines "on-time" as any time between a bus's scheduled time and up to five minutes late, but less than 1 minute early. There is less tolerance for early trips because riders refer to a published schedule to time their arrival, and if buses leave earlier than scheduled, they may leave riders behind. However, late trips are also frustrating for riders, especially in a grid system like Sun Tran's. A late bus can mean a missed transfer, causing significantly longer delays.

The industry best practice on-time performance standard is 85 percent, and Sun Tran uses a 92% standard. This standard can be particularly hard to achieve due to natural variations in running time. The way to ensure routes hit this standard is to slow down running time to minimize variability – but this also has drawbacks. It artificially slows down the service and may result in routes sitting for multiple minutes in the middle of the street at time points when ahead of schedule. This is particularly frustrating for riders who perceive any in-vehicle delay as twice the actual length. Riders just trying to get to their destination are not at all receptive to waiting seemingly unnecessarily.

In total, 70% of Sun Tran trips are on time, 20% are early, and 10% are late. Route 421 has 100% on-time performance but runs relatively few trips. No other Sun Tran route hits the 92% standard, or the 85% industry standard. Routes 24 and 12 get closest at just over an 80% on time rate. Overall, there are twice as many early trips as there are late trips. Early trips are more avoidable, because they directly relate to operator discipline and adherence to the timetables. Late-running caused by congestion, slow boarding times, or signal variances are out of the operator's control. Leaving the end of the line on time and waiting at timepoints for the correct departure time is directly within an operator's control. Routes that are consistently early may be able to operate with less running time – saving costs for the agency.

