FINAL REPORT

Alexander Street and University Place Traffic
and Transportation Task Force

PRINCETON TRANSIT STUDY

Project #2012-001

April 2015

FINAL REPORT

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1. Project Overview

Introduction

The purpose of this report is to present the findings of the Princeton Transit Study, a two year effort to identify, evaluate and propose solutions to improve connectivity between Princeton Junction rail station and Nassau Street, one of downtown Princeton's main retail, commercial and entertainment districts.

With its unique rail connection to the Northeast Corridor (NEC), known as the Dinky, Princeton has long had a critical transit link to the most heavily travelled rail corridor in North America. The NEC in New Jersey has more than 117,000 boardings daily, with nearly 7000 passengers passing through Princeton Junction on a typical weekday. The Dinky offers commuter rail shuttle service over 2.8 miles from the NEC to Princeton Station and Princeton University along a dedicated rail right of way. This historic rail spur is an electrically powered overhead catenary line allowing for rail speeds up to 60 mph. However, passengers must transfer from the higher speed NEC trains at Princeton Junction to the Dinky. This transfer, coupled with the fact that Dinky trains stop short of downtown and Nassau Street by nearly a half mile, have impeded ridership growth. Surveys indicate that many 'Princetonians' have found it more advantageous to drive to Princeton Junction in order to minimize travel times and the stress of making connections between train lines.

In the Spring of 2012, the Alexander Street and University Place Traffic and Transportation Task Force (the ASUP Task Force) was assembled to "study, evaluate, and make recommendations concerning the long-term transit needs of the Princeton community that may be affected by development of the Arts and Transit Project." The Task Force resulted from a Memorandum of Understanding (MOU)[1] between the University and the Princeton community. The Task Force was formed to seek an objective, technical assessment of possible solutions that would enhance the transit link between Princeton Junction Rail Station and Downtown Princeton. This includes the potential extension of a transit route towards Nassau Street with the goal of connecting transit to the center of town. Other factors considered were the development of a one-seat ride from Princeton Junction via a fixed-guideway rail or transit option directly to Nassau Street. This transit expansion/extension considered the existing system infrastructure/service and how it has been modified by the University's Arts and Transit Neighborhood plan as acknowledged in the MOU.

As a first step in this process, the ASUP Task Force hired two consultants to conduct this work. AECOM was assigned the task of examining ways to improve street traffic circulation within the community, and URS was to explore improvements to the transit connection to Downtown Princeton. In January of 2015, AECOM and URS merged operations as one of the largest engineering consulting firms in the world. For

[1] A copy of the Memorandum of Understanding between Princeton and Princeton University is in Appendix 4.

this project, the work for the street traffic circulation and for the transit study have primarily been handled in separate offices, and have been treated as separate projects, each being handled by its own staff. This report is focused primarily on options to improve transit connectivity between Princeton Junction and Nassau Street.

The work in this report is organized as follows:

Section 1 - Project Overview

This section presents an overview of prior studies, provides background on the project, and presents the project's Goals and Objectives as developed with the ASUP Task Force.

Section 2- Long List of Alternatives

This section presents the initial list of transit and rail modal options and potential alignments originally considered by the ASUP Task Force. The Long List of alternatives is intended to be broad in nature, to provide a comprehensive "first look" at possible strategies and solutions. A preliminary screening of these options was prepared with input from the Task Force. A total of eight alternatives were initially identified, and four were dropped from further consideration following initial screening. Two overall alignments were identified.

Section 3 - Short List of Alternatives

In this section, the four alternatives resulting from the preliminary screening were further examined and an Evaluation Matrix was developed to compare each alternative to how well each met the project's Goals and Objectives. At the end of this process, two alternatives were carried forward. Further evaluation of the alignments focused on the University Place segment.

Section 4 – Preferred Alternatives

In this section, the preferred modal alternative selected was identified as a Streetcar/LRT alternative. A total of four alignment options were selected, two affecting potential service on University Place and two that additionally affect portions of Alexander Street.

A preliminary investigation into the operation of a system using the preferred alternatives was made to test the feasibility of operations, and to better define available headway and required number of vehicles.

Section 5 - Ridership Analysis

A detailed ridership analysis was prepared to determine potential ridership resulting from various options.

Section 6 - Cost Estimate

A conceptual cost estimate was prepared for the Preferred Alternatives.

Overview of Previous Studies

As a first step in the process, the Consultant Team reviewed studies, plans, and planning documents that had been prepared by various agencies to identify and address transportation needs within the study corridor. Detailed summaries of the findings of each report can be found in Appendix 6. In reverse chronological order of publication, these studies are:

1. Princeton Residential Mixed Use (RMU) Zoning Code (Proposed), 1968 (amended 2012, DRAFT)
2. Princeton Community Master Plan, 1996 (Amendments through November 2012)
3. Community Transportation Coordination Initiative, 2010
4. Princeton University Campus Plan, 2008
5. Viability of Personal Rapid Transit in New Jersey, 2007
6. Penns Neck Area Environmental Impact Statement, 2004

In addition, two websites that chronicle construction projects by Princeton University were reviewed:

7. Princeton University Arts and Transit Neighborhood Plan
8. Redevelopment Plan for Hibben-Magie Site

1. PRINCETON RESIDENTIAL MIXED USE (RMU) ZONING CODE (PROPOSED)

Completed by: Township of Princeton, 1968 (Draft amendments through 2012)

Based on this code amendment, a wide variety of residential, office, retail, service, transit, and accessory uses would be allowed within the RMU zone. The RMU zone encourages mixed-use development that is consistent with the principles of Smart Growth and transit-oriented development (TOD). At this point, the code amendment is only in its draft form.

2. PRINCETON COMMUNITY MASTER PLAN

Completed by: Planning Board of Princeton, 1996 (amendments through 2012)

The Princeton Community Master Plan outlines the goals and ideals for development in Princeton in terms of housing, land use, open space, community facilities, utilities, conservation, and historic preservation. Within the chapter on the "Circulation Element", the portions relating to transit and bicycle/pedestrian improvements are most applicable to the Princeton Transit Study. For these items, the Master Plan:

- Encourages the further development, extension, and use of both public and private mass transit
- Calls for better information on available transit service using print and electronic media
- Makes provision for a pedestrian and bicycle path network for maximum recreational and circulation use between neighborhoods, recreational areas, schools, and shopping areas
- Improves parking opportunities for mass transit facilities.

3. COMMUNITY TRANSPORTATION COORDINATION INITIATIVE

Completed by: Gannett Fleming, April 2010

The goals of this initiative were to identify transportation improvements that would create a coordinated and integrated transit system to:

- Increase ridership and reduce dependence on motor vehicles;
- Reduce redundant services and improve connections between existing transit systems;
- Provide increased and timely service to underserved population centers;
- Support community businesses; and
- Preserve flexibility to integrate with future NJ Transit service enhancements and potential Bus Rapid Transit.

To respond to these goals, the current transit systems were analyzed and remedies to address current deficiencies and to leverage opportunities for the future were identified. This process included developing several shuttle service route options that would provide expanded coverage in both Princeton Borough and Princeton Township via expanded routes and hours of service. Ten proposals were considered to serve as many of the area's traffic generators as possible. Ultimately, a single recommended shuttle alternative was selected and then refined to more fully meet specific goals of the project. The Community Transportation Coordination Initiative recommended hourly service between 10:00 AM and 4:00 PM on weekdays, which would generate an annual ridership of 7,590 persons at a first year operating costof approximately $113,380.

4. PRINCETON UNIVERSITY CAMPUS PLAN

Completed by: Princeton University, 2008

A core component of the Princeton University Campus Plan is to create a multi-modal transportation hub alongside a new arts complex to create a clear and welcoming point of entry to both the University and the township and borough of Princeton. This effort, known as the *Arts and Transit Project,* envisions a pedestrian-oriented transit plaza, new pathways, signage, and maps to direct visitors to destinations across campus and in the community. The Plan recognizes the need to reconfigure the transportation infrastructure in the area to alleviate existing congestion.

5. VIABILITY OF PERSONAL RAPID TRANSIT IN NEW JERSEY

Completed by: Jon A. Carnegie, AICP/PP (Alan M. Voorhees Transportation Center at Rutgers, The State University of New Jersey) and Paul S. Hoffman (Booz Allen Hamilton, Inc.), 2007

At this point, the code amendment is only in its draft form.

Key components of this study included reviewing the technical components of Personal Rapid Transit, identifying potential scenarios where PRT could be appropriate in New Jersey. The study identified urbanized areas, suburban employment centers, activity centers, and university campuses as potential areas where PRT could be implemented.

6. PENNS NECK AREA ENVIRONMENTAL IMPACT STATEMENT

Completed by: US Department of Transportation Federal Highway Administration and New Jersey Department of Transportation, 2004

The Penns Neck Area EIS analyzed a variety of potential alternatives to address traffic congestion, mobility, constraints and safety concerns in the Penns Neck area including various roadway and transit actions. However, with the elimination of light rail, bus rapid transit, and rail options, the EIS proceeded to analyze a series of 19 roadway modifications

Five improvements were combined into a single preferred alternative that provided a reasonable level of transportation benefit, while avoiding and minimizing environmental impacts

7. PRINCETON UNIVERSITY ARTS AND TRANSIT NEIGHBORHOOD PLAN

Completed by: Princeton University

Princeton University created a website (http://www.princeton.edu/artsandtransit) dedicated to its Arts and Transit Project.

Princeton University Campus Plan. The purpose of the website is to provide information about the project's history, design and construction. The site also includes pages dedicated to recent news, frequently asked questions, and contact information for the project team. The new Dinky station was slated to be opened on November 17, 2014.

The website summarizes the transportation-related Arts and Transit Project improvements, and provides information about the project's history, design and construction. It also offers the most up-to-date information regarding the construction of Princeton University's Arts and Transit Neighborhood.

8. REDEVELOPMENT PLAN FOR HIBBEN-MAGIE SITE (LAKESIDE GRADUATE STUDENT HOUSING)

Completed by: Princeton University

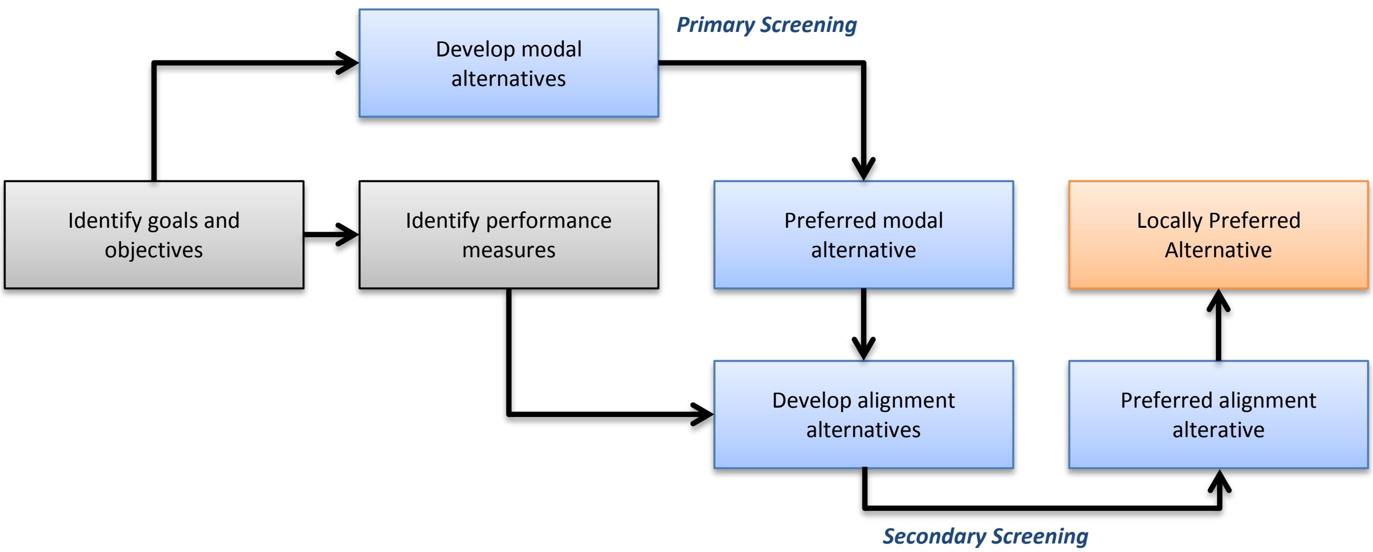
The purpose of the website is to provide information about the project's design, purpose, and construction progress.

