

# Princeton Campus Mobility Framework

## Vol 2: Choices Report

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# 1. Introduction

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This report is the second element of a new Princeton Mobility Framework. It illustrates choices that decision-makers at Princeton University would consider while reimagining and redesigning the campus's mobility system.

For a detailed analysis of the current state of mobility on campus and the challenges and trade-offs that need to be taken into account, consider reading the Current State Report, which is available at: [www.princetoncampusmobility.org/discovery](http://www.princetoncampusmobility.org/discovery).

## Executive Summary

Transportation on campus grew organically over many years, answering a variety of needs, wants and desires. As the TigerTransit system approaches its first decade, and Princeton plans intense redevelopment in the East Campus and an entirely new Lake Campus, it makes sense to ask which mobility services and facilities are working, which are not, and if they will still be useful and relevant in the future.

In addition to the changing campus, a new consensus around values that relate to transportation has emerged in recent years. Sensitive to the special role walking plays in campus life, Princeton has placed a premium on protecting and improving the pedestrian experience on and around campus. Sustainability, more than ever, demands serious attention. Whether or how to embrace category bending innovations like e-scooters also needs careful consideration.

## How does campus mobility work today?

When we started the Princeton Mobility project, we heard a variety of concerns about transit and mobility on campus. These were, in no specific order, that the buses were empty a lot of the time, that they were loud and dirty, and that the buses themselves were too big for the campus.

We also heard that walking, which is deemed important to the life of the campus, was a sort of dying art. Many people seemed to prefer buses, bikes, scooters, and most alarmingly cars or golf carts, over walking. Others expressed concern about utility vehicles, trucks, and mini-wagons buzzing by walkers and haphazardly parking seemingly everywhere.

There was a general worry that the peaceful campus they expected or remembered was being overrun by vehicles of all types.

To get started, the consultant team spent about six months analyzing data, speaking to people on campus, walking, biking, and riding buses and cars around the campus—taking lots of pictures and videos—to understand the nature of these concerns. For the most part, we found that, yes, the buses are quite loud and emitted visible exhaust, which is to be expected since they are nearly ten years old. We also observed that some, but definitely not all, routes had very few riders. Others, especially the graduate residence routes, posted healthy numbers, even when compared to well-used city buses. And for the most part, we saw that people were riding the buses for very short trips. In fact, the boarding data seems to suggest many people ride the bus in only one direction, presumably walking or riding a Zagster shared bike back.

Was walking a lost art? That's hard to say. We did a 24-hour camera count of 12 locations in and around campus and tallied lots of walkers and quite a few cyclists as well. In fact, in the core of campus, on Elm and Pyne Drives, bikers and walkers were five or six times as common as cars. But without data from before, we don't know if walking is trending up or down.

Without a doubt, though, many places where people walk and bike are cramped and some are downright uninviting; which may be why so many healthy and mobile people are choosing to hop on a bus or a golf cart rather than take a 20-minute walk across campus.

We also found the various transportation options on the campus were not easy to understand. Yes, the bus routes are complex, but the maps and schedules didn't help much. Our experience with TransLoc was a bit better but required more time than we expected to orient ourselves.

So what to do about this? This report lays out the choices Princeton faces in transportation.

## What kind of campus mobility is right for the future?

In the medium and long term, the most pressing question for Princeton in terms of transportation is how much the movement of people on campus should be motorized. **If Princeton hopes to maintain or reduce the number of motor vehicles on campus, then bicycling (or rolling on other small devices, like scooters) must become easier and more prevalent.** Walking is important and can be made more dignified and attractive, but people must have a way to move longer distances across campus at speeds faster than they can

walk. Those speeds can be provided by transit, by private cars, by bicycles or by other small rolling devices.

Widening walkways, developing a bicycle network, and perhaps even transforming Elm Drive into a car-free promenade are capital investments that coupled with a super-sized and modern bike-share fleet of electric-assist bikes and scooters could allow Princeton to reduce its bus network and cut down on the use of golf carts and personal vehicles for travel to meetings during the day.

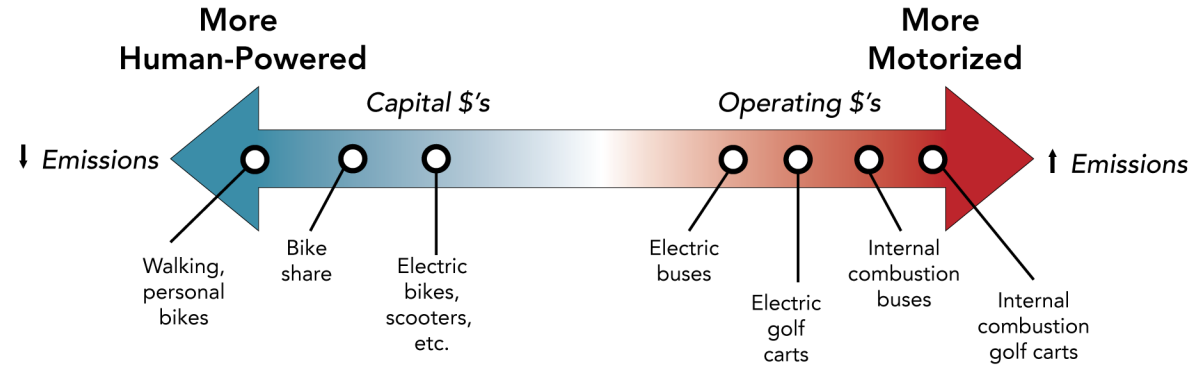
A more human-powered future will require more capital investment, but cost less to operate. A more robust bus system that serves more trips within campus won't require much, if any, capital investment in the existing roadways, but costs money to operate every year. Thus the choice between a more and less motorized future is also a choice between more one-time capital investments or more on-going operating investments.

In the immediate term, Princeton can redesign the bus network, as early as September of 2020 to address, at least in part, the concerns that too many buses seem to run empty.

### Can anything be done about "empty buses"?

But the perceived problem of transit vehicles being empty a lot of the time can only ever be addressed *in part*, because even the most heavily-used routes at Princeton are in fact empty half the time. The nature of the demand on campus is one-way. A bus that picks up a full load of parkers at, say, the West Garage in the morning, will invariably return empty after dropping them off because no one wants to

## In 10 years, Princeton's campus will be...



return from campus to the garage at that time. Similarly, routes connecting purely residential developments (like Lawrence Apartments) to campus will generate one-way demand during most of the day.

Note also that five people sitting on a bus make it look "empty" but by various measures this can be a more efficient outcome than if those five people arrived by car.

Because the cost of operating transit is barely affected by vehicle size, and because smaller vehicles make the system vulnerable to crowding and delays, we must be careful about decisions made to avoid the appearance of empty buses.

However, there are many existing TigerTransit routes (such as the routes serving the outlying locations at 693 Alexander, 701 Carnegie Center, Forrestal, and PPPL) that have only a few riders at any time of day, and therefore probably appear "empty" all the time. Whether to keep all, some or none of these routes is key

choice that will be contemplated in this phase of the project.

### Are shared bikes and scooters part of the solution?

The pace of change in micromobility offerings is dizzying. (In this report we will use the word "micromobility" to refer to any small-sized, individual rolling vehicle, such as a bicycle, scooter, skateboard, or future inventions that resemble these.) Princeton University's Zagster bikeshare system is only a few year's old but there are already new technologies for electric bikeshare that should be considered. The falling price of batteries have made small electric scooters cheap enough to manufacture that private companies now offer shared scooter fleets, similar to shared bicycle fleets already deployed successfully in cities and on college campuses around the world.

Princeton can decide how much to embrace, manage or prohibit scooters and any future

micromobility tools on campus. The University can also make a choice about whether and how much to subsidize bikeshare and scooter rides for some or all campus users. It will have to choose whether to go fully dockless, partly docked, or all docked. And perhaps most importantly it will have to decide how big to go with micromobility on the campus. Shoot for the moon and deploy 1,000 or more bikes to campus, or make a small increase to two or three hundred? Or even, scrap the system altogether. We will discuss these choices and more in further detail below.

Finally, the information systems used today can be improved, but in this arena too Princeton faces some choices. Should the University develop its own transportation app with information about TigerTransit, micromobility, perhaps parking and other resources? Or is it better to focus on publishing accurate data streams that can be used by the most common transportation apps already on most users' phones?

Few of the choices we present in this report are technical in nature. Most are, ultimately, about the values of Princeton and how those should be expressed in the ways that people move about campus.

## About This Report

The purpose of this report is to illustrate the different ways mobility around the Princeton University campus could be provided in the future. More specifically, it focuses on the walking and cycling (or rolling in general) networks, and the TigerTransit network, fleet, and information provision.

Some of the ideas in this report are presented as potential improvements or modifications. In such cases, the choice lies in whether or not (and to what degree) Princeton decision-makers choose to implement those (or similar) ideas. For major trade-offs between competing goals, this report presents differing Concepts which illustrate different places along a spectrum, and are not meant to be seen as discrete choices.

### Choices, not proposals

*None of the Concepts presented in this report are proposals.* At this stage, neither Princeton University decision-makers nor the consulting team is proposing or recommending anything.

The purpose of these Concepts is to illustrate the degree of and differences in the various choices that could be made while redesigning the campus's mobility system and their potential outcomes. Input about the Concepts from the Princeton community and stakeholders will help guide the development of an actual mobility plan.

### No preferred Concept

Neither the consulting team nor the Transportation and Parking Services (TPS) staff has any "preferred Concept".

The most important word in this report is *if*. The High-Coverage Transit Concept shows what might happen *if* Princeton tried to ensure that all campus buildings get some degree of service. To contrast this, the High Frequency Transit Concepts show the possibilities *if* Princeton decided to prioritize frequent service, with longer hours of operation, without an obligation to go to every Princeton building.

The Concepts also show degrees of possible change. For example, the Neighborhood Bikeway Concept shows the extent of treatments that could be implemented *if* Princeton chose to prioritize bicycle safety and comfort on some streets.

## 2. Walking and Biking

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Princeton is approaching a fundamental dilemma in the movement of people around campus. Walking is important to campus life because it provides a sense of place and connection among staff, students, and faculty. A great walking experience is almost an extension of the liberal arts mission of the University. Walking, and the spontaneous interactions it provides, is mentioned in many of Princeton's strategic planning documents.

Yet as the campus continues to expand outwards (into East Campus and the Lake Campus), trips will become longer and people will need a way to make those trips at faster-than-walking speed. If Princeton does nothing to provide more faster-than-walking options, individuals will naturally provide for themselves, using personal cars, hired cars, bikes, scooters or other tools. Private companies may also be interested in entering the Princeton "market," selling services like hired cars, shared bikes or shared scooters, with or without Princeton's blessing.

The campus is growing outwards, and new buildings will also be added within the existing campus. In addition, Princeton is planning to increase the size of the student body. All of these factors will increase demand for scarce space among walkers, cyclists, scooters, utility vehicles and golf carts. Unmanaged, this could degrade the great walking experience offered on many parts of campus today.

Today Princeton provides faster-than-walking mobility in two forms: TigerTransit routes and Zagster bike share. The University permits people to keep and use their own bikes and scooters, but lightly-regulates where they can be parked.

In making choices about the future role of the TigerTransit network, Princeton will have to think about the trip lengths for which transit is its preferred mobility option. Today, and in the Concepts shown in this report, the TigerTransit network serves some trips that are very short, and that could be walked in ten or twenty minutes or cycled in even less time.

For example, transit ridership from Graduate College, Lawrence and Lakeside to the historic campus is very high, and makes those routes very productive, but the trips they serve are short enough that on many other college campuses most people would bike or walk. The streets and intersections connecting those graduate residences to the rest of campus were optimized for car traffic, which probably discourages many would-be cyclists from pedaling onto campus.

## Lake and East Campus Development

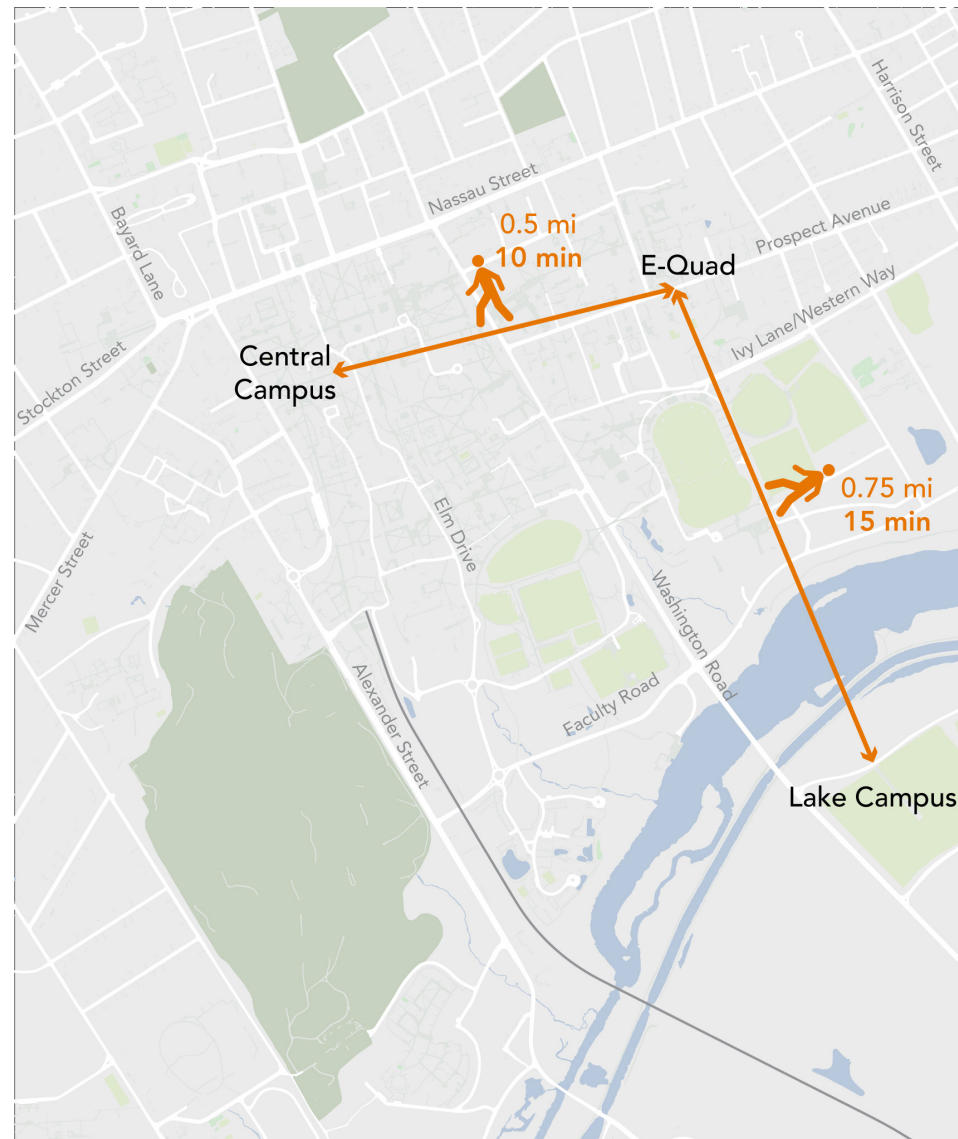
The sharpest challenge to the transportation status quo on campus will be development of the Lake Campus, which is sure to increase the demand for biking, scooting, rolling, or transit as it increases the average distance among campus buildings.

The walk between the historic campus and Lake Campus, or the E-Quad and Lake Campus, will take about 20-25 minutes. The walk between Ivy Lane and East Campus will take about 15 minutes. Different people have different tolerances for walking distance, but fewer people will be willing to make an intra-campus walk part of their daily commute as it gets longer.

The beautiful lake flyover will make cycling between the Lake and East Campuses easy and direct, but cycling between the Lake Campus and historic campus will be subject to the same limitations on cycling today, which are the lack of clear, spacious and low-stress bikeways.

Depending on how badly congested Washington Road is, transit could be a faster way to get to and from the Lake Campus than walking, cycling or scooting.

The distance between the Lake Campus and the rest of campus raises some basic questions about the way campus is designed for different modes, as longer distances make faster modes more attractive and important. What routes will people rolling on bikes, e-scooters, or hoverboards follow once they've crossed the lake? Will motor vehicle trips increase among campus



The Lake Campus development will increase the average trip distance on campus. Lake Campus will be about 0.75 miles from Prospect Avenue (a 15-minute walk) and an additional half mile from the historic center of campus (a 25-minute walk). While such walks might be workable as part of peoples' daily commutes, few people are likely to be willing to walk such distances multiple times a day as they move around campus.



buildings? How will the campus preserve a pristine walking experience in its narrow, meandering paths?

The rebuilding of East Campus will affect travel between the Lake Campus and historic campus. It is an opportunity to plan for direct transit routes, shortest-possible walks, easy cycling and scooting routes, and the management of these modes on streets and paths.

## More Motorized Vehicles

One way to deal with lengthening trip distances is to allow for or encourage the use of more motorized vehicles, while protecting the walking experience.

