Princeton Campus Mobility Framework

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NUNES-UENO CONSULTING

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Table of Contents

1. Introduction 4
   - Vision 5
   - What tools are available? 6
     - Four types of action 6
   - Defining Success 7
2. Existing Conditions for Walking and Cycling 8
   - Walking 9
   - Cycling 15
   - Bikeshare 18
     - Coverage and accessibility 18
     - Usage patterns 20
   - Policies Impacting Biking and Walking 23
   - Service and delivery vehicles 24
3. Existing Conditions for TigerTransit 26
   - Transit's competing goals 27
     - High ridership is not the only goal of transit 27
     - The Ridership Recipe 30
   - Frequency in the TigerTransit network 32
   - Performance of individual routes 34
     - Example: Route L 35
     - Example: Route E 36
     - Example: Saturday Shopper 36
     - Example: Route A 37
     - Ridership expectations from suburban areas 38
     - The cost of 100% coverage 41
     - Policies that can influence transit ridership 41
   - On-Demand service 42
   - Peaking 44
   - Future development and street design 47
     - Roundabouts and transit stops 48
     - No linearity without walkability 49
     - Transit patterns for a larger campus 50
   - User information 52
4. Challenges, Choices and Next Steps 53
   - Transit ridership relative to costs is low. 54
   - Cycling is discouraged by road and path design. 54
   - Historic walkways are busting at the seams. 54
   - Longer distances are coming. 54
   - Micromobility and other small devices 54
   - Investments can be made at multiple levels. 54
   - Next steps 55

Appendix 56
   - Transit Network Map – Campus Area 57
   - Transit Network Map – All Routes 58

Table of Contents

Route A Boardings by Stop 59
Route B Boardings by Stop 60
Route C: East Commuter 61
Route D: PTS/West 62
Route E: EQuad. 63
Route F: Forrestal/PPPL. 64
Route H: Evening Circulator 65
Route L: Lawrence/Lakeside 66
Route M: Merwick/Stanworth 67
Route O: 100 Overlook/701 CC 68
Route S: Shopper 69
Route W: Weekender 70
Summary of Traffic Counts by Location. 71

1. Introduction

The report you are reading is an analysis of the current state of mobility at Princeton University. It is the first element of what will become a new Princeton Mobility Framework. When complete, the Framework will help the University develop the policies, services and infrastructure needed for people to move around the growing campus in the next five years and beyond.

The Framework starts with some very high-altitude questions, and then descends into more detailed questions about the transportation system:

- **How do today's campus transportation systems support the University's goals?**
- **What are the goals of a future campus mobility system?** When those goals compete against one another, how should they be balanced?
- **How will growth affect mobility needs?**
- **What type of campus experience should be provided, and for whom?**
- **Which modes of travel should have priority for which types of trips?** Where are these differentiations between modes important?
- **How far will people be asked to walk?** What will that experience feel like?
- **How will success be measured?**

Vision

At the founding of the University in the late 18th century, walkers shared roads, not necessarily easily, with horses and horse-drawn wagons. The railroad brought more people on foot. Next, the automobile became widespread, chased the horses away, and reshaped the campus and the township.

Ten years ago, Princeton introduced TigerTransit bus service. More recently Zagster brought shared bikes to campus. Uber and Lyft cars now appear at the click of an icon. Golf carts and e-scooters scurry among cyclists and walkers on paths and sidewalks throughout campus. These recent innovations exist in a continuum of change that the University has been managing since its founding.

What changes are coming next? Will robots start driving our cars? Will they be any good at it? Will e-scooters, monowheels, hoverboards and other 'micromobility' conveyances become the norm, or will they fade away? The answers are far from clear.

What is clear is that walking should continue as an integral part of the Princeton experience into the future. The 2016 Campus Plan established a framework of its own that will:

"...Encourage interchange through planned events both large and small, and serendipitous encounters of various kinds."

"...Preserve and enhance [the campus's] special character by promoting human scale, spatial cohesion and walkability."

The University's 2016 Strategic Framework named as a defining characteristic of the University *"a vibrant and immersive residential experience on a campus with a distinctive sense of place that promotes interaction, reflection, and lifelong attachment."* In its 2019 update to that Framework, the Board affirmed its commitment to *"healthy habits that will promote wellness over a lifetime."*

Technology will bring new modes of transportation to the University. Depending on one's point of view these may be exasperating, delightful or inconsequential. If we allow new transportation modes to diminish the experience of walking, we will have lost something fundamental to the mission of the University.

Despite past predictions, new technologies have never eliminated our desires to get close to one another to share ideas and work together. New technologies will also not eliminate the fundamental geometric problem of fitting large numbers of people into and through shared spaces.

Now is the right time to examine how people move within Princeton University. TigerTransit and Zagster have been operating smoothly for multiple years and are due for a refresh. A major wayfinding study is underway, that will make it easier for people to navigate campus. Plans for the new East and Lake Campuses raise questions about the roles of walking, cycling, transit and other modes.

The Mobility Framework will offer policy guidance and concrete plans that address these changes and inform University decisions for years into the future.

What tools are available?

The University can take four types of actions in creating its mobility future. Some of these relate to tools the University owns outright. Others require partnership with external actors such as the Townships, NJ Transit, private businesses and its own staff, faculty and students. Coordinating these actions, and using the right tool for the right job, will be a key to success.

Four types of action

Princeton University can:

- Invest in campus mobility *services* and *management*: Design and operate a new transit network; update the bikeshare system; manage micro-mobility offerings; and manage for-hire car services like Enterprise, Uber and Lyft.
- Invest in *places*: Change how space is allocated to different travel modes; develop a legible bikeway network; upgrade transit stops, shelters and vehicles.
- Foster a *culture* of healthy mobility: Use inspiration and policy to reduce the use of golf carts and cars on campus; increase the pleasure of walking and cycling.
- Increase the *knowledge* of staff, faculty and students about their mobility options through excellent information sources and communication.

Defining Success

The Mobility Framework will define performance metrics for each element of the campus transportation system. But the sum should be larger than the parts.

Two national parks with different approaches to transportation provide contrasting images to guide the development of Princeton's Mobility Framework. Yellowstone National Park's laissez-faire approach poses almost no barrier to entry with a motor vehicle. As a result, cars, motorcycles, RVs, hikers and cyclists jam the roads, at times interrupted by – or interrupting – the park's wild inhabitants.

Zion National Park does the opposite. Cars are barred entirely, and visitors are required to ride official buses and shuttles into the heart of the park. A bit of inconvenience at the start of their trip pays off as they gain a contemplative experience with little noise, pollution or traffic, and more contact with the landscape in its natural state.

President Eisgruber has challenged the University to grow. One measure of success for Princeton's Mobility Framework might be how much of this growth is handled without additional cars, noise, congestion or parking. Another form of success could be to grow the campus while reducing greenhouse gas emissions from transportation. Achieving noise, pollution and congestion levels below what we experience today, despite growth, would be a more ambitious goal. Perhaps more intangibly, we will know we have succeeded when walking, riding transit, and biking around the University start to feel irresistible.

Yellowstone National Park: Traffic jams are common.

Zion National Park: A quiet, contemplative landscape without cars.

2. Existing Conditions for Walking and Cycling

This chapter describes the existing conditions observed by our team relating to the different modes, in particular walking, cycling and transit.

In general, Princeton University's different populations are having different experiences of transportation on campus. In very generalized terms:

- Undergraduate students live and study in what is nearly a pedestrian paradise. Most of what they need to do can be done on foot, in a beautiful setting, in a reasonable amount of time.
- Staff and faculty commute fairly long distances to campus, mostly by car. Having borne that expense privately, they can then use a campus transit system designed to minimize their walking distance, though it requires enough waiting that simply walking is often faster. The longest walks from parking lots to buildings are 12 minutes long. Walkways from staff and faculty parking lots are serviceable but rarely celebratory.
- Graduate students live in housing that is a 20-40 minute walk from academic buildings. Many of them have access to high-frequency transit during commute hours. Bikeshare is available and well used, but the design of roads and paths barely acknowledges cycling as a respected mode.
- All three groups travel at varying frequencies to and from nearby but off-campus locations such as the Princeton Plasma Physics Laboratory, 701 Carnegie Center, and 693 Alexander. The facilities for walking and biking connecting these buildings to campus are minimal. Most of this movement is made via shuttles or private cars.
- Travel to the wider world beyond campus is served minimally by NJ Transit, whose transportation goals are very different from those of the University, and by private bus and car companies.

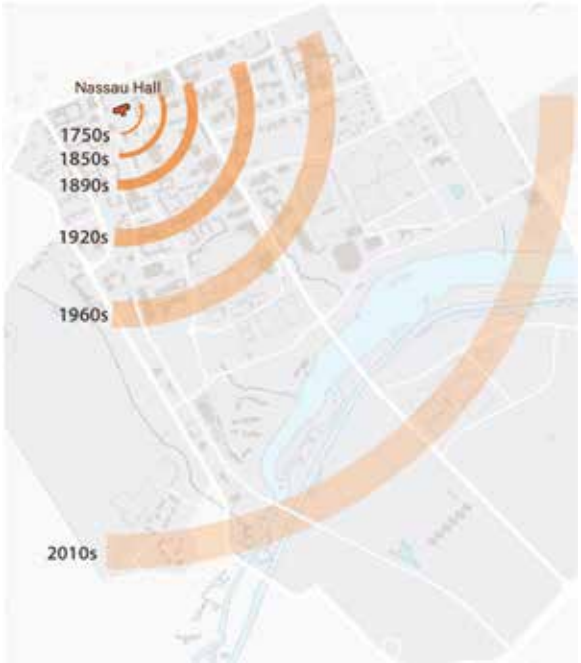
Walking

For the first 150 years of Princeton University's history, walking was the only mode of transportation available for students, faculty and staff on campus. The core of campus was therefore built like the historic cores of all cities, with every building and road designed for walking. The historic campus is small, and all corners of it are a short walk from one another.

Over decades, as the University grew out of the walkable core surrounding Nassau Hall and automobiles came into the picture, the newer infrastructure being constructed, and also the existing walk-focused infrastructure, had to accommodate cars and vehicular traffic.

Much of the core of campus was built before people with physical disabilities were expected and permitted to participate in public life, and so numerous stairways present barriers to people using wheelchairs or canes. The University has been working to retrofit buildings and walkways to improve accessibility but difficulties remain.

The historic campus has a dense network of interconnected walkways with some roadways interspersed among them. These roadways allow some vehicles – like TigerTransit buses and service vehicles – access, but at the same time, also act as pedestrian and bike thoroughfares. This leads to pedestrians and bikes forming a very large share of users of these transport facilities. In places like Pyne and Chapel Drives, there are usually between 6 and 8 people walking or biking for every one vehicle. Elm Drive sees heavier traffic of buses and service vehicles, but pedestrians and bicyclists still outnumber vehicles: at least two-to-one, and as much as six-to-one during times when classes begin/end.[1]



For most of its lifetime, until after the 1920s, Princeton University's internal mobility framework was very simple: walk.

The incremental growth of the historic campus over many years means that there are few

1 Data from a traffic count of all modes at sample locations on campus is reported starting on page 71.

walkways that invite long cross-campus walks. Instead, the walking experience feels more organic, like tunnels through a warren or game trails through woods. There are multiple possible walking routes between two points, most of the paths are narrow, and no one path is very direct or clear. This offers opportunities for seclusion, discovery and appreciation for the unique architecture and landscape of the campus. It also surely makes walking routes difficult for visitors and newcomers to deduce, and makes walking more challenging than it otherwise could be. (The University is currently engaged in a wayfinding study to address this challenge.)

This warren-like pattern also divides people onto numerous small paths. This may be part of the reason that so many people are drawn to the wider, more direct roadways such as Pyne and Elm Drives, where their numbers overwhelm the narrow sidewalks.

For longer walks across campus, especially in the east-west or diagonal directions, there are few direct walking routes that do not deviate around buildings, go onto and off of roadways, or go up and down stairs. The 2016 Campus Plan calls for new East-West and North-South "Campus Connectors" and extension of the Diagonal Walk to support longer cross-campus walks.

Some of the pathways and sidewalks planned decades (if not centuries) in the past are much too narrow for the volume of students and staff using them today. Numerous paths show wear beyond their paved edges, where people have worn the grass down to dirt or mud. In some cases, the University has covered these margins in straw (as a quick fix) or, recognizing the insufficiency of the path, widened them with asphalt.

In some parts of the historic campus old walkways are too narrow to handle modern demands, or don't serve intuitive walking routes.

Some paths next to some roadways are still too narrow to walk two- or three-abreast, and so people naturally walk in the roadway with their companions until a car or golf cart comes along and they yield.

Friction among golf carts, bikes and people on foot arises on many paths and sidewalks. There is no differentiation among paths that would reduce conflicts among people walking, cycling or driving golf carts, nor is there enough width on most paths to accommodate the three modes together.

There are paths, sidewalks and roads on campus that provide examples of good design, the type of design that makes walking irresistible. The University has some elegant walkways, wide enough for people to walk side-by-side, such as the two at right. The visible work of grounds staff to quickly address under-sized pathways by putting down straw (to prevent mud from developing), and to widen pathways with brick or asphalt, shows that the University is already aware that many historic paths are too narrow, and is addressing them incrementally.

Recently constructed roads on campus have given the University an opportunity to build places for walking that meet modern standards, such as the elevated crosswalks across Station Drive and University Place. The elevation of these crosswalks makes pedestrians more visible to drivers and sends the message to everyone that the crosswalk is an extension of the sidewalk. They also act as soft speed humps for cars, and the different paving texture and color provides mental friction that tends to slow drivers.

Some of the walkways on campus were built, or have been re-built, with enough width to handle groups of people walking together.

New construction at Station Drive includes a raised crosswalk, which is a great example of infrastructure that treats walking as the priority mode by extending the sidewalk across the street.

Narrow streets with no markings cause cars to drive slowly.

The University has also made some subtle design choices for campus pathways and roadways that probably have the effect of slowing down cars, trucks and golf carts, and making those roads more comfortable for walking and biking.

Elsewhere on the historic campus, the University has used a paving technique that is known to slow down motor vehicles: visually narrowing the roadway to a width that is less than two full car lanes, and forgoing a center line. In the example at right, pavers on the margins are slightly bumpy and look like a sidewalk, which would naturally encourage people to drive down the center. The center is narrower than two car widths, so people drive slowly and anticipate the need to pull over to pass another car.

Some roads without sidewalks have been striped like a crosswalk, as in the two photos at right, to send the message that people are expected to walk in the road. Because these roads welcome two-way car traffic, however, the striped portion is often occupied by cars.

The design in the two photos above suggests that people should walk in the road, but many people still show with their actions that cars have priority.

In Europe and Asia, and particularly in the Netherlands where this photo is taken, some streets are designed to treat cars as guests, and people walking or cycling dominate. Drivers travel at extremely low speeds on such streets thanks to law, design and culture.

In these ways, the University is experimenting with a change to the hierarchy of the past century, in which people driving cars are entitled to go faster than walking speed any place there is asphalt, while people walking or biking in such places are expected to move aside.

The best examples of streets that are designed primarily to be social places, places for the exchange of ideas and commerce, and places for walking and cycling, and on which motor vehicle throughput is a very low priority, come from northern Europe. The photo above shows a "woonerf," or "living street," in the Netherlands. People driving on such streets do not expect to drive any faster than slow cycling speed, or even walking speed in some cases. As a result the street is a lively and productive place and a wonderful place to walk or bike. Given the University's plans and goals relating to walkability, social connection, health and spontaneous interaction, more "woonerf" design tools may be of value on campus.

Younger universities' campuses are more likely to have been master-planned on a larger scale, and therefore often include grand pedestrian concourses linking major academic buildings, social spaces and residences. Such concourses would be out of character in many parts of Princeton's historic campus, but the University may be able to learn from what they offer:

- Clear and walkable axes along which campus life is organized, which help visitors and newcomers learn their way.
- Enough space for peak pedestrian and bike volumes during class-change times without causing crowding, conflict or damage to landscaping.
- A large number of serendipitous encounters and events among students and staff, because so many people are sharing the same public space and have enough space to stop and talk comfortably.

This type of concourse is foreseen in the Lake Campus Walk, a sort of "main street" for the Lake Campus.

The existing campus is organized around three north-south axes: Alexander Street, Elm Drive and Washington Road. Only Elm Drive is under the control of the University. None of these three north-south axes serves as anything like a concourse or mall, or like the planned Lake Campus Walk.

Between the guard house and Dillon Gym, Elm Drive has sidewalks on both sides of the road (which is not the case for many other campus roadways), and wide enough to handle large numbers of people walking. It is not a coincidence that this is the section of Elm Drive with fewer buildings nearby and more open space, which makes it possible to provide full sidewalks without reducing the road width. But this also means that there is less pedestrian demand because fewer buildings are nearby. North of Dillon Gymnasium, where the density of buildings and students is higher, the sidewalks become narrow. They are just wide enough for two people to walk side-by-side but no more, and certainly not wide enough for bikes and scooters as well.

The Lake Campus Walk (here illustrated in the 2016 Campus Plan) will be a direct walking route to many destinations and a generous space for movement and interaction.

Elm Drive has lovely wide sidewalks on both sides of the road in the southern part of the historic campus. To the north, where there are more buildings and activity, the sidewalks are narrower.

In the parts of campus built during the 1960s, a different set of challenges arises for walking. While in this era wider and more direct walkways may have been built, these parts of campus reflect the culture of the era through the dominance of cars on the landscape.

Rather than walkways being the main linkages between buildings, roads are the main linkages, and walking is provided for by a narrow sidewalk. Parking spaces and parking lots make the distances between buildings longer.

Motor vehicle intersections barely exist on the historic campus. In the 1960s campus, intersections are large and the engineering treatments that help people traveling by foot or by bike get through them are minimal.

Many of the University's parking garages are located within these parts of campus, and motor vehicle traffic on internal campus roadways can be heavy during rush hours or, in the case of roads near maintenance facilities, all day long.

Elm Drive is the only north-south axis of the campus controlled by the University, yet it is also a major service road. It handles private cars, golf carts, maintenance vehicles, TigerTransit buses and delivery trucks. Its intersections are designed for the largest and fastest vehicles – motorized trucks, as in the photo at right. This is true of other roads, especially those in the post-1960s part of campus, like Faculty Road and South Drive.

Pedestrian and bike volumes on some of these roadways can be quite high, despite the many ways in which their design and their motor vehicle volumes discourage walking and biking. There are times at which one quarter of the movement on Alexander Street (near the Dinky station) are people walking or biking.[2]

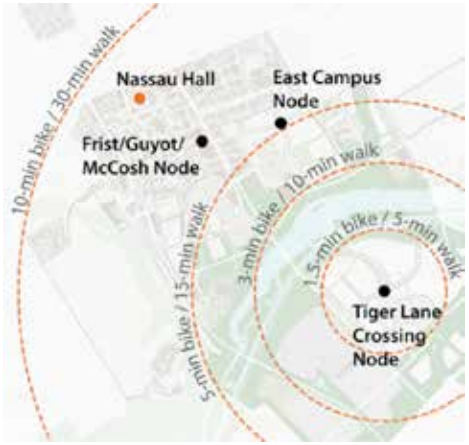
Intersections built or re-built since the 1960s are designed to handle many cars smoothly, which makes them large. Crosswalks alone do not make walking or biking through these places appealing.

The number and share of people walking/biking on Washington Road is much higher, because it lies between the historic campus on one side, and large academic buildings, eating halls, sports facilities, and parking lots on the other. More than 300 pedestrians and 90 bikes were observed on Washington Road between 10:45 and 11:00 am, which together accounted for more than three quarters of the total pedestrian/bike/vehicle count.

2 Video surveys were conducted in October 2019, capturing counts of cars, trucks, buses, golf cars, and people walking or cycling.

Cycling

Planned growth into the new East Campus and Lake Campus presents a new challenge for walking, which is acknowledged in the 2016 Campus Plan: the Lake Campus's center, at "Tiger Lane Crossing Node," will be nearly a 30 minute walk from the center of the historic campus.



This raises questions about how people will make intra-campus trips if their activities are spread across both sides of the lake.

While a 20- or 30-minute walk is a lovely one-way commute for many people, it is not something most people are willing to do repeatedly throughout their day. In addition, few people are likely to be willing to add that commuting time to whatever time they spend getting to campus.

The 2016 Campus Plan puts forward transit and cycling as important modes, given the increase in distances induced by the spreading campus.

For cycling to become more useful and more popular for intra-campus trips, without becoming more disruptive to walking, a more legible and dedicated bicycle network will be needed.

Especially in the historic campus, people cycling and walking will struggle to share a network of undefined paths, with no modal differentiators (other than the presence or absence of stairs), if the number of bike trips is to grow.

In the 1960s parts of campus, cycling is unlikely to grow if people are asked to ride bikes on a roadway shared with large numbers of cars, trucks and buses. If people biking on these roadways use the sidewalk instead, that is again degrading the walking experience.

For example, people living in Lakeside wishing to cycle to the EQuad or Chapel Drive have three choices of routes, none of which are encouraging:

- They can cycle uphill on Elm Drive with numerous cars backing up behind them, and navigate two auto-oriented roundabouts that require them to keep up with car traffic in order to use the intersection (as in the picture at left on the previous page).
- They can cycle on the narrow path that begins at Hibben Magie Road (the wooded entrance is shown at far right), degrading the walking experience for other people (especially when they are rolling fast downhill on their way home).
- They can ride uphill on Alexander Street, University Place or Washington Roads, which are even more discouraging to cycling than Elm Drive, especially when people need to cycle slowly uphill.[3]
- They can ride on the sidewalks of those roads, again degrading the walking environment for people on foot.

Lakeside residents are the perfect distance from the historic campus to use cycling for many of their trips, yet the design of the roadways around Lakeside suggests that motor vehicles are the mode they are supposed to choose first. This is reflected in the low levels of bike usage - no more than 15 bikers per hour are observed at any time during the day leaving Lakeside.

3 Alexander Street near the Dinky station sees more than 1,200 motor vehicles per hour during morning and evening peaks. Washington Road sees 600 vehicles per hour at those times.

The Lakeside Apartments are connected to the historic core of campus by a lovely walking path (shown at top) that is much too narrow to expect cyclists and pedestrians to share, or by roadways with gestures at cycling (a bike "sharrow" painted on Alexander, at bottom) but no real safe and dignified place to ride.

Cycling on Elm Drive from Lakeside requires navigating car traffic in roundabouts and sharing the road with cars and trucks, or getting in the way of people walking on the single sidewalk.

The roundabouts on Elm Drive minimize delays for motor vehicles and reduce low-speed motor vehicle crashes compared to signalized intersections, but they have negative consequences for walking, cycling and transit.

Roundabouts make walking distances longer, because pedestrian crossings are recessed from the intersection. They also require people walking to wait for permission to cross the street from people driving. Roundabouts are frightening for most people to use by bike because they require merging into the car lane at the speed of "traffic," a much higher speed than most people can bike, especially uphill.

When large numbers of people walk and bike through roundabouts despite these discouragements, their presence causes surprises and delays for cars that the roundabout was meant to eliminate. For this reason, roundabouts are no longer considered "best practice" at intersections where walking and cycling are desired.

A problem that roundabouts present for transit access is described in the next chapter.

For more remote University buildings, such as PPPL and Forrestal, cycling can be much faster than taking infrequent transit. Unfortunately, the bike routes are hard to discover, both because they are so invisible in the car-centric high-speed landscape, and because the publicly-provided Princeton Bicycle Map is so hard to read.

The Atmospheric & Oceanic Sciences Department offers excellent cycling directions to Forrestal on its website, demonstrating the need for better guidance. The 20-minute bike ride is mostly on side-paths and along the Lake, though it includes a difficult segment on Alexander Road and crossing of a freeway on-ramp without a signal.

Off of campus, the roads around the University are discouraging of cycling. The design of the roads encourages people to drive fast, and no space is set aside for bikes. Sidewalks are narrow and full of conflicts with cars pulling into and out of driveways. The buildings at 701 Carnegie Center, 100 Overlook, PPPL and Forrestal are all reasonable biking distance from campus, but without roads and paths that offer a pleasant and encouraging experience, very few people should be expected to bike.