The renovation of Hibben and Magie apartments includes the replacement of existing undergraduate housing with 329 one- to four-bedroom townhomes and apartment units in 13 structures, wtih a capacity for 715 graduate students and their families. The site will be served by the university shuttle. Because of its proximity to the Arts and Transit Neighborhood, its residents represent potential transit users.

Project Goals and Objectives

To determine the preferred alternative for the Princeton Transit Study, an evaluation methodology was developed and tailored to this project and was used as the project evolved. This process is shown graphically in Figure 1, and is described in greater detail in the following sections.

Figure 1: Evaluation Methodology Process



The Consultant Team identified a preliminary list of goals and objectives to guide the evaluation process. In addition, the Team developed a list of modal alternatives. These modal alternatives were qualitatively evaluated using the primary goals and objectives to determine a preferred modal alternative, which was moved forward for further analysis.

In consultation with the ASUP Task Force, the URS Team developed alignment alternatives. For the evaluation of the alignment alternatives, the URS Team developed performance measures to expand on both the primary and secondary goals and objectives. Using these performance measures, the URS Team analyzed the alignment and service pattern options. With the input of the ASUP Task Force, preferred alignment alternatives were selected.

Draft Goals and Objectives

Based on input from the ASUP Task Force, a list of preliminary goals and objectives was developed to guide the Princeton Transit Study. These were reviewed by the Public at public forums held in the Spring of 2013. Comments were accepted by the Task Force through the end of June, 2013. The final goals and objectives that were agreed to are presented in Table 1.

As shown in Table 1, the primary goals of the Princeton Transit Study are to:

1) Improve transit mobility, connectivity, and accessibility;
2) Provide cost effective and efficient transportation services;
3) Encourage sustainable development; and
4) Maintain/enhance livability and quality of life.

Combined, these goals aim to provide a service that improves accessibility and reduces travel time within a reasonable timeframe and cost. At the same time, the transit improvements should benefit community character and avoid or minimize impacts on the environment.

The identification of project goals and objectives is an integral part of the evaluation process, as these goals and objectives will be used in the primary screening to qualitatively evaluate the modal alternatives and determine the modes that best meet the project's goals. In addition, the goals and objectives are the building blocks for developing the performance measures to consider and compare the relative benefits and potential adverse effects of the alignment alternatives and select a preferred alternative. While the primary screening will be more qualitative in nature, the secondary screening will evaluate the alignment alternatives using both qualitative and quantitative performance measures, including ridership estimates, constructability, refined property requirements, and order-of-magnitude cost estimates, among other performance measures.

Table 1: Study Goals and Objectives

GOALS	OBJECTIVES
IMPROVE TRANSIT MOBILITY, CONNECTIVITY, AND ACC**ESSIBILITY**	Provide connections to existing and future transit services
	Increase transit demand
	Accommodate future transit demand
	Maintain existing commuter level of service
	Maintain existing comfort of service
	Minimize transfers within the transportation system
	Improve operating speed
	Maintain bicycle friendly atmosphere
PROVIDE COST EFFECTIVE AND EFFICIENT TRANSPORTATION SERVICES	Implement within a reasonable time frame
	Implement at a reasonable cost
	Minimize operating and maintenance costs per passenger mile
	Consistent with NJT or Princeton University operating technologies
	Maintain emergency vehicles access to system
	Maintain access to arterial roadways
	Maintain access to existing and future users
	Minimize property acquisition
	Ability to phase construction
	Minimize turning radii that meet current alignments
ENCOURAGE SUSTAINABLE ECONOMIC DEVELOPMENT	Improve connection between residential/commercial/educational destinations
	Stimulate economic development
MAINTAIN/ENHANCE LIVABILITY AND QUALITY OF LIFE	Minimize/avoid impacts on historic resources
	Minimize construction impacts
	Reduce vehicle congestion emissions and noise
	Improve energy efficiency

2. Long List of Alternatives

1. DRAFT MODAL ALTERNATIVES

At the start of the study, the URS Team, in conjunction with the Princeton Transit and Traffic Task Force, developed a list of rail and non-rail based modal alternatives to make certain that a wide range of options were considered. In total, a set of seven modal alternatives was identified, in addition to a Transportation System Management (TSM)[2] option. These alternatives are:

A. Commuter / Heavy rail – this option would extend the existing electrified NJ Transit Dinky commuter rail line from the new Princeton station to Nassau Street.

B. Light Rail Transit (LRT) – this option would convert the existing Dinky line between Princeton Junction and Princeton Station to a light rail system; this would then be extended to Nassau Street primarily using a dedicated right of way.

This technology encompasses lightweight passenger rail cars usually operating in short trains, on fixed rails in right-of-way that is parallel with, but separated from other roadway traffic for most of the route. Light rail vehicles are driven electrically with power typically being drawn from an overhead electric line via a trolley or a pantograph. LRT systems require relatively large turning radii, but have high passenger carrying capacity (15,000 to 30,000 pphpd).

Light Rail Transit technology includes a range of vehicles between 80 and 160 feet long in single and articulated arrangements. High operating speeds are possible on exclusive rights-of-way.

C. Streetcar – also sometimes referred to as 'Light' Light Rail, a streetcar would be similar to the LRT option. It would convert the existing Dinky operation between Princeton Junction and Princeton Station to a streetcar system, and then include in-street running, fixed guideway service with options to operate in mixed traffic, and with portions of the route possibly operating without overhead wires.

Streetcars can be either vintage or modern designs. The vehicle is typically 8 feet high, approximately 8 feet wide, and 60 to 80 feet long with maximum speeds of 40 to 50 mph. and a minimum turning radius of 50 to 65 ft. Streetcars generally have the capability to operate on roadways intermixed with vehicle traffic. Power is typically provided by

[2] The Transportation Systems Management approach to congestion mitigation seeks to identify improvements to enhance the capacity of existing system of an operational nature (e.g. traffic signal optimization). Capital investments are minimal.

overhead catenary, but diesel, battery, and underground power systems are optional.

D. Bus Rapid Transit (BRT)– this would convert the existing Dinky line to a dedicated bus right of way from Princeton Junction to Princeton Station, then continue in a bus only lane or in mixed street traffic to Nassau Street. A majority of the route would be a dedicated bus lane.

Bus Rapid Transit, or BRT, is defined as "flexible, rubber-tired rapid transit mode that combines stations, vehicles, service, running-ways and Intelligent Transportation Systems (ITS) elements into an integrated system with a strong positive identity and a unique image." It has been compared to light rail transit, but has greater operational flexibility and potentially lower capital and operating costs. The key difference is that BRT can utilize both exclusive rights of way and still operate in mixed city traffic to bring passengers in a one-seat ride to their specific destinations. The goal of BRT is to improve overall service by reducing bus travel times, increasing bus frequency and reliability, improving accessibility, and developing greater amenities for users.

BRT systems can include prioritization of traffic signals and can also be designed with automatic wayside fare collection to minimize disruption to the boarding process. Bus capacity can be increased with utilization of larger articulated buses, but a limitation of buses compared to all other options, is that they cannot be coupled into trains.

E. Conventional bus – Dinky service would be suspended and replaced by conventional bus operations on local streets.

F. Automated Guideway Transit (AGT) (also known as Group Rapid Transit, or GRT) – a “people mover” system similar to ones operated at many airports in the US and around the world would replace the existing Dinky from Princeton Junction to Princeton Station, and continue in a dedicated right of way to Nassau Street on an elevated structure or completely separated right of way. Vehicles operate on a fixed headway, not on demand, and can carry up to 20 seated passengers as well as standees.

G. Personal rapid transit (PRT) – similar to the Automated Guideway Transit (AGT) with some notable exceptions. PRT vehicles, with the ability to seat up to six persons per vehicle, would operate along the Dinky right of way from Princeton Junction to Princeton Station, then in a dedicated right of way (separated or overhead) to Nassau Street. Unlike the AGT, the PRT system would operate on demand.

These systems include all of the elements of an AGT System, but PRT systems utilize smaller 4-6 passenger vehicles that carry single groups of people going to a single destination. They utilize more sophisticated automatic train control, bringing vehicles to locations “on demand”.

Appendix 1 provides additional information on the vehicles described in Alternatives A-G above. In addition, the following alternative (H) was also considered:

H. Transportation Systems Management (TSM) – there would be no change in the current system of operations but service frequencies and efficiencies to reduce congestion issues and improve overall operations would be implemented with no major capital investment.

These eight alternatives were evaluated qualitatively in terms of two factors – how they met the study's goals and objectives; and whether there were any major obstacles that would make their implementation impractical or cost prohibitive (commonly known as "fatal flaws"). The purpose of the preliminary screening was to reduce the long list of alternatives to fewer than five options for further evaluation and comparison to the project's goals and objectives.

Based on the preliminary screening and evaluation, three alternatives were eliminated from the long list:

- **Commuter/Heavy Rail** – this option was eliminated as it was deemed impractical. Commuter rail operations require a separate, dedicated right-of-way (similar to the current Dinky operation). The location of the new Dinky station and the fully developed landscape between Princeton Station and Nassau Street make the provision of a separated Right-of-Way impractical.

- **Automated Guideway Transit (AGT)** – the infrastructure costs of creating a new AGT system and the inability to extend the Dinky in a straight line made this option impractical.

- **Conventional Bus –** this is currently operating within the Princeton transportation network and would not improve upon the existing transit system so it was dropped from further consideration.

In addition, it was agreed that no further development of **Transportation Systems Management** options would need to be developed as part of this study, but could be explored further following completion of the study.

2. PRELIMINARY ALIGNMENT OPTIONS

The Princeton Transit and Traffic Task Force reviewed alignment options presented by the Consultant team at the project Kick-Off meeting on November 6, 2012. It was agreed the Consultant Team would review and evaluate for the Princeton Transit Study the following two alignment options:

1) The first alignment option focused on extending transit service from the new Princeton rail station location to Nassau Street in the general vicinity of University Place to Mercer Street. The existing Dinky alignment between Princeton and Princeton Junction stations would remain the same. This option would evaluate potential alternative modes for the entire route, with an emphasis on improving connectivity from the new Princeton station to the Nassau Street area noted above. All four modes selected were included for consideration in this option.

2) The second alignment option focused on overall connectivity from the NJ Transit rail station at Princeton Junction to Nassau Street in the general vicinity of University Place to Mercer Street. The initial route from Princeton Junction station would follow the existing rail right of way until it crosses the Delaware & Raritan Canal. From there the route would turn west off the rail right of way onto Alexander Street, and then follow along Alexander Street to Mercer onto Nassau Street, or turn onto University Place toward Nassau Street. LRT, PRT and streetcar modes were considered in this option.

The map below, Figure 2, shows the study corridor with the alignment options described above. They include the existing Dinky line, Alexander Street and University Place segments.

Figure 2: Princeton Study Area Map

3. DRAFT PERFORMANCE MEASURES

The URS Team developed performance measures as a means of objective evaluation of the selected short list of modal and alignment options that were moved forward for further consideration. These performance measures, shown in Table 2, were used in the secondary screening to qualitatively and quantitatively evaluate the alignment alternatives and determine how well these alignment alternatives meet the project's goals and objectives.