- The use of golf carts and off-highway vehicles could be allowed to increase, though efforts should be made to regulate when they can use narrow walkways.
- Princeton could also consider expanding transit service to new places (including the Lake Campus), or improving bus frequencies and speeds in order to shorten travel times. Either move would require an increase in operating costs, or a cut in existing services.
- An additional option is to accept and manage that people will be driven among campus buildings in hired cars (such as Uber or Lyft), and Princeton could establish appropriate pick up and drop off spots.

A more motorized future – whether the motors are in transit vehicles, golf cars or cars – entails more operating costs and likely more GHG

emissions but requires little in the way of University capital improvements.

In this scenario, Princeton would not expand its bike-share system, and could consider scrapping it altogether. It could also consider ways to curtail the use of private scooters and ban private companies from distributing shared scooters on campus. Thoughtful management of Princeton's facility vehicles would be required, so that deliveries, repairs and construction projects could still proceed across the expanded campus, without overwhelming campus paths and sidewalks.

## More Micromobility

Another way to approach the problem of longer trips and greater demand for intra-campus travel is to make capital improvements that allow for peaceful walking even while more people use rolling modes. Best practice in bicycle facility design is to follow one of two guidelines: "All Ages and Abilities" (illustrated on the next page), or "Low-Stress." In both, riders are either fully separated from motor vehicles or they are sharing space with only small numbers of motor vehicles that are moving at very slow speeds.

# Creating an “All Ages & Abilities” Network

In order to attract a large number of people, Princeton’s bicycle and micromobility facilities must be safe and comfortable, particularly to the majority who express interest but are concerned about cycling in mixed traffic. If the only fast and direct routes for bicycles or scooters are on roads mixed with cars, in narrow bike lanes or on congested walkways, few people will choose to do so regularly.

Friction with pedestrians on the narrow and indirect footpaths in the historic part of the campus occurs today and will likely become

more acute. For cycling or scooting to become more prevalent without becoming more disruptive to walking, a more legible and dedicated bicycle network will be needed. If the number of bike trips is to grow, 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).

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.



The City of Vancouver, BC, has established “All Ages & Abilities” (AAA) as its standard for bicycle facilities. Implementing a similar standard at Princeton University, and modifying existing roads and paths to meet it, would allow cycling and scooting to handle some of the demand for longer-distance trips.



## Cycling network design

To improve conditions for cycling within campus, Princeton could consider developing a well-connected, contiguous, and legible bicycle network to accommodate increases in cycling or scooting while at the same time decanting traffic from the narrower walking paths on campus.

These routes can be designed using different designs and strategies depending on the context, but they should add up to a legible network that meets the All Ages & Abilities standard.

An example of a potential campus cycling “grid” is shown on the map on the right. There are clear north-south and east-west corridors. With appropriate design and clear wayfinding, they can provide a greatly improved biking experience on campus, while at the same time reducing pedestrian-bike conflicts.

In addition to providing a clearly defined cycling routes to campus, such a network could also help specific linkage needs across campus:

- **North-south between Nassau Street, Lakeside and Lawrence.** The 2017 Campus Plan calls for a “North-South Campus Connector,” but on the east side of Washington Road, connecting the E-Quad through future East Campus developments and across the flyover to the Lake Campus. A north-south cycling and scooting route is badly needed west of Washington Road, among the graduate residences to the south, the transit and parking at Princeton Station, the historic campus, and town. Elm Drive is an obvious candidate for much of this route.



A clear and legible bicycle network across campus can improve the cycling experience while preserving the pedestrian experience on campus's narrow walkways. It can also solve specific linkage needs of the campus community.

- **East-west between Graduate College and E-Quad.** The 2017 Campus Plan already calls for an “East-West Campus Connector,” a walking and biking route between Graduate College and Ivy Lane, passing by Dillon Gym and Wilson College.
- **Alexander Street.** As described at greater length on later pages, Alexander Street is unwelcoming to cycling or scooting, but is an important axis of travel for campus given the numerous graduate and undergraduate students living along its west side. In the long-term, if the Dinky right-of-way becomes a multi-use path, an entrance to that path from Lawrence Drive would reduce the need to make Alexander Street an All Ages & Abilities cycling street.

## Concepts for AAA interventions

If Princeton is interested in pursuing a more human-powered future for the movement of people on and around campus, developing a connected network of low-stress routes will be key to decanting bike and scooter traffic from campus walkways. The following design and management strategies can be used to create these routes:

### “Neighborhood Greenways” or “Woonerf Shared Streets”

Residential streets can be designed and managed to prioritize the movement of bikes and protect pedestrians while allowing slow movement of cars and other motor vehicles. This type of street has been given various names in different places, but is often called a “Neighborhood Greenway” or a “Woonerf Shared Street.”



A Woonerf Shared Street allows different modes of transportation to share the same space instead of dividing up the space for various uses and modes. (Photo by Dylan Passmore / [CC BY-NC 2.0](#))

College Drive, Lawrence Drive, and Hibben-Magie Road are potential candidates for this design type. Potentially, Elm Drive, with a major reduction in the number of motor vehicles using it, could be a candidate for a Woonerf design. The redesign of Ivy Lane/Western Way as part of East Campus development could also follow one of these shared street Concepts.

Neighborhood Greenways are designed to prioritize bicycling and walking, while still allowing car traffic up to about 20 mph. Woonerfs are more ambitious, designed to make driving a car feel like an imposition and only acceptable at very slow speeds with great deference

to the people on the street. Cars and buses can be allowed on either, but the streets feature a host of engineering treatments that reduce the speed of cars and making cycling in the road itself very comfortable, even for slow and timid riders (and even uphill).

The city of Portland, Oregon has fine-tuned the design of residential Neighborhood Greenways over the last 40 years. The 2015 [Neighborhood Greenway Assessment Report](#) lists some of the key tools and designs of Neighborhood Greenway, including:

**Speed controls:** Speed humps, raised



crosswalks, narrow road widths and the removal of center lines can all contribute to lower speeds.

**Traffic volume reduction:** Reducing motor vehicle traffic may be necessary to create a low-stress experience on certain campus roads. This can be achieved by a “soft” diversion that increases friction for autos, encouraging drivers to use another route, or a “hard” diversion that simply prohibits entry. Three roadway segments discussed above (Lawrence, College, and Hibben-Magie) serve large parking lots and are not candidates for hard diversion. There might be locations on campus where these design treatments are appropriate, such as on Elm Drive.

Refer to Appendix C of the Greenway Assessment Report for more details about speed control and traffic volume management measures.

### Protected bike lanes

Bike lanes that are physically protected from motor vehicles increase the comfort and safety of cyclists and have been shown to increase ridership. Elm Drive could be a candidate for separated bike lanes, as could Alexander Street (which is not controlled by Princeton). The [Federal Highway Administration’s Separated Bike Lane Planning And Design Guide](#) provides detailed guidelines for this.

### Pedestrian promenade

Pedestrian-only streets make walking a pleasurable and celebrated activity, and are most appropriate in corridors with high pedestrian volumes or with high activity on both edges of the street. Pedestrian streets offer opportunities for diverse activities such as walking or



Speed controls like speed humps (left), speed tables, and raised crosswalks (right, pictured in front of Princeton Station) can help control vehicle speeds on shared roadways.



“Soft” diversions like pinch points (left) increase friction for automobiles without necessarily prohibiting them from streets, while “hard” diversions (right) restrict through and left movements for automobiles while letting bicycles and pedestrians through.

sitting, dining or dawdling, promenading or performing.

On such streets, vehicular traffic is limited to few hours of the day for maintenance and delivery. Electric gates or bollards can be used to strictly control vehicle access. [The NACTO Global Street Design Guide](#) provides further resources.

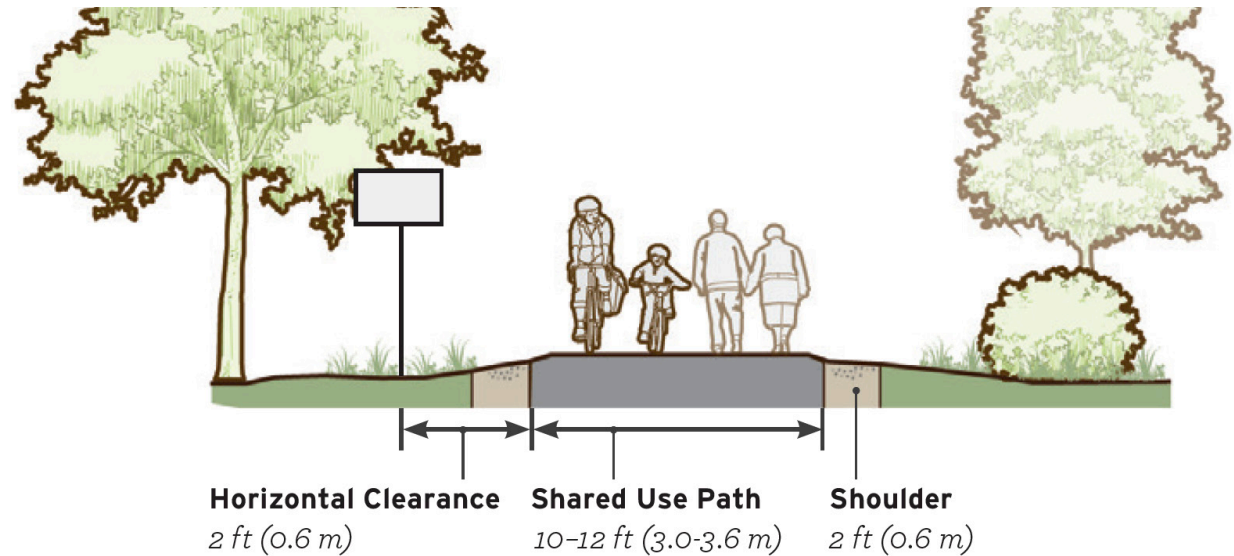
The northern part of Elm Drive from Nassau Street to McCosh Walk would potentially be a pedestrian promenade, at least on certain days or at certain times, given the high pedestrian volumes and the busy buildings on both sides of the road.

### Multi-use or side paths

Side paths and multi-use paths are often located in parks, along rivers, beaches, and in greenbelts or utility corridors where there are few conflicts with motorized vehicles. Side paths offer a low-stress experience for bicyclists and pedestrians on network routes otherwise inhospitable to walking and bicycling due to high-speed or high-volume traffic.

The side path along Alexander Street adjacent to the golf course is narrow and could be improved using the side path design standard. The Hibben-Magie trail would be a good choice for improvement to the multi-use path treatment. Both involve a grade, and bike traffic heading downhill on a narrow path can make people walking on that path uncomfortable. Whenever bikes are likely to be moving fast,

The [US Department of Transportation's Small and Rural Multimodal Networks Guide](#) provides more detail on how side paths and multi-use paths should be designed (refer to page 4-3 of the guide).



Multi-use paths offer network connectivity opportunities beyond that of the roadway network. These facilities are often located in parks, along rivers, beaches, and in greenbelts or utility corridors where there are few conflicts with motorized vehicles.



## Options for Elm Drive

Elm Drive today carries general-purpose vehicle traffic in two directions. Delivery vehicles, University vehicles, TigerTransit and numerous private cars have access to Elm Drive, though there is some measure of controlled access at the staffed gate booths on the north and south ends of the street. TigerTransit operates one-way northbound on Elm Drive. The southern, more recently built segments of Elm drive have 8 foot walking paths on either side while in the older part of campus north of Dillon gym the sidewalks are as narrow as 3 or 4 feet. There is no bike facility on Elm Drive.

Our observations and camera counts show that although pedestrians and cyclists account for around 80% of the traffic on Elm drive very little space is dedicated to walking and biking. Anecdotal observations of groups of people walking in the road are easy to come by.

If Princeton is interested in rebalancing the space on Elm Drive to more closely reflect the usage of the street, several options are available. Common to each of these options is a policy to restrict delivery vehicles, utility trucks, golf carts, and private car traffic from using Elm, at least during the daytime. The Elm Drive options are affected by the transit network design that Princeton selects, and in particular by the decision of whether to have the historic campus served by a one-way loop, a two-way line, or to not have transit going through the historic campus at all. In the Transit Choices section below we describe the positive and negative aspects of each Elm Drive Concept for the usefulness of transit service.



**Narrow sidewalks make it difficult for groups of people to walk more than two-abreast, which is an important consideration in a university setting. On campus roadways like Elm Drive, it is common to see people walking on the street.**

In this section, we will discuss how the Elm Drive Concepts would affect walking and cycling. We will also note more generally how 'rollers' would be affected, that is people using wheelchairs or other rolling assisted devices and people traveling on scooters, skateboards or other types of rolling personal mobility devices. While these Concepts are focused on

changes to the curb-to-curb Elm Drive roadway, spot-improvements for walking, where space is available, could be built as a complement to any of these options. However, historic buildings and trees limit the options for improving walkways along Elm Drive in the busiest places, which is why total conversion of the roadway is an option worth considering.



## Grand promenade with bikeway: vehicle-free Elm

In this Concept, no motor vehicles of any kind (except emergency vehicles) would be allowed on Elm during daytime hours. The street would be converted to a wide pedestrian promenade. The twenty-foot roadway is wide enough to include, should Princeton want it, a two-way separated bike lane.

Since Elm Drive would have no significant intersections with vehicular traffic, the design of intersections would need to manage bike-bike and bike-ped conflicts. Many engineering solutions have been developed effective to manage intersecting bikeways, in particular on college campuses where bike traffic can be heavy.

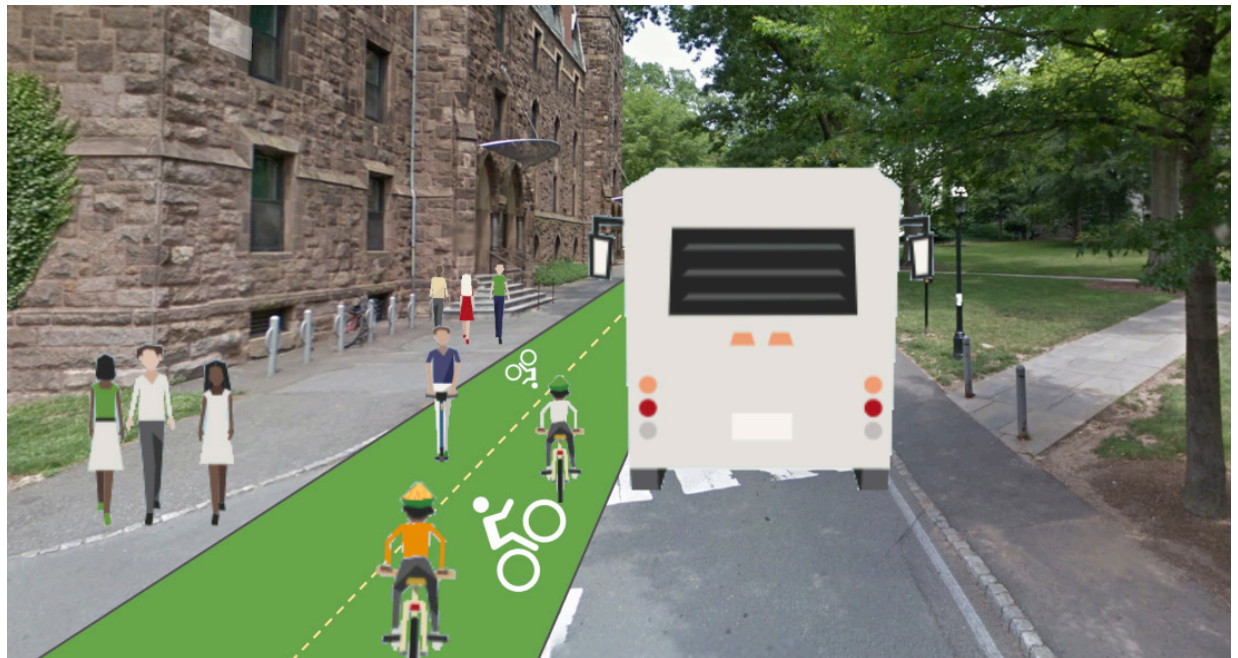
Elm Drive would become a primary north-south corridor for non-motorized travel on campus. This would greatly increase space for walking and would be the spine of a separated bicycle network that could include east-west routes connecting graduate residences, East Campus and the Lake Campus.



If Princeton chooses to remove all motorized traffic from Elm Drive, the freed space on one of the lanes can be converted to a two-way bike lane, while the other lane can accommodate a wide walking corridor.

## Cycling and rolling “Main Street”: one-way transit

In this Concept, transit service would be limited to one-way northbound, while the southbound travel lane would be repurposed as a two-way bike lane. This Concept does not greatly improve the walking experience but to the extent that the cycle facility decants bike traffic from walkways, it may reduce friction between pedestrians and cyclists. As in the previous Concept, Elm Drive’s intersections with other roadways would be designed to manage intersecting flows of cyclists and other rollers.