Moving people over those distances by transit requires both a capital investment (to buy buses) and an annual operating budget (to operate service in perpetuity). Moving people by bike has a one-time capital and political cost (to build roads and paths the right way) after which it has no operating cost and actually generates health benefits. Transit is a much more expensive way to move people such short distances, without even accounting for its higher environmental impacts.

Workable cycling routes exist to some University buildings, like this one to PPPL, advertised on the Atmospheric & Oceanic Sciences department's webpage. The quality of resources available for people who want to try biking off campus is not very high.

The University does not control the roadways and bikeways leading to these buildings, but the University could do more to advertise the safest and most pleasant cycling routes among its buildings. On campus, as described above in this report, there is no differentiation between paths for cycling and paths for walking, through design or signage. For trips beyond campus that use Township and state roads, the bike maps provided by the Township of Princeton could be helpful, though they are quite difficult to read and not focused on the places or the trips that are most relevant to the University.

Biking in the road on Alexander would be out of the question for most people, and even the sidewalks are substandard in places, to say nothing of the difficulty when people biking, driving golf carts and walking are all expected to share the same four feet.

Bikeshare

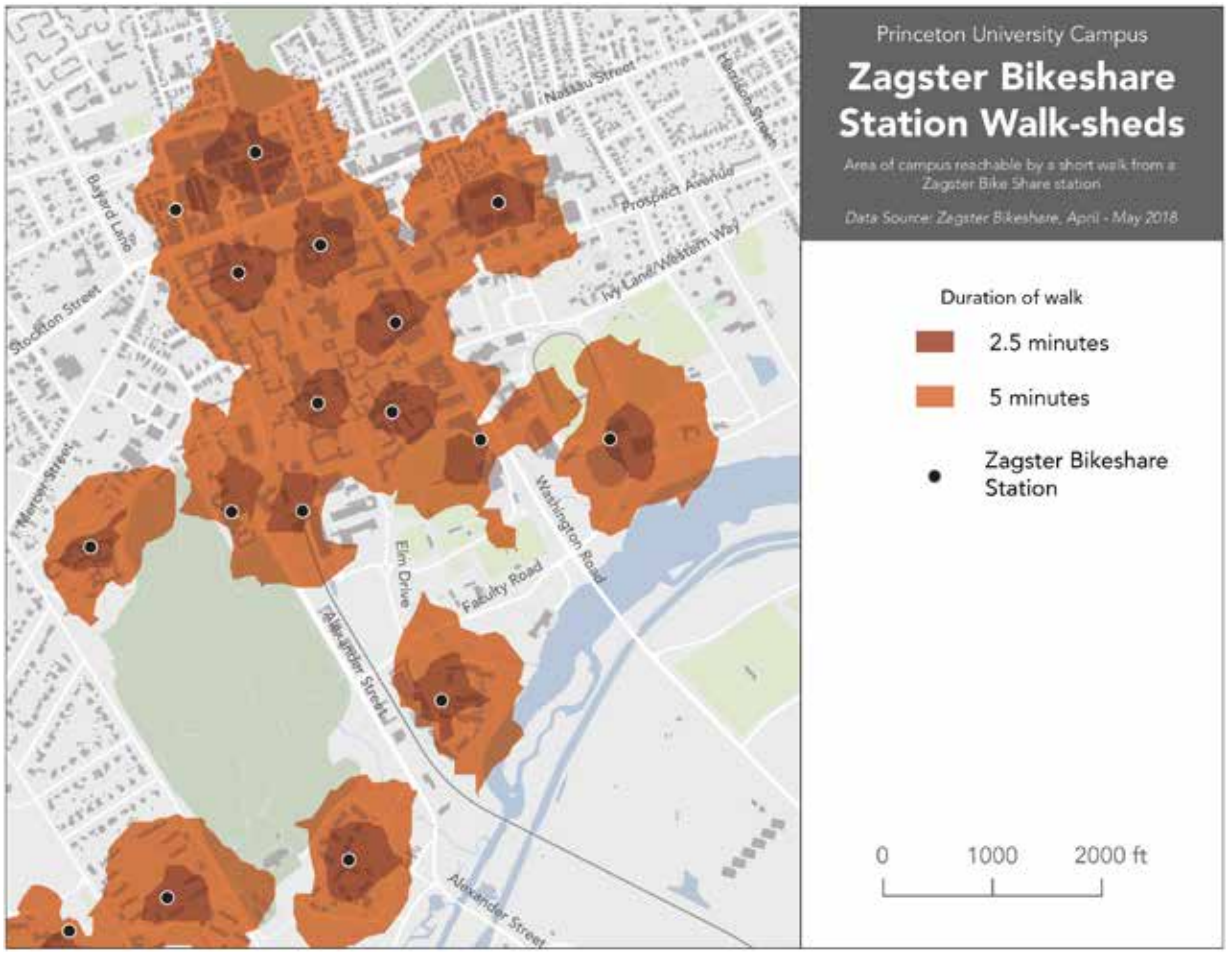
Coverage and accessibility

The University currently offers students, staff and faculty access to a bikeshare system operated by Zagster. Users can find and unlock bikes (at either bikeshare stations or distributed around campus) using a smartphone app. When they are finished with their ride, they lock the bike at another station or away from a station. Zagster "rebalances" bikes throughout the day, moving them back to high-demand stations and re-clustering scattered bikes at stations.

The Zagster fleet for the Princeton University system consists of 119 bikes. Within Princeton, the bikeshare system includes 19 stations, 16 of which are located on or within 1000 feet of land owned by the University. Graduate College, Forbes College, and the Lawrence and Lakeside residences each have one bikeshare station. The Central Campus has 7 stations, including one at Princeton Station/West Garage.

The map on the right shows the area accessible within short walks of bikeshare stations. A bikeshare station can be reached within a 5 minute walk from anywhere on Central Campus. On the other hand. buildings in the academic areas on the east of Washington Road as well as the athletics facilities on the southern side of Central Campus and east of Washington Road are relatively farther from bikeshare stations.

Within a small campus setting, bike trips tend to be shorter in distance and duration from one location to another. 46% of Zagster trips are 5 minutes or shorter in duration, and 67% less than 15 minutes.



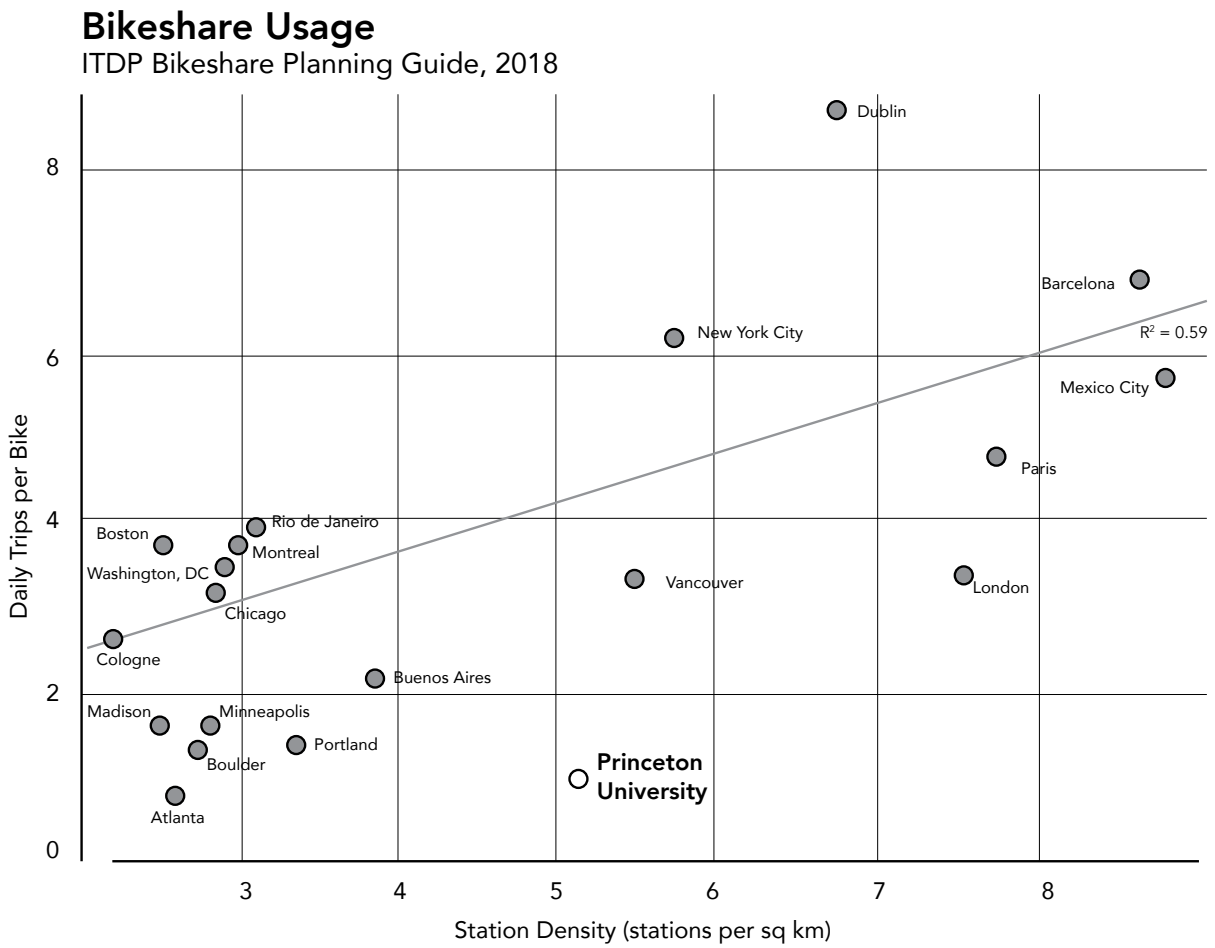
Bikeshare stations are available at the relatively outlying student residences. All of Central Campus is within a 5 minute walk of a bikeshare station.

Five minutes on either end of a five-minute bike ride is relatively more significant than at either end of a 20 minute bike ride. This means that proximity to a station is an important consideration when it comes to systems with predominantly short trips. The map shows that compared to the five-minute threshold, a much smaller proportion of campus is accessible within a 2.5 minute walk.

Another way to think of the proximity of bikeshare stations is to estimate their density. A higher density of stations would mean that there are more stations accessible within shorter walks. This also means that people have more options to end their rides closer to their destinations. For the 1.21 square miles of land in Princeton owned by the university, having 16 stations means that there are around 5 stations per square kilometer on average.

The station density of a docked system relates to some extent to the utilization of the bikes. For a fleet of 119 bikes, roughly 101 trips are undertaken during the day on average, which is equal to 0.8 trips per bike per day.

These metrics can be compared to other bikeshare systems around the world. The graph on the right is taken from the ITDP Bikeshare Planning Guide, and compares station density to daily trips per bike. There is some variation in utilization, but as mentioned before, there is a correlation between station density and utilization. Princeton's system has a lower-than-expected utilization of bikes compared to the density of stations. This could be related to the differing usage patterns over the span of the day, and also points to the need to examine other factors which influence bikeshare usage, like biking infrastructure around campus.



There is some correlation between utilization of bikes and station density. Having stations closer together enables easier access to bikes and more options of people to dock bikes at the end of rides.

Usage patterns

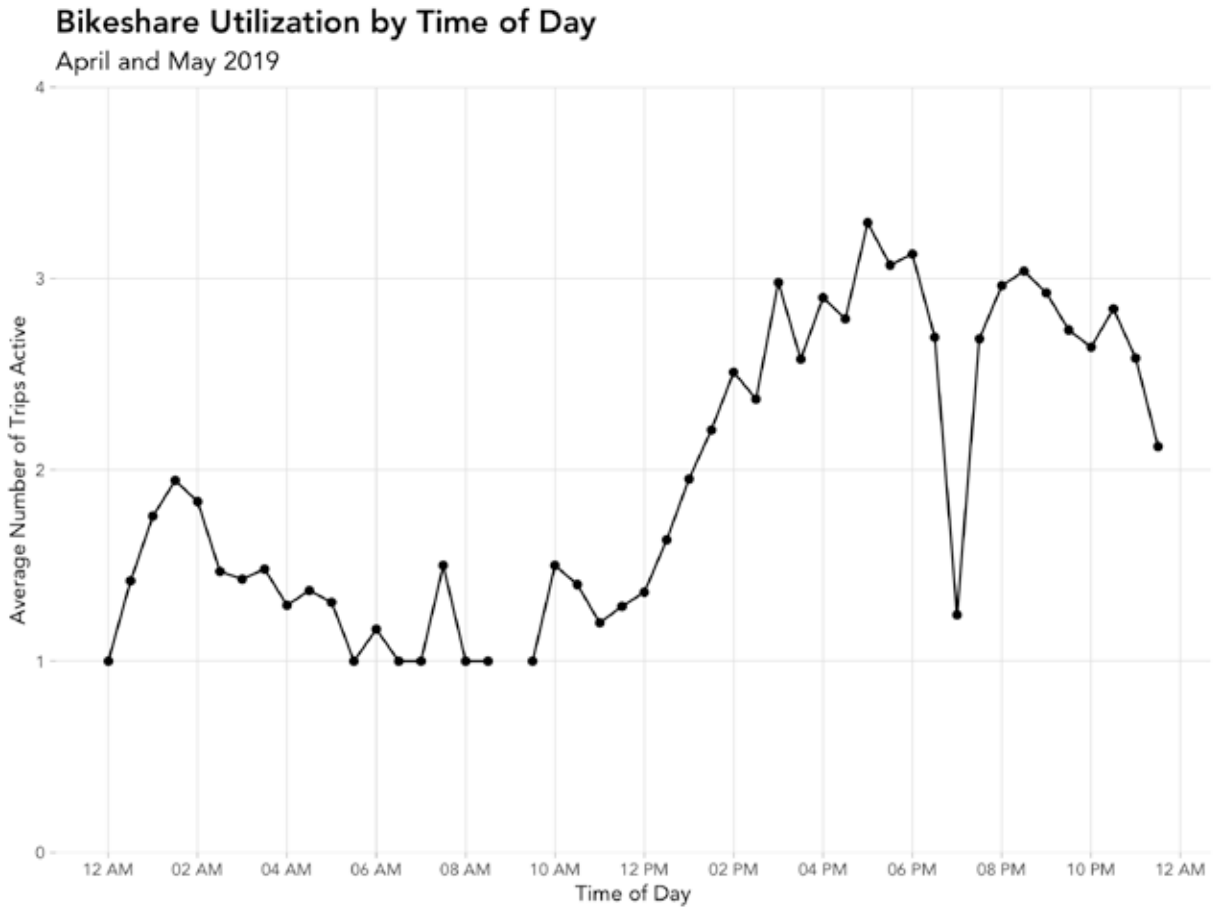
Bikeshare use is higher in the afternoons and evenings than in the mornings, and peaks between 7:00 and 9:00 p.m. The daily pattern of transit demand throughout the day is the reverse (as we explain in the next chapter), with much higher demand in the morning than in the afternoon or evening.

Bikeshare has peaking costs just like transit, and like any service that uses shared vehicles to serve one-way demands. When peak travel predominates in one direction in the morning, empty buses must drive back the other way, bikes must be transported back to the popular stations, and hired cars also must be driven back to where people are starting their trips.

The Lawrence Apartments bikeshare station is the most-often "overpopulated" with bikes, which is evidence that residents are getting to campus by some other mode and then returning home using bikeshare. The Lakeside Apartments and Caldwell House bikeshare stations are also often "overpopulated" with bikes. It is surely not a coincidence that these stations are downhill relative to the rest of campus.

In contrast, Graduate College West is under-populated with bikes at high demand times, which suggests that residents go to campus using bikeshare and then get home by some other mode. Other under-populated stations are Firestone, Friend Center, Richardson and Whitman.

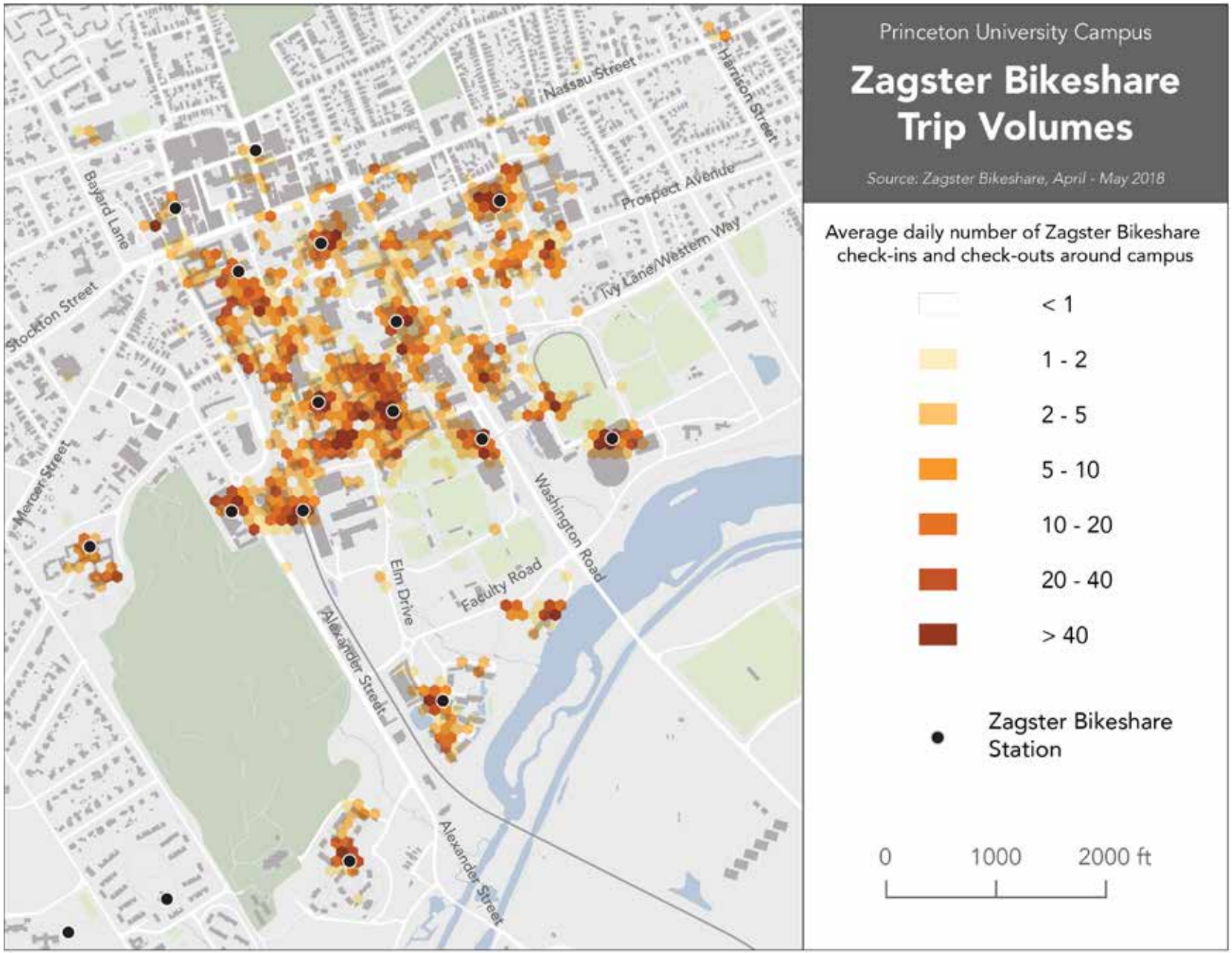
The maps on the following pages show lines linking bikeshare origins and destinations, and the density of the starts and ends of trips. Much of the activity is concentrated in the core of campus, where there is a higher density of bikeshare stations. Some spots not necessarily close to stations also see a lot of activity. This observation highlights the power of flexibility of hybrid and dockless systems, which gives people freedom to lock and unlock bikes closer to their origin/destination. The spatial distribution of activity patterns can also help identify locations where there is demand for bikeshare but which are currently not very close to stations: for example, in the eastern parts of campus.



Bikeshare use is highest in the afternoon and evening, showing the opposite pattern from transit use.

Because bikesharing is so new, the technology is evolving fast. The Zagster system currently in place was the height of innovation just three years ago when it was implemented. Innovation has continued to improve the bikes, the apps, the hardware and software that make bikeshare systems work.

Bikeshare trips are most concentrated within the core of campus, but trips to Lawrence, Lakeside and Caldwell Field House are also high.



The distribution of check-ins and check-outs highlights the importance of flexibility and helps identify potential spots for new stations.

The Lakeside bikeshare station is one of the most popular, especially for ending trips (as it is downhill from campus). Lawrence and Caldwell Fieldhouse are even more popular.

Policies Impacting Biking and Walking

Factors beyond the built environment also influence some people's ability or at least the perception of their ability to bike and walk to meetings or appointments during the day. At a workshop in the Fall 2019, some members of Princeton's Transportation Advisory Council expressed that the University's formal dress code kept them from walking and biking. However, people in northern European countries often cycling in formal clothes. Cultural norms about clothing and cycling will be explored as part of the Mobility Framework.

Meetings that both begin and end at the top of the hour leave no time to drive, much less bike or walk, to the next meeting. This scheduling problem was also flagged by members of the Council.

Service and delivery vehicles

Princeton University's historic campus may have been built for walking and horse carts, but today a lot of the maintenance, construction, business and catering happens thanks to motor vehicles.

The working vehicles on campus include outside delivery trucks (such as the UPS step-van, at right), the University's own maintenance trucks, vehicles belonging to contractors and construction workers, and a wide array of electric golf carts or diesel Off-Highway Vehicles (OHVs) that can fit down pathways as well as on roads.

The number of motor vehicles using campus roads, and in particular using pathways and sidewalks, is unusual for a university campus. The experience of sharing campus roads with so many cars and trucks probably does not rise to the level of consciousness for most people, especially since beyond campus the U.S. is dominated by cars to a much greater degree.

There is a clear need for motor vehicles or larger non-motorized vehicles on campus, to move equipment, tools and materials. There is a need to help people navigate campus despite disabilities that prevent them from walking. There is a need to store motor vehicles near some buildings (such as catering vehicles near Frist). At present, these needs seem to be met in an uncoordinated way, with each individual driver developing their own plan for how their vehicle should relate to the walking, cycling, scooting and socializing happening on campus roads and paths.

Vehicles are often parked on campus walkways or sidewalks, and parking prohibitions are regularly flouted by people driving private cars, commercial trucks, maintenance vehicles and golf carts.

One example is the southwest corner of Frist Center, which is both a major pedestrian entrance to the building and a loading dock. Pavement markings that say "Fire Lane" and "No Parking" are often covered up by parked vehicles. Walking into the building can require snaking between double-parked private cars and golf carts.

The golf cart fleet in particular seems to beg for greater coordination and some shared expectations for how and where carts will be used. Many people have stories about annoyances or close-calls involving golf carts and OHVs on pathways. Records suggest that there are 200 golf carts or OHVs in use on campus, owned by more that 20 departments.

As mentioned earlier, in places like Pyne and Chapel Drives, there are usually between 6 and 8 people walking or biking for every motorized vehicle. Elm Drive sees a greater proportion of buses and service vehicles, but pedestrians and bicyclists still outnumber vehicles: at least two-to-one during most of the day, and as much as six-to-one during the times when classes are changing.

One vehicle (be it a golf cart or a bus) occupies much more space than a pedestrian or a bicyclist. In an environment that was not built with such vehicles in mind, and in a historic context that limits the expansion of roads and sidewalks, we often see pedestrians and bicyclists competing with motor vehicles for space. While motor vehicles will be essential to much of the work that happens "behind the scenes" at Princeton University, they exist in tension with the University's goals of educating students in a beautiful setting; one that invites walking, reflection and interaction; designed for spacial cohesion and a distinctive sense of place.

3. Existing Conditions for TigerTransit

Transit's competing goals

TigerTransit is currently pursuing an implicit policy that all University buildings will be served with at least minimal transit service.

This policy should be debated and decided as part of this mobility plan, because this goal trades-off against other goals that the University holds for its transit system.

Transit can serve many different goals. But different people and communities value these goals differently. It is not usually possible to excel towards all of these goals at the same time, and it is mathematically impossible to *maximize* all of these goals within the same budget.

Understanding which goals matter most to Princeton University is a key step in redesigning the transit network.