Table 2: Draft Goals and Objectives and Performance Measures

GOALS	OBJECTIVES	PERFORMANCE MEASURES
IMPROVE TRANSIT MOBILITY, CONNECTIVITY, AND ACCESSIBILITY TO PRINCETON	Increase the number of transit trips	Transit trips within the study area
	Improve transit travel time and reliability	Travel times On-time performance
	Accommodate future transit demand	Transit capacity
PROVIDE COST EFFECTIVE AND EFFICIENT TRANSPORT OPTIONS	Minimize capital and operating costs	Capital and operating costs relative to benefits
	Implement within a reasonable timeframe	Implementation timeframe
	Ensure compatibility with NJ Transit operations	Compatibility with NJ Transit operations
	Ensure compatibility with existing and future Princeton University infrastructure and operations	Compatibility with Princeton infrastructure and operations
ENHANCE COMMUNITY CHARACTER	Support existing and proposed development in the study area	Number of commercial hubs along alignment and proximity to potential development areas
	Maintain/improve vehicular circulation	Number of conflicts with vehicle circulation
	Maintain/improve pedestrian circulation and safety	Number of conflicts with pedestrian circulation/safety
	Maintain/improve bicycle circulation and safety	Number of conflicts with bicycle circulation/safety
MINIMIZE ADVERSE IMPACTS ON THE BUILT AND NATURAL ENVIRONMENT	Minimize property acquisition to the maximum extent feasible	Square footage of property acquisition
	Avoid, minimize, or mitigate adverse impacts on historic resources	Proximity to historic resources
	Minimize encroachment on view corridors	Linear footage of encroachments on view corridors
	Minimize vehicular congestion, emissions, and noise Improve energy efficiency	Transit modal shift

4. PUBLIC OUTREACH PROCESS

Throughout the course of this study, the Consultant Team worked with the ASUP Task Force and participated in an extensive stakeholder and public outreach process. All ASUP Task Force meetings were open to the public. Presentations were also made to the Princeton Council and to the public. Copies of presentations to these various groups, as well as comments received from the public on the project, are included in Appendix 5.

3. Short List of Alternatives

The four modal alternatives that were carried forward for a more detailed review were:

Alternative 1 - Personal Rapid Transit (PRT)

Alternative 2 - Bus Rapid Transit (BRT)

Alternative 3 - Light Rail Transit (LRT)

Alternative 4 - Streetcar (Streetcar)

Alternative 1 – Personal Rapid Transit

Figure 3 – Depiction of PRT vehicle

Personal Rapid Transit (PRT) would operate as single cars, such as the Ultra PRT system shown above that operates at Heathrow Airport in the UK. A separate guideway is required. Each car would have capacity for 4-6 persons and operate as speeds up to 25 mph. A key characteristic of PRT is that it is Demand Responsive – it would operate as needed and the system would be designed to meet demand at Princeton Junction, Princeton Dinky Station and Nassau Street. In general, at lower speeds PRT can handle very tight curves for easy maneuvering; broad curves are needed for higher speeds. Below are two alignment options for PRT in Princeton.

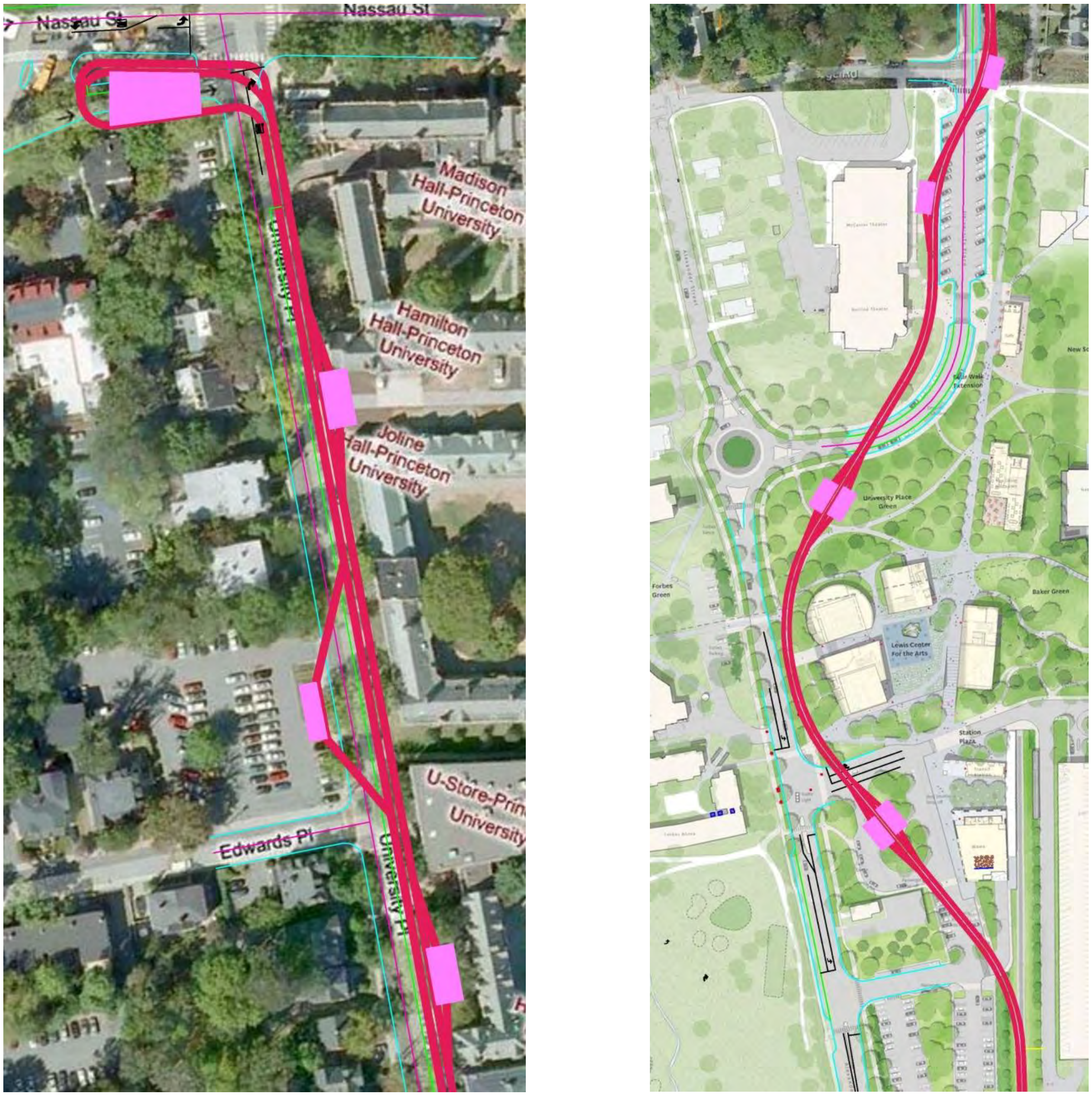


Figure 4: PRT Alignment Options

Alignment options along University Place and in the vicinity of the new Arts and Transit neighborhood are indicated above. The remaining alignment would follow existing Dinky commuter rail right of way to Princeton Junction.

Alternative 2 - Bus Rapid Transit

Figure 5 - BRT Station

Several studies have been completed that considered Bus Rapid Transit (BRT) as a viable alternative along Route 1 in the vicinity of Princeton. Alternative 2 (BRT) for this study focused on the Princeton Junction to Nassau Street corridor. The following BRT options were explored:

<u>Alternative 2 – Option A: Princeton Junction to Nassau Street</u>

This bus service replaces the Dinky rail line with a BRT guideway between Princeton Junction and Princeton Station. It then operates in the street to Nassau Street, and reverses direction back to Princeton and Princeton Junction via the former Dinky Right-of-Way.

Limited stop locations are proposed for:

- Princeton Junction
- Princeton Station
- Nassau Street at University Place

Proposed BRT treatments:

- Off board fare collection at Princeton Junction, Princeton Station and University Place
- Transit Signal Priority (TSP) along Hamilton Avenue and University place

<u>BRT Alternative 2 - Option A (expanded): Princeton Station to Princeton Shopping Center</u>

This bus service also replaces the Dinky rail line with a BRT guideway between Princeton Junction and Princeton Station. It then operates in the street to Nassau Street, and makes a one-way loop past the Princeton Shopping Center via Nassau Street, North Harrison Street, Terune Road and Witherspoon Street back to Nassau Street. The street portions of this route overlay parts of the existing NJT services 605 and 655.

Limited stop locations are proposed for:

- Princeton Junction
- Princeton Station
- one-way operation: Nassau Street at Witherspoon Street/ Palmer Square, Nassau Street at Chestnut Street, Nassau Street at Harrison Street, Princeton Shopping Center,
- one-way operation: Witherspoon Street at Henry Avenue/Franklin Terrace, Witherspoon Street at Wiggins Street
- Nassau Street at Palmer Square/Witherspoon Street

Proposed BRT treatments:

- Off board fare collection at:
  - Princeton Junction
  - Princeton Station
  - Princeton Shopping Center
- Transit Signal Priority (TSP) at:
  - Alexander Street and Station Access Drive
  - along Nassau Street: University place, Witherspoon Street, Washington Rd/Vandeventer Ave, Olden/Chestnut Streets and North Harrison Street
  - along North Harrison Street: Hamilton Avenue, Franklin Avenue, Valley Road, Terhune Road
  - (reverse 'Stop' regulation at Terhune Road and Jefferson Road)
  - along Witherspoon Road: Valley Road, Guyot Avenue, Wiggins Street

<u>BRT Alternative 2 - Option B: Princeton Junction to Princeton Station to Nassau Street (or Princeton Shopping Center)</u>

This bus service is the same as Option A (or A – Extended) between Princeton Station and Nassau Street/ Princeton Shopping Center. Between Princeton Station and Princeton Junction, Option B follows Alexander Street and approaches Princeton Junction via Wallace Road. This option leaves the rail operation on the Dinky intact as a parallel service.

Limited stop locations are proposed for:

- Princeton Junction

- Alexander Street at Roszel Road, Canal Pointe Blvd, Lawrence Drive
- Princeton Station
- one-way operation: Nassau Street at Witherspoon Street/ Palmer Square, Nassau Street at Chestnut Street, Nassau Street at Harrison Street, Princeton Shopping Center,
- one-way operation: Witherspoon Street at Henry Avenue/Franklin Terrace, Witherspoon Street at Wiggins Street
- Nassau Street at Palmer Square/Witherspoon Street

Proposed BRT treatments:

- Off board fare collection at:
  - Princeton Junction
  - Princeton Station
  - Princeton Shopping Center
- Transit Signal Priority (TSP) at:
  - along Alexander Street: Bear Brook Road, Roszel Road, Carnegie Center Drive, Route 1 NB on/off-ramp, Cana Pointe Boulevard, Lawrence Drive, Faculty Road
  - Alexander Street and Station Access Drive
  - along Nassau Street: University Place, Witherspoon Street, Washington Rd/Vandeventer Ave, Olden/Chestnut Streets and North Harrison Street
  - along North Harrison Street: Hamilton Avenue, Franklin Avenue, Valley Road, Terhune Road
  - (reverse 'Stop' regulation at Terhune Road and Jefferson Road)
  - along Witherspoon Road: Valley Road, Guyot Avenue, Wiggins Street

The alignment option for BRT along University Place, extended to the Princeton Shopping Center can be found in Figure 6.