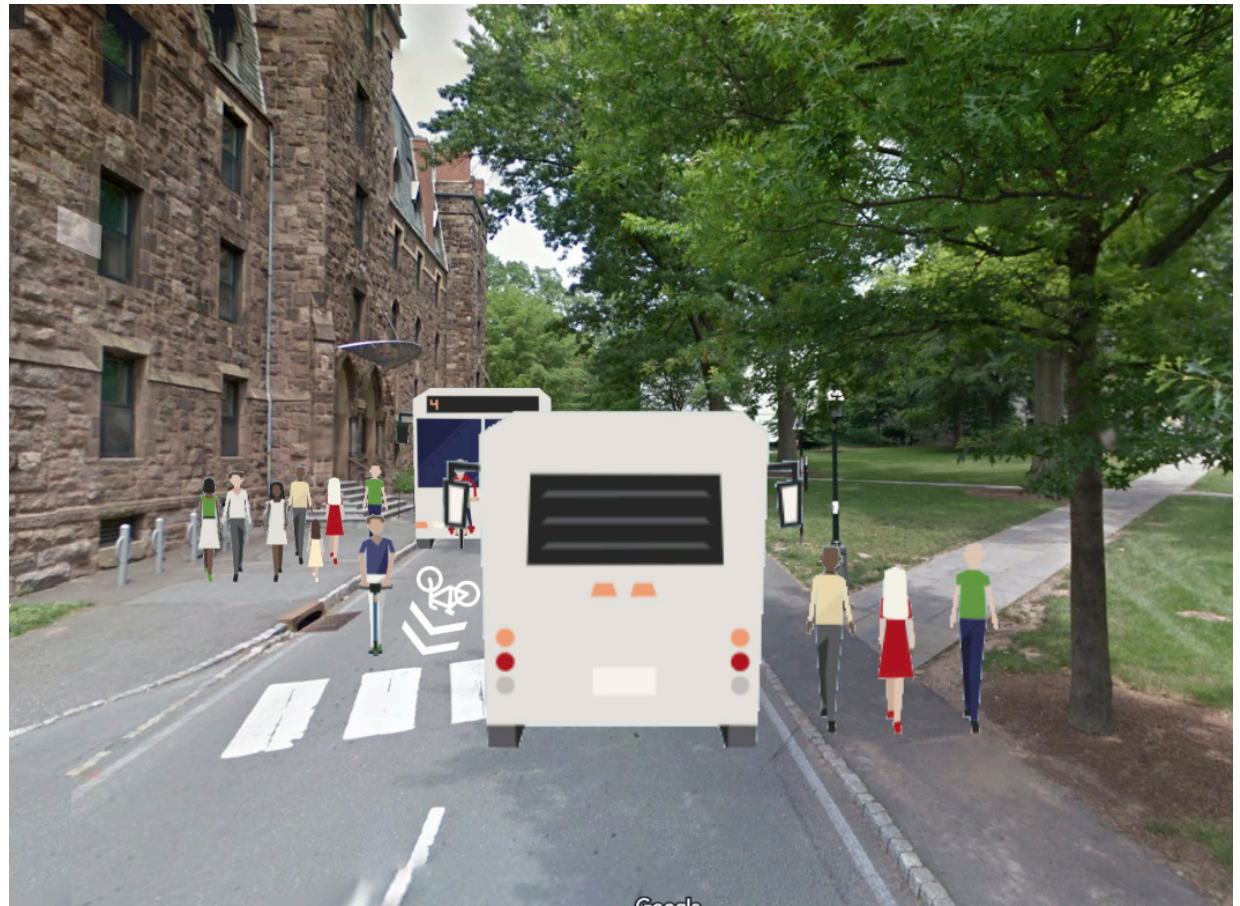


Alternatively, the northbound lane of Elm Drive could be kept aside for TigerTransit vehicles, with the other lane converted to a shared walking-rolling corridor (top) or a separated two-way bike line (bottom).



## Transit mall: two-way transit on Elm

One of the transit Concepts described later in this report includes frequent transit service going both directions on Elm Drive. In this Concept, the street would become the transit spine of campus offering very frequent all-day service between Princeton Station and E-Quad. As it pertains to Elm Drive, this Concept is most similar to the existing use of the road, except that there would be no general-purpose vehicle traffic on Elm Drive in this Concept. Bicyclists would share the roadway with buses or the sidewalks with walkers, and the only official space for walking would be on the sidewalks.



Elm Drive could serve as the “transit backbone” of Central Campus, with frequent two-way transit on the street.



## Case Study for a Potential AAA Network: Lawrence Apartments

The Lawrence Apartments graduate student housing is about 1.5 miles from the E-Quad—a thirty-minute walk, or a 9-minute bike ride which handily beats the combined waiting and riding time for even the most frequent and fast transit. Currently, though, the built environment sends a clear message that pedestrians and bicyclists are not welcome on the streets between Lawrence and E-Quad. Camera counts at the Lawrence entrance showed 1229 automobiles and only 653 pedestrians and bikes over 24 hours.

The most direct way to ride north out of Lawrence is on Alexander Street, which has bike lanes only between Princeton Station and the Skillman Furniture Store. Car traffic on Alexander is heavy and constant, and (when not congested) too fast for most people to be comfortable riding a bike in the lane with cars.

Someone can ride their bike on the Alexander Street sidewalks if they are not comfortable riding in the roads. But the walkway adjacent to the golf course on the west side of Alexander Street is of varying quality. It is a standard sidewalk width, which is wide enough for two people to walk side-by-side but not wide enough for shared biking, walking, and rolling.

In one section, it is separated from the road by a parking strip of grass, and in another section by an attractive row of trees. However, in its northern section it is directly adjacent to the

road with little or no buffer, which makes it feel even narrower.

The sidewalk on the east side of Alexander Street also offers mixed experiences. In some sections the design is modern and spacious, and in others the widened-road has squeezed the pedestrian space against the buildings to less than four feet. Regardless, it is not designed as a shared walking-and-cycling path, so heavy bike traffic would make it a less pleasant place to walk.



Sidewalks along Alexander Street leave a lot to be desired in some spots: west (top) and east (bottom).

## Options for Lawrence-to-Campus non-motorized connections

This route can be broken down into three segments (shown in the map on the right):

1) Lawrence Drive 2) North-South link, and 3) East-West link across campus. The potential solutions are different for each segment based on their different contexts and within each segment different types of treatment are available. These options are not mutually exclusive. Princeton could choose to pursue all, some, or none of these choices. Some improvements are entirely within Princeton's purview and might be achieved quickly, like resurfacing and widening the sidewalk adjacent to the golf course. Others, like widening sidewalks on the west side of Alexander Street, will probably need to be done over time and in collaboration with government partners.

### Lawrence Drive

Lawrence Drive serves the housing complex and the Springdale Golf Clubhouse connecting to Clubhouse Drive. Typical of suburban developments of the era, the pedestrian network inside the Lawrence complex is useful for someone going and coming from their car, and does not provide direct walkways to Alexander Street. Lawrence Drive includes a bridge over a creek and has a sidewalk on the north side.

Princeton could improve this segment of the route by reducing vehicle speeds along Lawrence Drive. This would encourage cyclists to use the roadway rather than the narrow sidewalk and would reduce friction with pedestrians. Princeton can also facilitate the movement of bikes from Lawrence Drive into and out of the path along the golf course.



In the example of trips between Lawrence Apartments and Engineering Quadrant, there are three main links which could be improved to create an AAA cycling path.



This is a place where the Neighborhood Greenway designs described above may be useful.

### North-south options

**Bike Lanes:** Alexander has bike lanes between the northern entrance of the Princeton Station parking lot and the Skillman Furniture Store. Southbound past the store the bike lanes disappear and shared use markings or ‘sharrows’ are painted in both directions. The purpose of these marking is to communicate to people driving that they should expect bikes in the road, and to show people biking where in the road to position themselves.

Extending the bike lanes to Lawrence Drive would improve the sense of safety and predictability for existing cyclists and might entice a few more. However, painted bike lanes are not considered an AAA bikeway. The existing and new bike lanes can be enhanced by adding protective buffers, which can make them suitable for AAA.

**Shared Use Path:** Princeton also might consider upgrading the sidewalk next to the golf course from Lawrence Drive to Princeton Station to a proper shared use path. The existing sidewalk is narrow, is perched right at the edge of the road in places, and the surface is bumpy from root incursions. A 10 to 12-foot path in this location, where there are no conflicts with motorized traffic (provided Princeton is able to keep golf carts off of it) would improve the biking and walking connection between the campus and Lawrence Apartments.

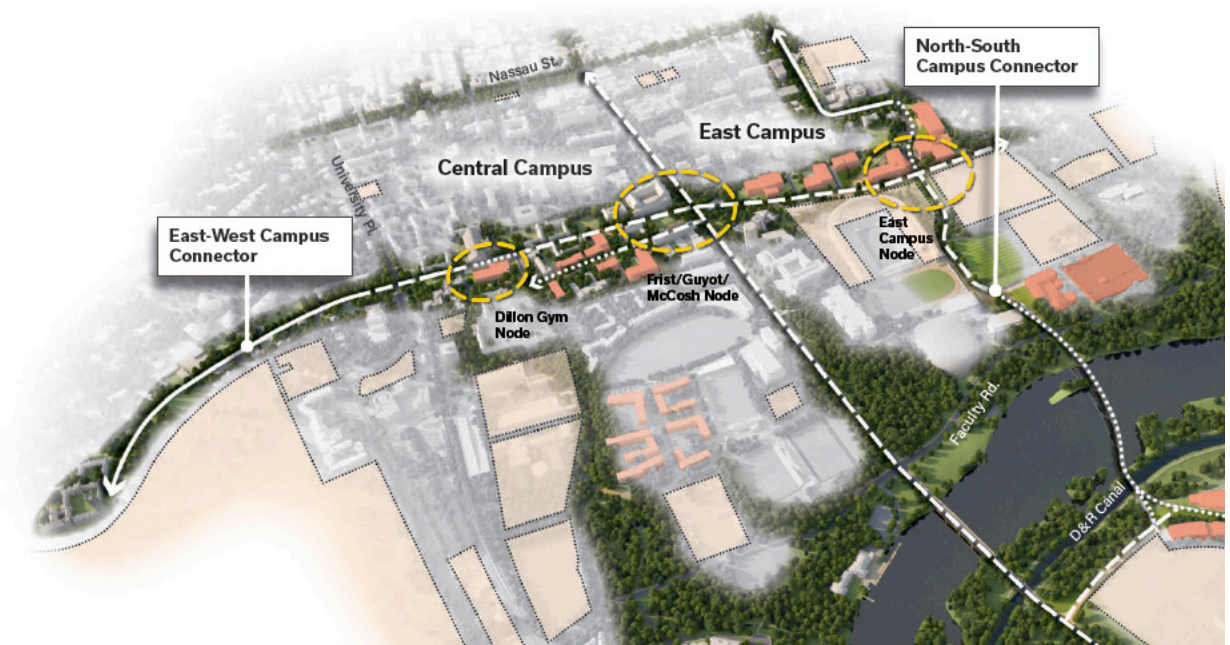
The Hibben-Magie trail from Faculty Drive to the class of 1895 baseball field could also be upgraded to a shared-use path. This would

provide a useful pedestrian and bicycle route from Lakeside to the heart of campus, and might also be useful for trips from Lawrence.

Both Alexander Street and the Hibben-Magie trail have a grade, with the northern ends at a higher elevation than the southern ends. This makes a wide path particularly important because people cycling downhill will naturally go faster than is appropriate on a narrow sidewalk with people walking. Even a bike going 10 mph, a very slow speed by modern standards, can feel much too fast to someone who is walking on a sidewalk.

### East-west link

This segment of the trip from Lawrence Apartments to the E-Quad puts cyclists on the walkways through the historic core of campus. These tend to be narrow and indirect causing potential conflicts between cyclists and pedestrians. The 2017 Campus Plan envisions an East-West Campus Connector from Graduate College through Central Campus to the East Campus. A design standard that promotes the movement of large volumes of pedestrians and cyclists with comfort would be needed for this segment of the route from Alexander to E-Quad—and from Grad College West. Whether these are separated bike facilities or wide shared paths is a choice Princeton will have to make.



The East-West Campus Connector envisioned in the 2017 Campus Plan would be restricted to walking and biking between University Place and Washington Road.

## Bikeshare Choices

Like many university campuses in the last decade, Princeton University offers its community members shared bikes. 119 bikes docked across 19 stations around the campus are available. Members pay a one-time fee to join and rides under two hours are free. Beyond that, rides cost \$2 an hour up to a \$20 cap. A fee of \$30 is charged to users who keep a bike for over 24 hours.

Proximity to a station is an important consideration when it comes to bikeshare systems with predominantly short trips, as is the case in Princeton. 16 out of the 19 Zagster stations are located on or within 1,000 feet of University-owned land. This translates to a station density of around 5 stations per square kilometer. Roughly 101 trips are undertaken per day on average, which is equal to 0.8 trips per bike per day.

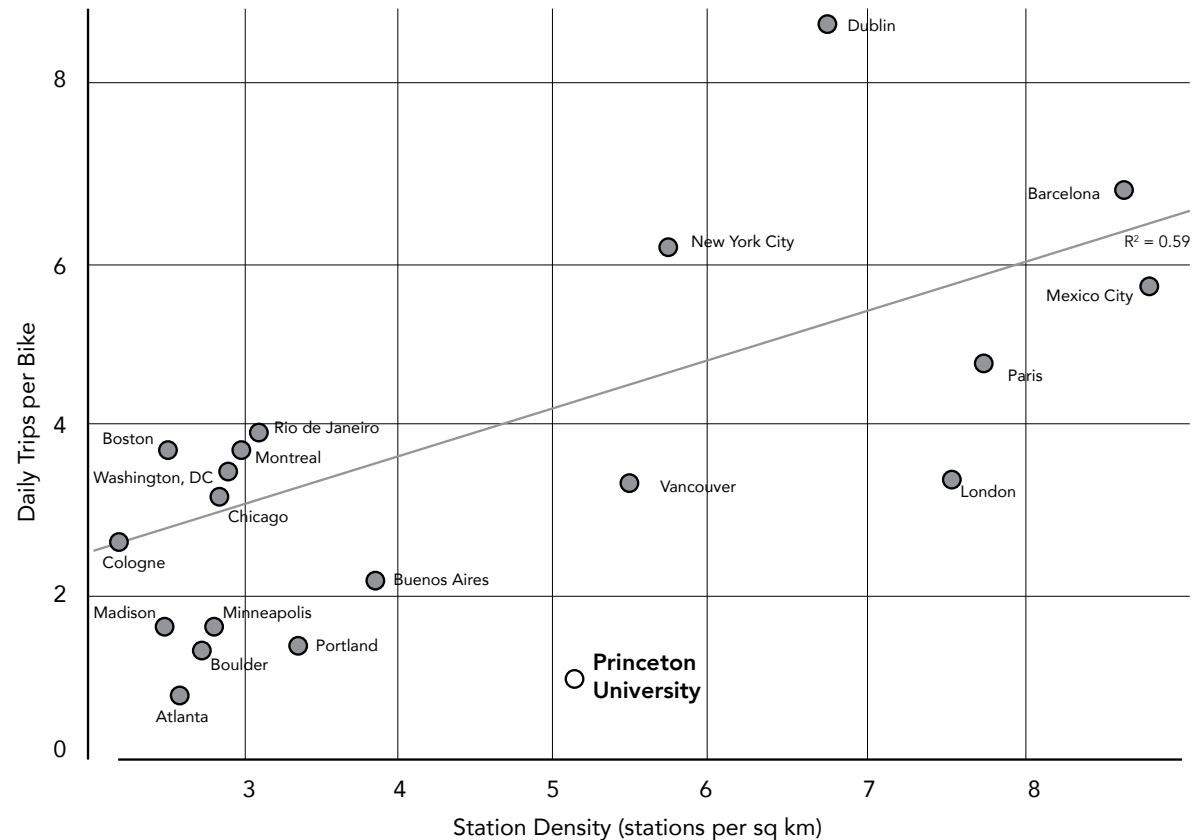
The station density of a docked system relates to some extent to the utilization of the bikes. The graph on the right is taken from the ITDP Bikeshare Planning Guide, and compares station density to daily trips per bike. On average Princeton's system has a lower-than-expected utilization of bikes compared 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.

Going forward, Princeton would face various choices with respect to its bikeshare system:

- Should it go for a docked or a dockless system?

## Bikeshare Usage

ITDP Bikeshare Planning Guide, 2018



**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.**

- Should bikes be mechanical or electric?
- To what extent should scooters be part of the system?
- What business model should Princeton follow for shared micromobility?

## Stations or no stations?

Since Princeton launched Zagster in 2016, the bikeshare landscape has gone through a seismic shift as private companies offering dockless bikes and scooters have entered the market. Dockless systems have clear advantages for users who can ride all the way to their destination. However, bikes and scooters parked haphazardly on walkways create obstacles for walkers and people using wheelchairs. This also gives the impression of areas being “littered” by bikes.

Stations, at least to some extent, provide some assurance that users will find a bike when they go looking. In practice, how often the operator rebalances bikes across stations during the day is the real determining factor behind whether users can find bikes (or free slots to park) at stations reliably. One advantage that free-floating systems is that they eliminate the problem of lack of docks at the end of the ride for users. However, free-floating systems still need to be rebalanced if demand for travel in an area is strongly directional by time of day, as is the case in Princeton.