Possible goals for transit include:

- **Economic and social**: Transit can help people avoid the costs of owning and driving a car, and allow them to spend their money in more productive ways.
- **Environmental**: Increased transit use can reduce air pollution and greenhouse gas emissions. Transit can also support more compact development and help conserve land.
- **Health**: Transit can be a tool to support physical activity by walking. This is partly because most riders walk to their bus stop, but also because riders will tend to walk more in between their transit trips. Transit, as an alternative to driving, also increases peoples' social interactions with one another.

Some of these goals are served by high transit ridership. For example, the environmental benefits of transit only arise from many people riding the bus rather than driving (or being driven). Subsidy per rider is lower when ridership is maximized. We call such goals "ridership goals" because they are achieved through high ridership.

Other goals are served by the mere presence of transit. A route to a distant building provides people with a non-driving option in case they need one, even if few people ride it. A route may fulfill political or social obligations, for example by getting service close to every University building or department. We call these types of goals "coverage goals" because they are achieved by covering certain places with service, regardless of ridership.

High ridership is not the only goal of transit

If the University wanted to maximize TigerTransit ridership, it could focus service only on routes useful to many potential riders. An important consideration would be how *competitive* transit is for a large number of people, compared to their other options. TigerTransit services would not be provided where there are few people, or where the service is expensive to provide.

This is more like the way that businesses make decisions about where to sell their products. Businesses are under no obligation to operate where they would spend a lot of money to reach few customers.

For example, Starbucks is under no obligation to provide a cafe within 1/2 mile of everyone in Mercer County. If it were, then the company would have to add dozens of additional locations, some serving just a handful of homes, and most operating at a loss because of the few customers nearby.

People understand that rural and suburban areas will naturally have fewer Starbucks locations nearby than urban areas. We don't describe this as Starbucks being *unfair* to rural or suburban areas; they are just acting like a private business. Starbucks has no obligation to cover all areas with its restaurants.

The University is not a private business, it is not in pursuit of profits, and TigerTransit riders are not customers. A private business plan is not a model for how the University should design its transit network, but as a metaphor it illustrates how we would design a *ridership-maximizing* transit network.

Transit providers are often accused of failing to attract high ridership, as if ridership were their only goal. In fact, most transit providers – public or non-profit – are intentionally operating "coverage services" that are not expected to generate high ridership. In this Mobility Framework, Princeton University can strike a deliberate balance between the competing goals of high ridership and wide coverage. The University can also think about whether attracting more riders to transit is desirable if their alternatives are walking or cycling.

High ridership and high coverage goals are both laudable, but they lead us in opposite directions. Within a fixed budget, if a transit provider wants to do more of one, it must do less of the other.

Here is an illustration of how ridership and coverage goals conflict with one another, due to geometry and geography.

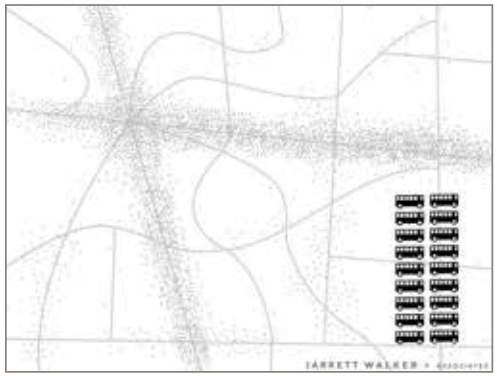
In the fictional town at right, the little dots indicate dwellings and commercial buildings and other land uses. The lines indicate roads. Most of the activity in the town is concentrated around a few roads, as in most towns

A transit agency pursuing only a ridership goal would focus service on the streets where there are large numbers of people, where walking to transit stops is easy, and where the straight routes feel direct and fast to customers. Because service is concentrated onto fewer routes, frequency is high and a bus is always coming soon. This would result in a network like the one at bottom-left.

If the town were pursuing only a coverage goal, on the other hand, the transit agency would spread out services so that every street had a bus route, as in the network at bottom-right. As a result, all routes would be infrequent, even those on the main roads.

On a fixed budget, designing transit for both ridership and coverage is a zero-sum game. In the networks at right, each bus that the transit agency runs down a main road, to provide more frequent and competitive service in that market, is not running on the neighborhood streets, providing coverage. While an agency can pursue ridership and provide coverage within the same budget, it cannot do both with the same dollar. The more it does of one, the less it does of the other.

These illustrations also show a relationship between coverage and complexity. Networks offering high levels of coverage are naturally more complex.

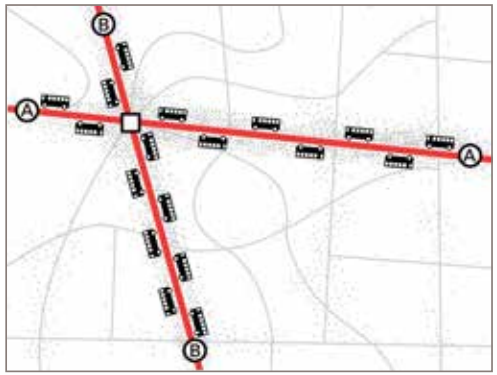


Imagine you are the transit planner for this fictional town.

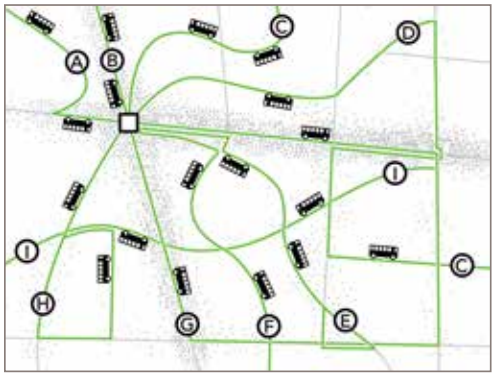
The dots scattered around the map are people and jobs.

The 18 buses are the resources the town has to run transit.

Before you can plan transit routes, you must first decide: What is the purpose of your transit system?



You can focus all 18 buses on the busiest areas. Waits for service are short. Walks to service are longer for people in less populated areas. Ridership is high, but some places have no service at all.



You can spread out your 18 buses so that there is a route to every building. Everyone is near a stop so walks are short. Every route is infrequent, so waits for service are long. Few people can bear to wait so long, so ridership is low.

In this imaginary town, any person could keep the very simple high frequency network in their head, since it consists of just two routes, running in straight lines. They would not even need to consult a schedule to catch a bus because one is always coming soon. The high coverage network would be harder to memorize, requiring people to consult a map (to understand the routing and a schedule (to catch these infrequent services).

The TigerTransit network is very complex, and this relates to the very high coverage it provides. Every University building has a bus route serving it very nearby. The result is many routes, each of them designed to a specific niche market (in some cases a single building), and few of them offering the high frequency that makes transit useful to large numbers of people.

In transit conversations, there is always a great focus on *where* transit is provided, but sometimes not enough attention paid to *when* it is provided.

The "when" of transit service can be described as "frequency" or "headway" (how many minutes between each bus) and "span" (how many hours per day, and days per week, it runs).

Low frequencies and short spans are one of the main ways that transit fails to be useful, because it means service is simply not there when the customer needs to travel.

Frequent service:

- Reduces waiting time (and thus overall travel time).
- Improves reliability for the customer, because if something happens to your bus, another one is always coming soon.
- Makes transit service more legible, by reducing the need to consult a schedule.
- Makes transferring (between two frequent services) fast and reliable.

In order to think about whether any frequency is "frequent enough," imagine waiting one-half of the frequency, on average (since statistically, you will) and ask yourself whether you could tolerate waiting that long as part of an everyday trip.

Many people assume that today, when so many transit systems offer real-time arrival information, nobody needs to wait for a bus anymore, and frequency therefore doesn't matter. If a bus only comes once an hour, that's fine, because your phone will tell you when it is a few minutes away and you should walk to the stop.

Despite all these new technologies, frequency still matters enormously, because:

- ***Waiting doesn't just happen at the start of your ride*, it also happens at the end.** You may not need to leave the house long before your departure, but ***if your bus is infrequent, you have to choose between being very early or too late.*** If you start work at 8:00 am but the hourly bus passes your workplace at 8:10 am, you have to choose between being 50 minutes too early or 10 minutes late.
- ***Many of the places we spend time don't let us hang out until our bus's arrival is imminent.*** We can easily do this when leaving home, but it is more awkward when leaving a restaurant or a workplace that is closing. Affluent people can afford to buy an unneeded coffee or beer in order to spend 40 minutes waiting indoors rather than at the transit stop, but working class people do not have that luxury.
- ***Real-time arrival information doesn't make the bus more reliable, but frequency does.*** Your phone can tell you when your bus is arriving, but it cannot prevent your bus from having a problem and being severely delayed, or not showing up at all. Only frequency – which means that another bus is always coming soon – can offer this kind of resilience.

The Ridership Recipe

Achieving high ridership requires more than frequent service. Many factors outside the control of TigerTransit or even Princeton University – land use, development, urban design, street networks – affect transit's usefulness. For this reason, land use planning by the University, the townships, counties and state will be an essential part of transit's success.

The way that TigerTransit could attract higher ridership, within a fixed budget, is by targeting places where the "Ridership Recipe" is in effect:[1]

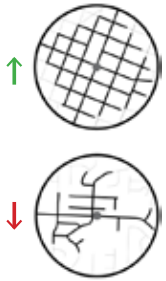
- **Density**: Demand for transit is higher when there are more people and activities near each transit stop.
- **Walkability**: Service is only useful to people who can safely and comfortably walk to the transit stop.
- **Linearity**: Direct routes among destinations are faster, cheaper for TigerTransit to operate, easier to understand and more appealing to customers.
- **Proximity**: Shorter distances between destinations attract more riders per hour and are cheaper for TigerTransit to operate.

These are geometric facts of a city and its design. They are not a matter of opinion or personal values.

***The Ridership Recipe*: Higher Ridership, Lower Costs**

DENSITY *How many people, jobs, and activities are near each transit stop?*

WALKABILITY *Can people walk to and from the stop?*

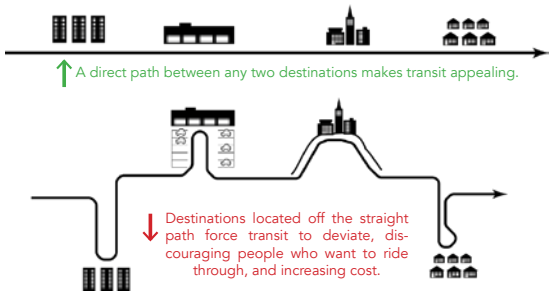


The dot at the center of these circles is a transit stop, while the circle is a 1/4 mile radius.

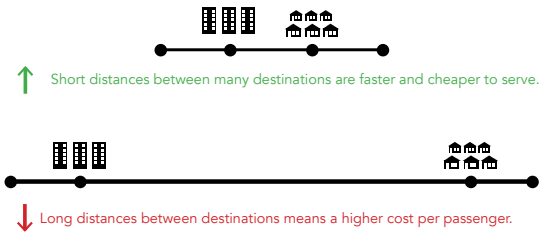
The whole area is within 1/4 mile, but only the black-shaded streets are within a 1/4 mile *walk*.

It must also be safe to cross the street at a stop. You usually need the stops on both sides for two-way travel!

LINEARITY *Can transit run in reasonably straight lines?*



PROXIMITY *Does transit have to traverse long gaps?*



All of these factors affect both the costs of providing transit and the number of people who will find the service useful.

- *Density and walkability tell us about the overall ridership potential*: *"Are there are a lot of people around, and can they get to the transit stop?"*
- *Linearity and proximity tell us about both ridership potential and cost*: *"Are we going to be able to serve the market with fast, direct lines, or will we have to run indirect or long routes, which cost more to operate (and cost riders time)?"*

The mix of uses along a route also affects how much ridership transit can achieve, relative to cost. This is because a mix of uses tends to generate demand for transit ***in both directions, at many times of day.***

Transit lines serving purely residential buildings tend to be used in mostly one direction and mostly during rush hours – away from the residences, towards jobs and services. This is true of TigerTransit's Route L (Lawrence/Lakeside), which in the mornings is extremely full going towards campus but empty coming back. Routes serving a mix of uses and a diverse group of people can be full in both directions, all day long.

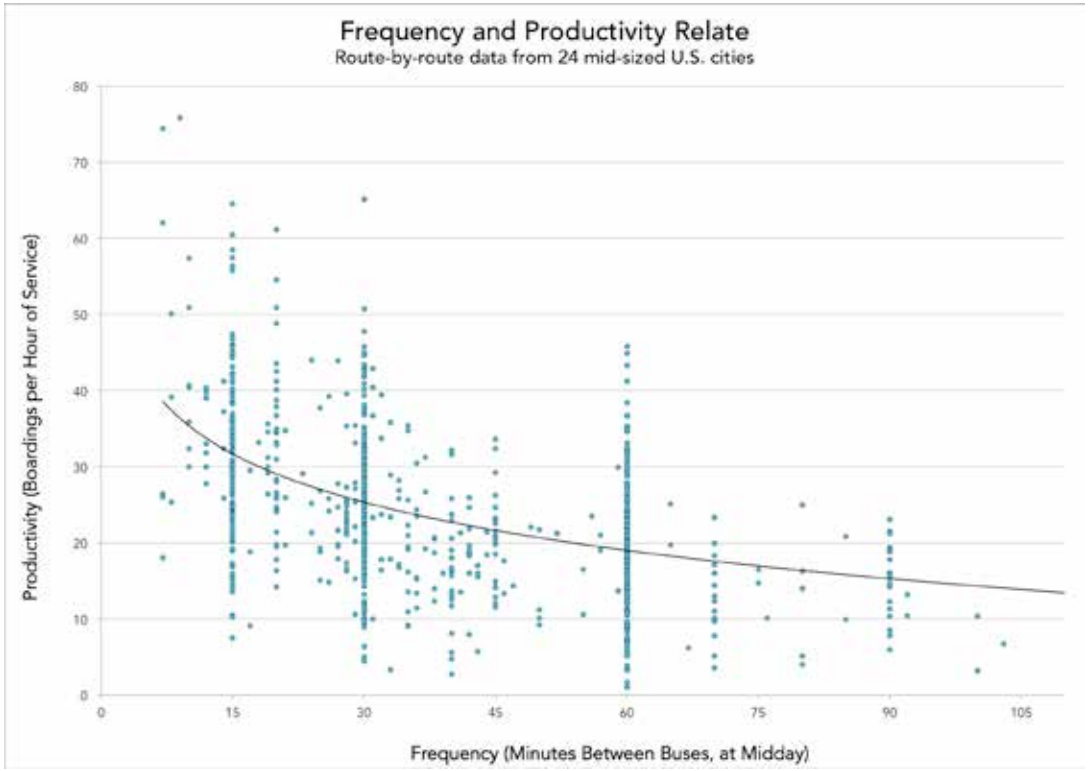
[1] Research describing the relationships among transit ridership, transit cost, and land use and street design factors is abundant. For an introduction, see *Travel Demand and the three Ds: Density, Diversity and Design*, by Cervero and Kockelman and *Travel and the Built Environment: A Synthesis*, by Ewing and Cervero.

In the diagram on the previous page, the title "Ridership Recipe" elides an important fact: achieving high ridership within a limited budget requires paying attention not only to a route's ridership, but also to its costs. An organization that wants to raise total ridership on its system will monitor not sheer ridership on each route, but *ridership relative to costs*.

In transit, this measure of efficiency is called "productivity." The productivity of a transit route is its total ridership divided by the total hours vehicles are driving that route. These vehicle hours are an excellent proxy for operating cost, and they also describe the level of service provided to the route: a more frequent route requires more drivers and buses on the road simultaneously, and therefore more vehicle hours; a route with later night service requires an additional vehicle to stay late; a route that runs 7-days-per-week requires more vehicle hours than a route operating on weekdays only.

There is a well-documented correlation between high frequency and high productivity. The scatterplot at right shows a dot for every route from 24 transit systems in mid-sized U.S. cities. More frequent routes tend to be more productive – this means they not only attract more riders in total, they attract more riders relative to their costs, *even though higher frequency requires more vehicle hours and therefore more costs.*

This is not evidence that increasing the frequency of just *any* route will increase its productivity. The numerous dots in the lower left-hand corner of the plot are evidence to the contrary: these are frequent routes that attract few people per hour.



High frequency and high productivity are correlated – which is not to say that making any route more frequent will make it more productive.

Because high frequency is so costly, transit planners tend to deploy it in places where it can be provided for the greatest number of people. Those places are described in the Ridership Recipe: they are dense, walkable, linear and proximate to one another.

Frequency in the TigerTransit network

The map at right shows the TigerTransit network, with each route color-coded by its weekday midday frequency. A larger map that includes PPPL and other off-campus buildings is on the following page. Full-page versions of these maps are provided in the appendix starting on page 57.

The most frequent TigerTransit is Route A, which circles the core of campus every 7-10 minutes during most of the day on weekdays. It is not, however, the most productive route.

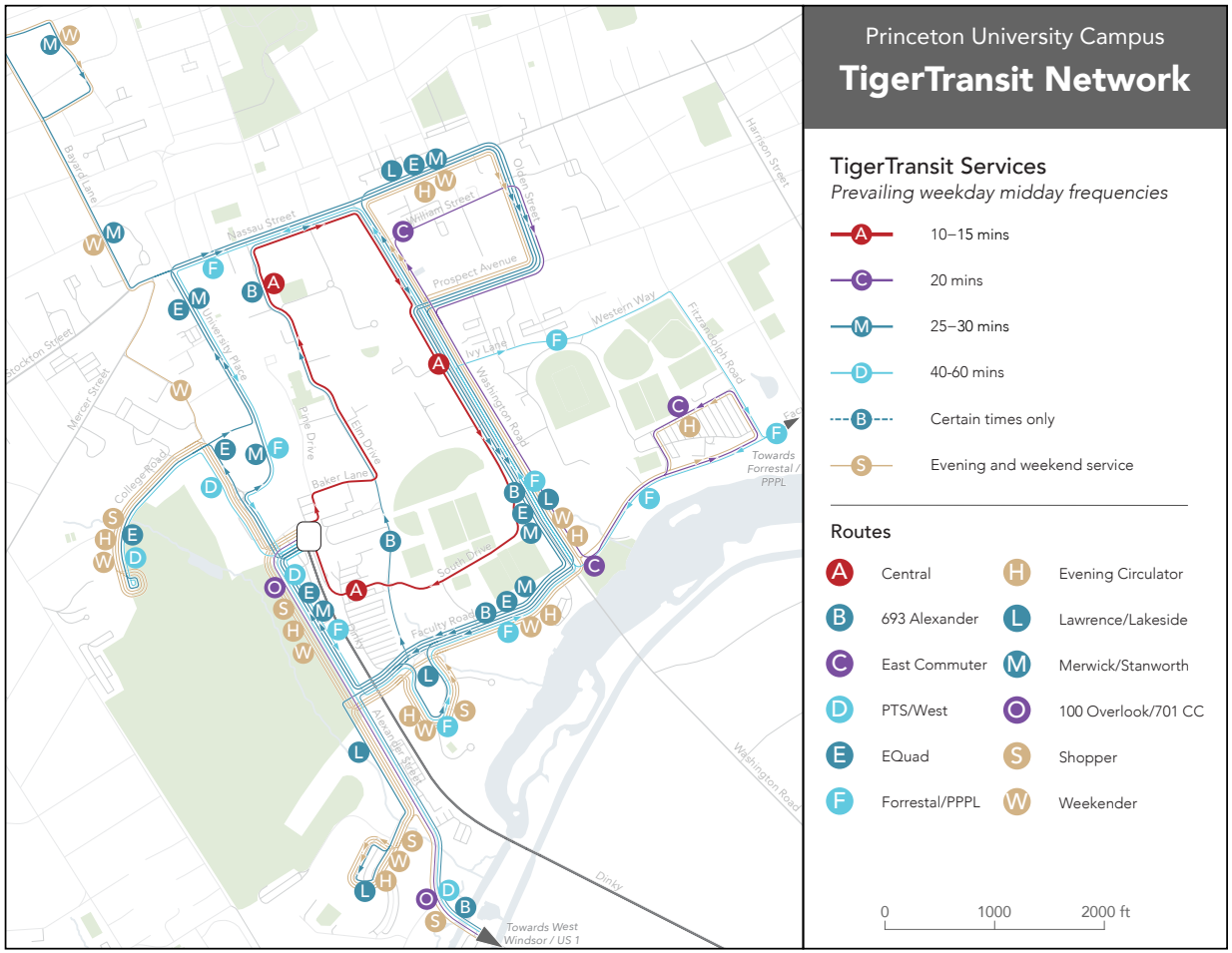
The next two most frequent routes are Routes C (East Commuter) and O (Overlook/Carnegie Center). They come every 20 minutes, though Route C has a longer daily span of service than Route O and offers extra frequency during morning rush hour.

Route O is provided with 20-minute frequency not because of high demand, but as an artifact of the urgent decision to split Route O off from Route B last year, when the Human Resources group was relocated to the Overlook building. The simplest thing to do was to operate Route O with a single bus, and one bus can make the round trip about three times per hour, so the frequency is three times per hour. TigerTransit staff have been planning to revisit Route O's design and frequency as part of this project.

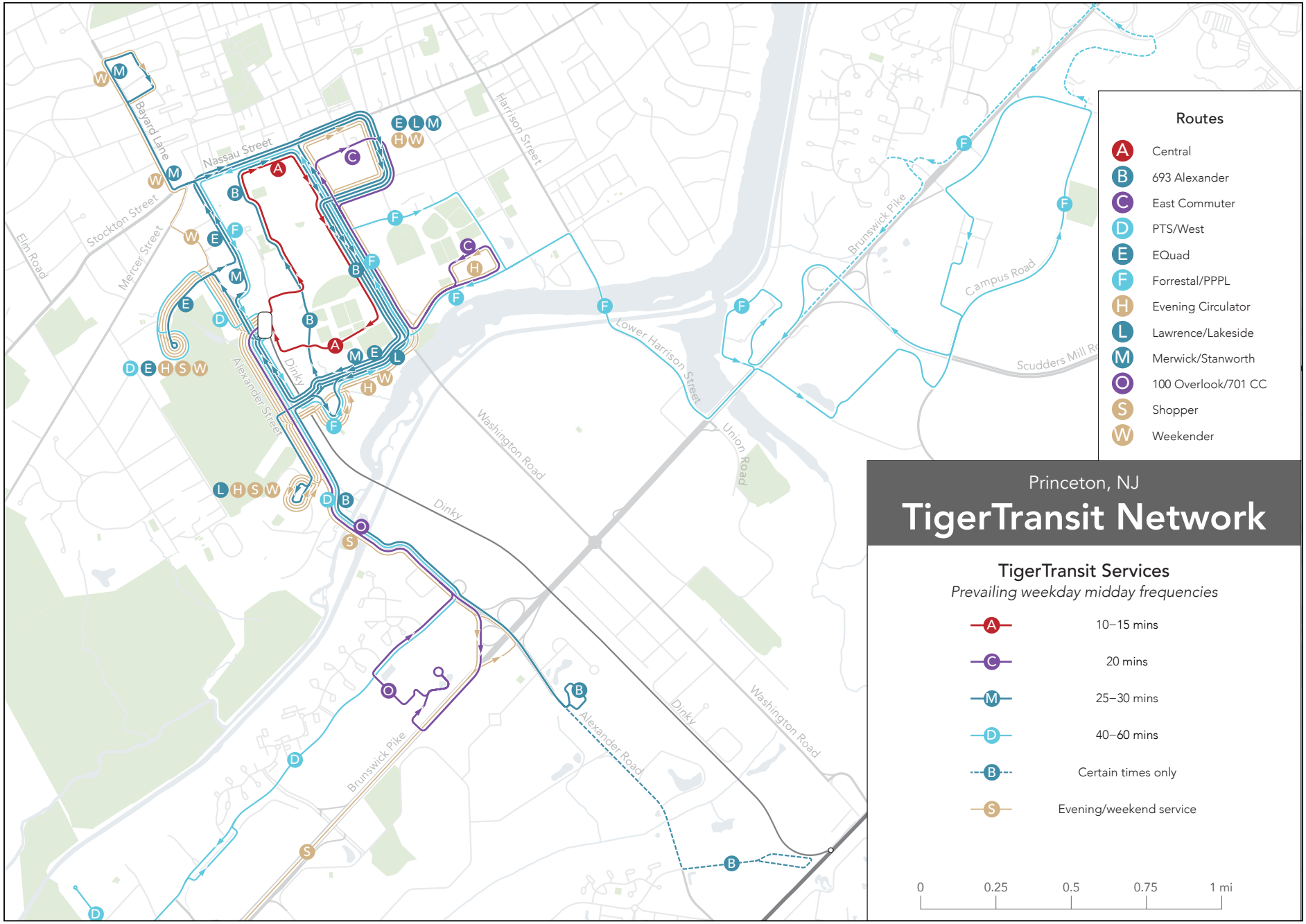
Route B (693 Alexander) comes every 20 minutes at midday, but every 40 minutes during rush hours when the bus makes the longer trip to Princeton Junction.