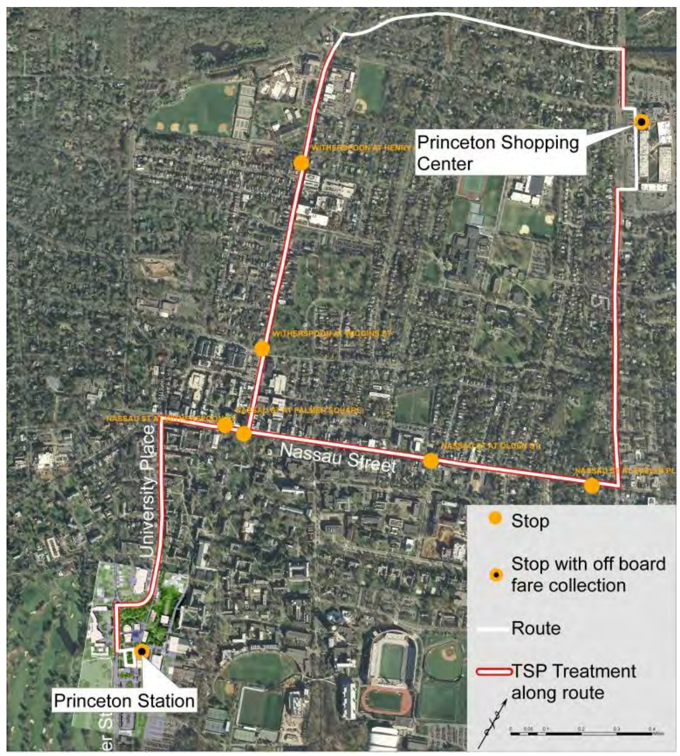


Figure 6: BRT Alignment along University Place Extended to Princeton Shopping Center

Alternative 3 - Light Rail Transit (LRT)

Light rail transit can operate as single cars or as short train sets. Typically, LRT runs in exclusive or separated Right of Way with station stops one quarter mile or more apart. It can also operate within streets, but has somewhat limited turning ability. Compared to Streetcar, it has generally higher capacity and can reach speeds up to or exceeding 60 mph. Generally, it requires a minimum of 82 foot turning radius, but some newer LRT systems have the capacity for tighter turning capabilities. Shown below (Figure 8) are two alignment options for LRT around the new roundabout off Alexander Street.

Figure 7 - LRT at a Portland State University Campus

Figure 8: LRT Alignment Options around Roundabout off Alexander Road

Alternative 4 - Streetcar

Streetcars often operate as single cars or single articulated vehicles. They generally run in streets with traffic, have moderate capacity and can achieve speeds typically 40-45 mph. They are capable of handling tight turns (50 foot radius)

There are several types of streetcar rolling stock available, including the Modern streetcar (shown right); Heritage Cars (primarily historic cars) and new replica cars designed to look like historic ones. In addition, there are hybrid vehicles (Modern) that can run off batteries as well as overhead wire to avoid visual impacts in historic districts.

Figure 9 – Modern Articulated Streetcar

Shown below (Figure 10) are two alignment options, including how the streetcar would operate through the roundabout and how it could leave the existing Dinky right of way and proceed onto Alexander Street in the vicinity of Faculty Road.

Figure 10: Streetcar alignment options through the Roundabout on left; on right, connection from Dinky line to Alexander Road in proximity of Faculty Road.

Short List Evaluation Matrix and Results

The following Evaluation Matrix was developed to help determine how each of the modal alternatives meets the goals and objectives of the study. A team of seven transit professionals within the industry were asked to independently evaluate each alternative using a defined scoring method.[3] The scores were then tallied to create a total for each alternative. Total scores within 50 points of the highest score were considered as essentially the same, given the qualitative nature of the evaluation. Following this initial evaluation by the transit professionals, members of the Princeton ASUP Task Force were asked to review the results. The ASUP Task Force met separately without the Consultant Team and concluded that the scores were an objective, unbiased result and should be used to further reduce the number of alternatives. As a result of this effort, PRT was dropped from further consideration. Additionally, going forward the Consultant Team would consider only two modal alternatives: BRT and LRT/Streetcar (for the purpose of further evaluation, LRT and Streetcar would be considered as essentially the same alternative.

After reviewing these results, the ASUP Traffic and Transportation Task Force determined that sufficient study had already been completed by others or was underway by NJ Transit regarding the viability of the BRT option for Princeton within the overall study area. As a result, the Preferred Alternative evaluation process would focus exclusively on the LRT/Streetcar option and would not duplicate BRT efforts being undertaken by others.

In particular, the LRT/Streetcar alternative closely examines the University Place options for LRT/streetcar, which are presented in Section 4, Preferred Alternatives. It is anticipated that there would be minimal change to the existing rail infrastructure necessary for the segment between Princeton and Princeton Junction (the existing Dinky right of way), in that the right of way, rail bed and catenary system could continue to be used for the LRT/Streetcar option. Therefore, this segment is not thoroughly reviewed in Section 4. Nonetheless, pertinent construction elements for this segment are included in the overall cost estimate presented in Section 6

[3] The transit professionals who evaluated the options were employed by URS and have worked with all four transit modes; none have worked for an equipment/vehicle manufacturer, but several have worked for transit operating agencies in multiple capacities covering the various modes.

LRT	Streetcar	PRT - abv grd	PRT - at grade	BRT	Comments
0	120	100	90	130	
0	10	0	10	15	BRT is easier to extend in the future, with less infrastructure needed than PRT, LRT, or SC. Existing connections may be easier with LRT since lines are already in place.
5	15	20	15	15	PRT above grade would have quicker travel times because it is on-demand and has complete separation from traffic.
0	15	5	5	15	LRT, SC and BRT vehicles are larger with greater capacities and can accommodate standees. PRT with a 1 minute headway (20 vehicles) can accommodate up to 240 p/ph. BRT with 15 minute headway, 60' bus = 240 p/ph seated, SC is similar. LRT has larger capacities than BRT. PRT will reach max vehicle capacity along the line much quicker than the others.
0	20	20	20	20	This would be the same across all mode options.
0	20	20	15	10	PRT is designed to be small personal cabs that provide a high level of comfort. It is a general consensus that rail is considered a much smoother ride than rubber on road.
0	20	15	15	20	PRT must operate in a closed loop system; the others do not need to. therefore it is easier to extend their services.
0	15	5	5	15	The max operating speed along the existing rail corridor for PRT is 25 mph as opposed to speeds of 40 or 45 in BRT or SC. LRT can reach up to 55 mph. [1,2,5]
5	5	15	5	20	All roads either have bike lanes or sharrows. SC is not as cyclist friendly because the imbedded rail lines pose a safety threat. PRT above grade requires posts to support the infrastructure, which may block cyclist lanes. PRT at grade separated is too narrow to accommodate bikes.
0	130	70	35	150	
5	15	0	0	15	BRT is generally quicker to construct but in this the case existing infrastructure in place, that favors rail, between Princeton and Princeton Junction would make the timeline for construction similar for both BRT, SC and LRT. PRT would require all new infrastructure for the entire route.
5	15	0	0	15	PRT at grade would require ROW acquisition. PRT above grade would be $40 million per mile[2]. LRT, SC and BRT would have similar costs due to similar time frames and infrastructure needs[3]. LRT and SC can use the existing rail line for the majority of the trip and the bridges over Carnegie Lake and Delaware & Raritan Canal are double tracked.
0	10	20	20	15	PRT requires no on-board operators, decreasing the operating cost. According to a report prepared for the NJDOT PRT is $0.4/pass-mi, bus is $0.6 and LRT is $0.55.[2]
5	10	0	0	15	BRT and LRT exist within the NJT system but not in Princeton. PRT has never existed in the state. SC used to operate in the state but no longer does.
5	15	5	10	20	Assumes access for emergency vehicles to respond to an incident along the line. PRT at grade would be too narrow; above grade would require ladder trucks. Rail options not in the street would be harder to access or traverse but are still possible. BRT is easily accessible by all emergency vehicle sizes.
0	20	20	0	20	PRT at grade would block access to properties beyond the ROW because of separation requirements for safety, while overhead PRT would provide full access.In-road or at grade rail lines are traversable, but must be controlled. BRT is generally completely traversable.
5	15	10	5	20	PRT requires a whole new set of infrastructure.
5	20	15	0	15	LRT and SC assume the ROW is wide enough to accommodate them along the existing rail line. PRT and BRT may require ROW acquisition. ROW property acquisition may be required at Nassau St. PRT - at grade would require ROW acquisition along Alexander St and University place because it must be separated to meet safety standards.
0	10	0	0	15	PRT can not be phased; all technology must be purchased at the onset. TSP technology phasing is possible for BRT, SC, and LRT. BRT could phase in new vehicle technology, LRT would require purchasing new vehicles.
5	10	20	20	15	Based on the required turning radius. PRT =18 ft, Bus = 45, LRT =82, SC= 55
5	40	10	20	35	
5	20	5	5	15	BRT and LRT have been shown to attract cluster development and TOD. Historically SC was a main driver of economic development. It is unknown if PRT has similar impact. This assumes that the zoning allows for more development or would be changed to do so.
0	20	5	15	20	LRT, SC and BRT would be running at grade un-separated. PRT at grade may not improve connections because it is separated and above grade removes the infrastructure and thus connection completely from the street level.
5	75	60	85	80	
5	15	0	10	15	Assumes LRT and SC are not using overhead catenary. BRT, SC and LRT would run in the current ROW avoiding impacts on historic resources. PRT at grade would widen the travel way and impact resources. Above grade PRT would change the historical nature of the area.
5	15	0	15	15	LRT, SC and BRT would have the same encroachment on the view corridor that currently exists with local bus service. PRT- above grade would be unsightly and at grade would have significant impact on the view corridor.
0	10	0	10	10	LRT and SC requires roadway construction to lay track, PRT at grade would require laying magnets in pavement and constructing a barrier, PRT above grade would require intense construction, BRT requires constructing a bus way along the existing rail corridor and replacing both bridges.
5	15	20	15	15	LRT, SC and BRT would have similar noise levels (LRT abd SC are the quietest). SC and LRT have no vehicle emissions. PRT has no emissions, noise is unknown.
5	15	20	15	15	BRT, SC and LRT would have the same reduction on the system, PRT at grade may contribute to congestion as it would take away from traffic lanes.
5	5	20	20	10	According to NTD and the Transportation energy data bank data LRT averages 6.311 Kwh/P/Mi, BRT is 1.216 Kwh/P/Mi. PRT companies claim .24kWh/P/Mi. [3,4,6]
370	365	240	230	395	

Scale

= 0	○	Does not meet the criteria
nd <= 5	◔	
nd <= 10	◑	Partially meets the criteria
nd <= 15	◕	
nd <= 20	●	Fully meets the criteria

Sources:

[1]Report to US General Accounting Office (2001), Mass Transit - Bus Rapid Transit Shows Promise. http://www.gao.gov/new.items/d01984.pdf

[2]Viability of Personal Rapid Transit in New Jersey Final Report (2007) http://faculty.washington.edu/jbs/itrans/big/PRTfinalreport.pdf

[3]APTA 2012 Fact book - http://www.apta.com/resources/statistics/Documents/FactBook/APTA_2012_Fact%20Book.pdf

[4]U.S. Department of Energy, Transportation Energy Data Book -Chapter 2 (2012), http://cta.ornl.gov/data/tedb31/Edition31_Chapter02.pdf

[5]FTA report, Characteristics of Bus Rapid Transit for Decision-Making (2004) http://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf

4. Preferred Alternatives

Initial Screening

From the initial list of possible modes (PRT, BRT, LRT and Streetcar), it was determined that light rail/streetcar share many operating characteristics, and would be combined into a single modal category for continued evaluation. It was determined that the existing Dinky catenary and trackage could be utilized for this service. Six potential alternatives for operation on University Place were determined to best accommodate the goals and objectives of the study (See Table 4 – University Place Transit Alternatives):

A. Dual Track in-street running – No Parking – No Widening
B. Single Track in-street running – No Parking – No Widening – One Way traffic
C. Single Track Exclusive Right-of-Way – No Parking – No Widening – One Way Traffic
D. Single Track in-street running – With Parking – No Widening – One Way Traffic (Single Lane)
E. Dual Track in-street running – With Parking – Widening Required
F. Single Track Exclusive Right-of-Way – No Parking – Two Way Traffic – Widening Required

Final Screening

From this initial list of potential alternatives, two primary alternative alignments were chosen for consideration for operation between Princeton Station and Nassau Street.