## Managing misparked bikes and scooters

If the University chooses to adopt a free-floating system, proactive management and pointed design choices could limit the impacts of bikes or scooters parked in the right of way. Chief among these is a fee for misparked vehicles. Some systems require users to take a picture of where they parked their bike or scooter. This can be combined with “geo-fenced” areas where users are prohibited from ending their trip. Finally, and likely most effective, installing bike racks near entrances of highly used

locations can also greatly reduce nuisance parking.

## Bikes, scooters, or both?

Private dockless bikeshare systems are largely disappearing from US Cities being replaced by shared scooters.<sup>1</sup> Companies that provided free-floating bikes have either pulled out altogether or switched to scooters. These were private companies making business decisions. Princeton University can make its own choice of how to provide micromobility on its campus.

## Mechanical or electric?

According to a 2018 report by the National Association of City Transportation Officials,<sup>1</sup> e-bikes are the most used micromobility vehicles (as measured by rides/vehicle/day)—on average twice as frequently as standard bikes. This could be because electrical assistance, especially uphill, makes biking much less exhausting for people. E-bikes today can function without stations. The advantages of e-bikes are made up for by the increased cost of bikes, charging infrastructure, and operations. The operators collect bikes, charge them overnight, and place them back for use. Unlike the “juicer” programs where independent contractors are paid to charge scooters, e-bikes are, at least of this writing, generally rebalanced and charged by staff working for the operator.

## Business model

Originally bikeshare systems were city programs funded by a mix of user fees, advertising, and public subsidy. The private

micromobility companies, some of which have been acquired by the ridehailing companies Uber and Lyft, operate only with user fees and no subsidies, sometimes even paying cities or campuses for the right to operate there. Princeton University’s arrangement with Zagster is more like the former with users paying a small percentage of the operation’s cost, while the University subsidizes the rest.

The micromobility space is changing so quickly that it is hard to make any assertion about the range of business model choices available to the University even in the next few months. However, there are other ways to approach this decision—for example, how Princeton would like bikeshare users to interact with the system.

## Should users pay?

Today Zagster is free for the first two hours, making almost every trip free. A private system without University subsidy would not offer this. Lime bikes and scooters at Texas Tech University, for example, cost \$1 to unlock and \$0.15 for every minute of riding, while Pell Grant recipients and students receiving other government assistance get a 50% discount. TTU negotiated to receive a fee to allow Lime on campus and the university gets 20% of revenues. Would Princeton be able to negotiate a similar agreement? The state of play in the industry is unclear. Lime and Jump have, at the end of 2019, laid off hundreds of staff between them.

## How important is predictability?

Many cities around the country are learning that uncertainty is one of the prices to be paid for private micromobility. Take Seattle for instance. Over the course of a few years, Seattleites have

<sup>1</sup> “[Shared Micromobility in the U.S.: 2018](#)” by National Association of City Transportation Officials

seen a dizzying array of short-lived bikeshare options. First, a city-sponsored docked system stopped operating when the city cut funding—a loss that was easily recouped as five different private free-floating companies provided residents with, at their peak, over 20 times as many bikes as the city system had. But over the last two years, one by one these companies closed up shop. Today only Jump operates in the city.

If Princeton is willing to accept such uncertainty and it is willing to charge for use, it may be possible to reduce what it spends on micromobility. But the lack of control and unpredictability that come with such an arrangement may not be worth the cost savings.

## 3. Transit Network

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# Introduction to the Concepts

This chapter introduces three Concepts which illustrate differing ways that the TigerTransit network could be designed in the near future. All three Concepts use the same amount of transit service, measured by the number of hours of buses' and drivers' time on the road, available to passengers. All three Concepts would therefore use very similar amounts of funding for transit operations. The Concepts differ greatly in how that service would be allocated to different purposes and different places. As mentioned before, **these Concepts are not proposals, and none of them is "recommended"** to the rest of the Princeton community by the planning team. A recommendation will only be developed once the community has given input on these Concepts.

The three Concepts are:

1. A High-Frequency network with no transit on Elm Drive.
2. A High-Frequency network with frequent, two-way linear service on Elm Drive.
3. A High-Coverage network with frequent, one-way looping service on Elm Drive

## Design criteria and assumptions

The High-Coverage Transit Concept shows what it would be like if Princeton continued providing every campus building with at least some transit service. This Concept is very similar to the existing network. Dividing the transit budget into more routes means that

each route gets less service, which means that many routes come infrequently and for few hours of the day. This is why high coverage, with many routes to many places, trades-off against high frequencies and long hours of service. Within a fixed budget, the more routes we provide, the less frequency we can provide on each route.

To contrast this, the High Frequency Transit Concept shows what might happen if University decided to concentrate its service in the places where the most people travel. Concentrating on fewer routes would allow Princeton to offer more frequent service, with longer hours of operation. People near these routes would have more choices of when to travel. But the consequence of concentrating on fewer routes is that less transit service is available to spread out to cover every University building.

The network Concepts presented in this chapter show only the regular academic year TigerTransit daytime networks. The Concepts do not consider changes to night, weekend or school-break services. All three Concepts aim towards making the campus more conducive to walking and cycling, while asking this big-picture question about the most important goals of the TigerTransit network.

A simple way to measure the efficiency of a transit service is to average the number of people who board it over each hour that each bus and driver are out providing service. A "service hour" is a good approximation of each route's operating costs and negative impacts such as congestion or pollution. This boardings per hour measure is referred to as "productivity". Productivity affects the cost per rider and greenhouse gas emissions per rider, because the more riders are using the service, the more

	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/Stanzworth	3	\$43
	On-Demand Bus Service	3	\$47
O	100 Overlook/701 CC (new)	2	\$56
B	693/701 Carnegie Center (old)	2	\$56

**Productivity is inversely related to average operating costs per passenger. The productivities of the routes differ substantially. Some routes like L compare to urban bus routes, while routes like O and B have extremely low productivities.**

riders the costs or emissions are divided over.

The table above shows the productivity of each existing TigerTransit route. Some routes attract many more boardings per service hour than others. This variation is more affected by the development patterns and built environment, than by characteristics of the routes themselves: the density, walkability, linearity, and proximity of development all affect a service's boardings per hour.<sup>1</sup> Demographics also play a role, as do parking restrictions and costs. Universities, with their youthful populations and parking restrictions, tend to generate very high transit ridership wherever they have dense

<sup>1</sup> For a detailed discussion about the causes of transit ridership and cost, refer to page 30 of the Current State Report



and proximate developments served by linear transit.

The development patterns that affect TigerTransit ridership and costs cannot be changed in the near-term, but can be changed as Princeton continues to develop and adapt its properties. Whether TigerTransit achieves high ridership relative to costs will depend in large part on whether it serves University developments that are transit oriented (dense, walkable, proximate to one another and arranged in linear patterns) or not. It may also depend on how much Princeton encourages people making trips of 2 miles or less to walk, cycle or roll instead of taking transit.

Each Concept presented here has slightly less total service than the current system. This allows us to ask the question of how different goals of transit can be met with the same cost, while providing a very obvious contrast among the Concepts.

The three Concepts differ from each other primarily in two aspects:

- Whether they emphasize transit frequency or transit coverage.
- The purpose and design of Elm Drive.

Within the same budget, it is possible to provide a High-Frequency network with various levels of transit service on Elm Drive. That is why there can be High-Frequency alternatives with no transit on Elm Drive as well as two-way frequent transit. On the other hand, in a High-Coverage network, while some level of transit service on Elm Drive is necessary, it is not possible to dedicate too large a portion of resources in order to put buses on Elm Drive without also taking away service from other

routes. Doing so would not satisfy the high-coverage goals of such a network.

## Conflicting goals of transit

High frequencies and long spans of service through the day and the week make transit useful and usable for a larger number of people, and in that way tend to increase the number of people riding.

Higher frequencies make transit more useful for accessing scheduled events, like classes and meetings, by giving people more choices in when to travel. An infrequent transit line forces people to make their trip earlier than they would otherwise want to, and they end up waiting at their destination for their event to start. For short trips in particular, the amount of time someone spends waiting can be greater than their time actually riding, and long transit waits make the alternatives (walking, cycling or driving) more attractive. As a result, very high frequencies are critical to attracting high ridership on short transit lines and circulators.

For all these reasons, high frequency is often related to high ridership. Some of transit's outcomes are achieved by high ridership. For example, the environmental benefits of transit only arise from many people riding the bus rather than driving. The same is true of transit's power to reduce parking needs or congestion. Transit that attracts only low ridership does not reduce emissions or congestion.

Other transit outcomes are unrelated to ridership, and are achieved simply by getting service close to people in case they need it. A bus route through an area provides people in that area insurance against isolation, even if the route is infrequent, indirect or only runs

at certain times. People with severe needs for transportation live everywhere, and a route nearby helps them meet their needs. Coverage may also fulfill other obligations. For example, in Princeton's case, this could be to provide connections to every building owned by Princeton, especially when it is physically distant from the rest of campus. These outcomes arise from what we call "coverage goals" because they are achieved by covering areas with service, regardless of ridership.

Within a fixed budget, designing a transit network for both frequency and coverage is a zero-sum game. While an agency can provide a mix of frequent service and coverage service within the same budget, it cannot do both with the same dollar. The more it does of one, the less it can do of the other. For a more thorough explanation of transit's competing goals, refer to Page 27 of the Current State Report.

In the High-Frequency Concepts, TigerTransit's most productive routes are retained, with some changes to their service patterns and their hours of service. In the High-Coverage Concept, even the least productive routes, that move just a few people per service hour, are retained, because the purpose of the network is to cover all University buildings rather than to be maximally useful to large numbers of people.

## Walking vs waiting

An important aspect of the frequency-vs-coverage contrast is the tradeoff between waiting and walking. In a high-coverage network, routes are spread out and bus stops are generally located closer to where people are. Hence people do not have to spend much time in order to walk/bike to a stop. However, when at

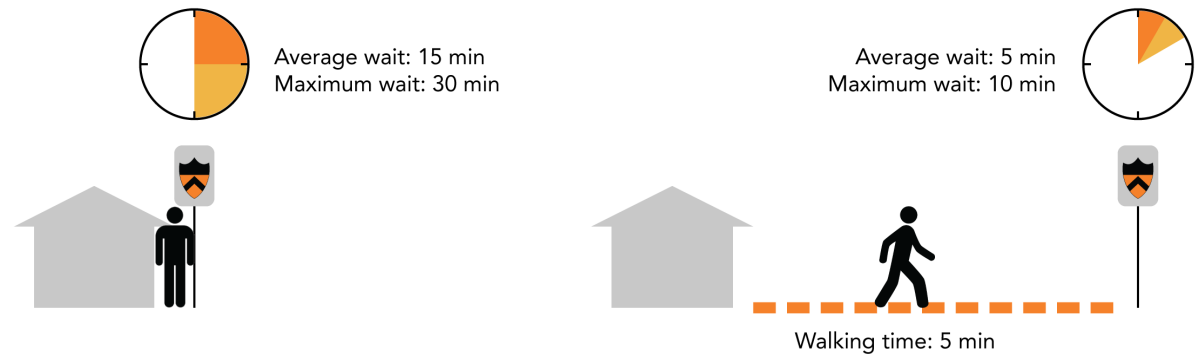
the stop, there is a longer wait between each bus on the route because of poorer frequency.

In a High-Frequency network, service is concentrated into fewer routes with more frequent service. This means that for some people, the bus stop may be farther away than it would be in a high-coverage network. This would require a longer walk to reach the stop. However, once at the stop, people would not need to wait as long since buses would turn up more frequently.

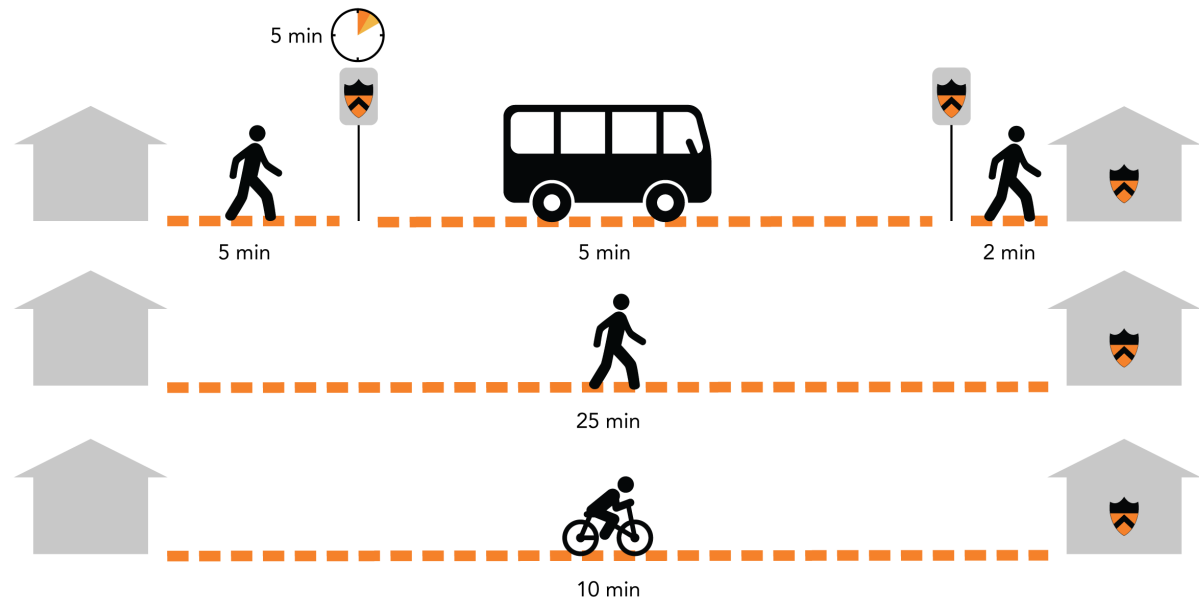
In a campus setting, the waiting-vs-walking tradeoff is further nuanced. Distances are smaller, and in many cases, the time it takes to get between places by bus (including the waiting time at the stop) is no shorter than the time it takes to walk or bike. Hence, in order to be productive over short distances, transit has to be very frequent and offer short waiting times at bus stops.

In Princeton University's case, this raises a really interesting question about the role of transit for trips of different distances:

- How short of a trip should transit routes be designed to serve? (The shorter the trip, the more frequent the transit must come to compete for ridership.)
- Are other modes as attractive as they should be for really short trips?
- Should Princeton encourage or even nudge people to not take transit for trips of 1-2 miles?
- How would the network be different if Princeton tried to lose transit ridership for very short trips?



Transit spread out over more routes can cover more areas and lead to bus stops being closer (left), but not all routes can be as frequent. Service that is concentrated into fewer routes where more people will use it (right) can be very frequent, but bus stops would be farther away.



In a small campus setting, distances are smaller, and in order to be productive over short distances (that is, to compete with walking and biking), transit has to be very frequent and minimize waiting at bus stops.

Accounting for weather in such policy decisions is never straightforward. People all over the world walk to and wait for transit in extreme weather. People also cycle in temperatures that we might consider far too hot or too cold. If paths and bikeways are snowy or icy, transit may be more attractive even if cycling is much faster. If sidewalks are icy, people may want transit routes to be more circuitous and indirect, so that their walks are shorter (even if it makes their total trip time longer). In this way, the maintenance priorities of Princeton can affect peoples' transportation choices. Severe cold and severe heat can both make people excited about the climate-controlled transit vehicle, regardless of travel time.

## Vision for Elm Drive

Connecting graduate housing, athletics facilities, NJ Transit and parking lots in the south to Nassau Street and the campus's historic core in the north, Elm Drive is a key corridor for Princeton University. Unlike Washington Road and Alexander Street, it is fully owned and controlled by Princeton. This gives a lot of flexibility in envisioning what Elm Drive would look like in the future. Because it is so central to iconic places, it has the potential to be a distinctive north-south axis of campus.

The design of the transit network affects and is informed by the choices for Elm Drive. The three Concepts offer differing levels of transit service on Elm Drive, though all three assume that only pedestrians, bicycles/scooters, and TigerTransit would use Elm Drive.

**One High-Frequency Concept would have no transit on Elm Drive.** This would free up all of the width of the street for use of pedestrians and bicyclists. Wider walking spaces would

enable people to walk more comfortably in groups, while the dedicated bike lanes would enable faster, safer, and more comfortable north-south travel for bikes and scooters and other rollers.

**The other High-Frequency Concept would have very frequent two-way transit on Elm Drive.** In this case, pedestrians would be restricted to the sidewalks, and the street would be shared by buses and bikes. This would provide a fast but less comfortable biking experience, but would enable frequent and direct bus service along the central spine of the historic campus.

**The High-Coverage Concept envisions one-way service on Elm Drive,** as the most frequent transit service possible in the historic campus would be a one-way loop (rather than a two-way line). This would free up the current southbound lane, which could be used in a variety of ways: on one extreme, it could be converted to a two-way bike lane, and on the other, combined with the sidewalk to form a shared pedestrian-bike promenade.