Figure 27: Weekday On Time Performance by Route



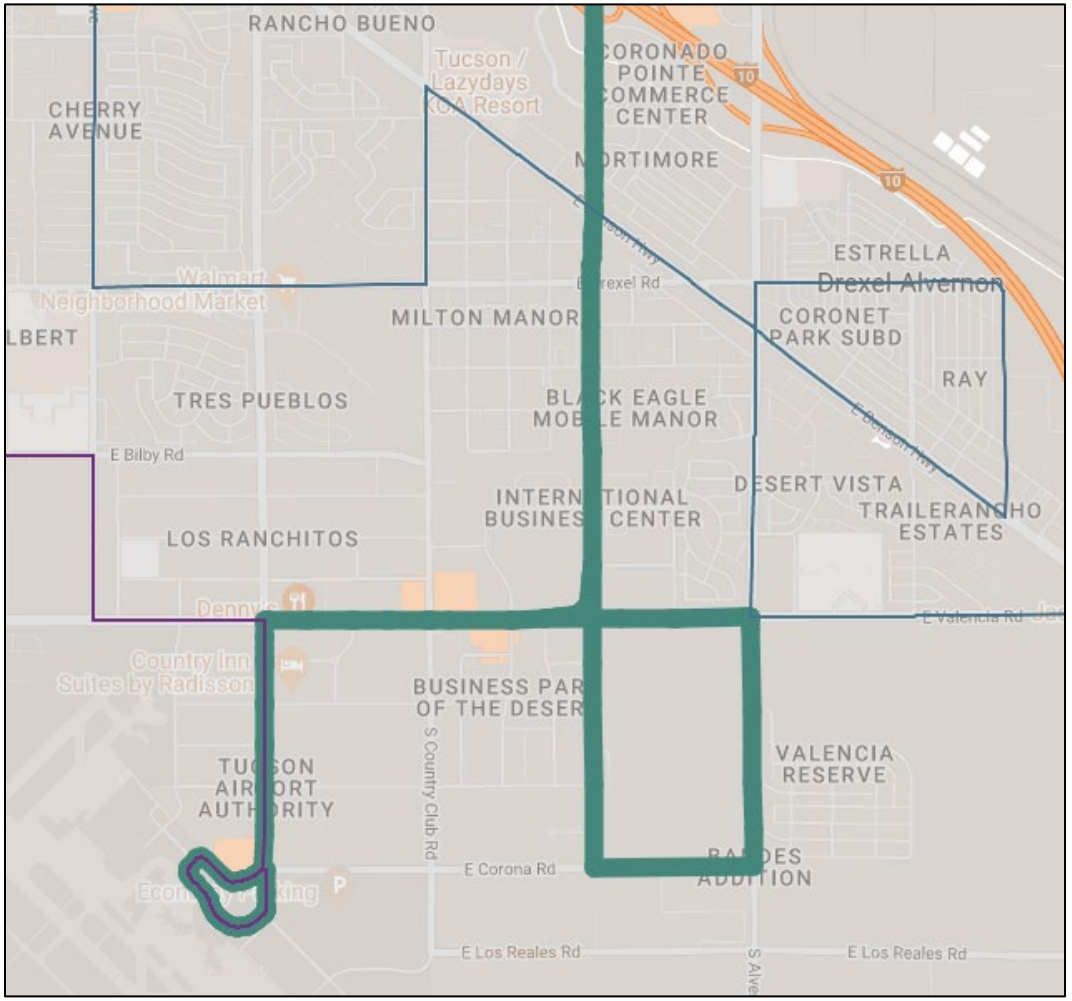
Directness and Deviations

Travel time is also affected by the directness of a route, and deviations from a route's primary alignment play a significant role in increasing overall travel time. Route deviations are usually in place to provide "front door" service to neighborhoods, shopping centers, medical facilities, or employers that are located off the main corridor. Rather than requiring riders to walk from the main corridor, the bus deviates from its main alignment to serve the destination, increasing travel times for riders. Industry best practice says that there should be **no more than ten passenger-minutes of delay per boarding gained along the deviation**.

There are very few deviations on the Sun Tran Bus network, a result of the grid-patten. Most routes operate on a single road for much of their alignment. Where routes do deviate, they typically deviate to major transit centers where the value of the connection outweighs the additional travel time.

Some deviations are quite costly for Sun Tran to operate. One example is on Route 11 to warehousing centers off Corona Rd. The route makes a 2.5-mile loop before heading into the Tucson airport. Averaging 19 mph, the loop should take just under eight minutes to complete. In both directions, there are a total of 278 riders on the bus when the deviation starts, 21 get off during the loop, so a total of 257 passengers ride all the way through the deviation. All 257 passengers incur an additional eight-minute delay, for a total of 2,030 daily minutes of passenger delay. A total of 15 riders board the bus along this deviation, so there is a penalty of 135 minutes of passenger delay per boarding gained along the deviation.