Route L (Lawrence/Lakeside) comes every 10-15 minutes during rush hours, when large numbers of graduate students are commuting to campus, but only comes every half hour in the middle of the day.

All other routes come every 30 minutes or more.



On this map, TigerTransit routes are color-coded by their midday frequency. Some routes offer a different frequency at rush hours. A larger map including off-campus routes is shown on the next page.


Princeton, NJ
TigerTransit Network
Routes
Central
693 Alexander
East Commuter
PTS/West
EQuad
Forrestal/PPPL
Evening Circulator
Lawrence/Lakeside
Merwick/Stanworth
100 Overlook/701 CC
Shopper
Weekender
TigerTransit Services
Prevailing weekday midday frequencies
10–15 mins
20 mins
25–30 mins
40–60 mins
Certain times only
Evening/weekend service
0
0.25
0.5
0.75
1 mi
Nassau Street
Harrison Street
Bayard Lane
Stockton Street
Mercer Street
Elm Road
Alexander Street
Dinky
Washington Road
Lower Harrison Street
Union Road
Brunswick Pike
Campus Road
Alexander Road

Performance of individual routes

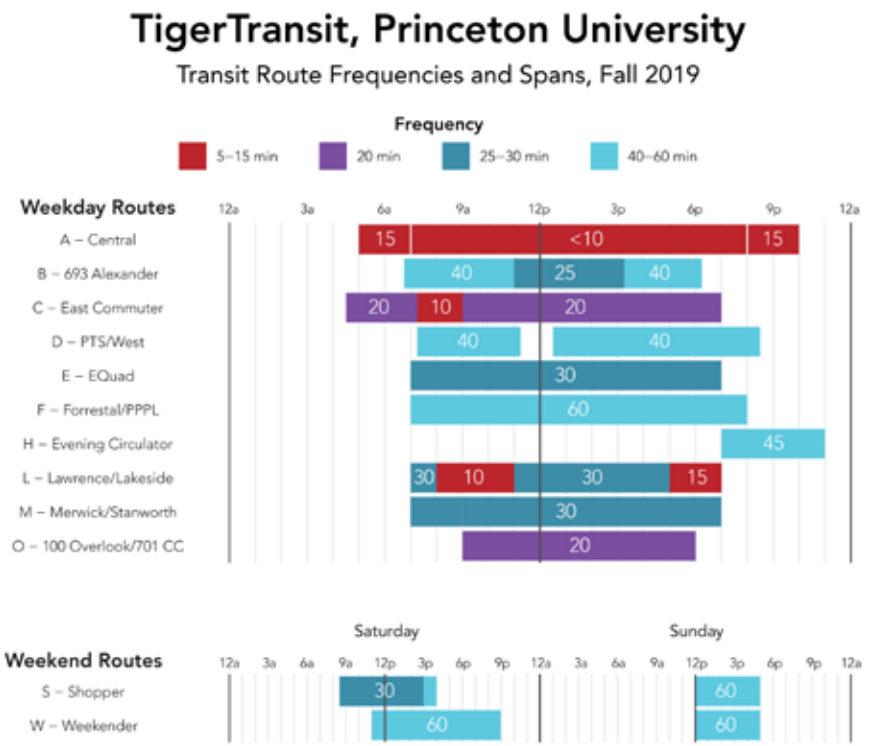
Productivity data from TigerTransit routes demonstrates some of the strategies for attracting high ridership relative to costs.

While high frequency and high productivity are correlated, high frequency alone does not cause high productivity, as we can see by comparing the frequency chart at right with the productivities reported in the table below.

Route A (Central) offers the best all-day frequency, but is the third-most productive route. Route L (Lawrence/Lakeside) offers high frequency during rush hours, but not midday, and it is very productive. Route C (East Commuter) also offers high frequency at rush hours, but is not very productive. And Route O offers good frequency all day but has very low productivity.

	Route name	Average boardings per hour	Average operating cost per boarding
L	Lawrence/Lakeside	30	$4
S	Shopper	28	$5
A	Central	19	$7
C	East Commuter	12	$10
W	Weekender	12	$9
E	EQuad	8	$17
B	693 Alexander (new)	6	$21
D	PTS/West	6	$18
F	Forrestal/PPPL	4	$36
M	Merwick/Stanworth	3	$43
	On-Demand Bus Service	3	$47
O	100 Overlook/701 CC (new)	2	$56
B	693/701 Carnegie Center (old)	2	$56

Routes with higher productivity have lower average operating costs per passenger.



This chart shows the frequency of service on each route throughout the day.

The range of route productivities for private or special-purpose shuttle services generally varies considerably, as seen in the table on the right. These differing productivities can be compared to typical ranges of productivity numbers for other transportation services. On the higher side, TigerTransit routes fall well within the ranges of typical surburban (and even some urban) bus routes. Towards the lower end, productivities are comparable to those of on-demand transit and ride-hailing services.

Example service	Typical boardings per vehicle hour
Subways in major cities	>200
Urban light rail or BRT	80-200
Urban buses	25-50
Infrequent suburban/rural routes	10-20
Private, non-profit and other special-purpose shuttles	5-50
On-demand transit (“Dial-a-ride”, “Microtransit”)	1-4
Uber (and UberPool), taxis	1-3
Paratransit (senior/disabled)	0-2

TigerTransit productivities are comparable to typical productivities of various types of services.

Example: Route L

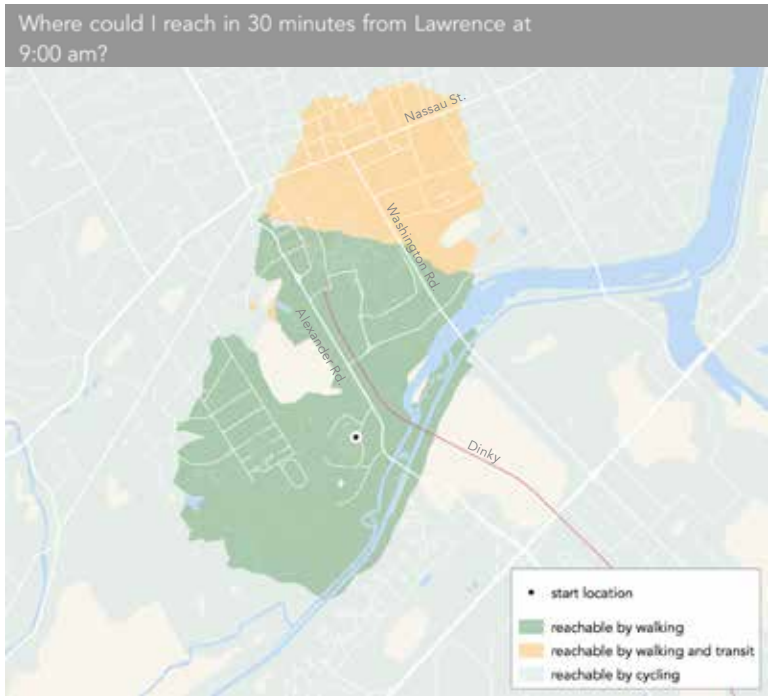
The most productive TigerTransit route is Route L connecting Lawrence/Lakeside to Washington Road and E-Quad. It attracts 30 boardings per vehicle hour on average throughout the day.

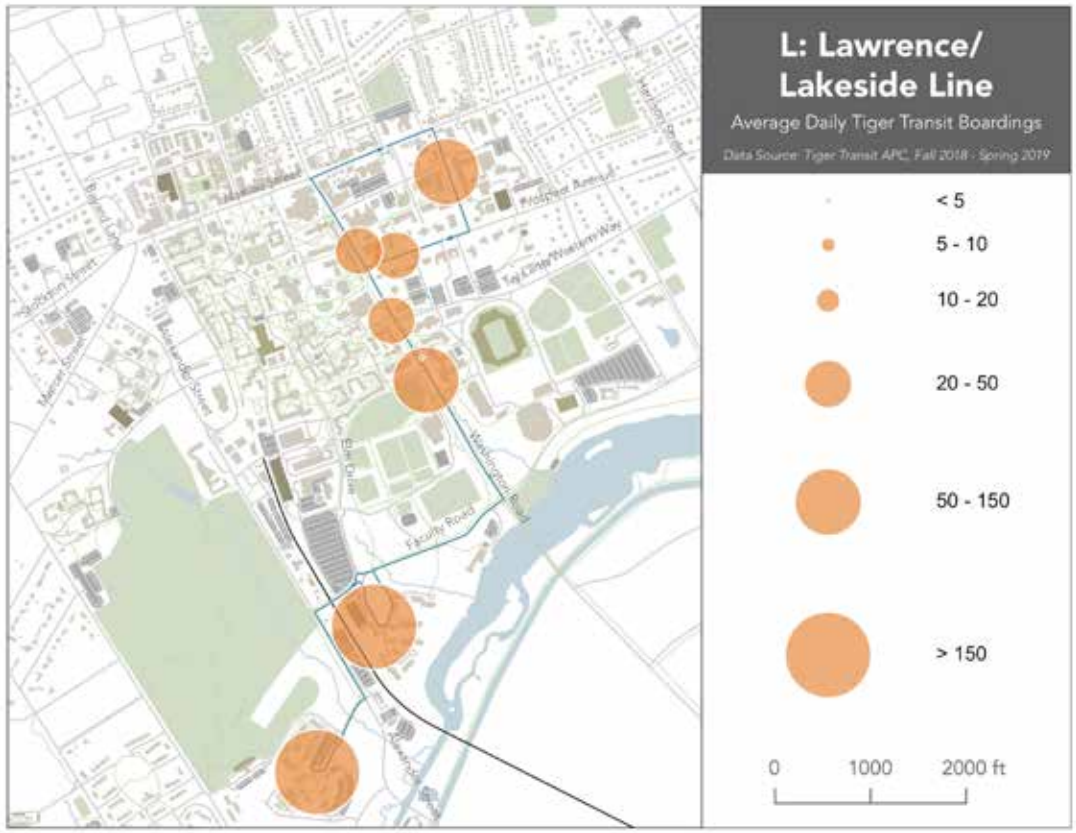
Of the routes serving the central campus, it is the most competitive with walking, especially for trips to buildings near Chapel Drive or EQuad. The map below shows that these areas can be reached within 30 minutes by a combination of transit and walking, but cannot be reached in that time by walking alone.

Because Route L is so frequent during rush hours (coming every 10 minutes), people needn't spend much time waiting for the bus, nor are their forced to arrive at their destination earlier than they want to. Because it is linear and direct, they don't spend time riding out of their way or around a loop.

The map below shows how many people get on Route L stops on the average weekday. (Larger versions of such maps for every route are included in the appendix starting on page 59.)

Especially large numbers of people are boarding near the ends of Route L, from which it can help them make a trip that's a bit too far to walk. Its ends are also anchored in very dense places, with large numbers of apartments in Lawrence and Lakeside, and a high density of busy academic buildings at the north end of campus and in the EQuad.



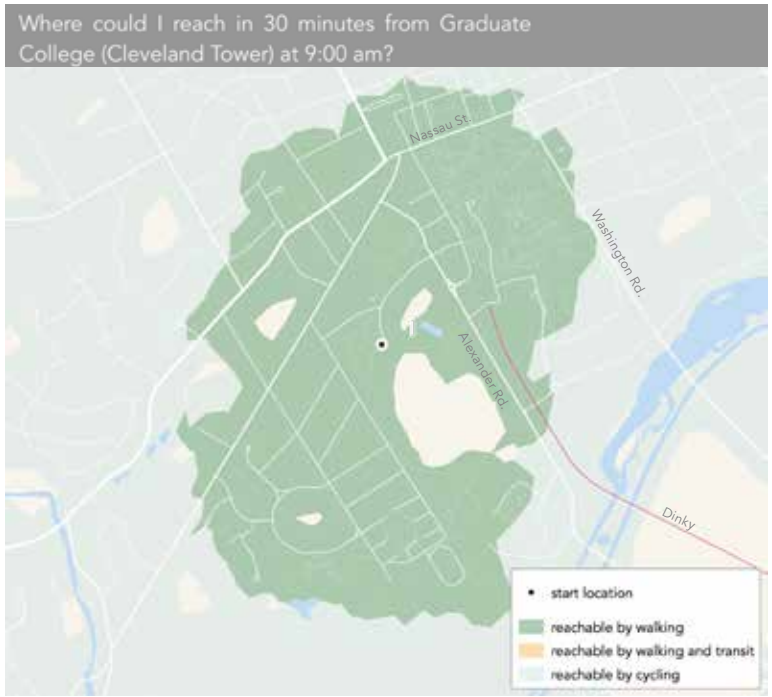


Example: Route E

In contrast, Route E connects Graduate College West to Washington Road and EQuad, with a big one-way loop around campus, as shown in the map below at right.

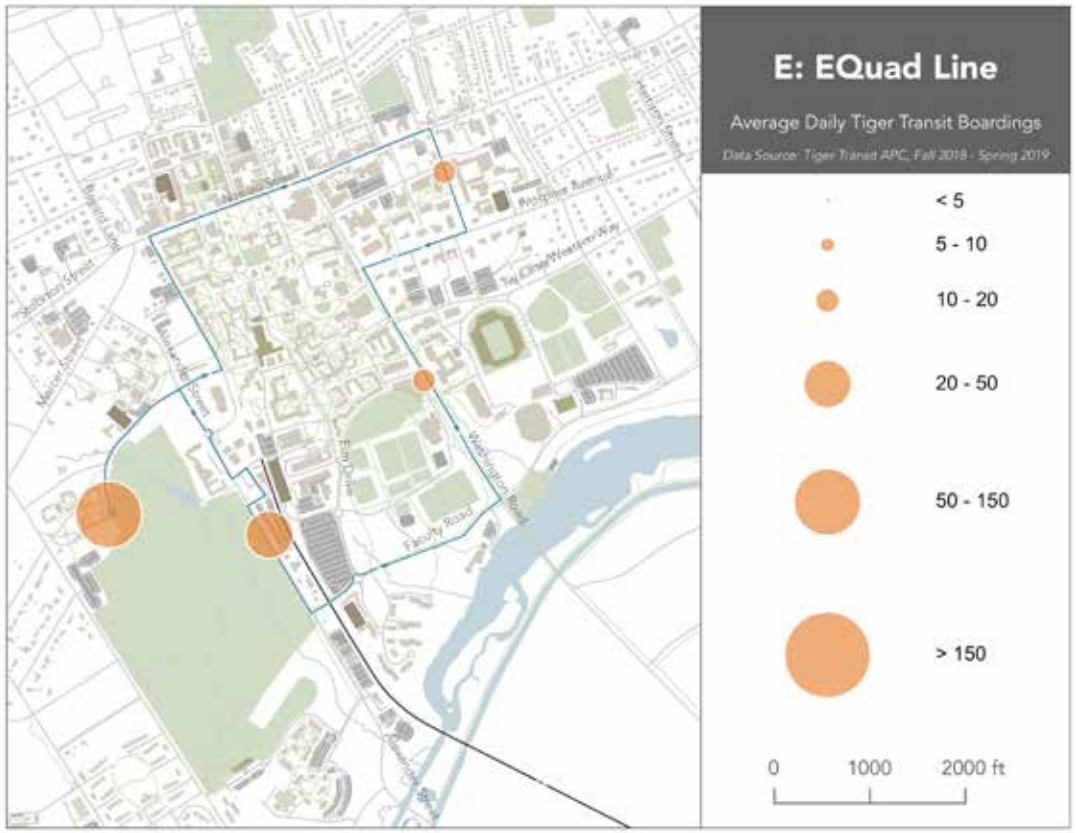
Route E's frequency is not nearly as good as that of Route L (with a bus every half hour during rush hours), so to use it people spend more time waiting. They also spend more time riding in circuitous or semi-circular patterns, when if they were walking they could go more directly towards their destination.

For both of these reasons, it is almost always faster to walk from Graduate College West to a campus destination, as shown in the map below at left.



Example: Saturday Shopper

The Saturday Shopper route is also highly productive. This is likely because it is taking people a distance that is much too far to walk, from central campus to shopping centers along US 1. Because shopping trips tend to be done at peoples' leisure, they are often more tolerant of low frequencies that require planning the trip around the transit schedule, compared to trips that have to be on-time every day for the start of a workday or a class.

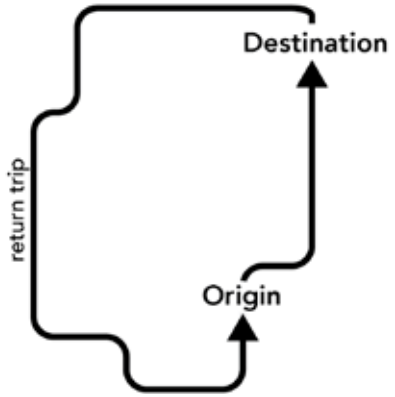


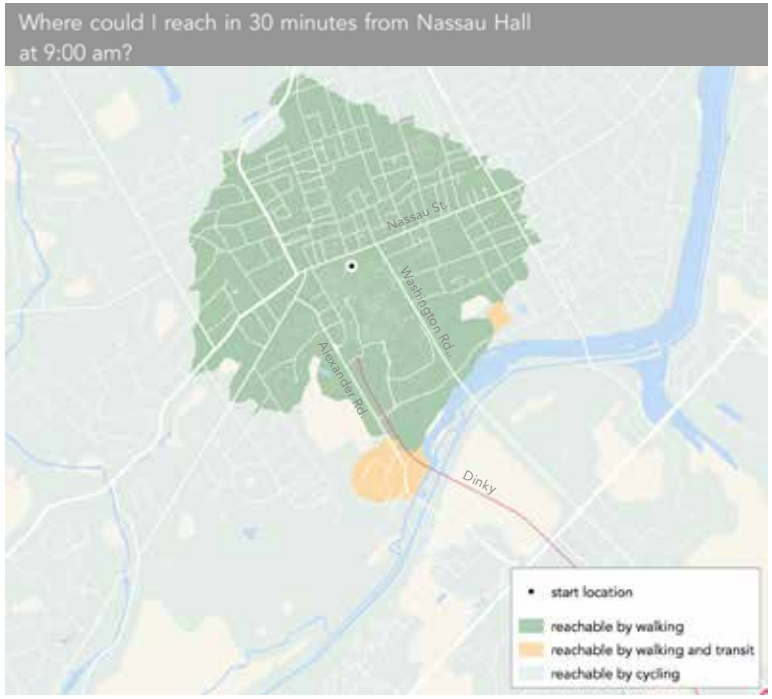
Example: Route A

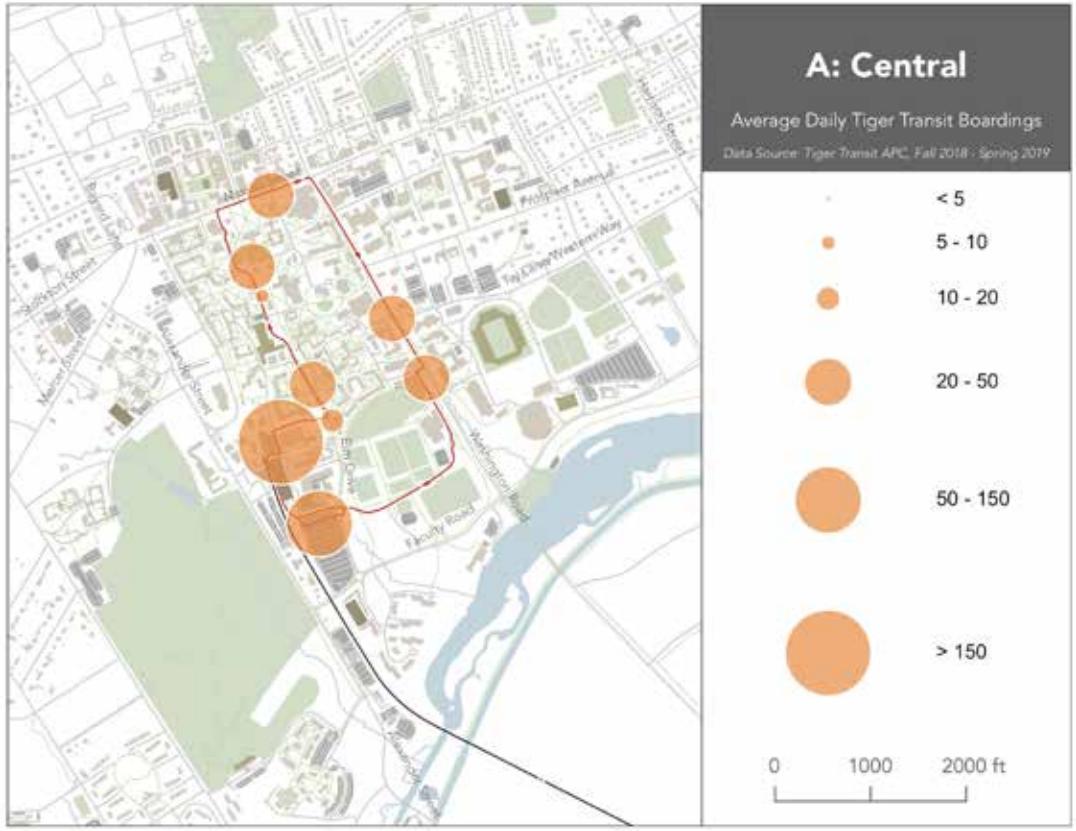
Route A (Central) offers very high frequency (no worse than every 10 minutes, all day) and yet is the third-most productive route in the system, with fewer than two-thirds the boardings per vehicle hour as Route L.

This is probably related to its design as a big one-way loop, which makes it not very competitive with walking (and certainly not with cycling) because for a round trip people end up riding around the whole loop (as shown in the drawing at right). Only for trips between its corners does it offer a travel path that is a bit far to walk, and equally direct as someone would take on foot. For all other trips, it is either taking people in a semi-circle or it is taking people a distance they most of them can walk in ten minutes.

In the map below at left, a trip to or from Nassau Hall is no faster by transit than by walking, except for people coming from Lawrence Apartments (the area in orange) via Route L. This is true even though Route A passes close to Nassau Hall every 10 minutes. From everywhere else (shown in green), if someone is willing to spend no more than 30 minutes traveling, it is faster to just walk.







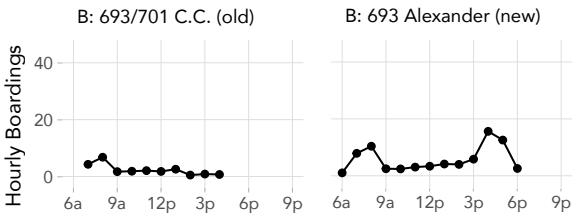
Ridership expectations from suburban areas

TigerTransit's experience with ridership from the 701 Overlook and 100 Carnegie Center buildings illustrates why transit providers generally deploy their most expensive services (frequent services) in places that embody the Ridership Recipe, rather than in suburban car-oriented developments.

Prior to 2019, TigerTransit ran a circuitous Route B that connected 693 Alexander, 701 Carnegie Center and Princeton Junction to campus, with service every 20 minutes during midday and every 40 minutes during rush hours (when the route went the longer distance to Princeton Junction). This route attracted 2 passengers per vehicle hour, which translates to an average operating cost of $64 per boarding.

In 2019, TigerTransit split this into two routes, to provide more direct rides. The new Route B (shown in the map at right) offers more direct service from campus along Alexander Road. The frequency of the route stayed about the same, but it became a much more direct ride to the train because the bus no longer makes a long deviation into and out of the parking lot maze surrounding Overlook and Carnegie Center.