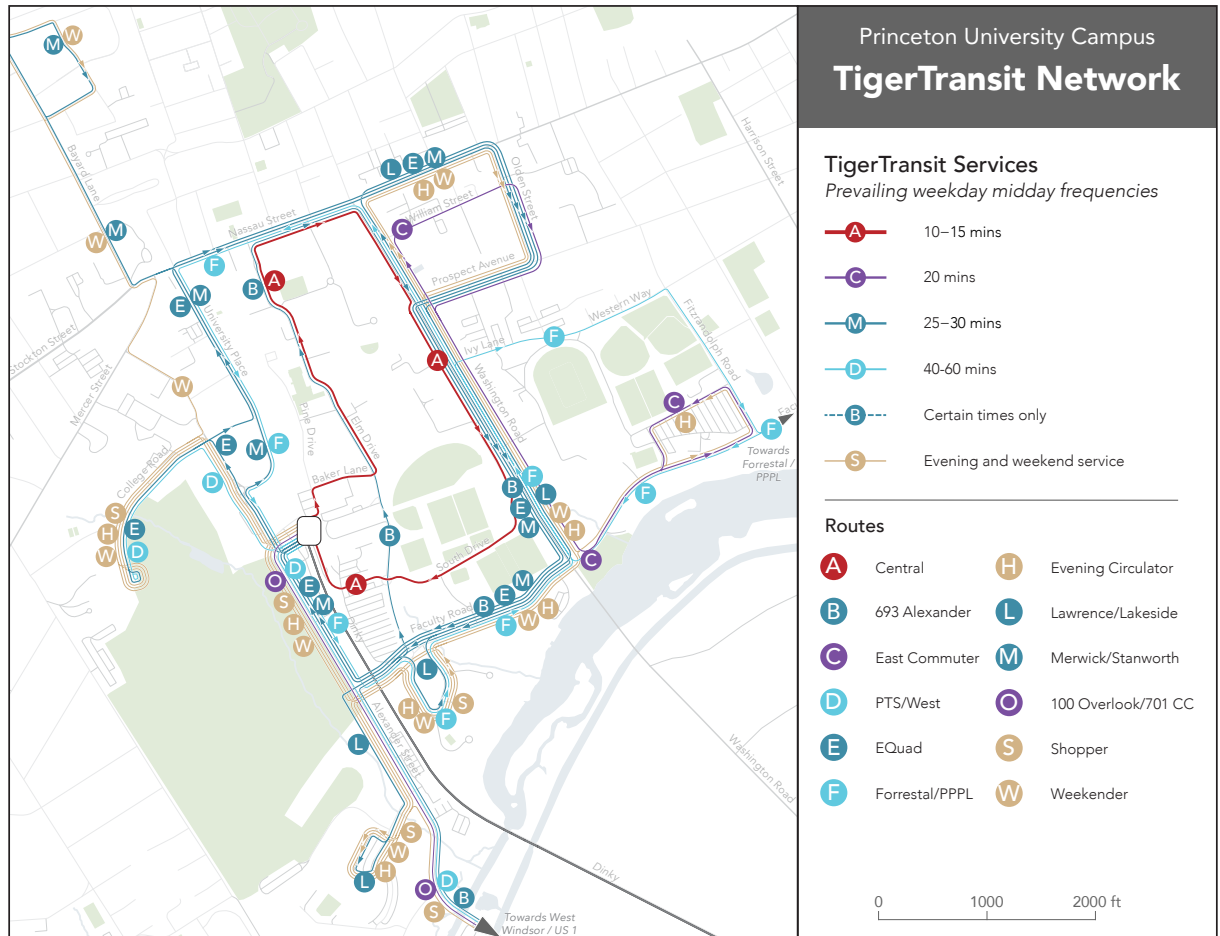
## Existing Network

A map of the TigerTransit network (as it operates when the Alexander Street bridge is not shut down) is shown on the right for reference. The weekday routes have been color-coded by their frequencies during the middle of the day. Some routes have a different frequency during morning and evening rush hours. A map covering a larger area that includes the Princeton Plasma Physics Laboratory and other off-campus buildings is on page 34.

TigerTransit is currently following an implicit policy that all University buildings will be served with at least minimal transit service. This includes serving buildings in and around Forrestal Campus, and ones along Alexander Road south of the lake. Because the transit budget is spread across so many routes, frequencies are high only on a few routes and only during rush-hours. Only the Central line (Route A) has a midday frequency higher than 15 minutes at midday. Routes B (693 Alexander), C (East Commuter), and O (Overlook/701 CC) come every 20 minutes in the midday. All other weekday routes come every 30 minutes or less frequently.

Route productivity data (refer to the table on the next page) from TigerTransit shows the wide range of performance of the routes in the system. There are various underlying factors for these differences in productivity, only one of which is frequency.

For example, Route A (Central), despite having the highest frequencies, is only the third most productive route. 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



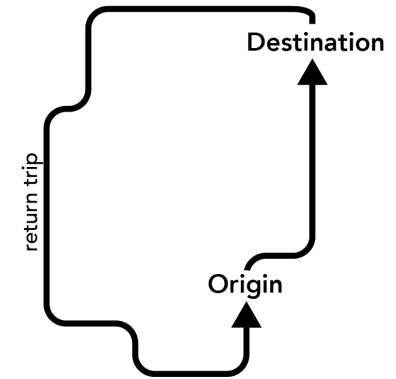
On this map, TigerTransit routes are color-coded by their midday frequency. Some routes offer a different frequency at rush hours. A larger version of this map is provided in the appendix on page 49. A larger map including off-campus routes is shown on page 34.

people end up riding around the whole loop (as shown in the drawing at right). It also runs through the most walkable part of campus, wherein a larger number of people might find walking more convenient. Route L (Lawrence/Lakeside) is much more productive than Route A as it offers direct, frequent, and fast service very close to large residences and academic areas. It also provides service at distances that would constitute very long walks.

Route O (Overlook/701 CC) shows the limited power of frequency to attract high ridership from car-oriented developments. The route is direct, offers fairly good frequency all day (20 minutes), and serves distances that are too far to be easy on foot or by bike. Yet it does not serve dense places (once the acres of parking lots between every building are accounted for), and it serves unwalkable places, and the population it could serve has few reasons to leave their cars at home (or forgo owning a car entirely). For all these reasons, it attracts very few passengers per service hour.<sup>1</sup>

	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/Stanzworth	3	\$43
	On-Demand Bus Service	3	\$47
O	100 Overlook/701 CC (new)	2	\$56
B	693/701 Carnegie Center (old)	2	\$56

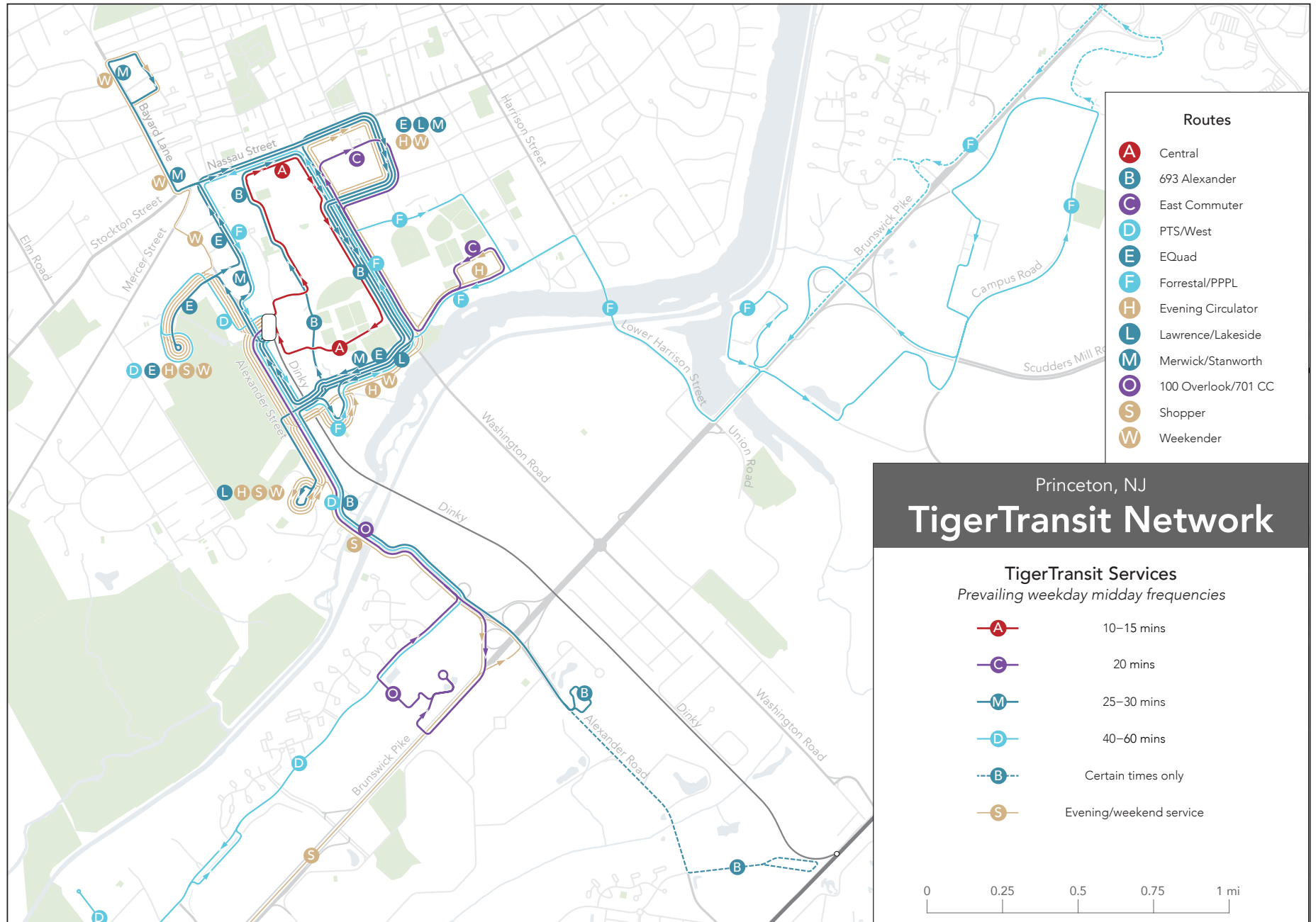
Routes with higher productivity have lower average operating cost per passenger. The productivities of the routes differ substantially. Some routes like L compare to urban bus routes, while routes like O and B have extremely low productivities.



With one-way loops, some trips are very short and direct going one way, but the return trip can be very long and indirect.

<sup>1</sup> A simple back-of-the-envelope calculation can help understand why the productivity on 693 Alexander and 701 CC routes is so low. Assume there are 500 workers in 701 CC, out of which 10% or 50 have a meeting in Central Campus on any given day (this is likely a very conservative estimate). Spread over 10 hours of service, this translates to an upper limit estimate of up to 5 boardings per hour per direction, or less than 2 people on the bus on average.





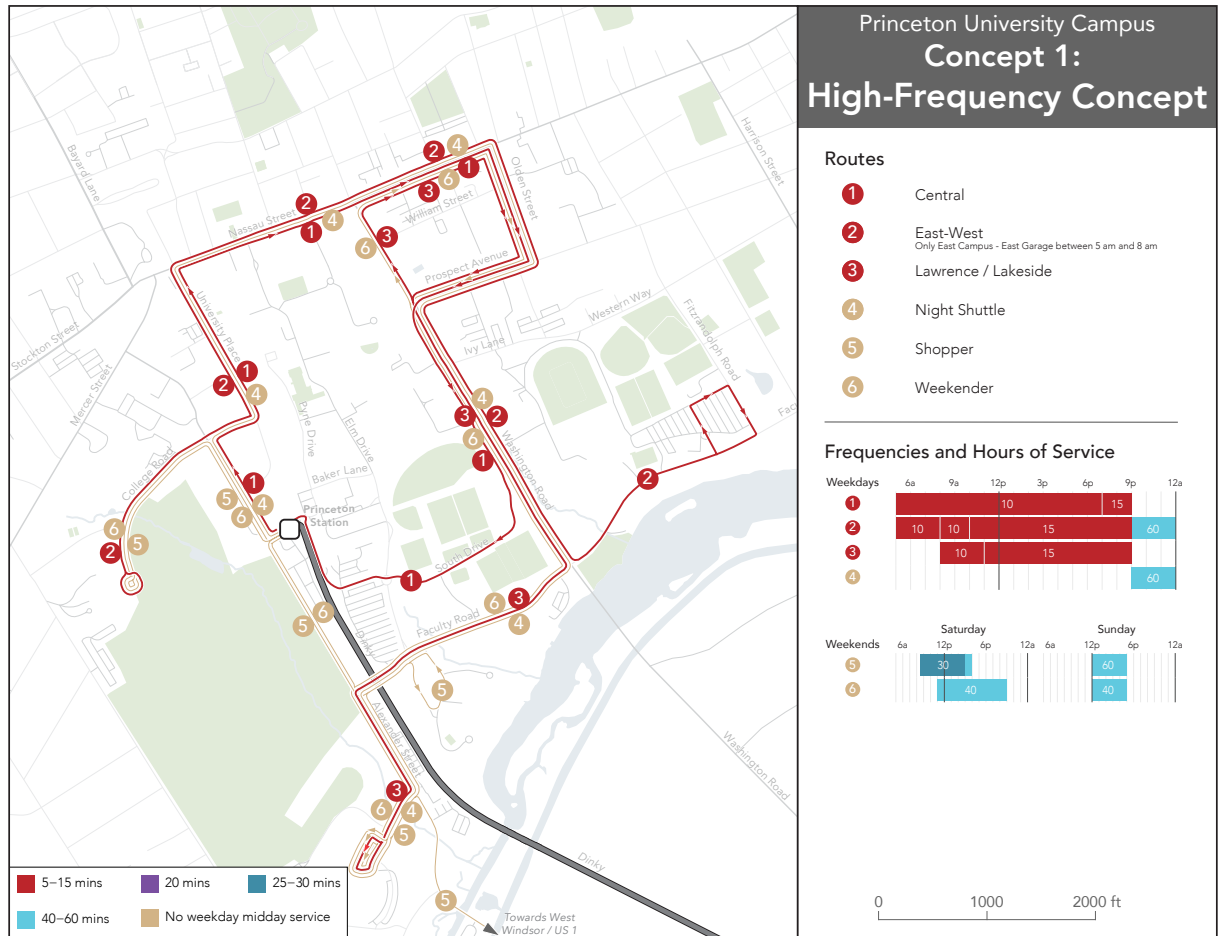
# 1. High-Frequency Concept (No Transit on Elm Drive)

The two High-Frequency Concepts are very different from the existing TigerTransit network. Service is concentrated into fewer routes closer to the heart of campus, where a large portion of the Princeton community lives, studies, and works. These fewer routes can be more frequent so that a bus is more likely to be coming when someone needs it. This also results in a simpler, easier-to-understand network.

Concentrating service into fewer routes means less is available to spread widely. Buildings in outlying areas, like southern Alexander Street and Forrestal Campus, would not be served by TigerTransit at all. They could be accessed by encouraging biking, reimbursed Uber/Lyft rides, parking policy changes, or providing shared cars at those buildings.

In some other cases, a place that is served directly by low-frequency routes today would be accessible by a walk from a route with better frequency or longer hours of service in this Concept. For example, Lakeside Apartments residents would have to walk 3–5 minutes to catch TigerTransit on Faculty Road on weekdays since buses would not pull into the Lakeside Road loop.

In both High Frequency Concepts, routes also run later into the evenings and with higher evening frequencies than in the existing network or in the High-Coverage Concept. This makes it more likely that anyone will find transit useful for the times they need to travel beyond what are considered regular 8-to-5 schedules.



In Concept 1, there are only three campus routes, each of which offer 10–15 minute frequencies till 9 pm on weekdays (and are hence colored red). There is no TigerTransit service along Elm Drive. A larger version of this map is provided in the appendix on page 51.

Concept 1 is shown in the map above with routes color-coded by weekday midday frequencies. This Concept envisions Elm Drive as the campus's signature north-south walking and biking promenade. For an unimpeded pedestrian and biking experience, no TigerTransit buses would run along Elm Drive. This would complement future policies restricting private vehicles, utility vehicles, and golf carts in this

part of campus. The freed-up street space would leave enough room to provide a wide walking area, as well as two-way bike lanes. This would make biking north-south along Elm Drive very fast and comfortable.

Route 1 in this Concept would make a one-way loop around the perimeter of the historic campus via University Place on the west and

Washington Road on the east, instead of running up and down Elm Drive, as it does in the other High-Frequency Concept. This is necessary to keep Elm Drive free of vehicles. Not having to interact with pedestrians and cyclists on narrow streets would make this route slightly faster.

Despite being the Concept with the highest frequencies, this Concept would probably not have the highest ridership because of Route 1's one-way loop pattern. One-way loops require enough out-of-direction travel that they struggle to compete with walking or cycling unless they are extremely frequent and fast. There is also a high degree of duplication among Route 1, Route 2 and Route 3 on University Place and Washington Road. This might make each of the three routes less productive despite being very frequent, because along some of their lengths they would be inadvertently competing with one another for riders.