Alternative F includes the construction of a single bi-directional track that would be placed in a separated right-of-way along the east side of University Place. This alignment would require the removal of parking on the east side of the street, and widening by approximately 7 feet to allow for the construction of the transit alignment. Because the single track would carry transit vehicles in both directions, it would have to be separated from street traffic by a small median island. The southerly portion of the alignment would pass by the new roundabout to the south-east, and would require some re-alignment of the sidewalks in this area.

This alternative results in the shortest overall track length, since virtually the entire transit corridor would be served by a single bi-directional track. Passing sidings would be strategically located to allow opposing vehicles the ability to pass. By removing the transit traffic from the street traffic, this alternative provides the best and most reliable overall travel time in the corridor. However, this alternative also provides the least flexibility in terms of scheduling, as the distance between passing sidings ultimately controls the schedule. It also has an impact on most of the trees located on the east side of University Place. At just over 45 million dollars, it is the least expensive option for providing transit service to Nassau Street.

As shown on the accompanying concept plans, this alignment would return to the existing Dinky right-of-way immediately north of the new transit station at Princeton.

Alternate E provides a dual track operation within the street, so transit vehicles co-occupy the street with normal mixed traffic. This alternative allows parking on the east side of University Place, although a widening of approximately 5 feet is necessary to accommodate both transit vehicles and parking.

This alternative, which passes through the roundabout within the roadway footprint, provides a single track in each direction through the corridor. Through the use of traffic signal pre-emption and priority signal control, it is possible to have the transit vehicles proceed through the area and delays from the ambient traffic can be minimized. Since the vehicles can pass each other without the use of a passing siding, great flexibility in scheduling and headway is possible. Select trees on the east side of University Place can be saved by eliminating some of the parking spaces, although many of the trees will have to be removed.

The initial concept for Alternative E included returning to the Dinky right of way immediately north of the new Princeton station. However, two additional options evolved from this alternative.

Alternative E1 follows the same two-track alignment north to Nassau Street, but leaves the Dinky right-of-way at Faculty Road and travels on Alexander Street to the roundabout, where it turns onto University Place. This alternative also provides two single-direction tracks on Alexander Street, with additional stations at appropriate locations to serve businesses, residents and students.

Alternative E2 follows the same path to Nassau Street, but extends the double track section along Alexander Street to the Metro North restaurant, where it crosses to the right-of-way. This option provides the greatest usage of the streets for the track alignment, and may have additional benefits in attracting ridership. It also has the largest amount of new track (and consequently uses the least amount of existing trackage) and is the most expensive, overall.

It is noted that the extension of the route down Alexander Street is not possible if alternate F is chosen since the in-street running on Alexander Street requires the installation of two tracks. It would be possible to construct a hybrid between E and F, where two tracks were installed on Alexander Street and combined to single track bi-directional operation on University Place.

Alternative	Description	Details					Impacts		
		Widen	Road	Parking	Track	Track Dir.	Positive	Neutral	Negative
A	**2 Track, in-street operation No Parking, No Widening 1 Lane each way**	NO	2 - Way	NO	In Street	2 - Tracks	No Widening No Track on Alexander	2 Way University Place In-Street Running	No Parking Mixed Traffic 2 Tracks (cost) Restricts stops Limits bicycles potential
B	**Single Track, One-Way In-Street Operation (Return on Alexander) No Parking No Widening 2 lanes (one-way)**	NO	1 - Way	NO	In Street	1 - Way Track	No Widening Vehicle Capacity	In-Street Running	No Parking Track on Alexander Mixed Traffic 2 Tracks (cost) Limits bicycles potential
C	**Single Track, Bi-Directional Separate ROW Operation No Parking No Widening 1 lane (one-way)**	NO	1 - Way	NO	Excl ROW	Bi-Dir Track	No Widening No Track on Alexander Exclusive ROW Reduced Cost		No Parking Off-Road Alignment Restricted Veh. Width
D	**Single Track, One-Way In-Street Operation (Return on Alexander) Parking Allowed No Widening 1 lane (one-way)**	NO	1 - Way	YES	In Street	1 - Way Track	No Widening Maintain Parking	In-Street Running	Track on Alexander Mixed Traffic 2 Tracks (cost) Limits bicycles potential Restricted Veh. Width
E	**2 Track In-Street Operation Parking Allowed Widening Required 1 Lane each way**	YES	2 - Way	YES	In Street	2 - Tracks	No Track on Alexander Maintain Parking	2 Way University Place In-Street Running	Widening Required Mixed Traffic 2 Tracks (cost) Limits bicycles potential
F	**Single Track, Bi-directional Separate ROW Operation No Parking Widening Required 1 lane each way**	YES	2 - Way	NO	Excl. ROW	Bi-Dir Track	No Track on Alexander Exclusive ROW Reduced Cost	2 Way University Place	Widening Required No Parking Off-road alignment

Princeton Transit Study

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July 15, 2014

Service Operations

Initially, a tentative operating schedule was determined based on the original study goal of meeting every train at Princeton Junction. Generally, this was assumed to mean that the Princeton car had to arrive before the arrival of a northbound NJT train to allow Princeton passengers to board that train toward New York. It also meant that vehicles departing Princeton Junction toward Princeton would leave after the arrival of a southbound NJT train, giving time for passengers to transfer to the vehicle to Princeton. Service between Princeton and Princeton Junction was specifically related to meeting trains; the number of passengers entering or exiting the system at Princeton Junction (and using the Dinky service) was considered negligible.

The operating schedule was formulated on the basis of Alignment F and known running times for the existing Dinky service. This is representative of any of the potential alignments, although some minor scheduling adjustments would be necessary if a different alignment was chosen.

Presently, the Dinky has a 5 minute run from Princeton Junction to Princeton. The run time of the new service is expected to be very similar. Measurements of the distance and street operating speeds between Princeton and Nassau Street suggest that a 4 minute run time should be achievable for this portion of the trip. In general, it was the goal of this exercise to have approximately 15 minute headways between trains. In order to maintain this headway, some trains shuttled between Princeton and Nassau Street if there was no train to meet at Princeton Junction.

The present Dinky service is generally twice per hour from 5 AM until the last train departs at 1:30 AM. There is no service between 1:30 AM and 5 AM. Not all NJT trains are met, but service is frequent enough that long waits are generally not an issue.

The proposed schedule, being driven by NJT arrivals at Princeton Junction, has infrequent service (six trains in total) between midnight and 5 AM. Service frequency increases rapidly (to approximately 10 minute headways) through the morning commuting period, then relaxes to 15 to 20 minute headways throughout the day. Evening commuter periods show increases in frequency to 10 minute headways, and then service frequency decreases through the late evening hours until midnight.

On this basis, trains were scheduled throughout the day to depart from Nassau Street to meet the Princeton Junction schedule for arriving and departing trains. The schedule was able to accommodate every NJT train, except 2, throughout the entire day. In order to provide this schedule, it was determined that three trains would be in operation during peak times, two trains would be needed in off-peak times, and a single train would be in service from 10 PM to 5 AM. Including one spare vehicle to accommodate repairs and servicing, a total of four vehicles would be necessary to accommodate this schedule.

Alternatively, it was determined that if the service was provided on a regular basis without the need to meet specific arriving or departing trains, that two vehicles could provide an average 15 minute headway throughout the day. Again, assuming that one additional vehicle was necessary to accommodate repairs and service, three vehicles would be required.

The estimate was prepared on the basis of three vehicles. The schedules are included in Appendix 2 of this report.

5. Ridership Analysis

DEMAND PROJECTION METHODOLOGY

Changes to Existing Ridership

The first component of the demand projection is to determine how many existing riders would continue using the service if changes to the existing Princeton Branch (Dinky) alignment and stops are implemented.

The starting data set is the average weekday ridership of the Dinky provided by New Jersey Transit (2,020 riders, averaging 1,010 in each direction).

From this base number, the number of riders who would be anticipated to no longer ride due to the following factors is subtracted:

- **Longer travel time due to route alignment:** Current travel time on the Dinky is 5 minutes end to end in each direction. The proposed new route would have a travel time of 8 minutes westbound and 5 minutes eastbound (three more and no change, respectively) to the new Princeton station[4]. The slight additional westbound travel time is unlikely to deter existing riders if the line becomes a different form of transit service, so no reduction of ridership is projected.
- **Perception of commuter rail versus alternative transit mode:** The perception of a streetcar versus a commuter rail vehicle may affect rider habits if the riders perceive streetcar service negatively compared to heavy rail. This may cause a reduction in riders. After a review of existing research no studies have shown there is any preference of mode between commuter rail and streetcar without significant changes in travel time or over longer distances than the

Travel Time Change
Westbound: 3 minutes
Eastbound: No change

Street Alternative =
No Change in Ridership

BRT Alternative
17% Decrease in Riders = 343 fewer Riders

[4] The full travel time between Princeton Junction and Nassau Street is estimated to be between 11 - 13 minutes depending on the peak/off peak period (11 -12 min eastbound, 13 minutes westbound).

proposed three mile route.[5]

Existing Average
Weekday Ridership
2,020 Riders

In comparison, Bus Rapid Transit (BRT) has been shown to underperform in achieving expected ridership gains compared to Light Rail Transit (LRT).[6] However, the research comparing LRT and RT generally fails to take into account a consistent level of service for both modes. After assuming the same increase in service levels, it has been shown that ridership increases are strongest for rail services over bus (27% for rail compared to 10% for bus services given the same 20% increase in vehicle revenue hours).[7] This potential 17% decrease in riders, would result in 343 fewer weekday riders, assuming a loss of riders from the perception of BRT, even if a new BRT service maintained a similar frequency of service compared to current rail options.

New Ridership

The second component of the ridership projection is to estimate how many new riders would come to the service if certain changes are implemented. Current proposals include adding stops to the corridor and extending the line to Nassau Street, both which offer new options to attract new riders. Additionally, new development has been approved near the current Princeton Branch terminus which would generate additional riders regardless of whether the current service or a revised service is in operation.

There are three major categories that new riders fall into: those who will be connecting at Princeton Junction for other rail services, those who will be riding locally within the existing corridor, and new riders as a result of development. A summary of each is provided below.