The productivity of the new Route B is higher than the old Route B. The new route is attracting more riders without an increase in service, and most of that new ridership is coming during rush hours, when route goes all the way to Princeton Junction.



On the old route, ridership was fairly flat all day (at left, above). On the new route (at right, above), ridership is many times higher during rush hours. The most likely explanation is that there is demand for service between campus and Princeton Junction.

The new, more direct Route B attracts an average of 6 boardings per hour (rather than 2) at an average operating cost of $21 per boarding. This demonstrates how productivity can improve when dense, walkable places are connected by more linear service.

(The new Route B is only productive compared to the old route. Six boardings per hour is still very low compared to other TigerTransit routes. On average, just 4.4 people board the bus each time it departs Princeton Junction.)

The other half of the old route became a new Route O between campus and 100 Overlook / 701 Carnegie Center. It offers a better frequency than the old route, with service now coming every 20 minutes all day long, including during rush hours (when the old route's frequency was every 40 minutes). The new route also offers a more direct ride between campus and Overlook.

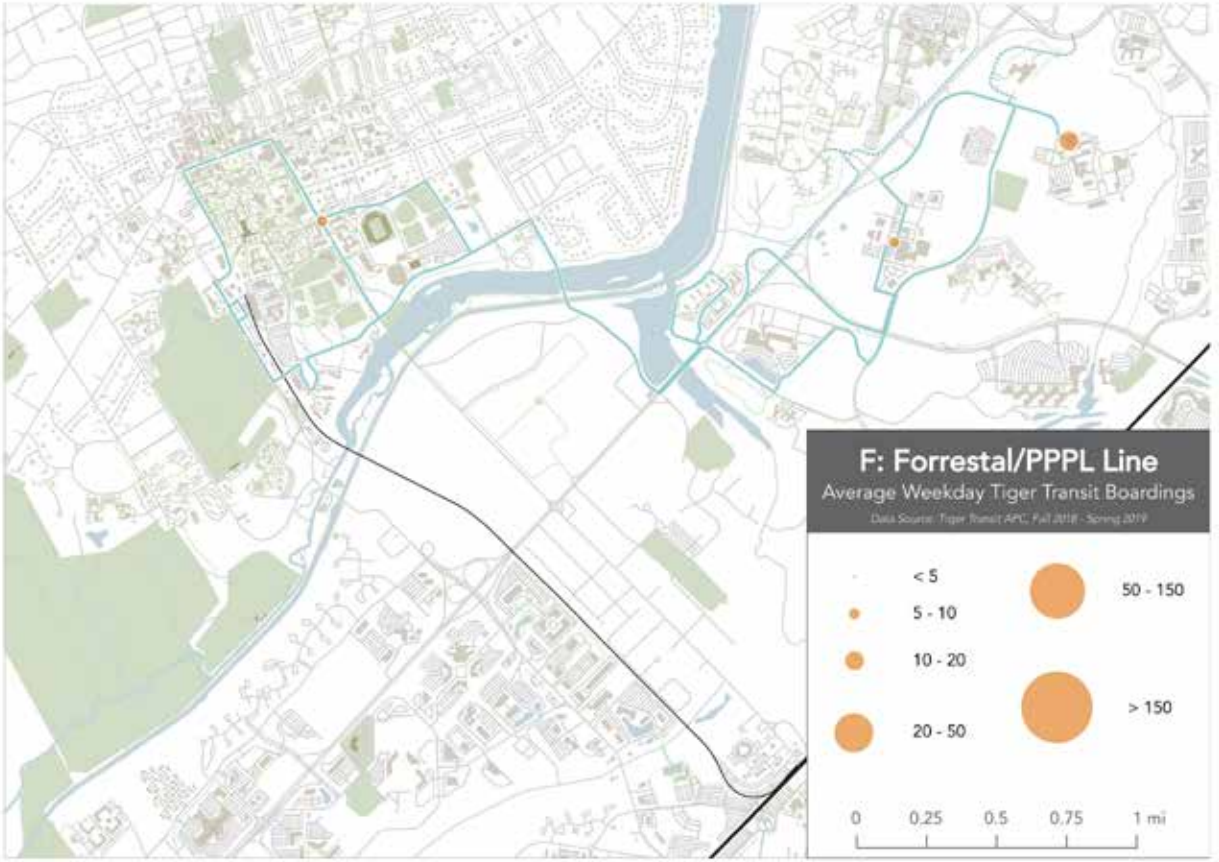
Yet productivity has not changed: the new, more frequent and more direct Route O still attracts just 2 passengers per vehicle hour at an average operating cost of $64 per boarding. This translates to just 0.25 passengers per one-way trip of the bus.

In the absence of supportive land uses (density, walkability, linearity and proximity) high frequency increases transit costs but does not cause a greater-than-proportionate increase in transit riders. This "tale of two routes" can help set the University's expectations for ridership relative to costs in suburban office parks and other transit dis-oriented development patterns.

People who work at Forrestal and PPPL often tell TigerTransit staff that a route serving them once every 60 minutes is nearly useless for travel between central campus and their work-places. The chance that the route's schedule brings them to campus at the right time for a meeting or an event are very low, so they end up wasting a great deal of time getting places too early.

Forrestal and PPPL are so far from campus, and the walkability so poor, and the buildings so isolated from one another down cul de sacs and on the opposite sides greenspaces and parking lots, that any route TigerTransit pro-vides will be either hugely expensive (if it offers decent frequency) or terribly infrequent (at the current cost).

(Recall that distance determines how much frequency a transit provider can offer relative to cost. The more circuitous and deviating a route is, the longer it is, and the worse its frequency or the higher its cost. The higher its cost, the higher ridership must be to justify that cost, but few people want to ride a very circuitous route for a long distance, even if it does come frequently.)



The cost of 100% coverage

As the experiment with providing more direct and frequent service to 701 Overlook / 100 Carnegie Center shows, high frequency service does not increase productivity, and therefore does not reduce cost per boarding, in transit-hostile land use patterns.

While it's possible that doubling the frequency of the Forrestal/PPPL route might double its total ridership, it would necessarily *double the route's operating cost*, which means that the route would still be attracting just 4 boardings per vehicle hour at an average cost of $36 per boarding. High frequency can cause high productivity only when it is serving areas that are dense, walkable, linear and proximate.

Princeton University is facing a policy question about how few passengers per vehicle hour it can justify in pursuit of 100% coverage of all its buildings. That question cannot be avoided by simply increasing the supply of service so that every route is frequent.

That question also cannot be avoided by turning to "flexible" or "on-demand" transit services.

Policies that can influence transit ridership

Low ridership is a defining feature of the routes connecting the worksites at 693 Alexander, 701 Carnegie Center and the main campus. Not surprisingly, these routes lack many of the elements of the Ridership Recipe described above; particularly density, linearity, and walkability.

Policies that allow staff who work at these buildings to drive and park on campus also likely depress ridership on the shuttles. Should the University require staffers to travel between the outlying worksites and the main campus via shuttle, it is likely that ridership on the shuttle routes will increase somewhat.

However, it should be noted that unless classes or other uses that require large numbers to make daily or weekly trips from campus are scheduled at these locations, the demand for travel between the more distant sites and the main campus will likely remain small. This is because most office workers tend to spend their day at the office, if not always at their desk.

To give an illustration of the travel demand associated with office-based staff, imagine that a total of 1,000 people work at these three sites. On any given day 800 might physically show up for work since 200 would be on vacation or traveling. If 10% of these travel to the main campus for meetings each day that would translate to 80 people a day or on average 9 people an hour and less than three people per shuttle if they run every 15 minutes.

On-Demand service

TigerTransit provides an "on-demand" or "flexible" service in the evenings. People can use an app to make a request, and are then picked up and dropped off at places of their choosing (within a defined zone).

Flexible transit is an old idea, and has long been in use throughout the world. The recent innovations are the software and communications tools for summoning and dispatching service. You can now summon service on relatively short notice, compared to old phone-based and manually dispatched systems ("dial-a-ride") that only guaranteed you service if you called the day before.

The efficiency of summoning and dispatching an on-demand ride has done almost nothing to change the efficiency of actually providing rides.[1] Flexible transit services have a very high operating cost per rider, and always will, for geometric reasons that no communications technology will change. Flexible services meander in order to reduce the distance that customers have to walk. Meandering consumes more time than running straight, and meandering paths are less likely to be useful to people riding through. Fixed-route transit can be much more efficient because customers walk to the route and gather at a few stops, so that the transit vehicle can go in a relatively straight line that more people are likely to find useful.

1 The founders of Uber and Lyft misunderstood this, believing that a big change in communication quality and efficiency would change the basic physical problem and costs of moving people from one place to another. Their "success" has so far been achieved by charging customers significantly less than the cost of their ride. Whether they can end these discounts without going out of business, and eventually turn a profit, remains to be seen.

	Route name	Average boardings per hour	Average operating cost per boarding
L	Lawrence/Lakeside	30	$4
S	Shopper	28	$5
A	Central	19	$7
C	East Commuter	12	$10
W	Weekender	12	$9
E	EQuad	8	$17
B	693 Alexander (new)	6	$21
D	PTS/West	6	$18
F	Forrestal/PPPL	4	$36
M	Merwick/Stanworth	3	$43
	On-Demand Bus Service	3	$47
O	100 Overlook/701 CC (new)	2	$56
B	693/701 Carnegie Center (old)	2	$56

TigerTransit's on-demand service achieves respectable productivity for a flexible service.

There is no particular efficiency in the fact that flexible transit vehicles are smaller than most fixed route buses, because the operating cost of transportation is mostly labor. We can of course create savings by paying drivers less to drive an on-demand service than a fixed-route, but that savings arises from how we compensate workers, not from any vehicle- or service-related efficiency.

Almost all of the on-demand services operating today – even the ones with the best apps and software – handle 2-4 boardings per hour. The record-setting service averages just 7 boardings per hour. TigerTransit's on-demand service is respectably productive for a flexible service, with 3 boardings per hour. Two buses are used simultaneously to provide this service, so an average of 6 people use it per hour.

These numbers should make clear that flexible transit is the right tool for the job sense *only if high ridership is not the goal of the service*.

There are some times and some places where the productivity of fixed route transit is so low that a flexible service can be no less productive. This means that it is generating no more vehicle hours on the road (with all of the associated negative effects) than the old fixed route bus. As we can see in the table at left, there are three TigerTransit fixed routes that are equally or less productive than the on-demand service, moving 3 or 2 people per hour.

Some providers have reduced the high cost per boarding of on-demand services by reducing their operating costs to provide the service. Under TigerTransit's current contract with its service provider, each vehicle hour is compensated the same for on-demand service and most of the fixed routes.

Flexible service isn't always the right coverage tool. There are areas where density is too low to attract much ridership, but where the street network puts most homes and destinations within a reasonable walk of through-streets. Fixed routes can provide coverage in such areas at vastly lower cost, and with many fewer vehicles, than a flexible service. But flexible services do have a place in the coverage toolbox, especially when street networks are very unwalkable.

However, ***high ridership is the death of flexible service.*** Suppose that the TigerTransit on-demand service were so attractive that many people began calling it at the same time. Then the two vehicles would be expected to go to an impossible number of pick-up and drop-off spots, quickly. Peoples' wait times would be much longer than promised, and they would end up on long deviating ride-alongs to pick up and drop off many other people. More vehicles would have to be added to handle

the demand, keeping the average productivity around the same 2-4 boardings per hour that is physically possible. This process could continue – growing popularity, longer waits and worse rides, adding another vehicle – until it devoured more of the TigerTransit budget than the University could justify. If the University hadn't established clear limit on what should be spent on low-ridership service, this process can start threatening high-ridership service. At that point, someone should ask: If you end up deleting a route carrying 10 people/hour so that you can run a service for 3 people/hour, aren't you basically telling 7 people/hour to take a car?

Attracting many riders to flexible services is therefore the last thing a transit provider should want to do if they have goals of achieving higher ridership within their limited budget. In fact, when flexible services become too popular, they have to be turned back into fixed routes. Imagine that a flexible service got so popular that it needed six vehicles to handle demand. At that point we could probably just design three fixed routes, heading off in three different directions, each operated by two vehicles, offering decent frequency, and handling many more boardings than the flexible service could.

Many public providers of flexible transit have learned that they must avoid making it more convenient than fixed routes, to prevent it from rapidly consuming their budget as it becomes more popular. They often charge a higher fare for it. They sometimes stop offering service to peoples' front doors or to minor streets, and ask people to walk out to a main street. They may shift to providing rides only to and from a major transit center, rather than from everywhere to everywhere. Sometimes they reduce expectations for how quickly they will respond to a ride request, which reduces demand for the service and the number of vehicles needed.

Princeton University is in a different position than most public providers of flexible service, because it cares for its transit customers much more holistically. Their health, safety and education are the business of the University in a way that cannot be said of public transit providers.

A nighttime on-demand service is typical at all universities because it keeps students from becoming stranded after working late, gives them an alternative to getting a ride home from someone who is inebriated, and ensures that they are always able to remove themselves from an unsafe situation. TigerTransit's nighttime on-demand services needn't be evaluated on the basis of their productivity at all, and certainly not on that basis *alone*, given the numerous other positive outcomes of the service for students.

However, it is important to keep in mind, with regards to the TigerTransit daytime network, that flexible service is a coverage tool, and is not a path to higher ridership.

Peaking

TigerTransit ridership is highly peaked in the mornings, when large numbers of graduate students use it to get to the core of campus, and when staff are arriving and using it to get from parking lots to buildings. Ridership in the afternoon and evening is much lower, which suggests that people are using other modes to return home, as do other observations:

- More pedestrians were observed walking on College Road (to West Graduate College) and on Lawrence (to the Lawrence Apartments) in the afternoon and evening than in the morning.
- Bikeshare use is much higher in the afternoons and evenings than in the mornings.
- The Lawrence Zagster station is the most-often over-populated with bikes, which suggests that residents are getting to campus some other way and then returning home using bikeshare.
- The Lakeside and Caldwell House bikeshare stations are also often "overpopulated" with bikeshare bikes.

Offering higher peak frequencies on transit, and peak-only routes, for a short period of the day has some unseen costs.

- Peak hour services have a slightly higher labor cost than service at other hours. This is generally hard to estimate, because it accrues in subtle ways, either to the transit provider or to the contract operator.
- Peaking can lead to split shifts for bus operators, which can be difficult to staff depending on the characteristics of the bus operator pool. Split shifts can also be more expensive, if operators are paid extra for those shifts.
- The transit provider must maintain a larger fleet of buses for the peaks, a fleet that sits idle at all other times. For each extra bus that is run during peak times, the provider had to purchase the bus, find land to store it on, pay people to maintain it.

High morning peaks in transit demand are typical at universities, and are observable on some TigerTransit routes. The graph on the next page shows how much peaking occurs in both ridership and service on the TigerTransit network. The graphs on the page following it show the average boardings during each hour of the weekday, on each individual route.

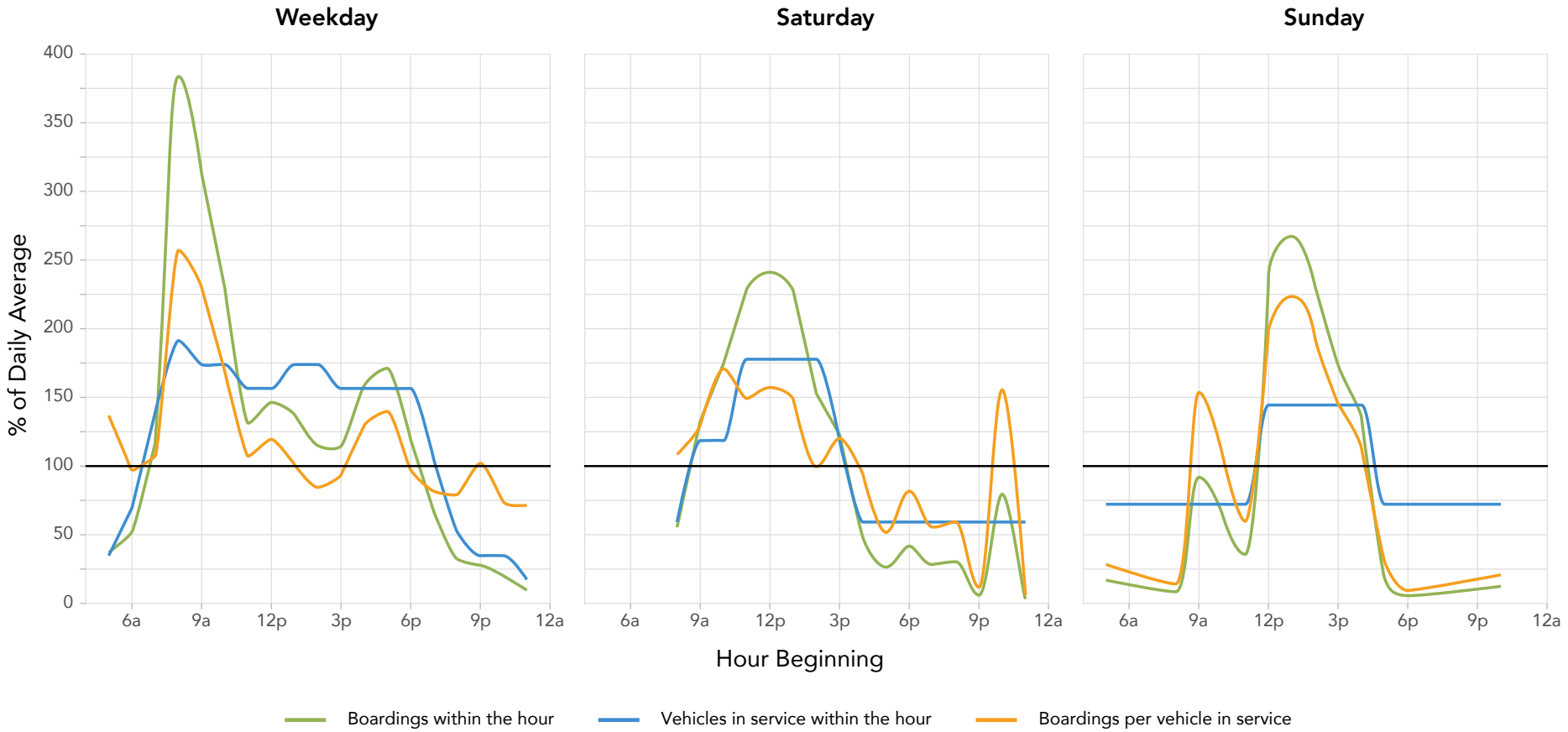
Providing at least some extra service during the morning peak will be unavoidable, but how much the University wants to encourage and serve a one-way morning transit peak is an interesting question. It seems, from the data available, that many of the people who ride transit in the morning either walk or cycle home in the evening. This suggests that they might consider walking or cycling in the morning under different conditions.

Under existing conditions, reducing transit service during the morning peak would cause severe crowding on at least two bus lines. This Mobility Framework is an opportunity for the University to decide whether it is better for large numbers of people to be driven 1.5 miles to class in the morning or for many of them to walk, cycle or scoot that distance.

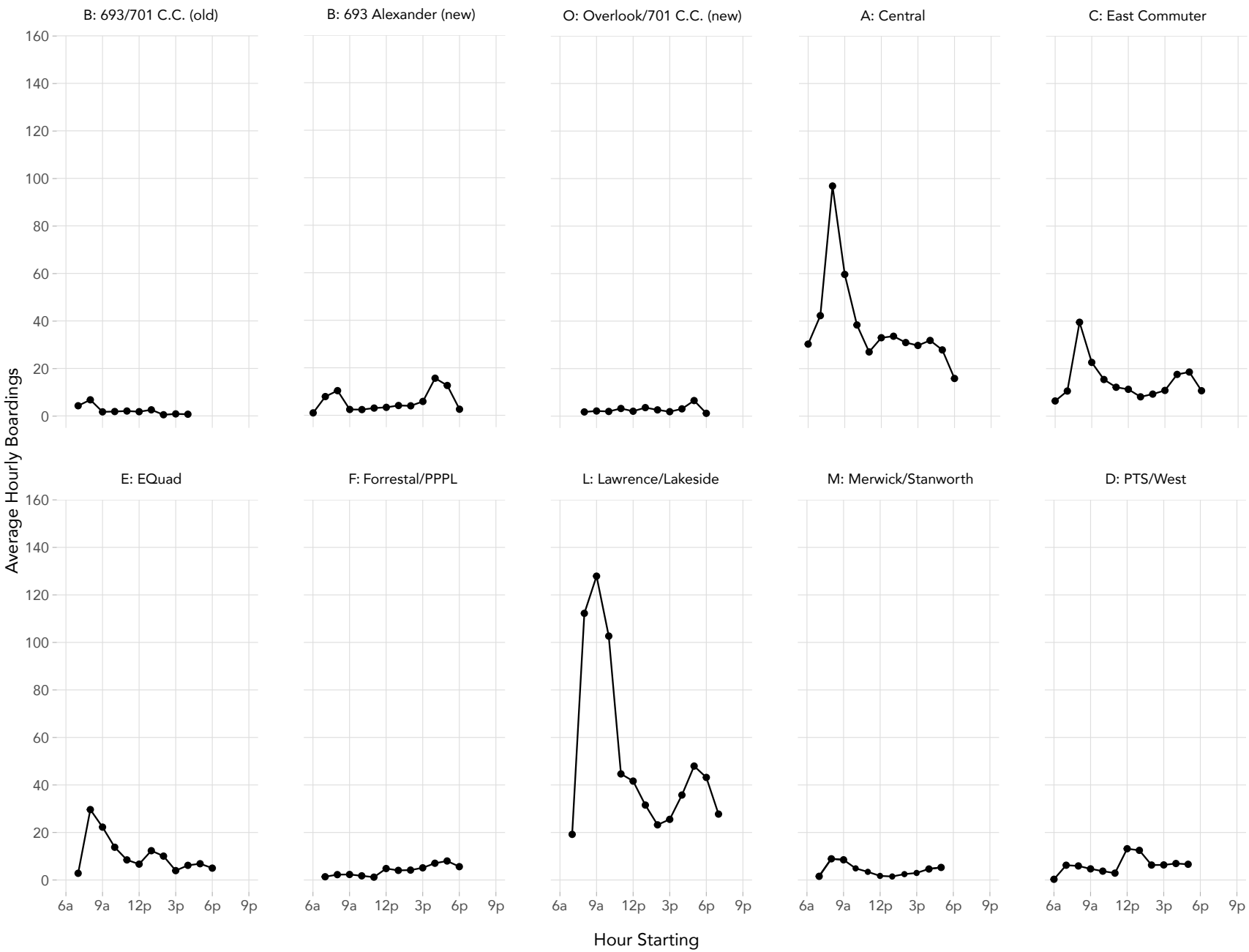
TigerTransit, Princeton University

Ridership and Service Levels Throughout the Day

Compared to Daily Averages



On weekdays (at left), there is a big surge in ridership in the morning, as shown by the green line. TigerTransit service increases in the morning to address that demand (as shown by the blue line), but the ratio of boardings to buses (green line) in service is still very high in the mornings.



Routes L and A have particularly big morning peaks in demand. The rush-hour peaks on Route B probably relate to its service to Princeton Junction.

Future development and street design

For all of the critiques on earlier pages about the predominance of motor vehicles on internal campus roadways, this has allowed TigerTransit to run services into the heart of campus, very close to peoples' destinations.

The existing TigerTransit fleet is mostly aged and very loud, which has a negative impact of the environment on campus. Future purchases of new vehicles will provide an opportunity to address noise and air pollution.

In the future, the design of campus and of streets can account for transit in a number of ways:

- Streets can be designed so that transit stops can be located very close to intersections, increasing the number of people who are within walking distance.
- Streets can be easily crossed on foot, so that transit vehicles needn't deviate into and out of parking lots or cul de sacs.
- Development can be arranged in linear patterns, so that it can be served by transit that is direct.

These characteristics are present on many University streets and some off-campus roads as well. However, challenges abound.

Transit service is permitted on campus roadways (like Elm Drive), which allows TigerTransit to get close to the densest centers of activity.