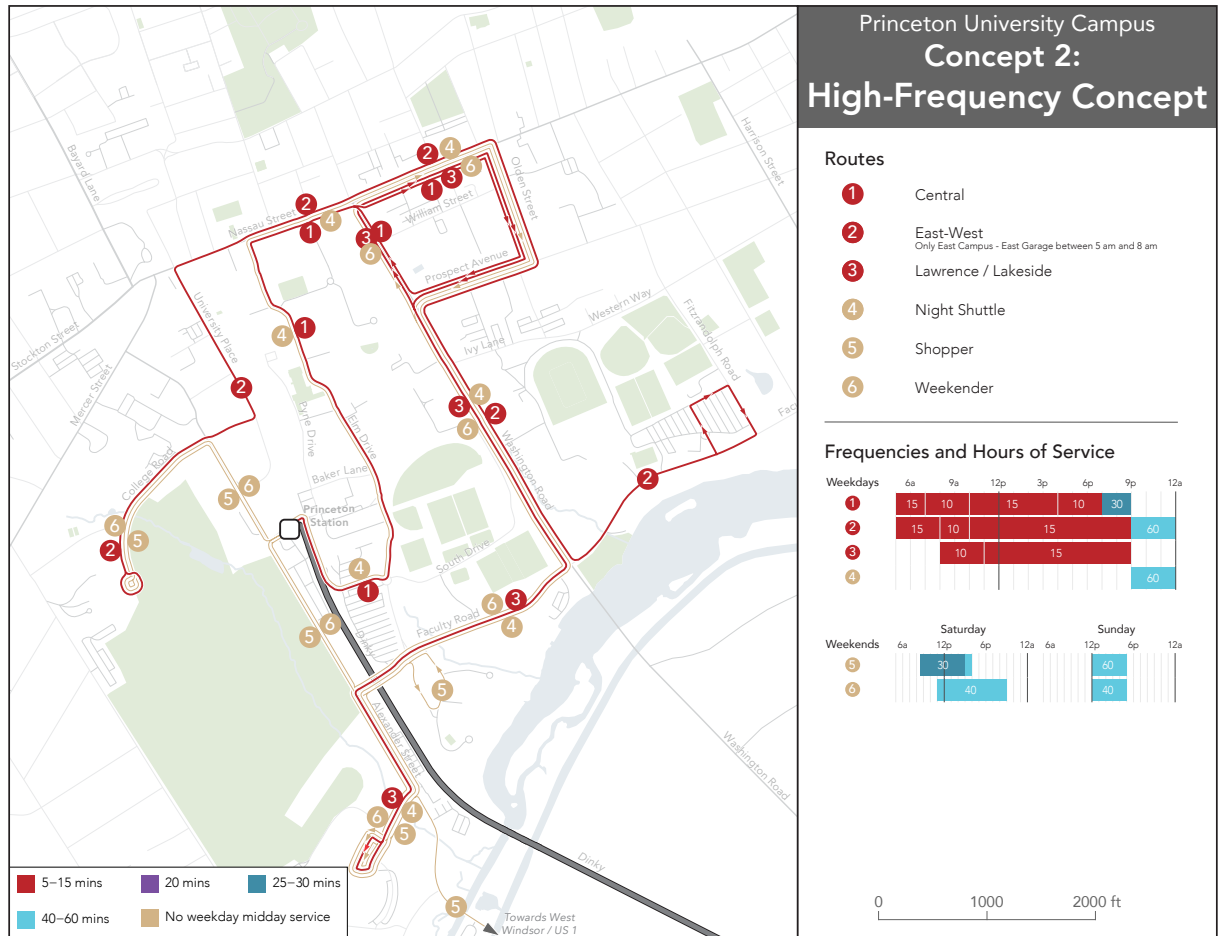


## 2. High-Frequency Concept (Two-way Transit on Elm Drive)

This Concept is similar to Concept 1 in that it provides a simple high-frequency network which runs longer during the weekdays than the existing network. The major difference between this and the previous Concept is that this Concept would run two-way frequent transit service on Elm Drive (as shown in the map on the right).

Route 1 in this Concept runs up and down Elm Drive instead of looping around campus. This two-way line is actually slightly more costly to operate than the one-way loop, partly because it is longer and partly because it would be a bit slower (due to pedestrians and bikes and physical constraints on Elm Drive). Hence, two-way routing on Elm Drive would require more operating dollars, and the cost of the two Concepts is kept equal by reducing the frequency of Route 1 slightly in this Concept.

This Concept imagines Elm Drive as the “transit spine” of Central Campus. Frequent and direct two-way transit service that connects Princeton station and parking lots in the south to academic and administrative areas in the north would be very useful to many people. This Concept also avoids large one-way loops and duplication of other routes found in Concept 1. Hence, despite having slightly lower frequencies than Concept 1, this Concept would probably attract the highest ridership of all three. However, some of the likely riders in this Concept would, in Concept 1, be walking or cycling within the Central Campus instead of riding transit, which may not be a bad outcome.



Concept 2 offer slightly lower frequencies than Concept 1. However, because route Route 1 can run directly and frequently along Elm Drive, it does not compete with Routes 2 and 3. Hence this Concept will have the most useful and productive network. A larger version of this map is provided in the appendix on page 52.

Other than superficial physical changes and the absence of private and utility vehicles and golf carts, Elm Drive would not be very different from today in this Concept. Both lanes would be needed for TigerTransit buses. Pedestrians would be restricted to sidewalks, and cyclists would need to share the street with buses.

### 3. High-Coverage Concept (One-way Transit on Elm Drive)

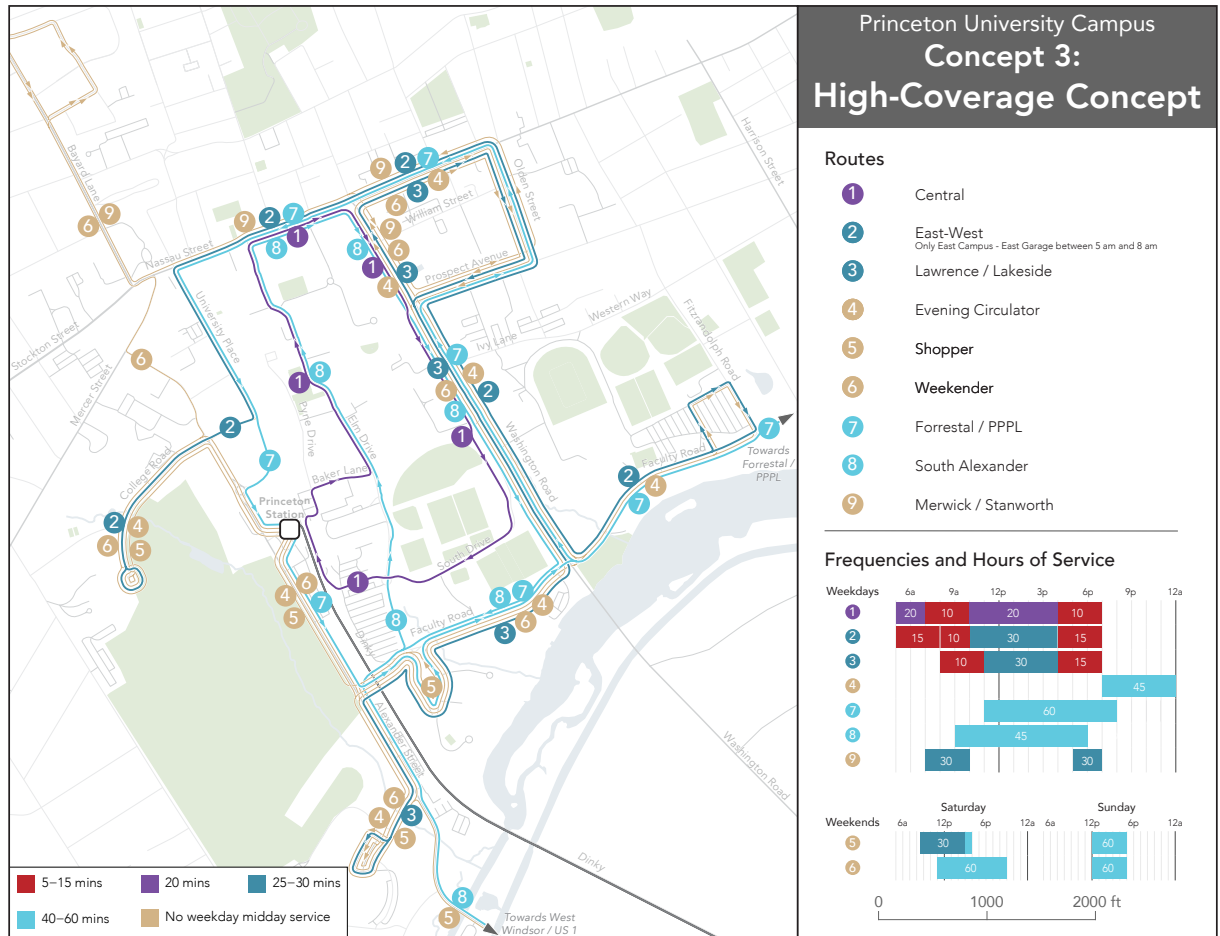
The High-Coverage Concept is similar to the existing network in that Princeton University buildings served by TigerTransit currently would also have service in this Concept. Because limited service has to be spread out to cover all campus buildings, it is not possible to provide as high frequencies during midday.

Note that all three Concepts involve a small reduction in the transit service (total number of hours buses run on all the routes) compared to today. This would imply a reduction in TigerTransit's total emissions, and increased allocation of transportation resources towards improving walking and cycling.

The coverage Concept is very similar to the current network, and thus a small reduction in service is achieved by reducing the lowest-productivity sections and hours of the network while still providing coverage. This reflects its purpose, which is to provide at least minimal service to all residential, academic, and administrative buildings during standard work hours.

In the high-coverage alternative, TigerTransit buses would go only one way, northbound on Elm Drive (similar to how TigerTransit currently serves the historic campus). Since there would be no other motorized vehicles allowed on Elm Drive in this alternative, the southbound lane would be for pedestrians and bicycles to use.

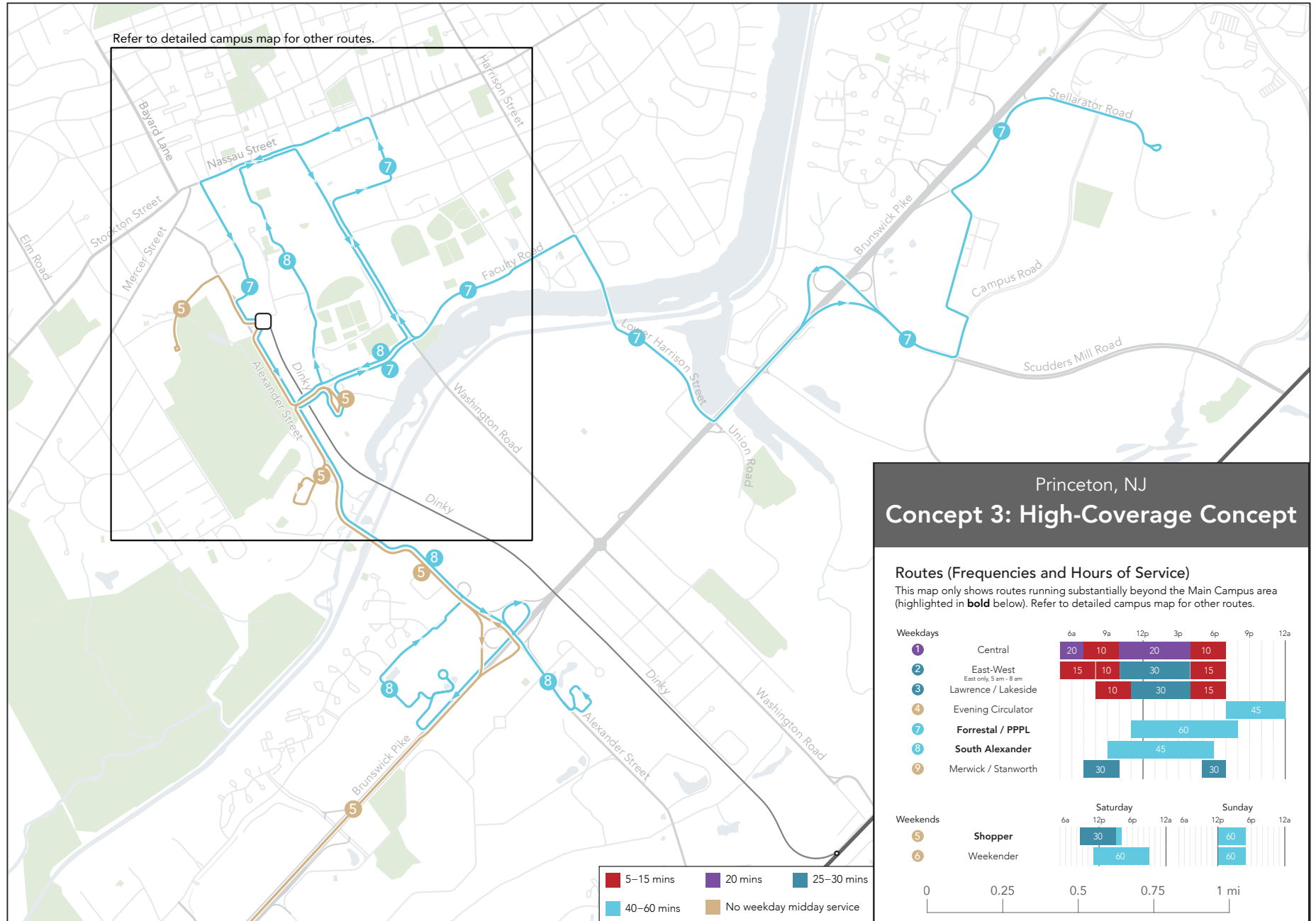
This can accommodate various treatments for pedestrians and bikes. On one hand, the southbound lane could be converted to a



**Concept 3 is geared fully towards coverage. All University buildings have some level of transit service. However, no route gets 15-minutes-or-better frequencies during midday (hence no routes are colored red). There is frequent service in the Central Campus during morning and evening peak periods. A larger version of this map is provided in the appendix on page 53. A larger map which shows the off-campus routings of Routes 5, 7, and 8 is on the next page.**

two-way bike lane. This would make biking much more convenient, but pedestrians would then be restricted to sidewalks. On the other hand, it is also possible to merge the sidewalk and the lane into a shared walking-biking promenade. An "intermediate" option could

involve expanding the sidewalk to cover part of the lane and turning the remaining part into a southbound bike lane, with cyclists sharing the northbound lane with buses. Concept 3 would not allow as much space for walking and cycling on Elm Drive as is possible in Concept 1.



## Comparison of Concepts

The features of the networks in terms of routes, hours, and frequencies are described in detail in the section above. This section summarizes the differences in these **features** (in the table on the right) and also compares some potential **outcomes** of the networks (in the table on the next page). The outcomes are meant to provide a general sense of the likely results of a redesigned network and are not forecasts.

Feature	Why is it important in a transit network?	Concept 1: High-Frequency (No Transit on Elm Drive)	Concept 2: High-Frequency (Two-way Transit on Elm Drive)	Concept 3: High-Coverage (One-way Transit on Elm Drive)
Simplicity	<i>More routes offer greater possibilities of coverage as they can go to different places. Fewer routes make for a less complicated system which is easier to understand.</i>	All Concepts maintain Weekend Shopper and Circulator routes as well as late night on-demand service.		
		3 weekday daytime routes 2 weekday night-time routes	3 weekday daytime routes 2 weekday night-time routes	6 weekday daytime routes 1 weekday night-time route
Hours of Service	<i>Longer hours of service make transit useful to more people during the hours they find useful.</i>	Frequent service in Central Campus and to graduate residences <b>till 9 pm.</b>	Frequent service in Central Campus <b>till 7 pm, and till 9 pm</b> to graduate residences.	Regular daytime service only till <b>7 pm.</b>
Frequency	<i>More frequency on routes makes transit more useful to people, is related to higher productivity.</i>	10–15 minute frequencies from start to end of service on all 3 weekday routes.	10–15 minute frequencies from start of service to 7 pm in Central Campus and to end of service on graduate residence routes.	10–15 minute frequencies only during morning and evening peak periods on Central Campus and graduate residence routes.
Elm Drive	<i>Elm Drive has the potential to serve as the campus's signature north-south connector. The choices for TigerTransit network inform and are affected by the choices for Elm Drive.</i>	<b>No transit</b> on Elm Drive. It can be converted to a north-south pedestrian and bike promenade.	Frequent <b>two-way transit</b> during most of the day. Walking and biking experience would not be very different from today.	Transit would go northbound on <b>one lane</b> as it does today. That would free the southbound lane for pedestrians or bikes.