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[5] Literature Review

Chen, P. and Naylor, G. (2011). "Development of a Mode Choice Model for Bus Rapid Transit in Santa Clara County, California." *Journal of Public Transportation.* http://www.nctr.usf.edu/wp-content/uploads/2011/10/JPT14.3Chen-.pdf

Currie, G. (18-19 June 2009). "Research Perspectives on the Merits of Light Rail vs Bus." http://www.infrastructureaustralia.gov.au/publications/files/lightrailvsbus.pdf

Currie, G. (2005). "Demand Performance of BRT." *Journal of Public Transportation*. http://nctr.usf.edu/jpt/pdf/JPT%208-1%20Currie.pdf

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Tennyson, E. (1989). "Impact on Transit Patronage of Cessation or Inauguration of Rail Service." *Transportation Research Record.* http://www.heritagetrolley.org/articleTennyson.htm

[6]Dobbs, D. and Henry, L. (2012).
"Comparative examination of New Start light rail transit, light railway, and bus rapid transit services opened from 2000." http://onlinepubs.trb.org/onlinepubs/conferences/2012/LRT/LHenry.pdf

[7] http://www.thetransportpolitic.com/2014/03/03/recent-trends-in-bus-and-rail-ridership/

New Riders Connecting to Rail Service at Princeton Junction

Adding stops and changing the route's alignment may add additional riders who are travelling to and from the Northeast Corridor. New riders can be categorized as follows:

> *Non-local Workers within Walking Distance of Nassau Stop*
> *1,089*
> *X*
> *12.8% Transit Mode Share*
> *=*
> *New Commuters Connecting to Princeton Junction*
> *140*

- **New Riders on an Extension to Nassau Street**: Extending the service to Nassau Street would bring the service closer to the center of the commercial heart of Princeton. The number of new riders is dependent on the accessibility to the stops on the Nassau Street extension. Using the American Community Survey's 5-year Estimates for 2008 to 2012[8] the number of workers within walking distance (1/2 mile) to the new stop was calculated at 1,175. The Census' Longitudinal Employer-Household Dynamics research shows that 92.7% of 1,175 workers living within walking distance of the new stops travel to work outside of the corridor (1,089 workers); see Figure 11.[9] Assuming transit ridership is consistent with the existing transit mode share of the corridor (12.82%), the extension would connect 140 new employment-based riders to Princeton Junction.
- **New Riders from New Stops on Corridor Extension**: Additional stops between Princeton Station and Nassau Street are unlikely to have an impact on new ridership since the stations are within ½-mile of each other. The walkable area of a station between Nassau Street and Princeton Stations coincides with the areas analyzed for new riders connecting to Princeton Junction, so no individual stop passenger increases are projected.
- **Bus Connections**: Extending the line to Nassau Street may allow for a truncation of local bus services, shifting ridership heading to Princeton Junction to the new Princeton service. Currently all bus services that serve the new Nassau Street station also serve the existing Dinky Line, so no new ridership has been projected (see Figure 12).

New Riders Using the Service within the Corridor

The existing service operates without intermediate stops, and primarily acts as a feeder service to the Northeast Corridor. Adding additional stops would allow for riders to use the service locally within the

[8] US Census. American Community Survey. 2012 ACS 5-year Estimates dataset used for analysis. Analysis area at the Census Tract level. http://factfinder2.census.gov/bkmk/navigation/1.0/en/d_program:ACS

[9] LEHD 2011 Workforce Indicators of Inflow and Outflow of Workers in the study area was found using the OnTheMap tool at http://lehd.ces.census.gov/

corridor. The number of new riders projected to use the service locally would be dependent on the following:

- **Transfer Opportunities:** If there are transfer opportunities to local bus lines, there may be an increase in ridership. As described above, there are no additional routes that would connect people to the new stations. The only existing route (NJ Transit 606 to Hamilton Marketplace) could offer additional transit ridership, but since it already connects to Hamilton Station, no additional transit ridership was assumed.
- **Journey-to-Work Trips:** The introduction of additional stops may allow for passengers who are traveling locally for non-work-related (leisure) purposes. Out of the 1,175 residents who commute to work, 7.3% commute within the corridor, equaling 86 residents working within the corridor.[10] Of these 86, 11 are likely to use transit to commute to work given the existing 12.8% transit mode share of commuters.

[10] US Census. 2012 ACS 5-year Estimates. Dataset ID: B08101. Means of Transportation to Work by Age. Geography: All Census Tracts in New Jersey.

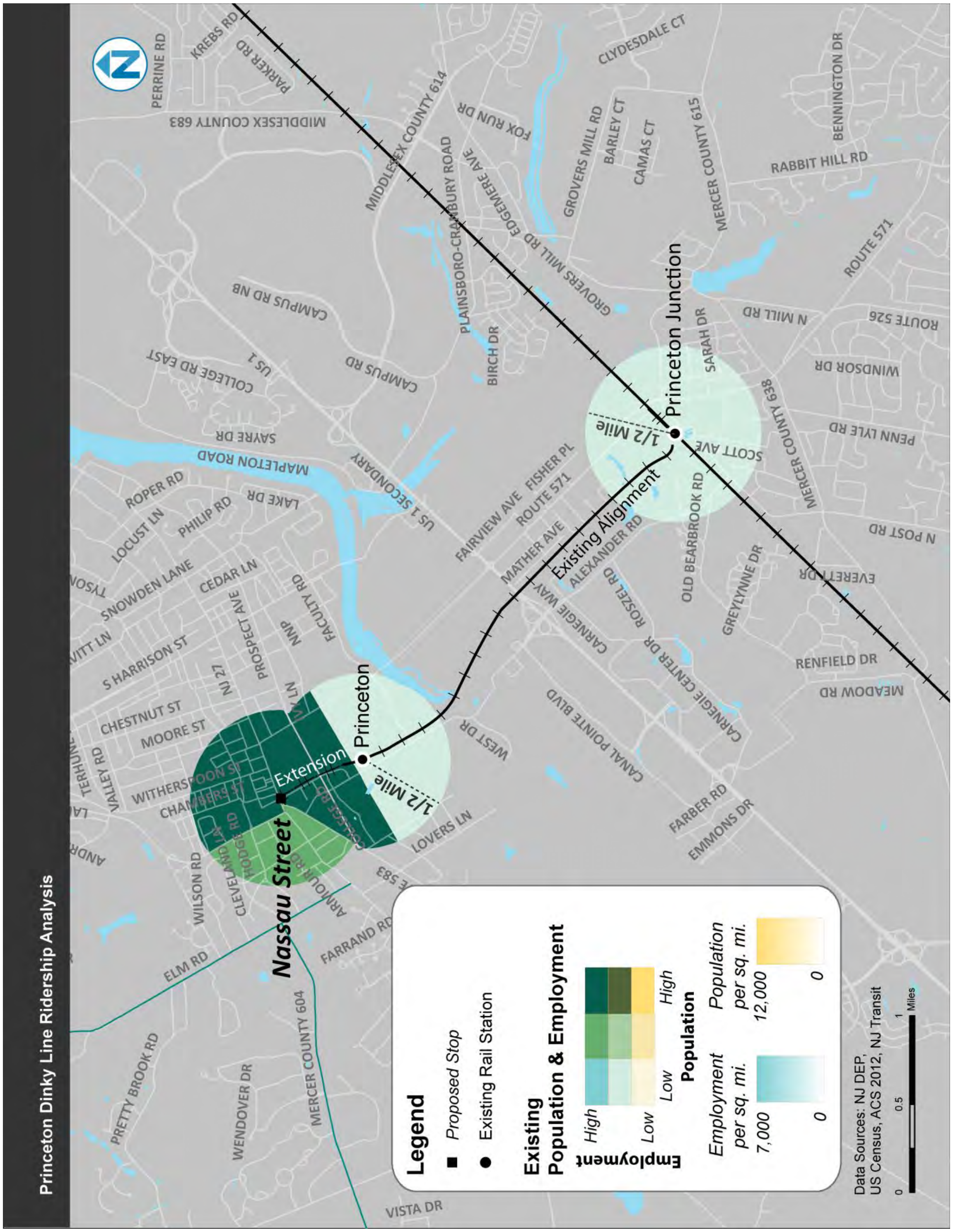


Figure 11: Existing Population and Employment Density

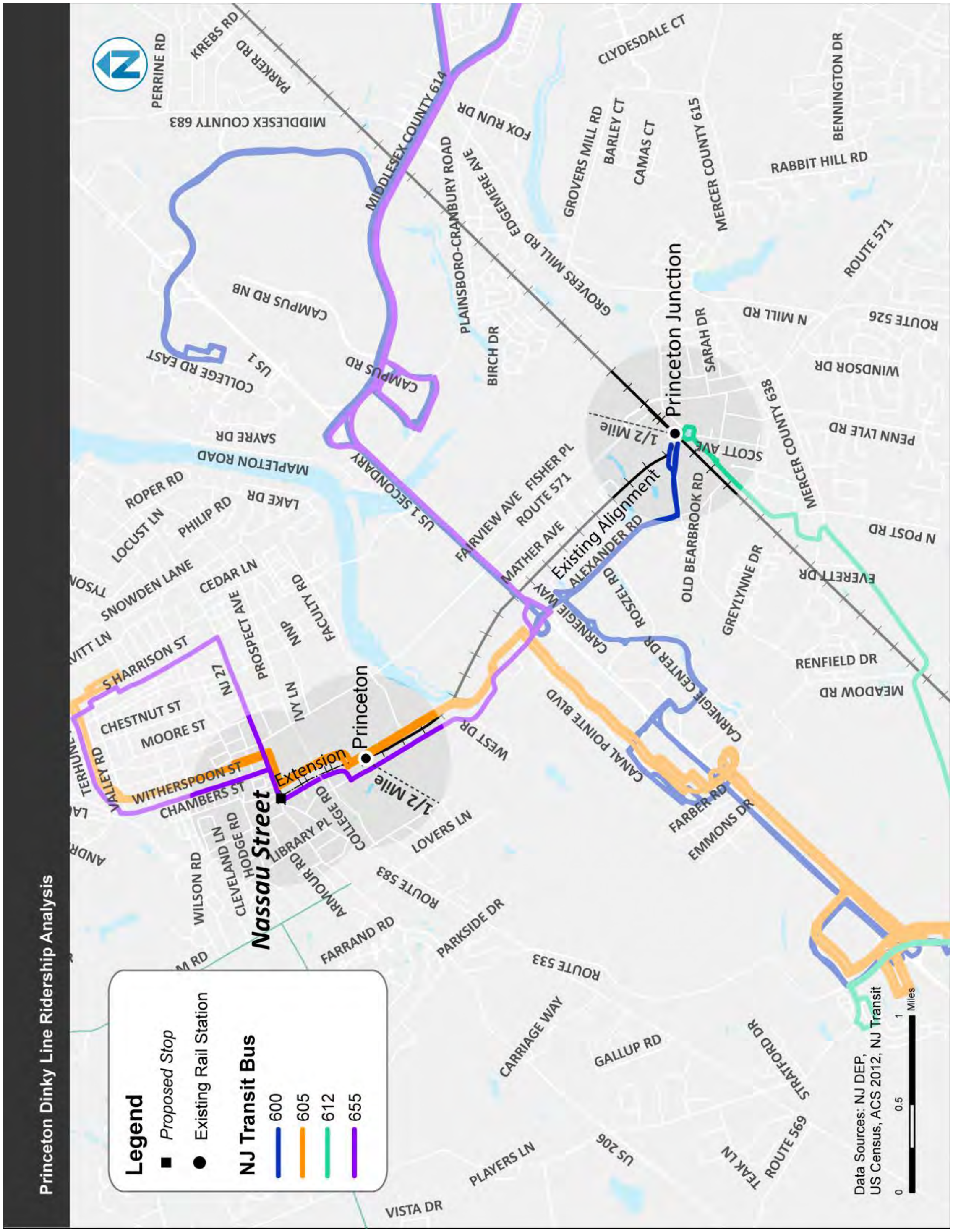


Figure 12: Existing Area Bus Route

Non- Journey-to-Work Trips: Ridership rates observed in New Jersey[11] and Chicago[12] show that between 44 to 49 percent of transit ridership is for non-work trips. Assuming the transit mode share for the 1,461 non-working residents within walking distance of new station is consistent with transit use amongst commuters (12.8% mode share), 187 residents would be attracted to new transit services. If a share of this ridership for non-work trips is consistent with observed trends in New Jersey (44% of trips are non-work trips), the mode share is reduced to 5.63% of residents and an estimated 82 new riders will use the system as a result of expanded service.

Local Workers: 86
X
12.8% Transit Mode Share
=
Within Corridor Commuters
11

Local Residents: 1,461
X
5.63% Resident Non-Work Trip Transit Mode Share
=
Within Corridor Local Riders (non-work trips)
82

- **Bicycle Infrastructure:** The expansion of the transit demand shed would also include 3 miles along bike paths providing access to the new transit line. A 2007 survey of Dinky line riders found that 5% connected to the train via bicycle.[13] Assuming these riders are commuters who are connecting to rail services to travel outside of the corridor, new commuters may similarly chose to connect by bicycle with the extension of new service. A three mile radius around bicycle lanes in Princeton, east of the existing station along Elm Road and Rosedale Road, excluding existing station areas, was assessed for potential ridership (see Figure 13). Of the 5,515 workers within cycling distance, 89.4% travel to work outside of the corridor. Assuming a similar transit mode share potential of 12.8%, comparable to existing, but modified to only include 5% that are likely to arrive by bicycle in this expanded service area, 32 new riders are expected to connect by bicycle.