Roundabouts and transit stops

Roundabouts make it hard to locate transit stops near intersections. They create the expectation that private motor vehicle traffic must flow continuously, and a bus stopped in the single lane leading to or from the round-about would halt cars behind it.

Intersections are the *best* places for transit stops because they are nodes to which people in all four directions can easily walk, down the four road segments leading to the intersection.

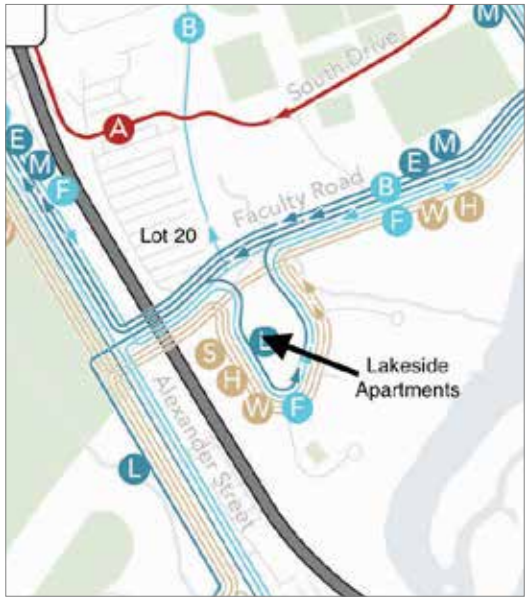
For example, numerous people live in the Lakeside Apartments (marked on the transit map at right), far enough from their work or class locations to benefit from transit service. Yet there is no way to stop a bus near the roundabout at Elm Drive and Faculty Road, which is a short walk from both the Lakeside Apartments and Parking Lot 20.

Bus routes must therefore deviate *into* the Lakeside Apartment road loop in order to make a stop, adding time and cost to routes and adding time to the commutes of people riding from more distant places, such as Lawrence Apartments or Graduate College West.

In addition, a single bus stop and a single bus route could be useful to both Lakeside residents and people parking a car in Lot 20, as they are across Faculty Road from one another each morning. Instead, the University pays for two separate routes and separate, distant stops for these two groups of people.

Placing a bus stop at the intersection of Elm and Faculty, and at certain other intersections around campus, would allow TigerTransit to reduce complexity, provide higher frequencies and provide more linear routes.

It is very hard to place bus stops close to roundabouts, yet intersections are the best place for bus stops because they allow the shortest walks for people from all four directions



No linearity without walkability

Challenges to walkability off campus cause TigerTransit to run deviating service. The University building at 693 Alexander Road is directly between campus and Princeton Junction, and should therefore be easy to serve on the way.

At 693, unfortunately, Alexander Road is harrowing to cross on foot, as shown in the image at right. At five lanes wide, with no nearby signal, nowhere to take refuge halfway across, and no reason for drivers to ease of the gas, few people would be happy to walk across the road to a bus stop on the other side.

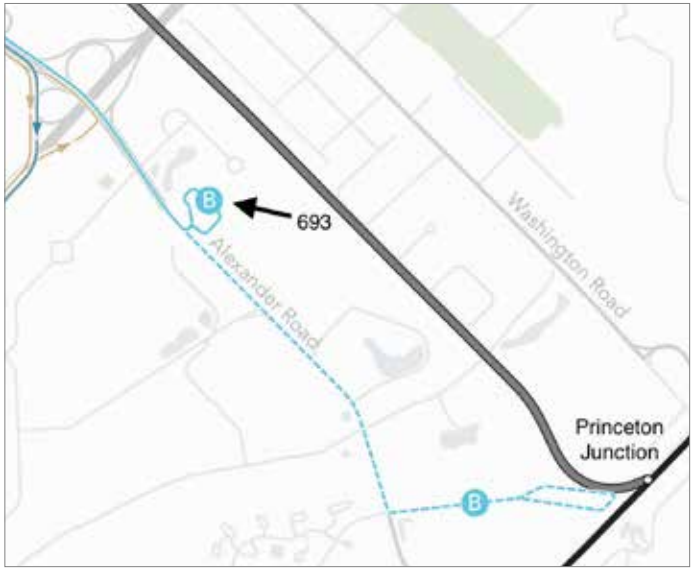
TigerTransit is therefore in a lose-lose situation:

- The bus route to Princeton Junction drive past 693 Alexander, stops on the road, and people who work in that building have to cross the road to reach the bus stop, or
- The bus route can deviate into the 693 Alexander parking lot so that people don't have to cross the road. This increases operating time and therefore costs, and adds travel time for everyone riding between campus and Princeton Junction.

Walkability problems, at a much larger scale, contribute to the circuitousness of Route F (Forrestal/PPPL) as well.

Linearity is an important element of the Ridership Recipe described on page 30, but it often depends on decent walkability.

The near impossibility of crossing Alexander Road (pictured above) on foot causes TigerTransit to deviate Route B into the 693 parking lot en route to Princeton Junction.



Transit patterns for a larger campus

The development of the East and Lake Campuses raises questions about future transit routes. To what extent will new development organized around roadways or transitways that offer linear, two-ways paths for transit, serving dense places that are proximate to one another? Will transit be circuitous, deviating, or costly to provide across long empty spaces?

Plans for the Lake Campus call for a new pedestrian and bike bridge across the lake, which would be a north-south connector that provides a very direct and linear path between the new Lake Campus and the East Campus. A linear, two-way transit route connecting Lake Campus to the main campus would therefore have to use the adjacent Washington Road in order to cross the lake. This would reduce the effectiveness of transit service to Lake Campus. Washington Road is slow, and is likely to be slow for many years in the future. Slower transit is less useful to riders. It is also more expensive to operate because more buses and drivers have to be on the road at the same time to provide a decent frequency.[1]

After crossing the lake, buses would need to travel for a short stretch on Washington Road before turning into Lake Campus. The near-term plan involves graduate housing, athletics amenities, and parking within close proximity of Washington Road. This would mean that after leaving Washington Road, buses will require a relatively short path inside Lake Campus in order to serve this development effectively.

The near term, most Lake Campus developments will be focused closer to the Lake, with a new pedestrian and bike bridge to East Campus. Buses would travel on Washington Road in order to cross the Lake.

1 The slower buses travel, the longer the waits between them, so as transit slows down transit providers have to add more vehicles and drivers to maintain frequency.

In the longer term, further development is planned outwards, along both sides of a new street. This street is planned to be constructed near and parallel to Washington Road, and would be able to accommodate buses. TigerTransit buses would be thus able to turn from Washington Road on to this nearby street and directly serve this future development. On the way, the buses would also serve then-existing development which would have been constructed in the near term.

In the more distant future transit will continue further south to future development. Development along the transit-operable street and its closeness to Washington would help the effectiveness of transit.

User information

Transportation & Parking Services provides a one-stop-shop for all mobility-related information and products. The integration of parking services with all other transportation services is extremely valuable, because it allows the University to manage transportation costs and outcomes holistically.

However, the sheer number of programs managed by TPS is unusually high given the size of the staff. At other universities, service investments as large as the one represented by TigerTransit would have at least one dedicated staff person attending to it, rather than receiving the finely divided attentions of staff who are also running many other programs.

The TigerTransit network and services are complex, for the reasons described in this report. Transit networks are like coral reefs – over time, they naturally accrue complexity. Public information systems are subject to the same forces. Just as it is time for a fresh look at the TigerTransit network is may also be time for a fresh look at the TigerTransit information systems.

New technology has made it possible for people to access great real-time information about how to drive, hire a car, take transit, bike, or even rent an e-scooter. TPS has been taking advantage of this innovation by producing real-time data about the locations and arrival times of TigerTransit buses. This data is available through an app called "TransLoc."

'This same real-time transit data can be released publicly so that anyone arriving on campus can use the trip-planning app that they already know (such as Google Maps or Transit App) to discover when a TigerTransit bus is arriving. TPS and its contractors have procured the software that is necessary for this next step, though lack of capacity has delayed it.

This is also an opportunity to improve the flow of information among TigerTransit service contractors, TPS, and potential transit customers. Information about schedules and routes is touched by numerous people in three different offices, is published in multiple formats, and is not always internally consistent. The TigerTransit arrangement is still fairly young and some of the procedures that older transit providers spent decades developing can serve as models.

As part of this project, TPS will be updating all of the materials that can make the transit system clear and legible: a transit network map, new route names, useful information to post at bus stops, and more. Materials developed many years ago have become obsolete, and staff has been able to keep pace updating materials as service changes but has not had the capacity to develop new materials following the latest best practices in transit information and design.

The level of effort required to make the new TigerTransit network clear and legible will depend partly on the complexity of the network: if it is made of many routes with many deviations and special trips, it will be much more work to show and explain than if it consists of fewer, more frequent routes.

4. Challenges, Choices and Next Steps

This chapter describes key challenges that the Princeton Mobility Framework can address, derived from the data and observations presented in this report. This report does not prescribe a particular type of response to any of these challenges. The right response, and the right policies should the University decide to set new policies, will be informed by input from stakeholders in 2020.

Transit ridership relative to costs is low.

Yet TigerTransit has achieved 100% coverage of University buildings.

- Is the current amount of ridership relative to cost acceptable, given the value of providing a little bit of transit service to every building?
- Transit routes have been designed to minimize walking. If people are asked to walk farther, routes can be more direct and more frequent. Is this a worthwhile trade-off?
- If some trips were shifted away from transit, to cycling, walking or micro-mobility instead, would that be a bad thing?

Cycling is discouraged by road and path design.

- Some trips that should be easy to cycle are hard to cycle, and transit is making up the difference. Is transit the right mode to serve large numbers of people traveling 1-2 miles?
- If transit is not the preferred mode for such short trips, what investments can the University make to shift people onto their feet, bikes or other micromobility modes for these trips?

Historic walkways are busting at the seams.

- Places on campus that were designed with only walking in mind now see cars and heavy vehicle vehicles, with huge numbers of pedestrians and bicyclists relegated to narrow walking and biking paths. Should every road on campus be open to every travel mode? Would greater differentiation between modal networks reduce conflict and improve everyone's experience?
- The addition of golf carts and OHVs to the mix presents a particular challenge because they are just narrow enough that they *can* fit down sidewalks and paths, and so they do. Yet they are wide enough to severely interrupt the flow of walking, talking students. What are the University's expectations for how, where and why these carts will be used?

Longer distances are coming.

- Expansion into East Campus and Lake Campus will create demand for trips that are much longer, and for more overall travel. Will those longer trips be handled entirely by cycling and micro-mobility? What role will transit play?

Micromobility and other small devices

- Micromobility devices such as e-scooters, hoverboards, motorized skateboards and likely many others yet to be invented will entice many to members of the campus community looking to speed up longer walking trips. Whether as part of a shared-mobility fleet or personally owned, these new types vehicles will need to be planned for both in policy and in the physical design of roads and paths.

Investments can be made at multiple levels.

- How can TPS keep up with innovation and provide information that is quickly accessible to the great number of new people arriving on campus each year?
- Many of the factors that affect transportation outcomes for Princeton University are controlled by the townships, the county or even the state. Should the University work with these partners to improve roads it does not control that are yet critical to achievement of its goals?
- The TigerTransit fleet is old and loud. When investing in new vehicles, what features will support the transit system and the University's larger goals?

Next steps

Members of the Princeton University community – in particular students, staff and faculty – will be consulted about some of these choices in 2020.

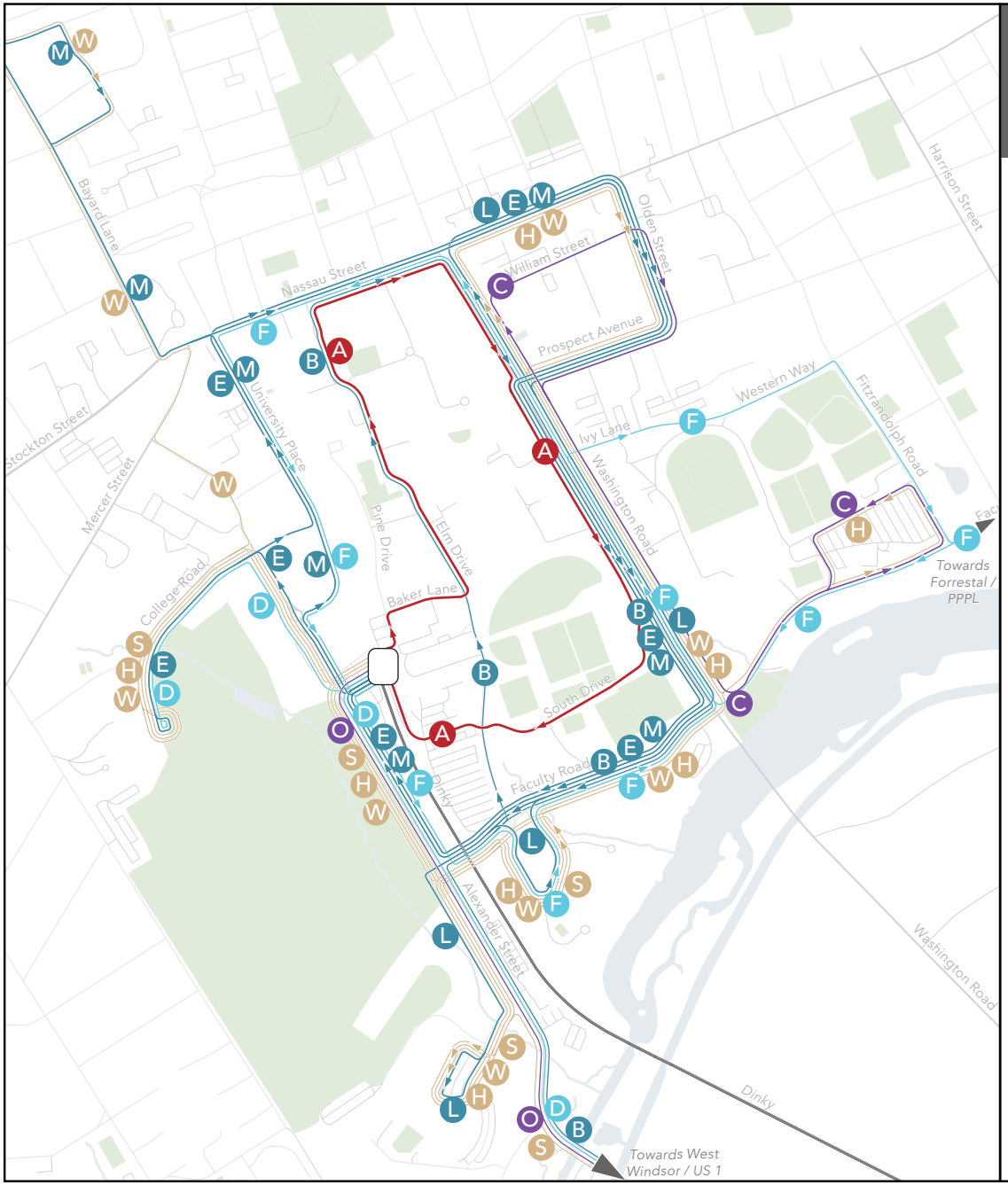
To facilitate that conversation, the consulting team and staff at TPS will design a set of illustrative and contrasting alternatives, showing how TigerTransit, cycling and walking could be different in the future.

The full timeline for development of the Princeton University Mobility Plan is shown at right.

Timeline for the Development of a Princeton Mobility Plan	
July 2019	*Stage project*
August–November	*Assess existing conditions*
November–February 2020	Design choice Concepts
February–March	Community engagement on choice Concepts
April	Review input received
May	Policy direction from University administration
June	Publish Mobility Plan
July	Begin procurement for 2021 transit service operator
September	Soft launch of new TigerTransit routes
January 2021[1]	Hard launch of new TigerTransit routes and vehicles

1 Vehicle choice will affect this timeline. A January 2021 launch is possible if the University procures diesel buses, but the wait to purchase electric buses may be longer.

Appendix



Princeton University Campus

TigerTransit Network

TigerTransit Services

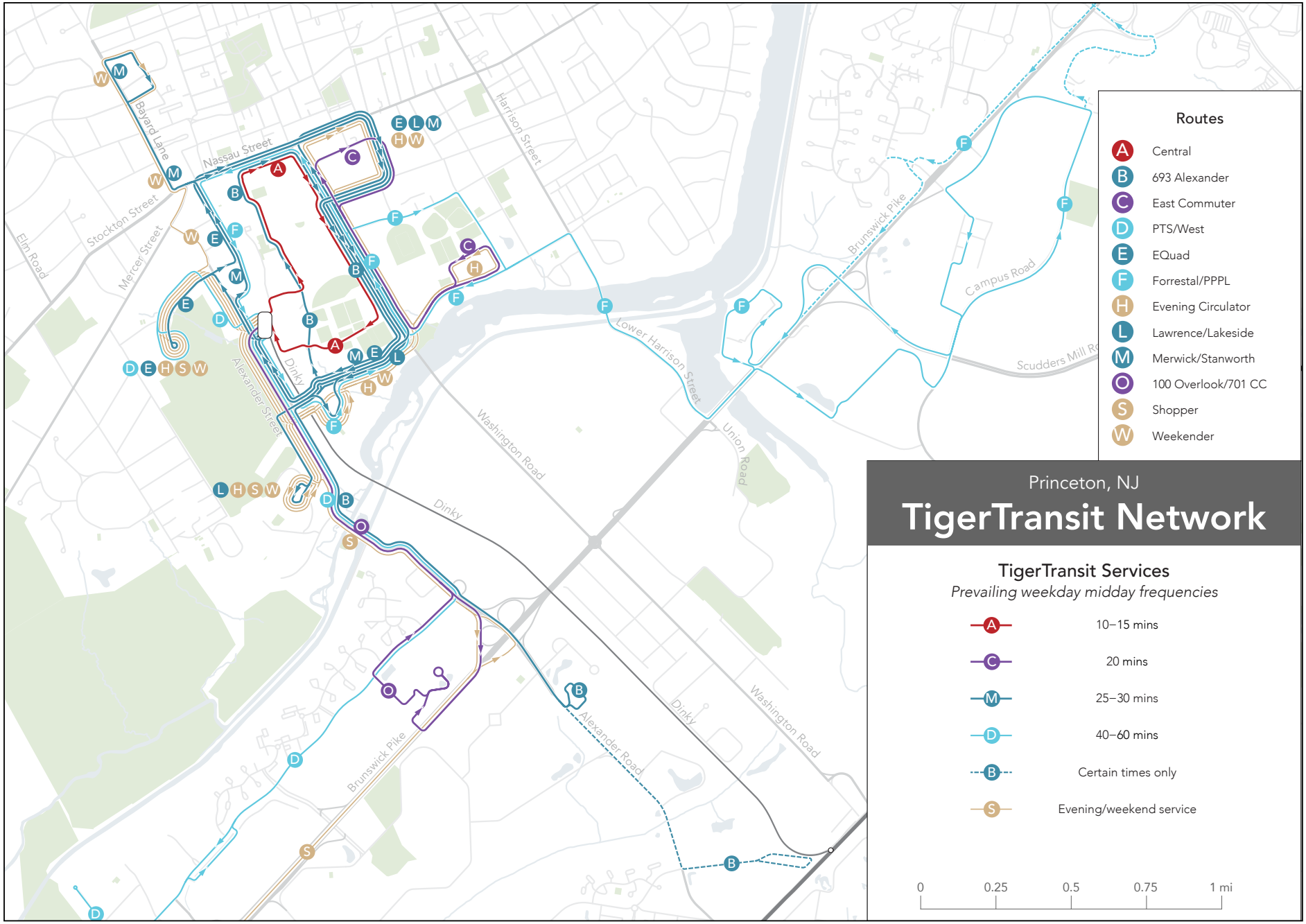
Prevailing weekday midday frequencies

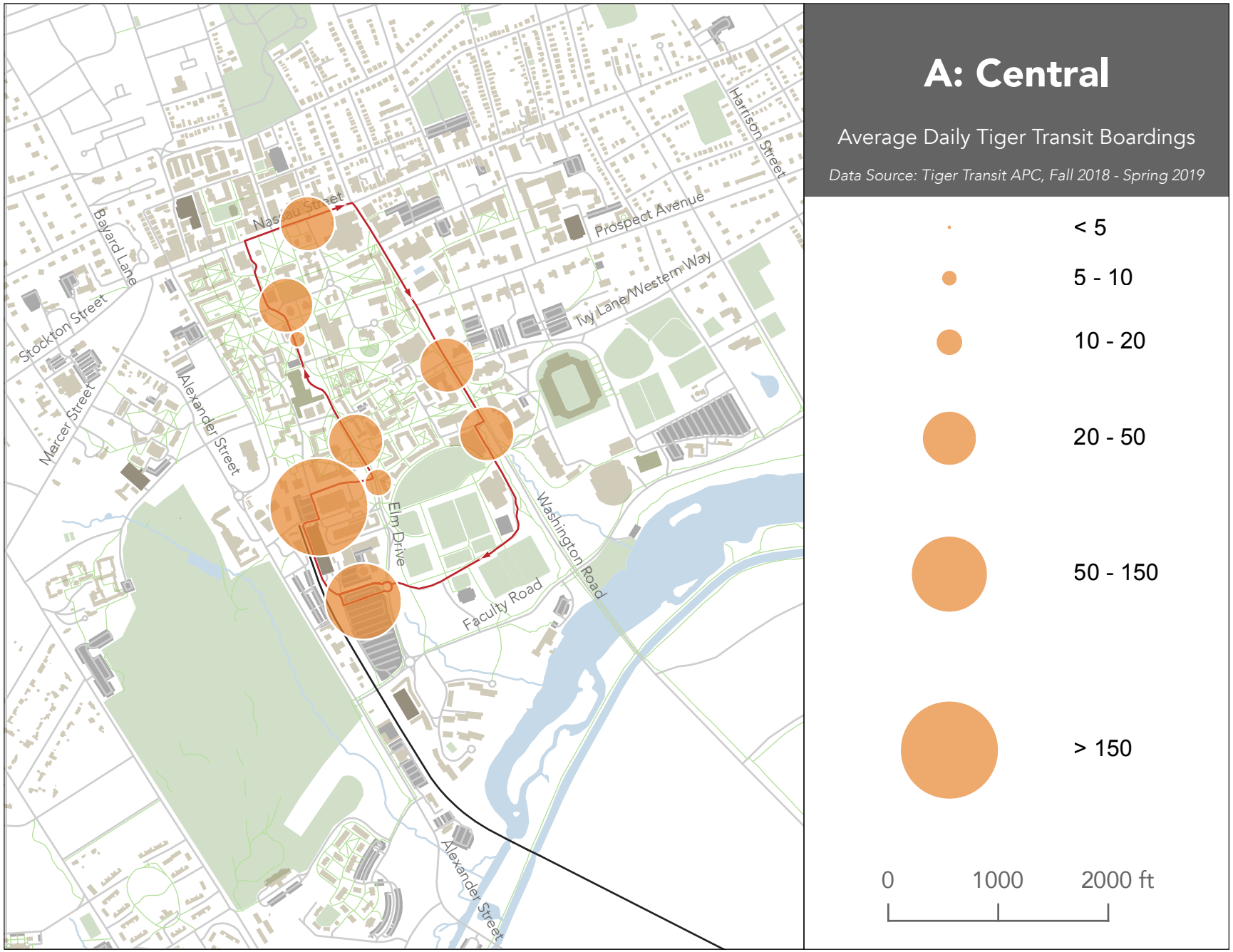
- A — 10–15 mins
- C — 20 mins
- M — 25–30 mins
- D — 40-60 mins
- B — Certain times only
- S — Evening and weekend service

Routes

A	Central	H	Evening Circulator
B	693 Alexander	L	Lawrence/Lakeside
C	East Commuter	M	Merwick/Stanworth
D	PTS/West	O	100 Overlook/701 CC
E	EQuad	S	Shopper
F	Forrestal/PPPL	W	Weekender

0 1000 2000 ft


Princeton, NJ
TigerTransit Network
Routes
Central
693 Alexander
East Commuter
PTS/West
EQuad
Forrestal/PPPL
Evening Circulator
Lawrence/Lakeside
Merwick/Stanworth
100 Overlook/701 CC
Shopper
Weekender
TigerTransit Services
Prevailing weekday midday frequencies
10–15 mins
20 mins
25–30 mins
40–60 mins
Certain times only
Evening/weekend service
0
0.25
0.5
0.75
1 mi
Nassau Street
Harrison Street
Bayard Lane
Stockton Street
Mercer Street
Elm Road
Alexander Street
Dinky
Washington Road
Lower Harrison Street
Union Road
Brunswick Pike
Campus Road
Alexander Road