Outcome	How does network design impact this outcome?	Concept 1: High-Frequency (No Transit on Elm Drive)	Concept 2: High-Frequency (Two-way Transit on Elm Drive)	Concept 3: High-Coverage (One-way Transit on Elm Drive)
Coverage	<i>Some level of transit service, even if infrequent or indirect, can help people feel less isolated and help achieve other coverage goals. High frequency and ridership are not transit's only goals.</i>	<b>No service</b> to outlying Princeton buildings in Forrestal Campus, PPPL, the southern portion Alexander Street near US 1, and Merwick/Stanzworth Residences.	<b>No service</b> to outlying Princeton buildings in Forrestal Campus, PPPL, the southern portion Alexander Street near US 1, and Merwick/Stanzworth Residences.	<b>Some service</b> to outlying Princeton buildings in Forrestal Campus, PPPL, the southern portion Alexander Street near US 1, and Merwick/Stanzworth Residences.
Waiting	<i>Waiting is inversely related to frequency and adds to the total travel time. In a campus setting with classes, meetings, and sports events scheduled at specific times, "waiting" can also happen at the end of trips if low frequency makes someone arrive at their destination too early.</i>	<b>Least</b> amount of waiting. Some trips can be served by more than one routes and they will have even less waiting at bus stops.	<b>Low</b> waits at bus stops. Slightly lower frequencies and duplicity of routes compared to Concept 1.	<b>Highest</b> amount of waiting, especially at outlying areas served by low-frequency routes.
Walking	<i>Fewer and more direct routes mean that people have to walk more to reach those routes, but reduced waiting time may still make the overall trip faster.</i>	Some Princeton buildings are <b>out of walking and cycling ranges</b> .		<b>Least</b> amount of walking to bus stops since all campus buildings would have bus stops nearby.
		<b>Highest</b> degree of walking since the routes only run on the peripheral streets of campus.	<b>Slightly less</b> walking required than Concept 1 since center of campus will have service.	
Utilization of Buses	<i>Frequent and direct routes tend to attract higher ridership for the same total number of hours buses run. The cost to operate the network per rider is hence lower for high ridership (and generally, high frequency) networks.</i>	<b>Medium</b> ridership potential and productivity despite highest frequencies. Some routes are indirect and overlap with other routes.	<b>Highest</b> ridership potential and productivity because of direct, frequent, and non-overlapping routes.	<b>Least</b> ridership potential and productivity. Routes are geared towards coverage and hence are not frequent, indirect, and overlapping.
GHG Emissions	<i>Total emissions are related to how long and how far all the bus routes run over the day. Emissions per rider are inversely related to productivities of the routes.</i>	The total number of hours that all buses operate is the same across Concepts. This means that the <b>total amount of CO<sub>2</sub></b> emitted per weekday in all three networks would be <b>similar</b> in magnitude.		
		<b>Moderate</b> CO <sub>2</sub> emissions per rider.	<b>Lowest</b> CO <sub>2</sub> emissions per rider due to highest ridership potential.	<b>Highest</b> CO <sub>2</sub> emissions per rider due to lowest ridership potential.



## User Information

TigerTransit currently has a very complex network. The number and complexity of routes has grown over time as demands from different parts of campus have arisen.

Similarly, as technology has developed over time, new ways of conveying information about this network have developed. Some of these have been implemented by TigerTransit, e.g. the real-time bus location application called TransLoc. However, many methods and materials developed just recently have already become obsolete, and some old-fashioned but timeless materials (like a system map or bus stop information panels) need updating. While staff has been able to keep pace with online materials as service changes, it has not had the capacity to develop new materials following the latest best practices in transit information and design.

Thinking of improvements in the flow of information for TigerTransit, there are three key areas which present choices:

1. Network design
2. Information at bus stops
3. Mobile information

## Network design

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

higher-frequency network also relies less on real-time information about arrivals if people can easily remember that particular routes come frequently and reliably. The choices about network design are explored in detail in the preceding sections of this chapter.

## Information at bus stops

Currently, the information about service at bus stops consists mainly of a map and schedule, both of which are extremely difficult to interpret. This leaves a lot of room for improvement in user information at stops. As part of this project, Transportation and Parking Services (TPS) will be updating all of the materials that can make the transit system clear and legible: a transit network map, new route names, and useful reference information to post at bus stops.

Many transit systems around the world have real-time bus arrival information on electronic displays at bus stops. This has many benefits. If people at bus stops can see that a bus is too far away, they can better make the choice of whether to stay and wait or choose another mode, and hence complete their trip faster. More importantly, real-time arrival displays reduce “waiting anxiety”, as they act as assurances that a bus is indeed arriving. This makes for a positive rider experience overall.

Often real-time displays at bus stops are in the form of LED displays. There might be a concern that these are too intrusive or incompatible with the aesthetics of the campus landscape and architecture. This can be addressed by providing smaller displays. Some agencies have started installing very small and discreet real time displays, that fit on top of a bus stop pole, and are solar-powered. However,



Currently, information about TigerTransit routes and schedules can be hard to understand, especially for new and occasional users.



Many transit agencies have electronic real-time information displays at bus stops along with useful information like maps of the neighborhood and nearby landmarks. (Photo by NACTO / CC BY-NC 2.0)



a major advantage to larger LED displays is that they are visible and readable from much further away. There are also alternatives to LED displays. LCD and E-paper displays can have much higher resolution and hence can provide the same or higher amount of information on smaller displays while being less intrusive and less contrasting with a historical aesthetic.

## Mobile information

The profusion of smartphones and widespread access to the internet means that many people can access information from their phones and other mobile devices. Currently, TPS publishes PDF maps and schedules online, and real-time bus location and arrival information is available on the TransLoc app (maintained by a contractor), the general Princeton Mobile app, as well as an associated website.

Going forward, the choice of how TigerTransit schedule and real-time information is distributed to mobile device users would lie on two ends of a spectrum. On one end, all of the information could be distributed through a custom application built and maintained by Princeton. On the other end, Princeton could distribute schedules and real-time information as GTFS (General Transit Feed Specification) feeds. For those who need to access printable schedules, they can be easily provided online and at bus stops.

Custom applications offer a large degree of freedom in terms of information provision. The variety of information, its branding, the target audience, and how quickly information is sent out can all be controlled. This is what happens currently with Princeton Mobile, where Princeton adds its real-time information along with other information like events and alerts.

This, however, means that applications have to be maintained continuously and laboriously, which requires a major commitment. From a user's perspective, custom applications add to an already large number of applications on their phones, which is discouraging for some people. This affects the utility of the application, even if it is very well-designed and maintained. This is especially true for irregular users, who could hesitate to download an app if they think they aren't going to use it regularly.

Princeton can, on the other hand, choose not to develop a separate application for information about TigerTransit. Many transit agencies make their schedules and real-time vehicle locations publicly available through GTFS feeds. GTFS is a very common format for transit schedule and location information. These feeds are open-source, and many existing applications utilize them. For example, when planning a trip in Google Maps, the transit suggestions are based on agencies' GTFS feeds. Usability is the major advantage of this Concept. Users can plan trips using TigerTransit and other modes all in one place (their preferred wayfinding application), which makes this information very conveniently accessible. Princeton also wouldn't need to spend resources on maintaining an application.

## TigerTransit in the Future

The plans for TigerTransit discussed above are based in the near future, with the existing buildings, facilities, and development patterns in and around campus mostly constant. This will change in the future. Significant development is planned in the eastern part of campus (this includes academic areas in the north and athletics, parking, and recreational areas towards the lake). Across Lake Carnegie, a completely new campus is being planned.

These plans 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 which would also be free from motorized vehicles.

The walking experience between Lake and Central Campuses, however, would be different. The distance between these two areas means that some walks could need half an hour or longer. This can be a pleasant experience when done at leisure, but may not be appealing if required multiple times during the day and during inclement weather.

The distances involved would be optimal for biking between the campuses. However, the new pedestrian and bike bridge may not always provide the fastest and most direct path between places in Lake Campus and Central Campus. This is also true for pedestrians. These cyclists and pedestrians could want to use Washington Road to cross the lake, finding the new bridge too out-of-the-way.

Transit would play an important role in connecting Lake Campus to Central Campus. Any linear, two-way transit route connecting Central Campus (and East Campus) to Lake Campus would have to use Washington Road in order to cross the lake since the adjacent pedestrian-bike bridge would not accommodate motor vehicles.

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.

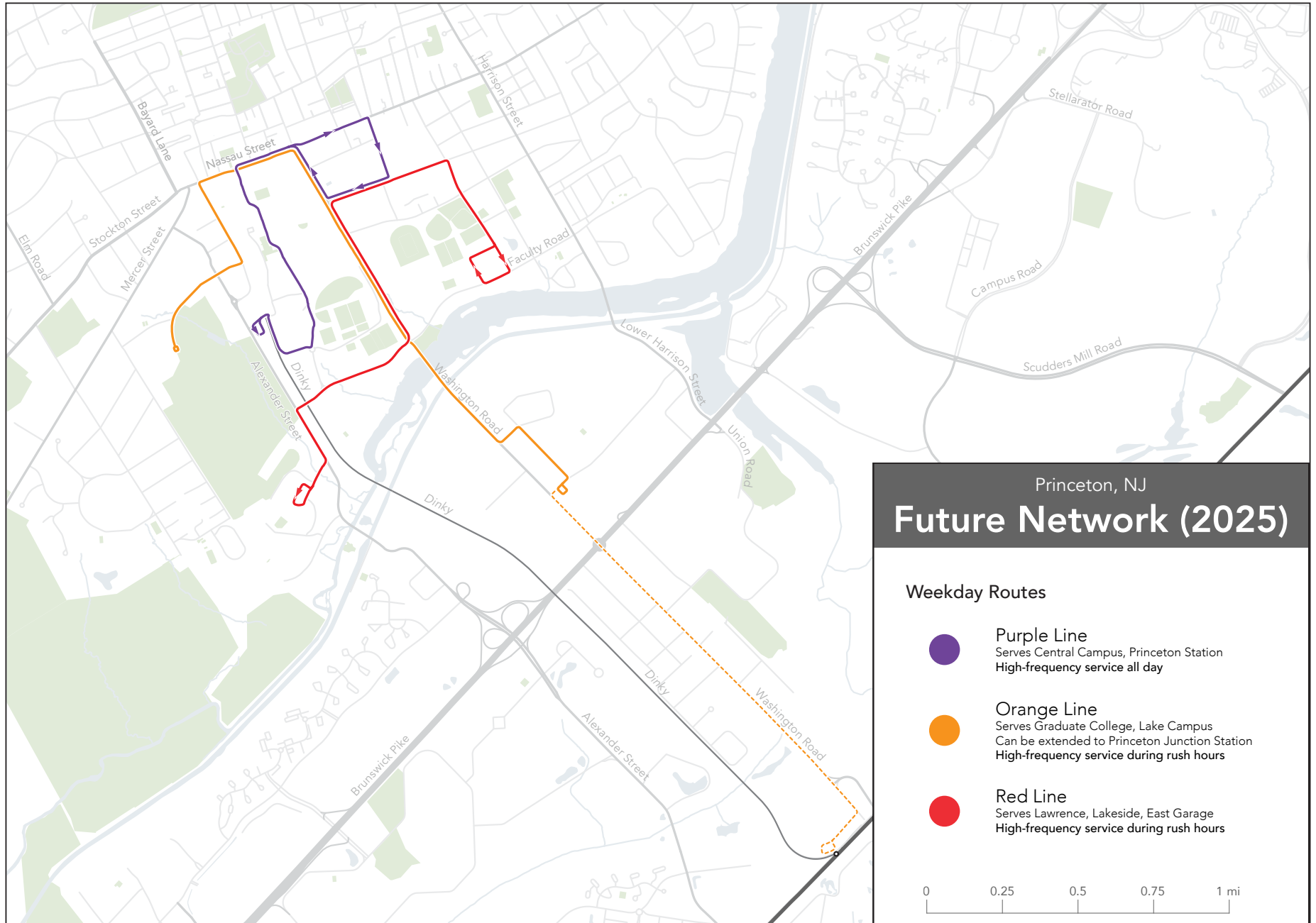
In the longer term, further development is planned outwards, along both sides of a new street. This street is planned to be constructed near and parallel to Washington Road and would be able to accommodate buses. TigerTransit buses would be thus able to turn from Washington Road on to this nearby street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

Because Princeton is planning more development further south in the more distant future, it is crucial that any transit service to the first Lake Campus buildings be designed with those future longer trips in mind. If near-term routes involve deviations up to the doorways of near-term buildings, then when in the future people want direct service that goes beyond those buildings, they will be frustrated at having to ride through those loops and extra stops. In addition, more loops and deviations

add operating cost, and thereby reduce the frequencies or hours of service that TigerTransit can offer within any given budget. These are reasons to resist the temptation to draw transit routes for the near-term that circulate down every Lake Campus road and get up to every building's door. Those patterns will not be tolerable once the Lake Campus develops further to the south.

A map of a potential Concept for TigerTransit in the future is shown on the next page.

**Remember that this is a Concept and not a proposal.** The main features of this network are similar to the high-frequency network with transit on Elm Drive discussed above. It has a Central Campus route (Purple Line), and a route which would connect Lawrence and Lakeside residences as well as the new garage in East Campus to the academic buildings around and north of Prospect Avenue (Red Line). Most importantly, there is a route connecting Lake Campus to Central Campus through Washington Road and Nassau Street, which also connects Graduate College to East Campus (Orange Line). As mentioned before, the proximity of planned Lake Campus development to Washington Road means that transit can be relatively direct in that area. Staying on and close to Washington Road also presents an opportunity to extend this route to Princeton Junction Station if needed.



## 4. Next Steps

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## Timeline

During the month of February 2020, the project team will engage the campus community through a survey, an open house, and many presentations. These will give students, staff, faculty and other community members a chance to share their preferences on the core choices we have identified in this report.

The consultant team will slice and dice this input and publish the third volume of the Mobility Framework: the Decisions Report. This document will color the choices we outlined here with the insights gathered from the community. It will also include discussion about bus fleet choices, after additional vehicle load data has been collected.

Princeton University decision-makers will then have the month of April to make decisions about mobility on the campus. These will be choices about the kind of transit network the campus will have, what kind of buses it will use and who will own them—the vendor or the campus. Campus leaders will also have to choose whether and how to expand bike share on campus and the best way forward to improve communication to users about the mobility options they have.

Once leadership has spoken, the Core Design Group will meet again and, with the help of the consultant team, will assemble the Draft Mobility Plan which the campus can review and make comments. Finally, in mid-June 2020 we will publish the Princeton Mobility Plan. The plan will guide the campus in the implementation of the 2021 Princeton Mobility Refresh and lay the groundwork for longer-term mobility improvements.

### 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 <sup>1</sup>	Hard launch of new TigerTransit routes and vehicles

## Get Involved!

If you're interested enough to read this far, we'd love to have you more involved in this project!