Non-local Workers within Biking Distance
4,930
X
12.8% Transit Mode Share
X
5% Commuters Cycling to Stations
=
New Commuters likely to cycle and ride transit
32

[11] New Jersey Future. (2012). "Targeting Transit: Assessing Development Opportunities Around New Jersey Transit Stations." http://www.njfuture.org/wp-content/uploads/2012/09/Targeting-Transit-New-Jersey-Future.pdf

[12] Florida Department of Transportation. (2008). "Transit Ridership, Reliability, and Retention." *National Center for Transit Research: Center for Urban Transportation Research*. http://www.nctr.usf.edu/pdf/77607.pdf

[13] Chance Management Survey 2007

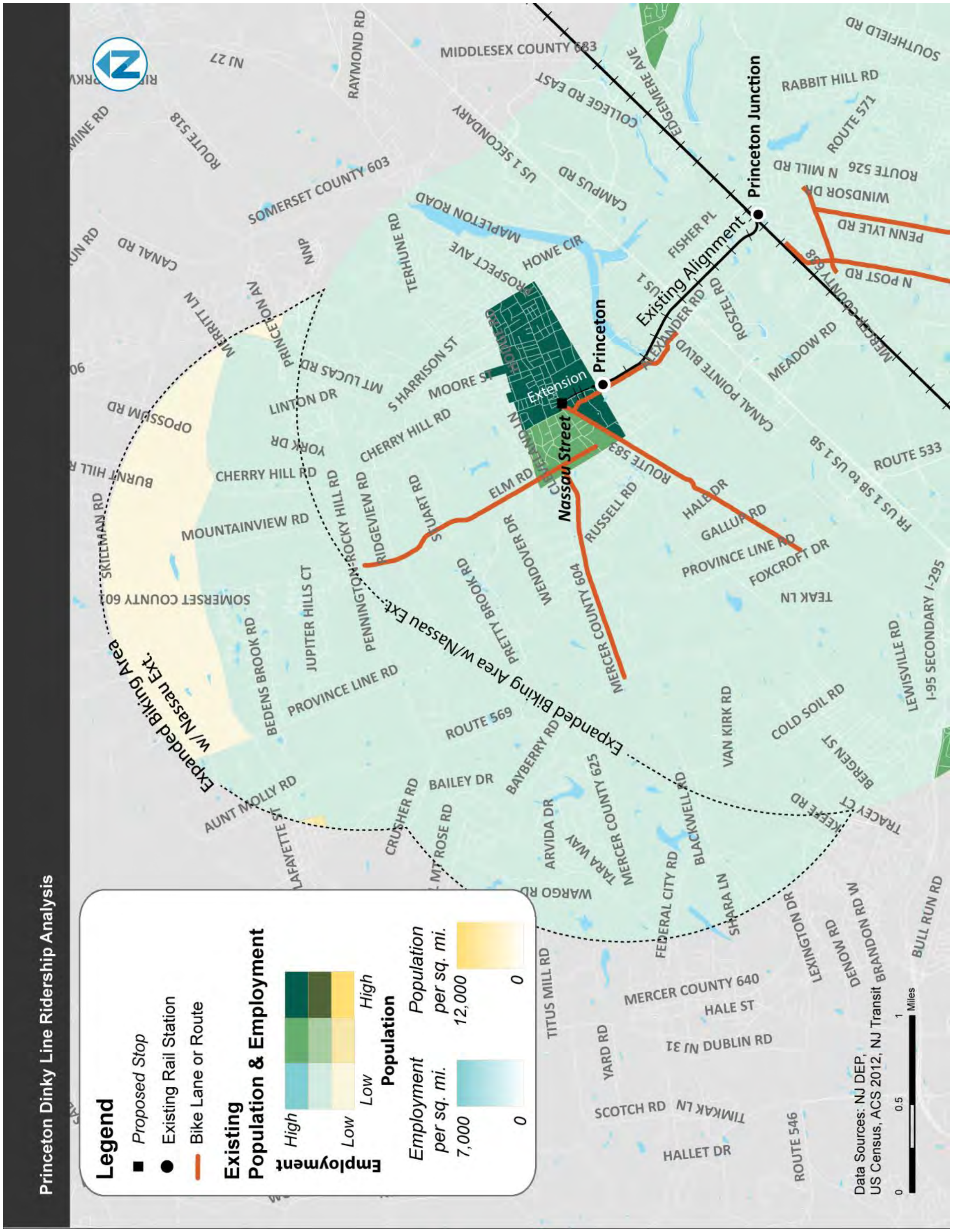


Figure 13: Existing Area Bicycle Facilities

Already-Proposed New Development

Development near the corridor is anticipated to generate additional ridership (Table 5). Currently, new development is already approved near the existing Princeton Branch terminus. By 2027 an additional 61,000 sq. feet of office space and 21,000 sq. feet of retail within a ¼ mile of Princeton Junction will attract an estimated 345 new workers. Of these new workers 25 are likely to live and work within the corridor (7.3% local commuters).7 Assuming the transit mode share for commuters is consistent with the existing area (12.8%) the new employment will contribute 3 new commuters to the line. The addition of 1,452 dwelling units within ½ mile of the proposed stations will increase the residential population by 2,869. Assuming a transit mode share for new residents is consistent with transit use among commuters, at 12.8%, and reducing this ridership rate by the non-work ridership factor above (44%), 5.63% of residents are likely to commute by transit for non-work related trips. Based on the 5.63% non-work trip transit mode share an estimated 162 new riders will use the system as a result of new residential development. This does not include any development that will happen as a result of service.

Planned New Developments

Additional Employees: 345
X
7.3% Local Commuters
X
12.8% Transit Mode Share
=
New Local Commuters
3

Additional Residents: 1,452
X
5.63% Resident Non-Work Trip Transit Mode Share
=
New Riders (not work related)
162

Table 5: New Developments

Station Area	Development Name	Additional Retail	New Retail Employees (529 sq.ft./employee)	Additional Office	New Office Employees (200 sq. ft./employee)	Local Commuter Transit Mode Share[14]	**New Local Commuters**	Additional Dwelling Units	Persons per Dwelling Unit[15]	Resident Non-Work Trip Transit Mode Share	**New Non-Work Related Riders**
Princeton Junction	West Windsor (w/o Samoff)	21,000 sq. ft.	40	61,000 sq. ft.	305	0.93%	**3**	490	2.49	5.63%	**69**
Princeton Station	Lakeside	-	-	-	-		**-**	329	1.00	5.63%	**19**
Nassau Street	Hullfish North	-	-	-	-		**-**	97	2.49	5.63%	**14**
Nassau Street	YMCA/YWCA	-	-	-	-		**-**	84	2.49	5.63%	**11**
Nassau Street	Merwick Stanworth	-	-	-	-		**-**	172	1.00	5.63%	**10**
Nassau Street	University Medical Center	-	-	-	-		**-**	280	2.49	5.63%	**39**
TOTAL		*21,000 sq. ft.*	*40*	*61,000 sq. ft.*	*305*		***3***	*1,452*			***162***

[14] 7.3% Local commuters within the corridor x 12.8% Transit Mode Share = 0.93% Local Commuter Transit Mode Share

[15] Lakeside and Merwick Stanworth are Princeton University Residential Facilities for graduate students and faculty, respectively. Free Princeton University transit services are provided to students and faculty (making them unlikely to use any new transit service) but not their spouses or children. A conservative estimate of one non-university resident per dwelling unit was assumed.

Summary

A sum of new riders from all of the previously mentioned categories will give a total estimate on new riders to the service.

Existing Weekday Average Ridership: 2,020 riders (averaging 1,010 in each direction)

LRT Alternative to Nassau Street: New Riders

- New commuters to Princeton Junction (non-local workers): 140
- Within Corridor Commuters: 11
- Within Corridor Riders (not work related): 82
- Cycle and Ride Commuters with Expanded Biking Distance: 32
- New Local Commuters with New Development: 3
- New Local Riders with New Development (not work related): 162

New Weekday Riders: 430 (averaging 215 in each direction)

Average Weekday Ridership Estimate: 2,450 riders (21% ridership increase)

Bus Rapid Transit Alternative to Nassau Street: New Riders

- Possible Reduction with BRT Alternative: 343 riders

Net Additional Weekday Riders: 430 riders – 343 riders = 87 riders (averaging 43.5 in each direction)

Average Weekday Ridership Estimate: 2,107 riders (4% ridership increase)

6. Cost Estimate

A capital cost estimate was developed for the Princeton Transit Study based on the findings of the identification of alignment options. Costs for similar projects in other cities, including Charlotte, North Carolina and Baltimore, Maryland were used to formulate unit costs for this project. Costs were inflated to reflect the anticipated 2016 design year, and an allocated contingency was applied to determine the final unit cost for each item. A 15% unallocated contingency was also applied to the subtotal to reflect the conceptual level of accuracy appropriate for this stage of the study.

The following general assumptions were made in determining the unit prices incorporated into this estimate:

- Guideway and Track Elements - This section includes the track and guideway elements necessary to complete the route, such as embedded rail, track slab, turnouts and frogs. Excavation and construction related to the track installation is included in this section. The track presently installed on the Dinky Right-of-Way is anticipated to be reused for the future service. An additional siding is proposed at the Princeton Junction station and at the Princeton Station.

- Support Facilities: Yards, Shops, and Administrative Buildings - the Maintenance and Storage Facility was assumed to be modest in size and scale related to the small number of vehicles being maintained. The structure would house typical streetcar maintenance operations, including a wash facility and bays to perform repairs and maintenance. Additional track and turnouts related to the non-paved Right-of-Way (such as a lay-over track at Princeton and Princeton Junction) is included in this section of the estimate, as well. The facility is described in more detail, below.

- Site work and Special Conditions – In general, minor impact on utilities is anticipated along this route. Some adjustments to stormwater systems and streetlights are anticipated to accommodate the alignment and proposed widening. Some reconstruction of curb and sidewalk is also anticipated, as shown on the concept plans for each alternative.

- Systems - Systems costs include all Traction Power Electrical work, Overhead Catenary System (OCS), and Electronics associated with operation of the streetcar. It has been assumed that the existing catenary on the Dinky right-of-way will be maintained for use by this system, and that battery hybrid power systems will be installed on the cars to allow wireless operation in the street sections. A section of “recharging” catenary has been included at the Nassau Street station. A system-wide signal system for the streetcar was included at a base cost (before adjustment) of $2.5 million, which is appropriate for the complexity of a signal system used for light rail/streetcar. Existing traffic signals along the route will be replaced or modified, as necessary to provide safe operation and priority clearances.

A typical fenced-in traction power substation can operate approximately one mile of dual track. Two substations will be required for any of these options. Each traction power substation is an approximately 30’ x 10’ prefabricated aboveground structure that is in a secure enclosure. This estimate assumes that the overhead catenary presently in place over the Dinky will be re-used for the new service.

Typical costs for a communication system and off-board fare collection system have also been included.

- Right-of-Way - Land purchase requirements are anticipated to be minimal. If the alignment is chosen that includes the crossing from the right-of-way to Faculty Road (Alternative E1), some rights may be necessary to accommodate the track alignment.

- Vehicles - Modern streetcar vehicles used in comparable cities cost approximately $4 million per car. A typical inventory of spare parts was selected to be purchased for the maintenance facility, as well. Using the proposed battery operation in the on-street sections adds approximately $500,000 premium per vehicle for the battery technology, and for the charging stations that will be required.