A: Central
Average Daily Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
< 5
5 - 10
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50 - 150
> 150
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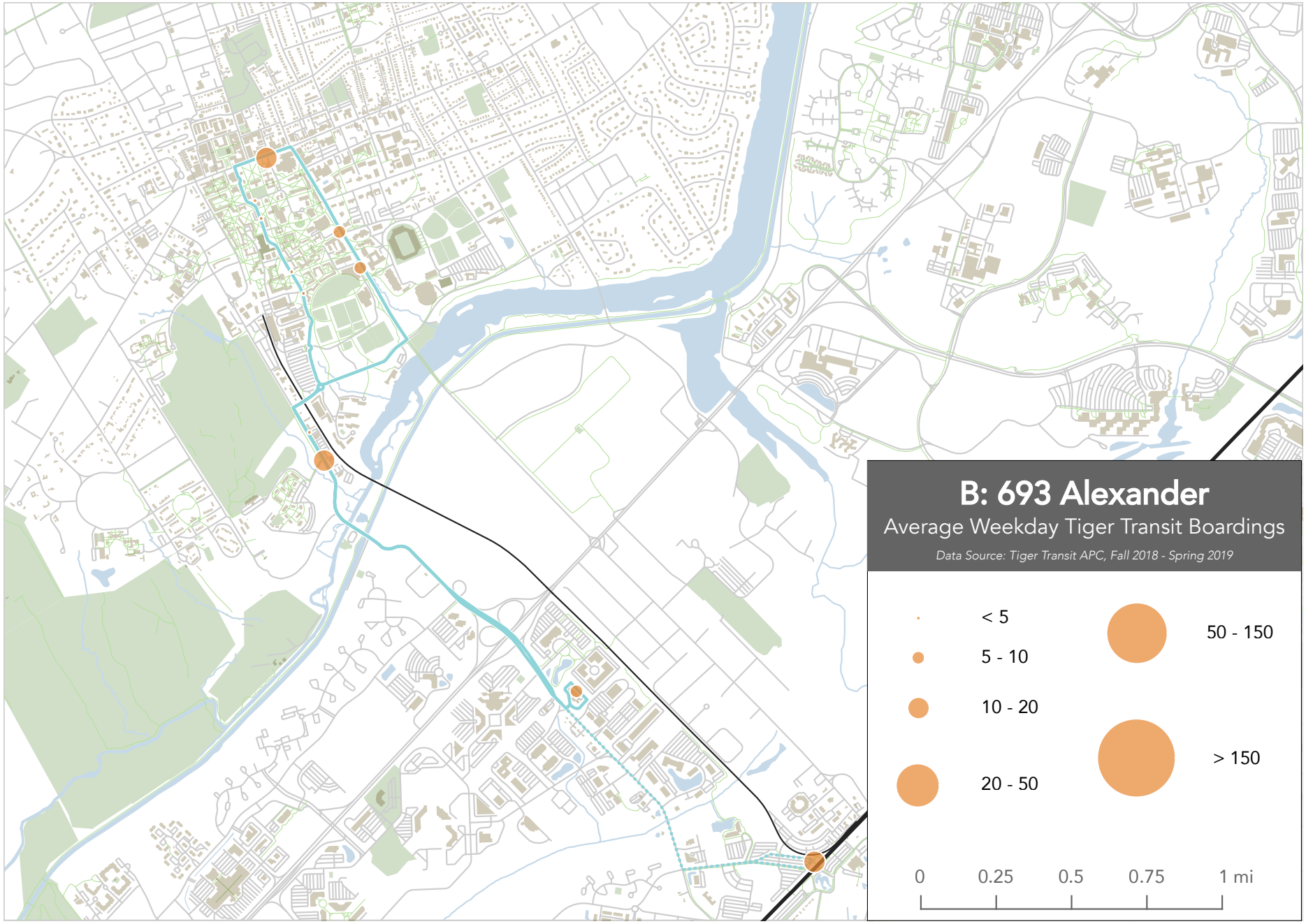
2000 ft
Nassau Street
Prospect Avenue
Harrison Street
Ivy Lane/Western Way
Bayard Lane
Stockton Street
Mercer Street
Alexander Street
Elm Drive
Faculty Road
Washington Road
Alexander Street


B: 693 Alexander
Average Weekday Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
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20 - 50
50 - 150
> 150
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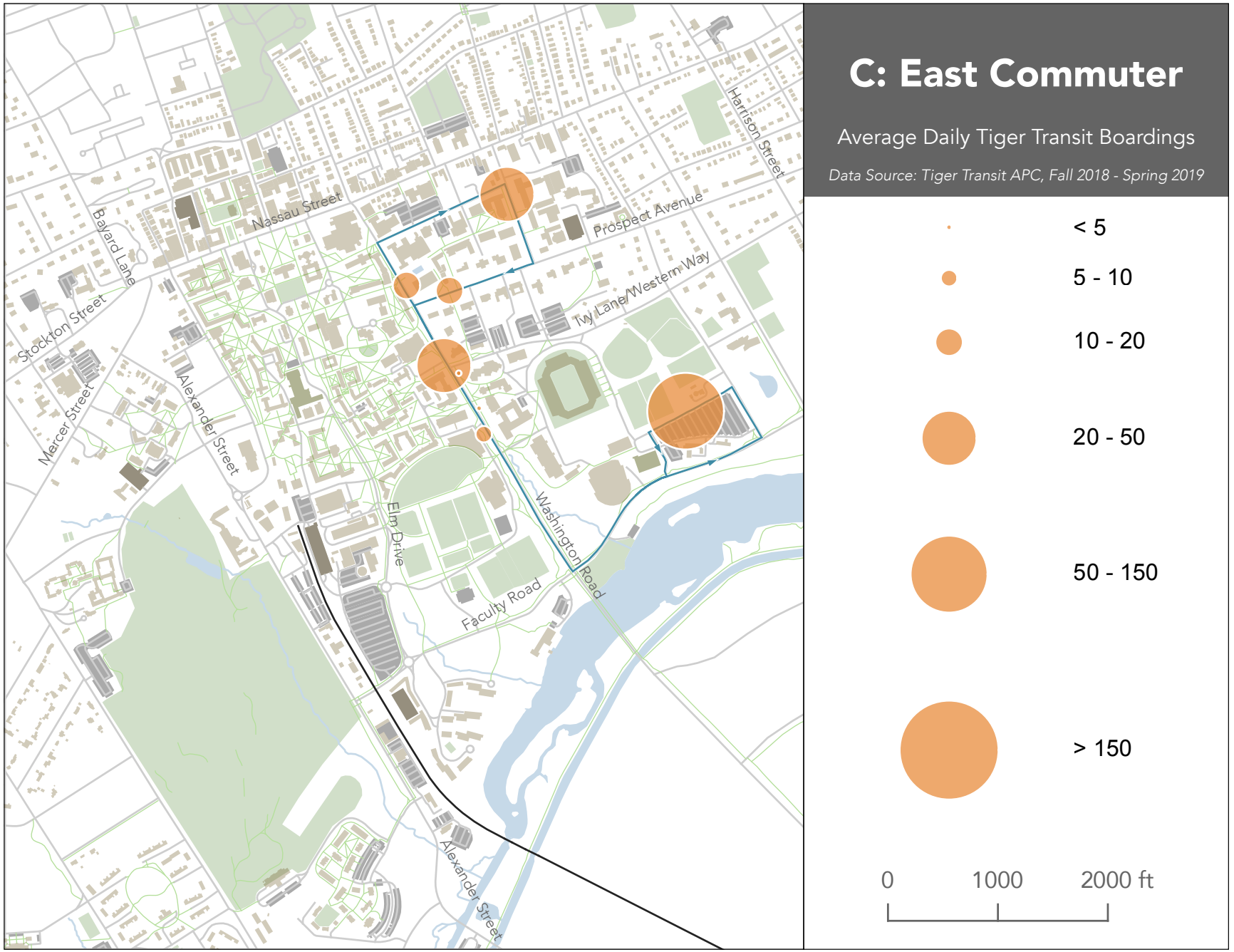
1 mi


C: East Commuter
Average Daily Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
< 5
5 - 10
10 - 20
20 - 50
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> 150
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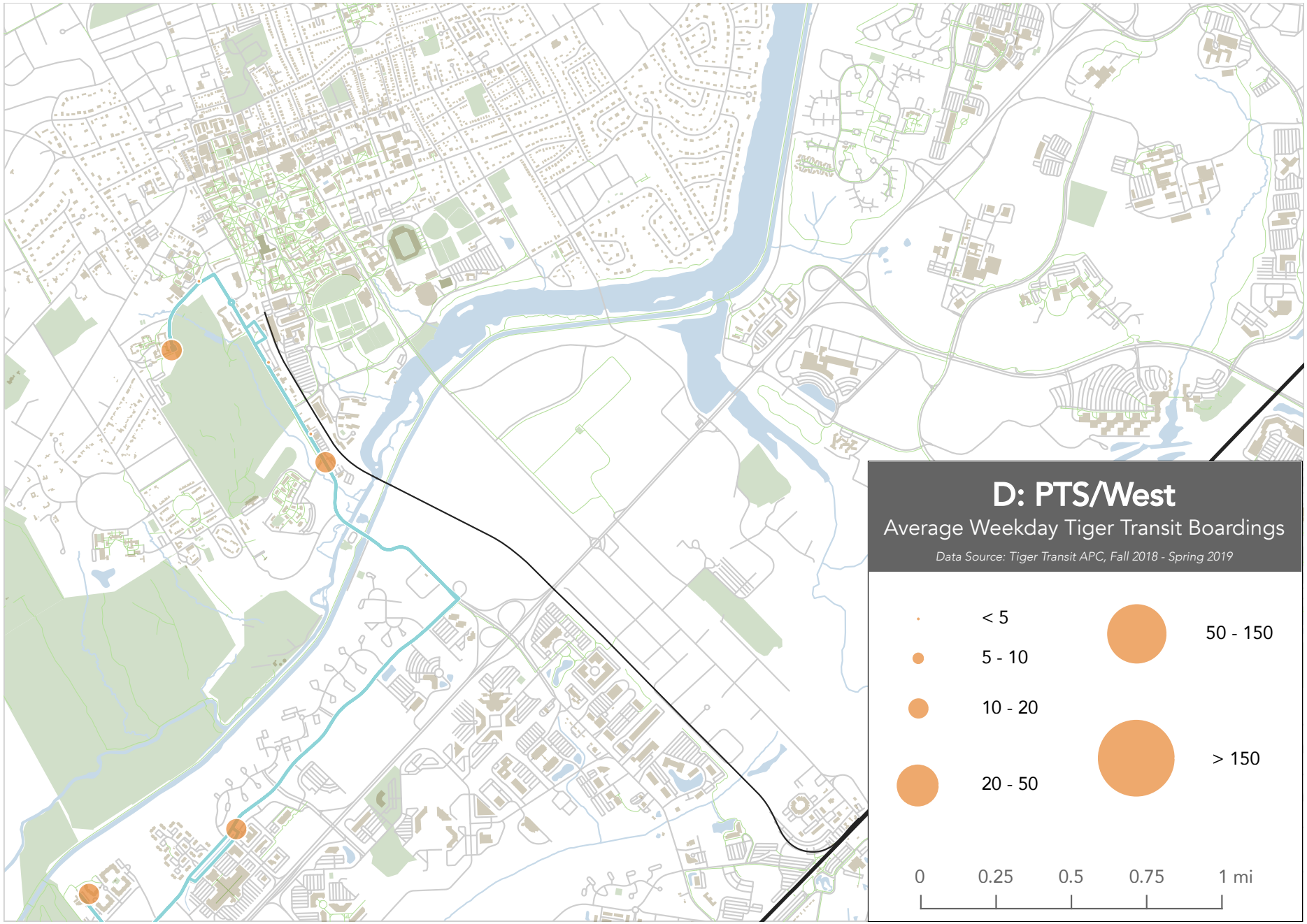
Nassau Street
Prospect Avenue
Harrison Street
Ivy Lane/Western Way
Bayard Lane
Stockton Street
Mercer Street
Alexander Street
Elm Drive
Faculty Road
Washington Road
Alexander Street


D: PTS/West
Average Weekday Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
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20 - 50
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> 150
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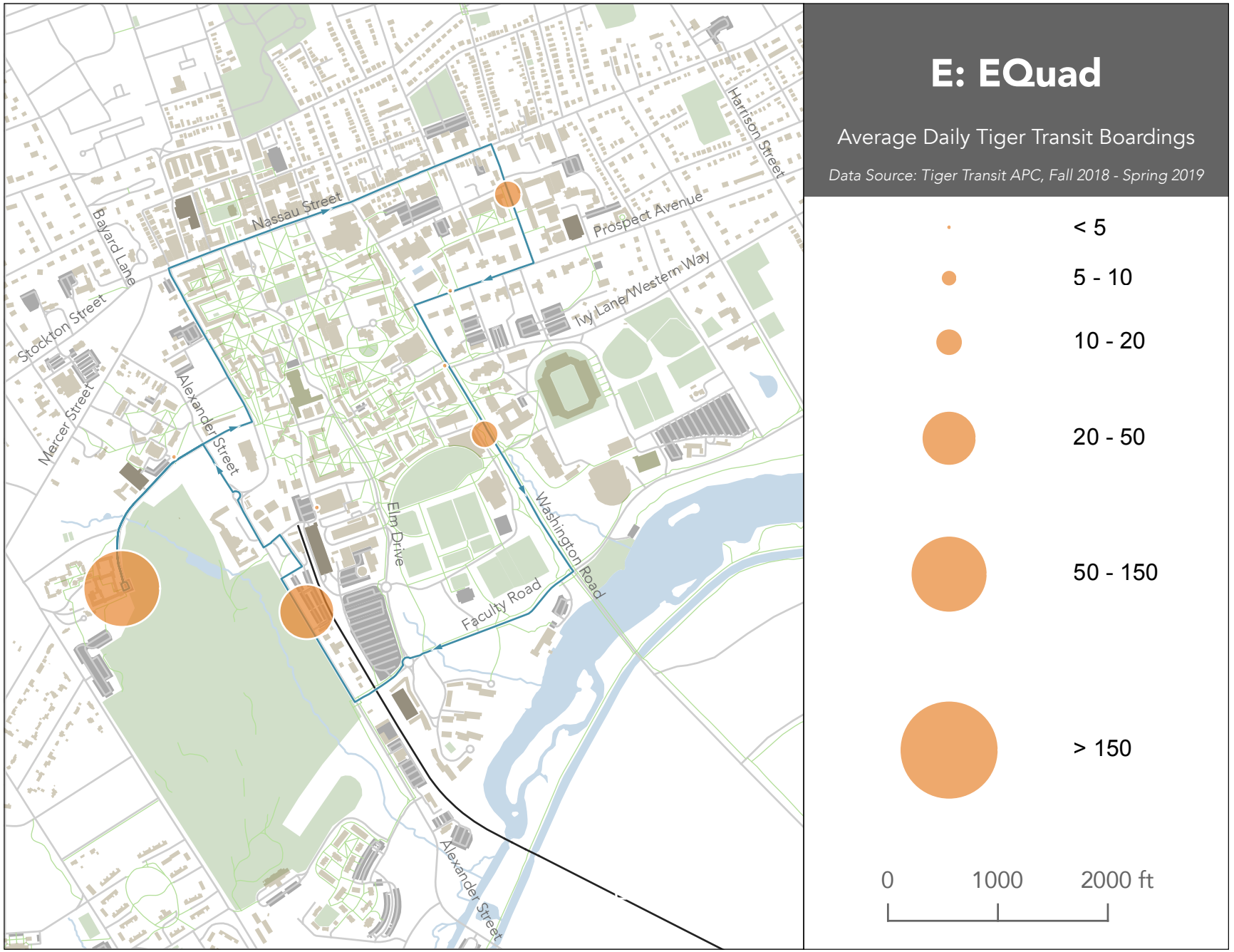
Nassau Street
Prospect Avenue
Harrison Street
Bayard Lane
Stockton Street
Ivy Lane/Western Way
Mercer Street
Alexander Street
Elm Drive
Washington Road
Faculty Road
Alexander Street
E: EQuad
Average Daily Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
< 5
5 - 10
10 - 20
20 - 50
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> 150
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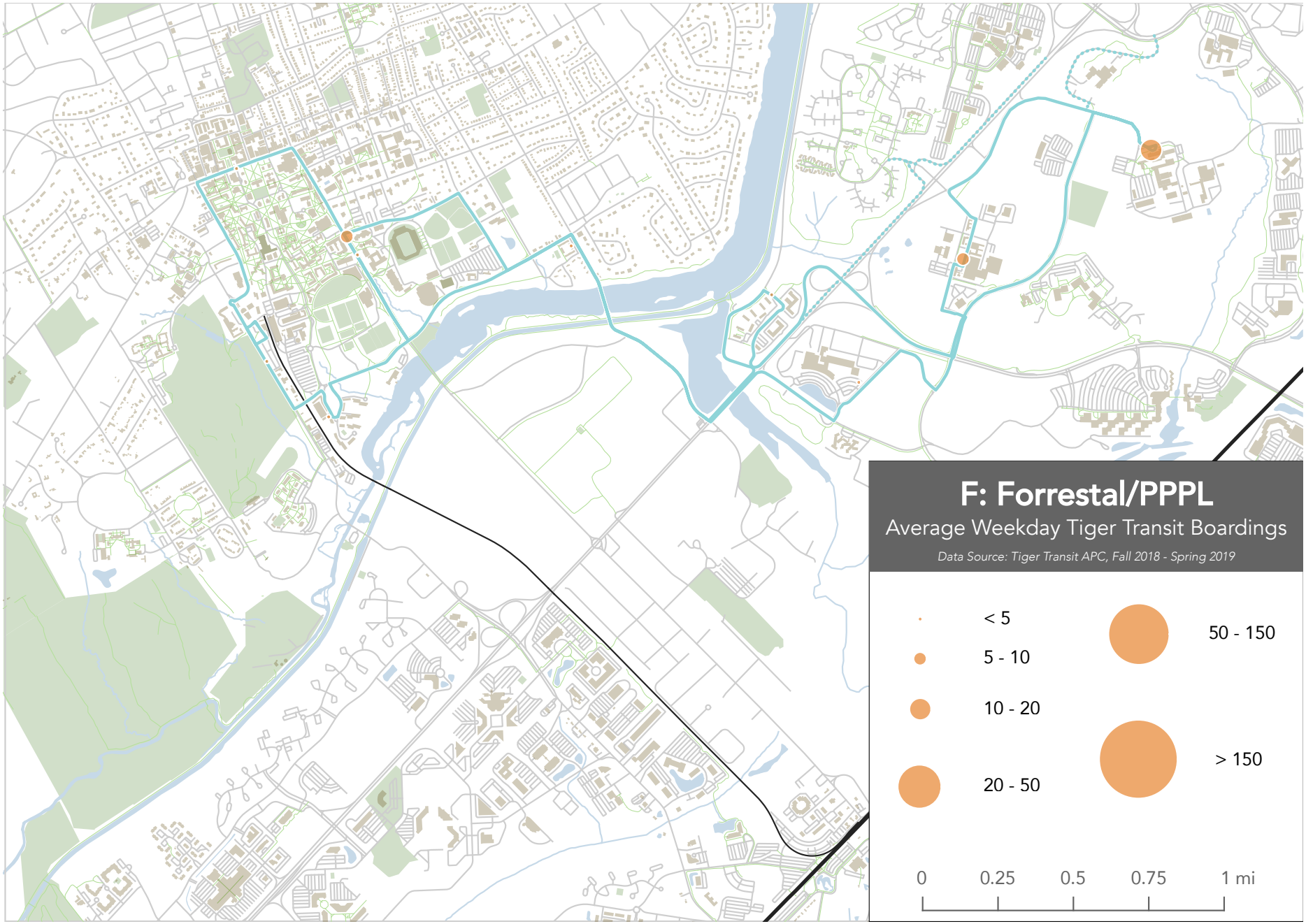
1000
2000 ft


F: Forrestal/PPPL
Average Weekday Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
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20 - 50
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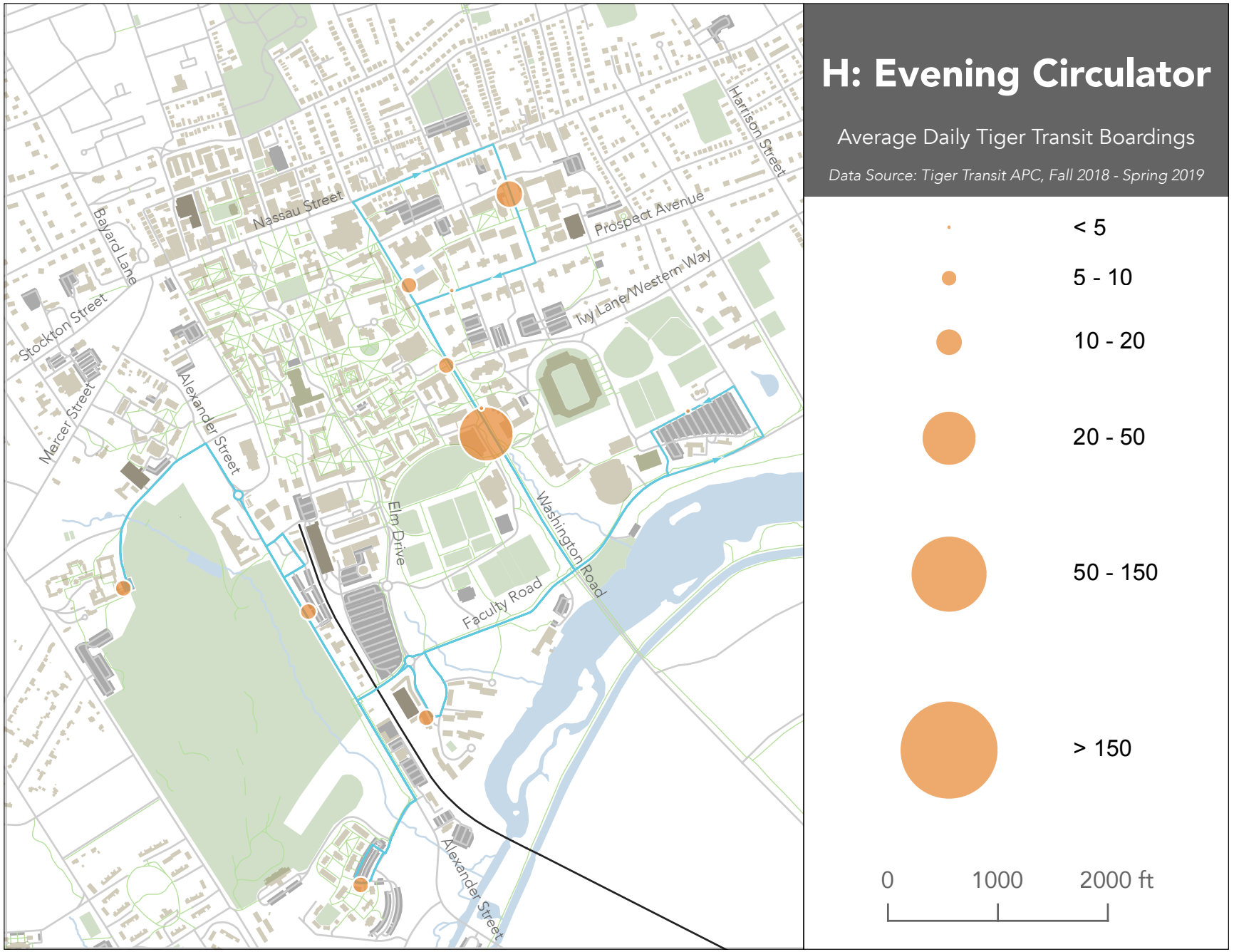
H: Evening Circulator
Average Daily Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
< 5
5 - 10
10 - 20
20 - 50
50 - 150
> 150
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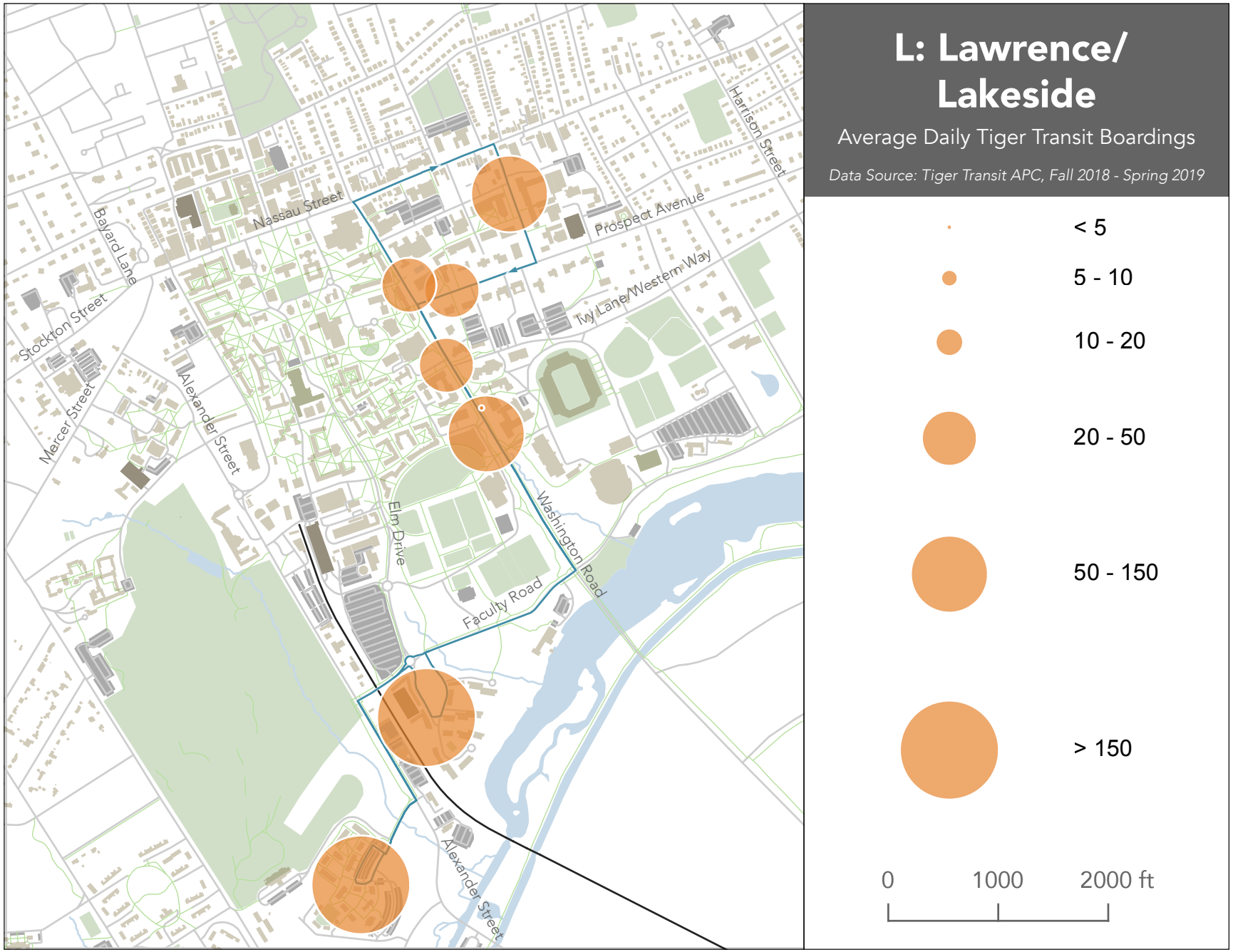
2000 ft
Nassau Street
Prospect Avenue
Harrison Street
Ivy Lane/Western Way
Bayard Lane
Stockton Street
Mercer Street
Alexander Street
Elm Drive
Faculty Road
Washington Road
Alexander Street