Figure 28: Route 11 Deviation



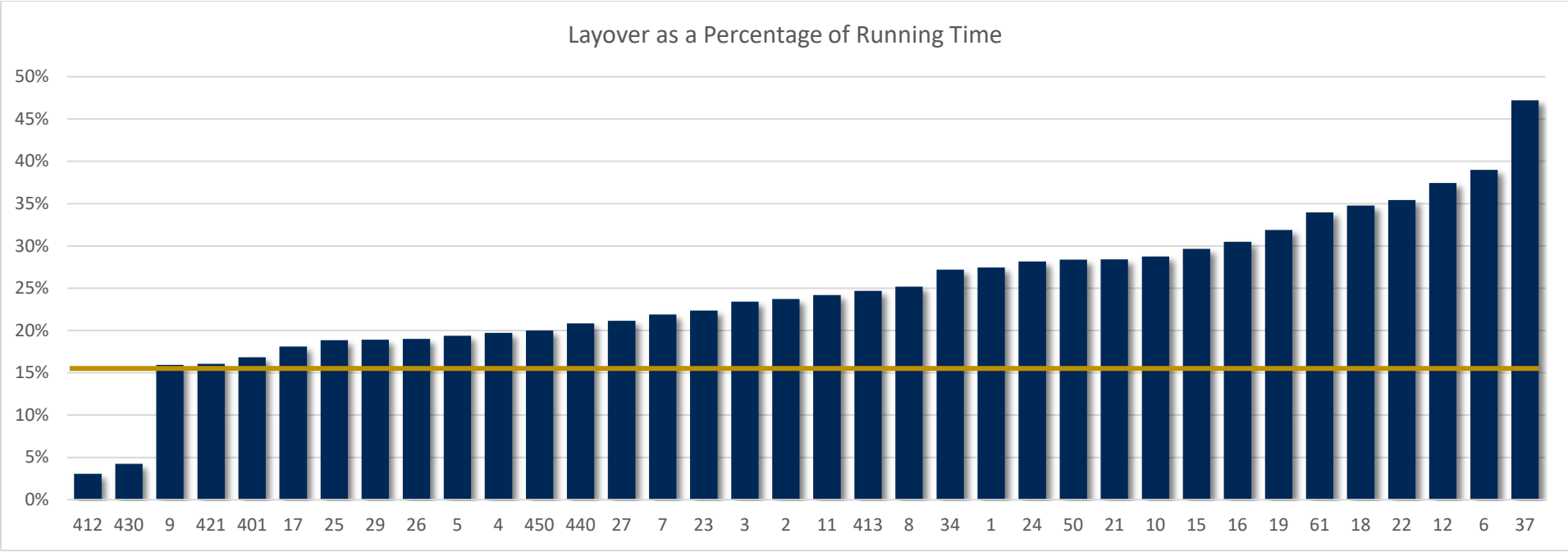
On the other hand, some deviations, such as those to major transit centers, are beneficial for riders. Route 25 deviates from S Park Ave to the Laos Transit Center, a 2-mile and 8.6-minute deviation. 609 passengers enter the deviation, but 378 get off, so only 229 ride all the way through. 229 passengers times 8.6 minutes is 1,969 minutes of passenger delay. There are 341 boardings at the Laos Transit Center, so there is an average delay of 5.8 minutes per boarding generated.

Schedule Efficiency

One of the major factors contributing to a route's productivity is the efficiency of service delivery. The fewer hours a route can use to carry the same number of riders, the higher its productivity will be. A route's cycle time is defined as the in-service time (time the buses are driving along the route) plus the layover/recovery time at the end of the route. Each trip has a few minutes of schedule recovery buffer so that running time delays do not automatically delay the next trip. Each trip also has a few minutes of operator layover which is time for the drivers to take a rest break. The industry standard target is for layover/recovery time to equal around 15% of a route's in-service time. Efficiency is most important to measure for all-day services. Express routes follow different rules since most of the time the operators are not driving a complete 8-hour shift.

Sun Tran and Sun Shuttle services average 24% recovery on weekdays. This means that recovery time accounts for one-fifth of total service time – one fifth of the time buses are sitting idle not generating revenue. One factor contributing to high recovery is the branching patterns of many routes. The patterns must be run at the same headway even if one has a longer running time than the other. Another factor contributing to higher recovery ratios is that all Sun Tran routes operate on clockface frequencies – every 15, 20, 30, or 60 minutes. This is great for the customer because they can rely on the bus to be at their stop at the same time(s) every hour. However, it can also lead to inefficiencies when the route's running time is not compatible with the desired headway.

Figure 29: Layover as a Percentage of Running Time



For example, Route 37-Pantano has the highest recovery percentage in the system at 47% (all-day average). The route is scheduled to run every 30 minutes. On an average trip, the total running time is 29 minutes northbound and 30 minutes southbound, for 59 total minutes. In order to run the route evenly every 30 minutes, the bus must sit for 31 minutes to reach a 90-minute cycle time. This means that one third of the time on this route, the buses are sitting idle. Route 37 is interlined with Route 5-Pima/W. Speedway. With interlining, a bus switches between operating different routes. This approach is often used to help yield more

efficient cycle times when two routes would be inefficient on their own. For example, consider two routes operating every 30 minutes that have 65 minutes of running time. Independently, these routes would each require three buses to complete, for a total of six. But together, the running time would be 130 minutes, and with 20 minutes of recovery (15.4%), the routes could operate every 30 minutes with only five buses on a 150-minute cycle. However, in the case of Routes 5 and 37, the interline does not actual yield any efficiencies. Buses switch between operating on Route 5 and Route 37 every three and a half hours (210 minutes). Of this cycle, 160 minutes is running time, and the remaining 50 is layover/recovery, 31.3%.