More information about this project is available at the project website:

[www.princetoncampusmobility.org](http://www.princetoncampusmobility.org)

There you can:

- Explore the current state of campus mobility in Princeton and read the Current State Report
- Provide your inputs about choices for campus mobility via an online survey
- Meet the project team at a public event—places and times are listed on the project website

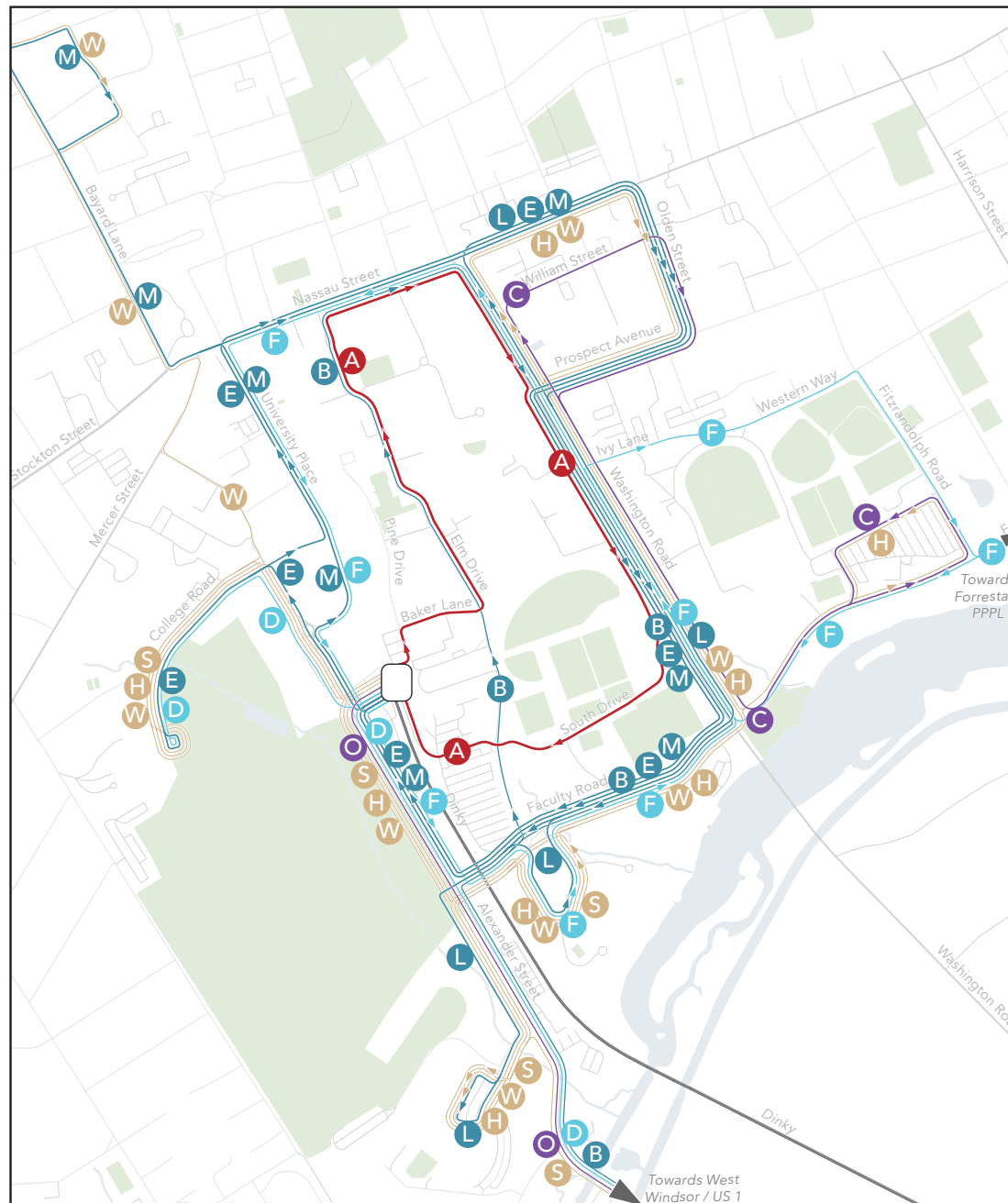
- Request a presentation at a meeting or public event
- Contact the project Working Group and the consulting team

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

# Appendix

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## 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

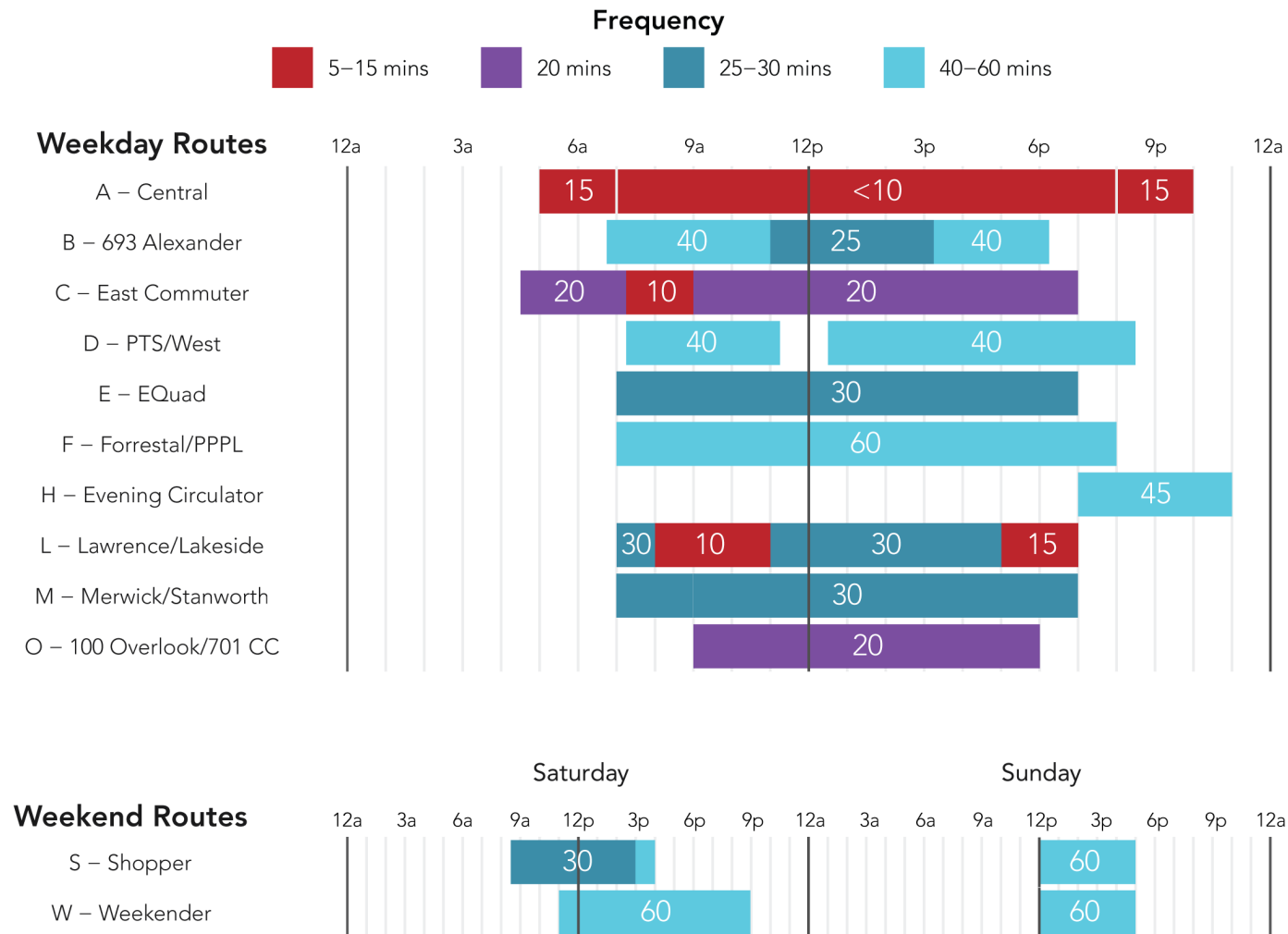
### Routes

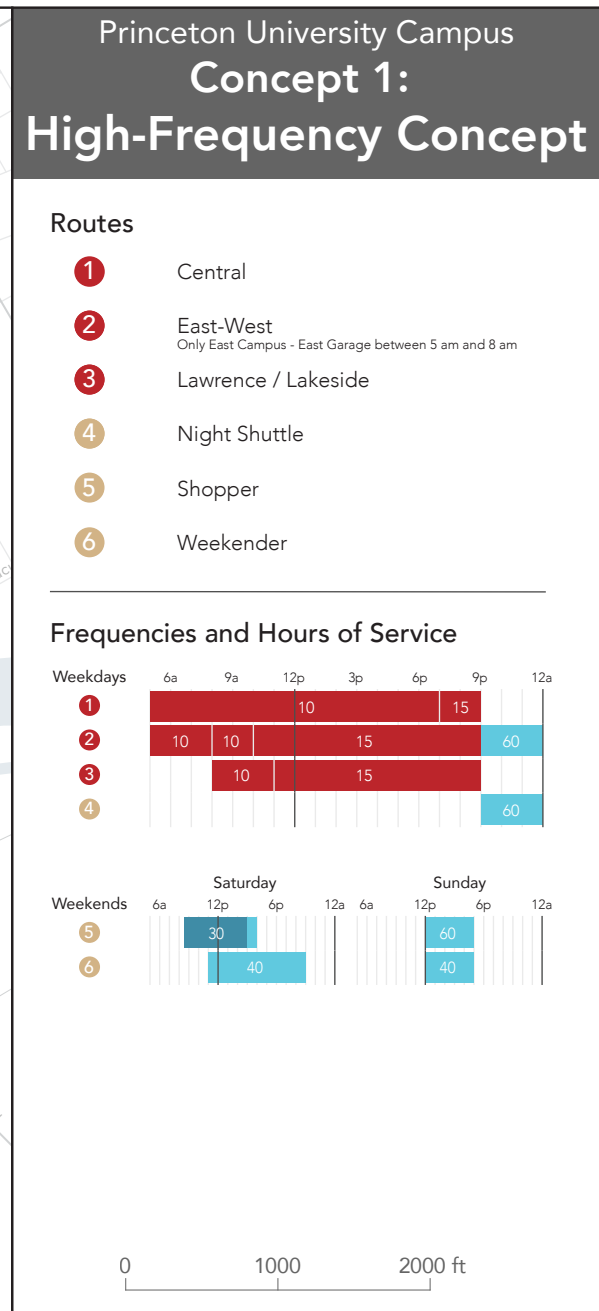
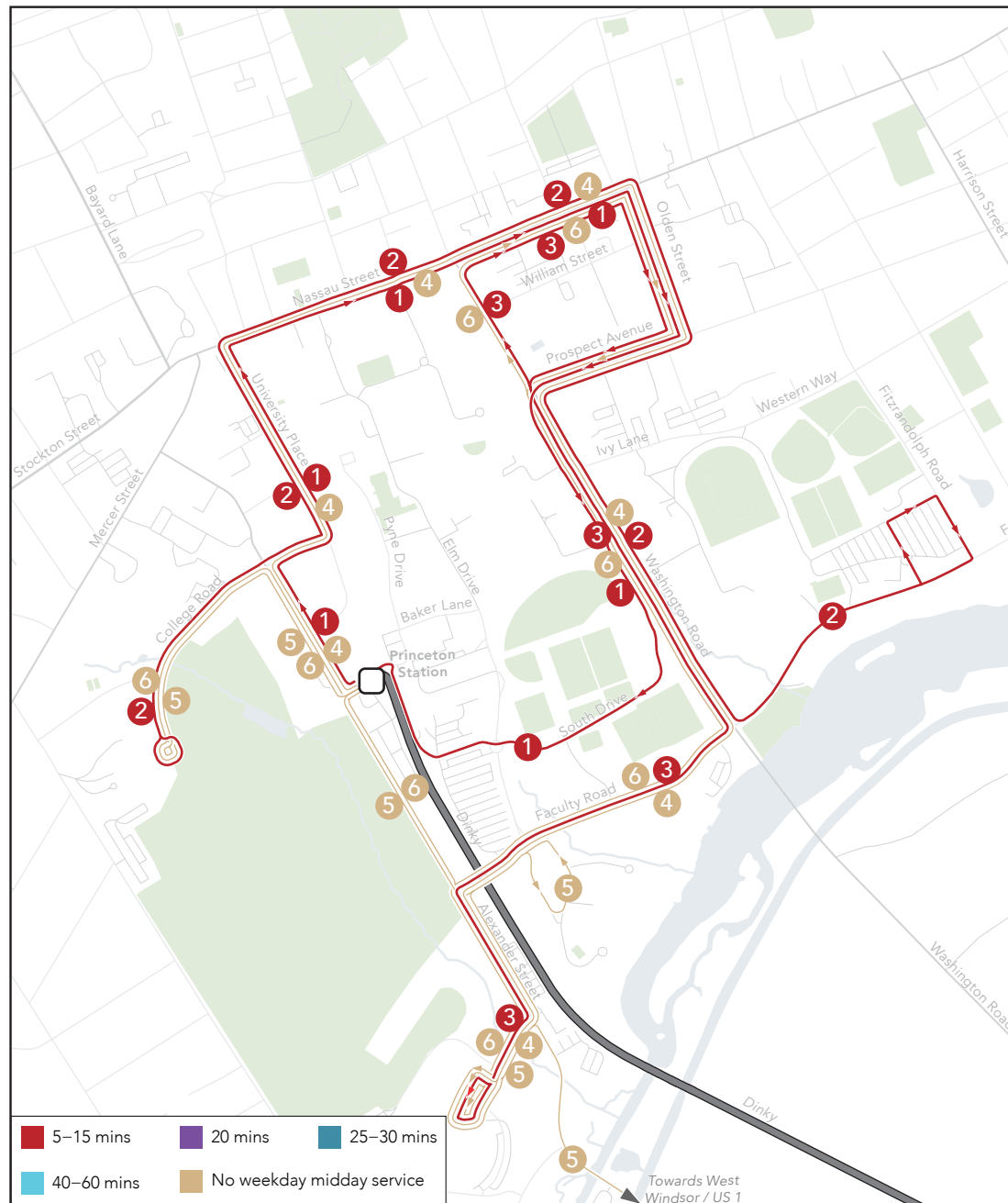
- |   |   |
|---|---|
| <span style="color: red;">A</span> Central              | <span style="color: orange;">H</span> Evening Circulator  |
| <span style="color: blue;">B</span> 693 Alexander       | <span style="color: blue;">L</span> Lawrence/Lakeside     |
| <span style="color: purple;">C</span> East Commuter     | <span style="color: blue;">M</span> Merwick/Stanworth     |
| <span style="color: lightblue;">D</span> PTS/West       | <span style="color: purple;">O</span> 100 Overlook/701 CC |
| <span style="color: blue;">E</span> EQuad               | <span style="color: orange;">S</span> Shopper             |
| <span style="color: lightblue;">F</span> Forrestal/PPPL | <span style="color: orange;">W</span> Weekender           |

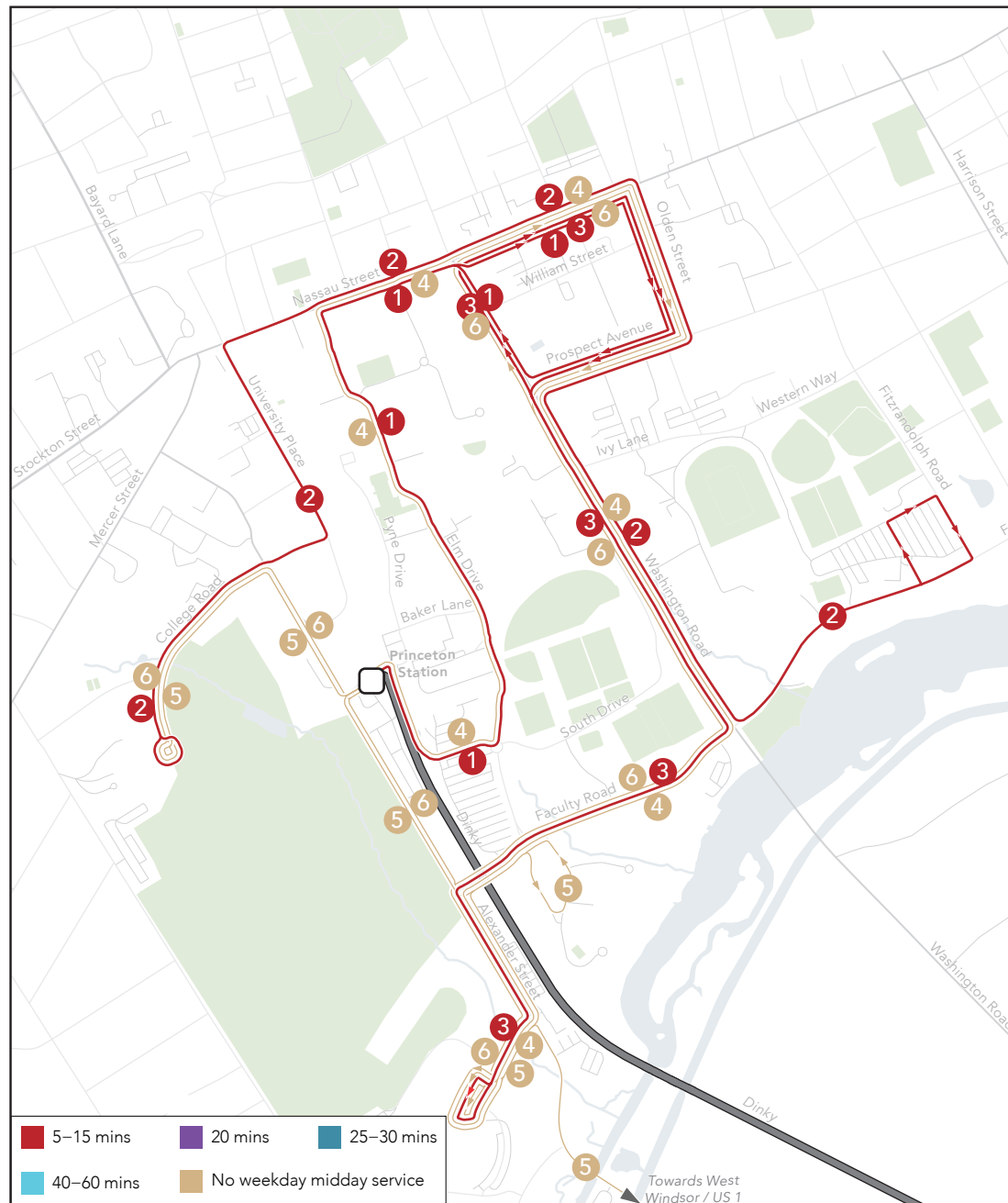
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# TigerTransit, Princeton University

## Transit Route Frequencies and Spans, Fall 2019







## Princeton University Campus Concept 2: High-Frequency Concept

### Routes

- 1 Central
- 2 East-West  
Only East Campus - East Garage between 5 am and 8 am
- 3 Lawrence / Lakeside
- 4 Night Shuttle
- 5 Shopper
- 6 Weekender

### Frequencies and Hours of Service

**Weekdays**

	6a	9a	12p	3p	6p	9p	12a
1	15	10	15	10	30		
2	15	10	15			60	
3		10	15				
4						60	

**Weekends**

	Saturday			Sunday				
	6a	12p	6p	12a	6a	12p	6p	12a
5		30				60		
6		40				40		

0 1000 2000 ft