L: Lawrence/ Lakeside
Average Daily Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
< 5
5 - 10
10 - 20
20 - 50
50 - 150
> 150
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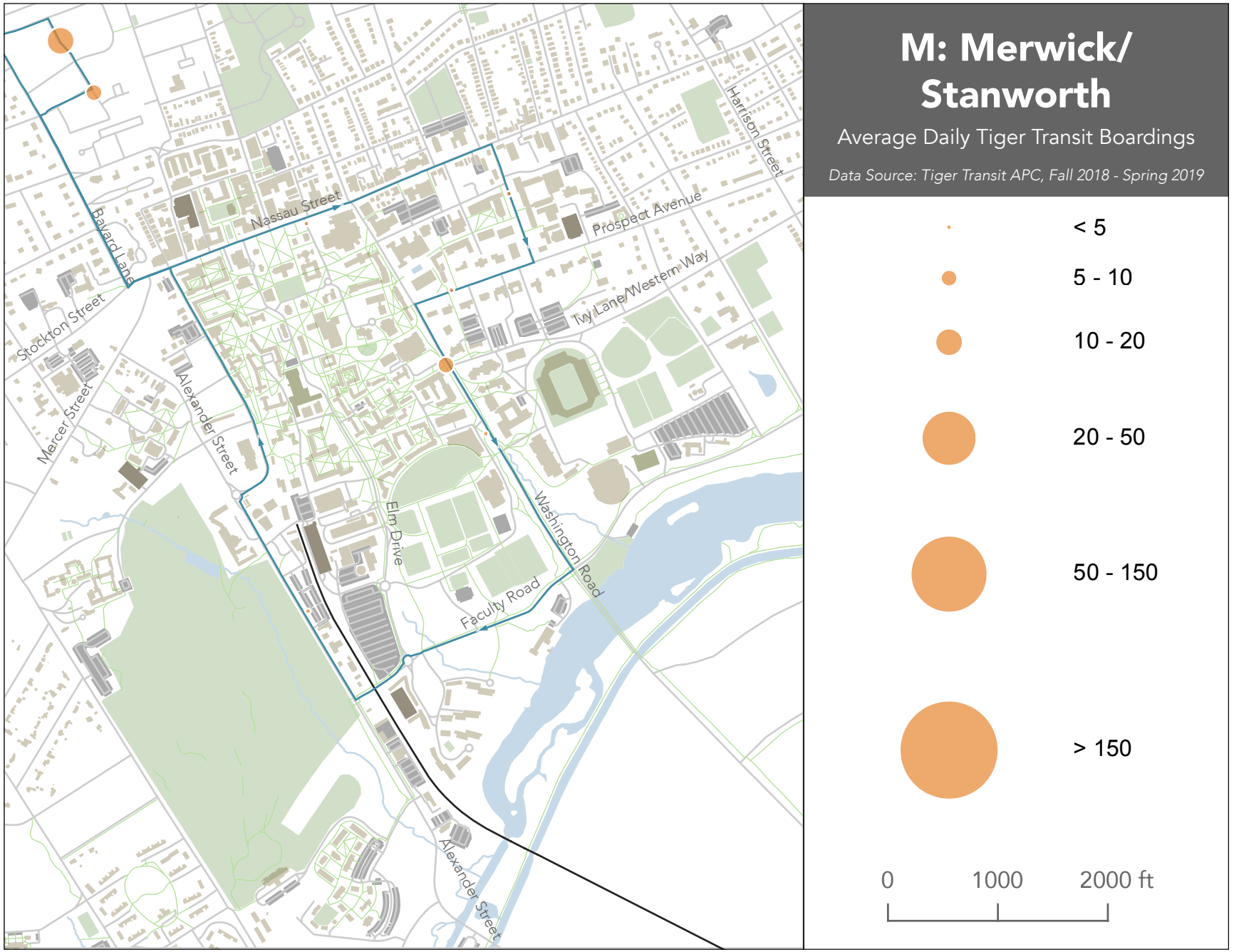
2000 ft
Nassau Street
Prospect Avenue
Harrison Street
Bayard Lane
Stockton Street
Mercer Street
Alexander Street
Ivy Lane/Western Way
Elm Drive
Faculty Road
Washington Road
Alexander Street


M: Merwick/ Stanworth
Average Daily Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
< 5
5 - 10
10 - 20
20 - 50
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> 150
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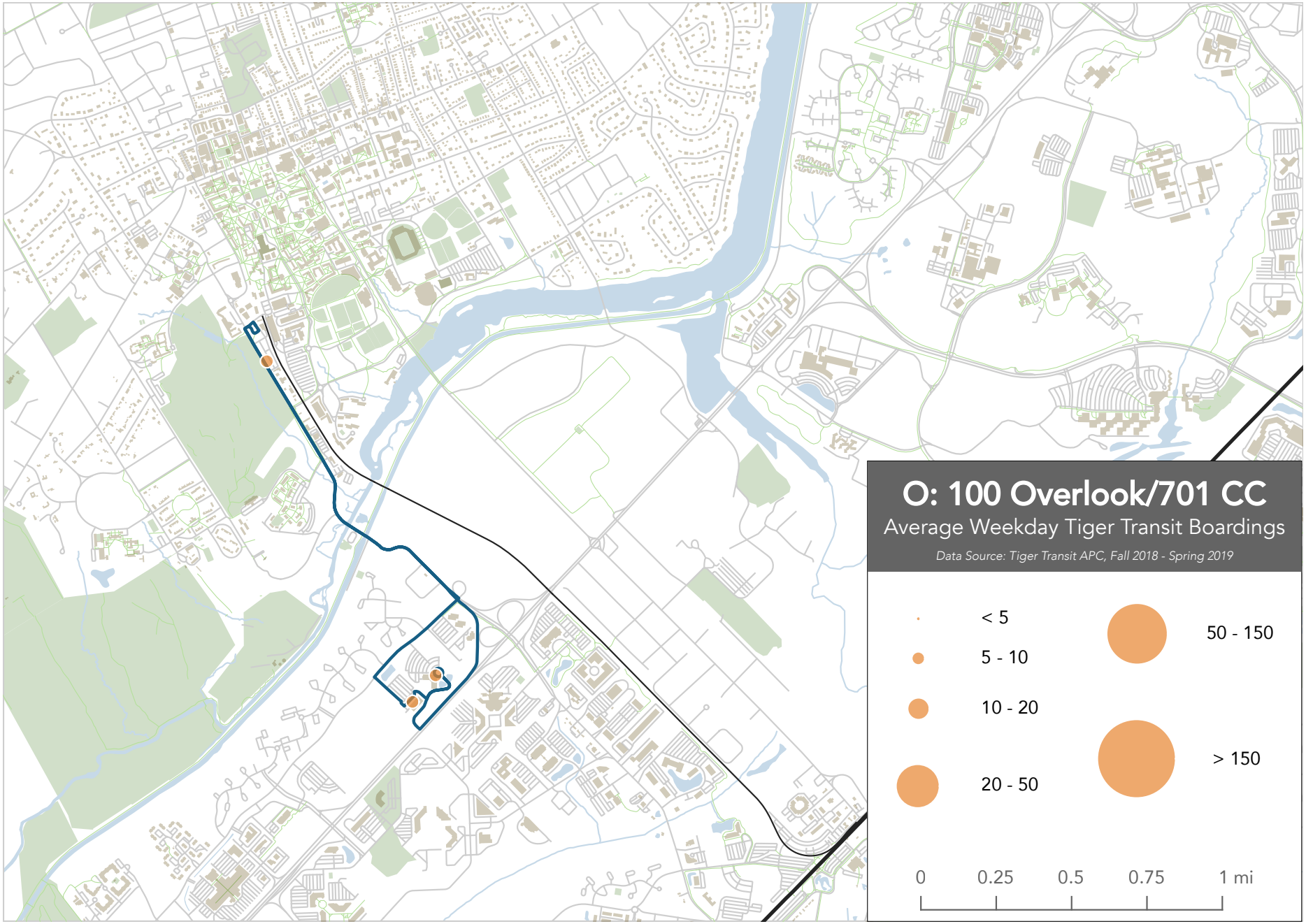
2000 ft
Nassau Street
Bayard Lane
Stockton Street
Mercer Street
Alexander Street
Prospect Avenue
Ivy Lane/Western Way
Harrison Street
Elm Drive
Faculty Road
Washington Road
Alexander Street


O: 100 Overlook/701 CC
Average Weekday Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
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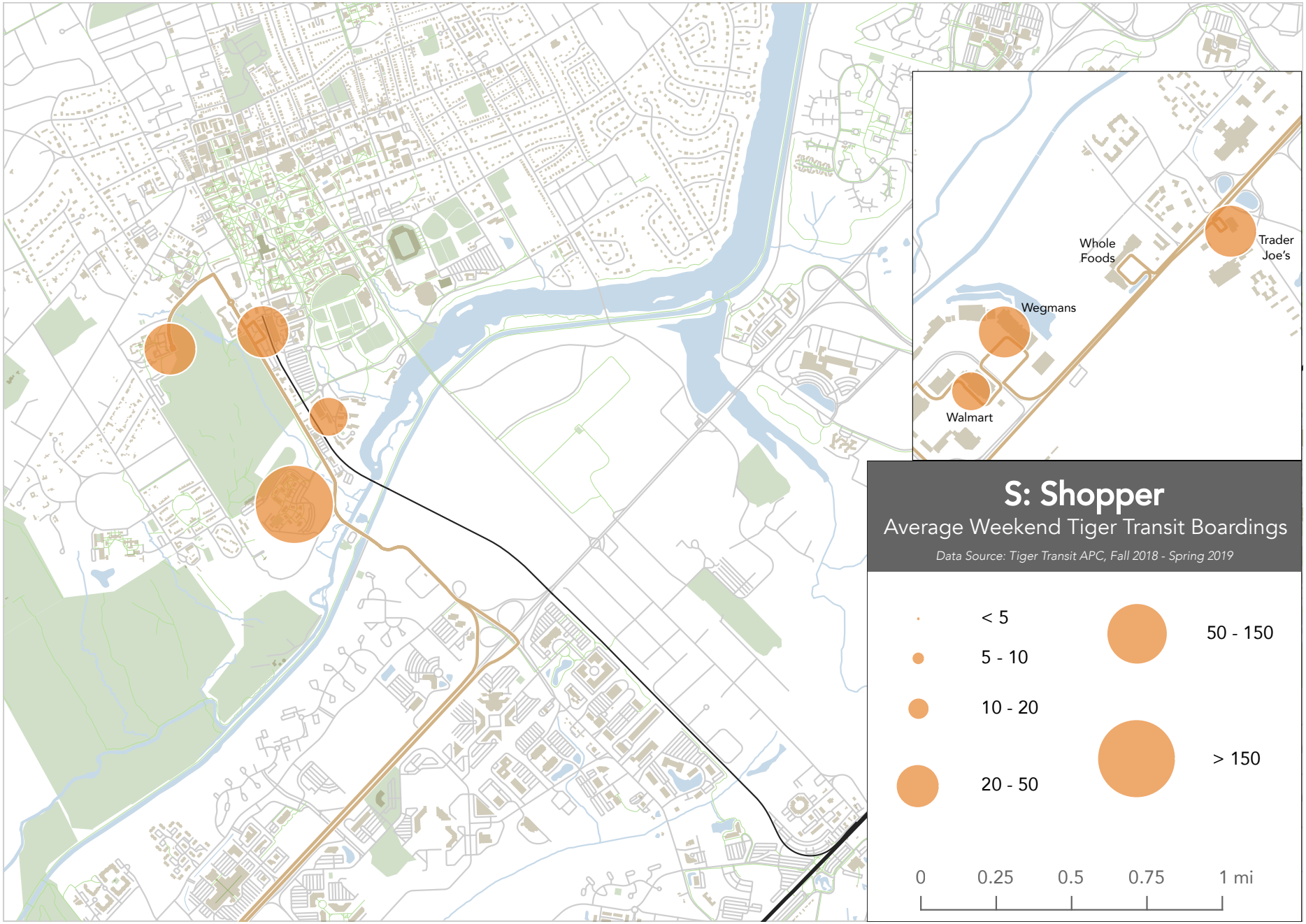
Whole Foods
Trader Joe's
Wegmans
Walmart
S: Shopper
Average Weekend Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
< 5
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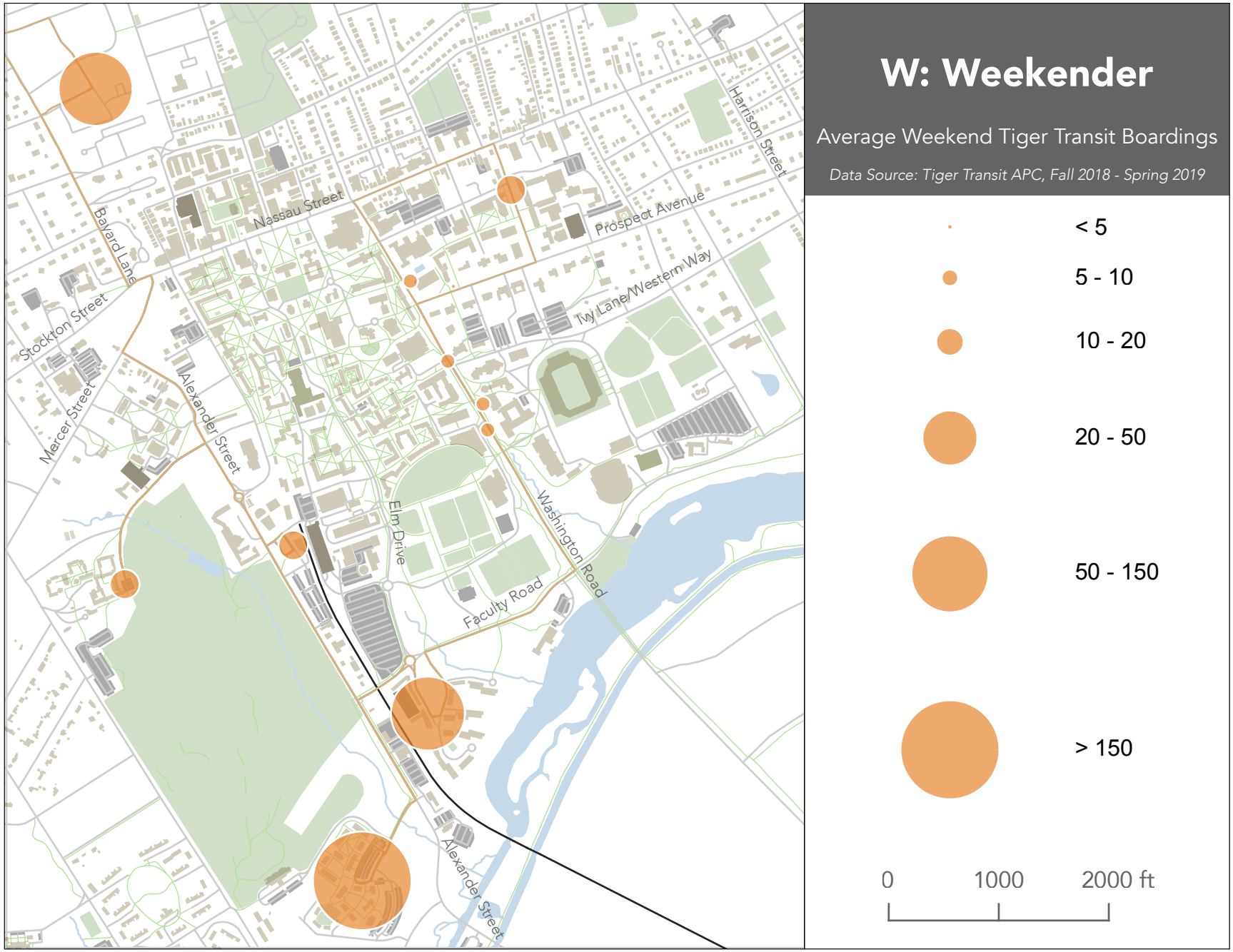
W: Weekender
Average Weekend Tiger Transit Boardings
Data Source: Tiger Transit APC, Fall 2018 - Spring 2019
< 5
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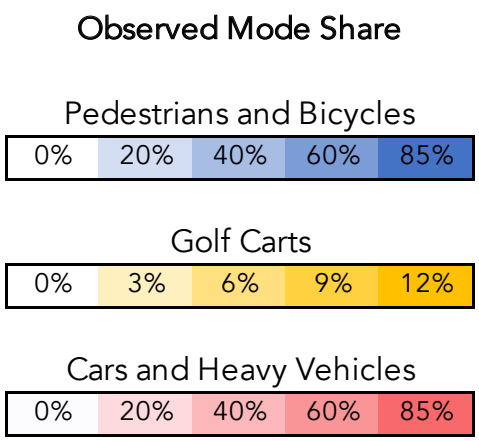
2000 ft
Nassau Street
Prospect Avenue
Harrison Street
Ivy Lane/Western Way
Bayard Lane
Stockton Street
Mercer Street
Alexander Street
Elm Drive
Faculty Road
Washington Road
Alexander Street

Summary of Traffic Counts by Location

Data collected for 24 hours by video observation on Tuesday, October 15, 2019.

Location	Period	Peds	Bikes	Golf Carts	Cars	Heavy Vehicles
Alexander Street	AM Peak	70	32	1	1146	159
	Late AM	66	26	1	635	143
	Lunch	90	35	3	740	129
	PM	85	25	1	1113	104
Chapel Drive	AM Peak	83	17	6	10	17
	Late AM	167	45	12	15	22
	Lunch	207	54	8	13	14
	PM	130	26	2	10	9
College Road	AM Peak	68	35	1	167	57
	Late AM	60	22	3	87	47
	Lunch	44	16	0	110	48
	PM	63	19	2	232	33
Elm Drive	AM Peak	113	47	10	23	46
	Late AM	129	58	19	27	51
	Lunch	212	77	18	20	45
	PM	186	60	6	18	22
Lakeside Road	AM Peak	17	4	0	23	10
	Late AM	22	7	0	13	7
	Lunch	8	4	0	10	6
	PM	23	6	0	30	9
Lawrence Drive	AM Peak	21	14	0	77	21
	Late AM	22	9	1	41	25
	Lunch	19	10	1	56	19
	PM	29	14	1	51	15

Observed Mode Share



Location	Period	Peds	Bikes	Golf Carts	Cars	Heavy Vehicles
McCosh Walk	AM Peak	150	45	0	0	0
	Late AM	455	100	0	0	0
	Lunch	603	105	0	0	0
	PM	239	50	0	0	0
Off Elm Drive	AM Peak	91	16	3	4	4
	Late AM	90	12	8	10	5
	Lunch	102	16	7	5	8
	PM	113	16	3	5	4
Olden Street	AM Peak	1	22	5	133	41
	Late AM	1	20	7	90	41
	Lunch	4	20	6	104	36
	PM	9	20	1	131	25
Prospect Avenue	AM Peak	99	31	3	106	48
	Late AM	132	34	2	88	56
	Lunch	254	44	2	94	44
	PM	172	32	1	117	25
Pyne Drive	AM Peak	111	20	4	3	7
	Late AM	103	19	6	9	7
	Lunch	129	13	6	3	13
	PM	173	17	6	3	4
Stadium Drive West	AM Peak	53	41	12	26	26
	Late AM	30	33	5	33	35
	Lunch	29	14	16	28	40
	PM	63	51	7	25	17

Observed Mode Share

Pedestrians and Bicycles

0%	20%	40%	60%	85%

Golf Carts

0%	3%	6%	9%	12%

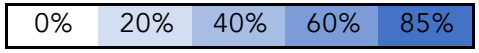
Cars and Heavy Vehicles

0%	20%	40%	60%	85%

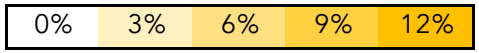
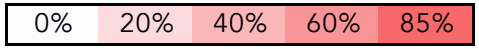
Location	Period	Peds	Bikes	Golf Carts	Cars	Heavy Vehicles
University Place	AM Peak	40	13	0	493	85
	Late AM	51	9	0	307	75
	Lunch	58	7	1	358	62
	PM	68	13	0	506	42
Washington Road	AM Peak	248	71	4	537	157
	Late AM	413	107	7	465	157
	Lunch	496	78	2	494	129
	PM	305	73	2	607	92

Observed Mode Share

Pedestrians and Bicycles



Golf Carts



Cars and Heavy Vehicles