There are three possible ways to improve the efficiency of Route 37. The first would be to operate the route more frequently. With a 59-minute running time, the route would require a minimum of 9 minutes of recovery to reach a 15% recovery ratio, a 68-minute cycle time. The route could be operated every 23 minutes with the same number of vehicle, improving frequency from 30 to 23 minutes. The pros of this are that there would be more trips throughout the day for riders to use. The cons are that Sun Tran would incur a higher mileage cost from operating more trips; it is hard for riders to commit 23-minute schedules to memory; and it is impossible to time transfers at the ends of the line. The second option would be to change the alignment of the route to shorten or lengthen running time to minimize the recovery percentage. The third option would be to find a different route interline partner that may be more efficient. This could be harder to do, since interlined routes must share a terminus and, for the most part, have the same operating hours and headways.

Conclusion and Key Findings

The following key findings summarize the main takeaways from Milestone Two. These findings, along with the key findings from Milestone One and community outreach efforts, will be used to developed the framework and guiding principles for the development of the draft service plan.

- **Strong Grid Performance:** Overall, Sun Tran has strong route performance, carrying an average of 24.5 passengers per hour (above a traditional standard of 20 pph for fixed-route service). The grid design of the street network allows for straight, direct routes that can be operated efficiently with few deviations. High-frequency routes in the core of the grid tend to have higher productivity than those with lower frequencies away from the urban center. The strong performance of these routes forms a solid foundation for a robust high-frequency transit network.
- **Need for Additional Weekend Service:** Lack of weekend service – both in frequency and span – greatly affects the use of the system. With service levels roughly half of what they are on weekdays on weekends, it is much harder for riders to rely on transit. There are roughly 90% as many trips across all modes being made on weekends as compared to weekdays, but transit only provides about 50% as much service. Additional weekend service is needed such that frequent riders can conveniently use transit for mobility every day of the week.
- **Clockface Headway vs. Efficiency:** All Sun Tran routes operate on clockface headways (15, 20, 30, or 60 minutes). This is great for helping passengers remember the schedules and for timing connections at transfer centers. However, forcing routes to fit within certain cycle times can create inefficiencies in scheduling by requiring complicated interlines with other routes or excess layover at the end of the line. In a resource-constrained environment, there is a tradeoff between maintaining clockface headways and scheduling to maximize efficiency to free up resources for investment elsewhere in the network.
- **Transit Centers:** In a truly grid system, transfers take place on-street where routes intersect. Sun Tran is organized such that most transfers take place at three major transfer hubs (RTC, TTC, and LTC), which collectively represent 20% of all daily boarding activity. Despite having other opportunities to transfer between two routes, most passengers ride to the end of the line in order to transfer at the hub. Needing to have routes converge at a hub inevitably results in considerable overlap between routes and can add running time and cost. However, with riders more comfortable transferring at transit hubs, moving to complete on-street transfers would likely reduce ridership.
- **Role of Sun On Demand:** Sun On Demand currently operates in two zones providing curb-to-curb service in areas with minimal fixed route availability. While these services helped Sun Tran save on fixed-route costs by replacing fixed-route service with on-demand service, they are relatively low-performing, carrying only 10 to 20 riders a day. In both zones, fixed-route service still operates, and many trips start and end along another bus route. The fixed-route service in these zones is also low-performing, and there may be some opportunities to further consolidate the services to gain more efficiencies and optimize the use of resources.