- Professional Services - Continuing project development engineering and professional services were incorporated into the estimate in accordance with the following schedule, as a percentage of construction costs:

    - Preliminary Engineering 2%
    - Final Design 6%
    - Project Management for Design and Construction 4%
    - Construction Administration & Management 5%
    - Professional Liability and other Non-Construction Insurance 2%
    - Legal; Permits; Review Fees by other agencies, cities, etc. 2%
    - Surveys, Testing, Investigation, Inspection 2%
    - Start up 2%

Maintenance Facilities / Power Distribution

Streetcar systems require a storage and maintenance facility, or 'car barns' for servicing and storing the vehicle fleet, administering the system operations, and supporting employees. The car barn typically accommodates vehicle storage, cleaning, and maintenance, equipment maintenance, materials storage, operations management and supervision, dispatching, emergency-response communications equipment and supplies, secure parking for nonrevenue vehicles, and employee locker rooms. In addition, due to streetcar systems' historic appeal, maintenance activities may be of interest to the general public. Maintenance shops can be sectioned off with glass to provide a controlled environment for active display of the work activity.

Although these are separate functional areas, for economy of space, the facilities can be constructed as separate portions of a single structure. Moreover, additional space should ideally be provided to allow for system expansion. However, land can be in short supply, particularly in urban areas. Similarly, financial constraints can restrict initial facility size.

Figure 14 –Typical Maintenance Facilities

The storage and maintenance facility should be located within close proximity to the streetcar route and outfitted to maintain the streetcar fleet, both now and in the future. The facility should be sized for a minimal, but adequate, maintenance regimen and consist of equipment that is typically required for continuous routine maintenance. For example, removing or replacing motors, removing wheels for re-truing offsite, performing routine repairs, and cleaning and washing streetcar vehicles.

Based on standard transportation planning of similar transit modes, the footprint for the entire facility is typically 75 feet wide by 150 feet long, to provide space for the total number of vehicles. One track should have a dual structured pit for maintenance repairs to be performed underneath the chassis. This dual structured pit should include a gauge pit, roughly four feet wide between the rails and an open pit, at least twelve feet wide with the streetcar vehicle supported on posts. In addition, the pit track should be long enough to provide walkways for employees to access the pit from both ends with two cars in place. The adjacent tracks could be utilized for internal repairs, cleaning, and washing the cars, as well as covered storage, providing adequate room for safety and car cleaning activity.

Rolling Stock / Schedule

As noted elsewhere in this report, a tentative operating schedule was determined based on the original study goal that included meeting every train at Princeton Junction. On this basis, it was determined that 3 trains would have to be in operation during peak times. Including one spare vehicle to accommodate repairs and servicing, a total of four vehicles would be necessary to accommodate this schedule.

Alternatively, it was determined that if 15 minute headway service was provided, two vehicles would be necessary for service, and an additional "spare would indicate that purchasing three vehicles would be required.

The estimate was prepared on the basis of three vehicles. The schedules are included in Appendix 2 of this report.

Summary

Cost estimates for the four final alternatives (Alternatives F, E, E1 and E2 - described in detail elsewhere in this report) were computed based on the above listed parameters. The complete breakdown of costs is included in Appendix 3 and the results are summarized as follows in Table 6:

Summary of Costs						
Alternative	Configuration	Leaves Dinky ROW at:	New Track Miles	Total Track-miles	Cost (Millions)	Cost per Total Track-Mile ($ Million per track-mile)
F	Single Track – Separate ROW	Princeton Station	0.5	3.3	$45	13.7
E	Dual Track In-Street	Princeton Station	1.1	3.9	$50	12.8
E-1	Dual Track In-Street	Faculty Road	1.6	4.4	$57	13.0
E-2	Dual Track In-Street	MetroNorth Restaurant	2.2	5.0	$63	12.6

Table 6: Summary of Costs

Based on these calculations, the total cost for the streetcar system is between 45 and 65 million dollars, or approximately $13 million dollars per total mile of track. For comparison purposes, the following Table provides the actual costs of other similar systems. The relatively low cost of the Princeton system (regardless of the alternative chosen) is due to the usage of a significant amount of existing infrastructure in the trackage and overhead catenary system of the Dinky, which can be re-used without significant expenditures. Remaining costs are related to the actual needs of the extended system, additional stations, rolling stock, and the significant cost of a maintenance facility for this relatively small number of vehicles. Table 7 below shows capital costs for similar systems in the U.S.

Capital Costs for Similar Systems

CITY	CAPITAL COSTS PER TRACK MILE (MILLIONS)	YEAR*
Portland	$13	2001
Portland Streetcar Loop Project	$22	2010
Seattle	$20	2007
Tampa	$20	2002

Source: Case Studies Report
*in 2010 dollars, Portland is $16 million; Seattle is $21 million; and Tampa is $24 million using Consumer Price Index to adjust for inflation.

Table 7: Capital Costs for Similar Systems

Operating Cost of Streetcar/LRT from Princeton Junction to Nassau Street

Operating cost is driven by the number of revenue hours of service, and can be estimated by applying a unit operating cost per vehicle hour to the quantity of service proposed. Within the NJT system, the operating expense for vehicle revenue hour for a bus is $149 and for commuter rail is $512 per vehicle hour (Source: 2013 National Transit Database, Federal Transit Administration). Table 8 below denotes reported operating costs per vehicle revenue hour for streetcar operations in select cities across the United States. Modern streetcar operating costs tend to be close to bus operating costs.

Using the actual costs of $149/hour for an NJT bus vehicle revenue hour, an annual operating cost of approximately of $1,740,320 can be projected for a streetcar operating every 15 minutes from Princeton Junction to Nassau Street. This is based on two vehicles in service an average of 16 hours per day on a year round basis (365 days).

State	Provider	Cost per hr	Cost per Mile
AR	Central Arkansas Transit Authority(CATA)	$91.10	$20.49
CA	San Francisco Municipal Railway(MUNI)	$156.06	$27.15
FL	Hillsborough Area Regional Transit Authority(HART)	$114.36	$21.25
LA	New Orleans Regional Transit Authority(NORTA)	$164.91	$27.70
OR	City of Portland(PBOT)	$228.33	$37.95
PA	Southeastern Pennsylvania Transportation Authority(SEPTA)	$170.76	$19.38
TN	Memphis Area Transit Authority(MATA)	$105.43	$14.34
TX	McKinney Avenue Transit Authority(MATA)	$79.52	$14.20
WA	Central Puget Sound Regional Transit Authority(ST)	$431.46	$55.84
WA	King County Department of Transportation - Metro Transit Division(King County Metro)	$259.55	$48.84
WI	Kenosha Transit(KT)	$124.81	$17.34

Source: 2013 National Transit Database, Federal Transit Administration

Table 8: Operating Costs for Streetcar Systems in the U. S.

Appendix 1

OVERVIEW OF TRANSIT VEHICLES IN USE OR UNDER CONSIDERATION FOR NORTH AMERICA

Types of Vehicles

The North American transit market includes a broad range of technologies operating to serve the riding public. However, in identifying the range of technology systems that can satisfy the need of the area and also promote harmony within the existing and future land uses, it is important to carefully examine the unique characteristics of Princeton such as types of users, type of trips, ridership demand, traffic congestion, existing transportation systems, and characteristics unique to college communities.

The corridor between Princeton Junction and Nassau Street is a unique urban corridor with land uses and development densities that generate varying travel demands throughout the day. Since this corridor serves Princeton University it is a college-oriented area with the majority of the trips beginning and ending at Princeton University. Although trips include a variety of users the majority are associated with the university. The end user of the new Dinky will be largely students, faculty and staff and those associated with Princeton University.

Multiple technologies exist in the mass transit industry. These range from common diesel buses, which have operated for the majority of the century, to highly sophisticated rail systems. In consulting with the Princeton Transit and Traffic Task Force, the study team identified three broad categories of technology: Bus, and Rail, and Personal Rapid Transit. Bus systems have the flexibility of utilizing existing street infrastructure, whereas rail systems require a specific dedicated location for the fixed guideway. Within each of these categories are a broad spectrum of vehicles and operating systems.

BUS TECHNOLOGY

Transit buses have a long history in the United States, and today transit buses account for more than half of the annual unlinked passenger trips across all modes. It is the most common form of mass transit service provided throughout North America. Transit Bus Technology can be defined as a self-propelled, rubber-tired road vehicle designed to carry a substantial number of passengers, commonly operated on streets and highways in mixed traffic and subject to the inherent constraints of roadway traffic.

In the U.S. new transit bus systems are being implemented that utilize exclusive rights-of-way, alternative fuels for propulsion and new guidance systems. All of these elements have applicability to Princeton. Currently there is growing interest in examining these emerging transit bus technologies as an alternative to the higher cost of fixed-guideway transit systems. Some of the salient features of Transit Bus Technology are:

- Low cost, proven vehicles
- Available for shared or exclusive rights of way
- Approximate per 40’ bus capacity – 85 passengers (~ 35-45seated)
- Headway dependent upon traffic conditions; with exclusive right of way, can be as short as 60 seconds.
- Bus system capacity with typical bus ~ 7,000 pphpd.

The National Transit Database (NTD) of the Federal Transit Administration (FTA) estimates that 5.2 billion passengers used transit buses in the U.S. in 2011, up from 4.8 billion in 1991. This represented nearly 52% of all modes of mass transit ridership in 2011. Transit buses operated a total of 1.9 billion revenue miles in 2011, or 48% of all modes of transit (Revenue miles is the number of miles buses operated in revenue service).

Despite the significant growth of other transit modes (particularly light rail), bus travel is once again garnering attention. The following is an overview of the operational and physical characteristics of the various types of transit buses, and their associated technology, in use or under development, that may have applicability to Princeton and a connector to Princeton Junction

Bus Rapid Transit

Figure 1-1 Typical Station along the new Cleveland Euclid Corridor BRT Project

Bus Rapid Transit, or BRT, is rapidly growing in popularity in the United States due to the advent SAFETEA-LU legislation that funds Small Starts programs. The FTA has promoted BRT installations across the U.S. in response to efforts to improve bus service in the transit industry, and as a lower cost alternative to Light Rail Transit (LRT) systems. New BRT systems are in development or have begun operations in Hartford, CT; San Francisco, CA; Cleveland, OH and Los Angeles, CA, There are current systems operating, planned or about to go into service in 45 cities around the country. The American Planning Association's Transportation Planning Division has defined BRT as "flexible, rubber-tired rapid transit mode that combines stations, vehicles, service, running-ways and Intelligent Transportation Systems (ITS) elements into an integrated system with a strong positive identity and a unique image." It has been compared to light rail transit, but has greater operational flexibility and potentially lower capital and operating costs. The key difference is that BRT can utilize both exclusive rights of way and still operate in mixed city traffic to bring passengers in a one-seat ride to their specific destinations. The primary features[16] of BRT are:

- Dedicated running ways
- Aesthetically designed station
- Efficient Fare Collection
- Accessible, attractive, safe stations
- Intelligent Transportation System applications
- Frequent, all-day service
- Easy-to-Board, environmentally friendly vehicles

The goal of BRT is to improve overall service by reducing bus travel times, increasing bus frequency and reliability, improved accessibility, and developing greater amenities for users.

BRT systems expand upon the provisions of a bus way, and can include prioritization of traffic signals and development of signaling timing for maximum throughput in a given direction at peak traffic periods. BRT can also be designed with automatic wayside fare collection to minimize disruption to the boarding process, thereby increasing average travel speed and therefore improve headway. Buses are now available in configurations that improve accessibility to the disabled with either the entire bus, or portions thereof designed with a low floor and precision docking. This passive design approach is an improvement over earlier “kneeling” buses and buses with active ramps and steps.

A study completed in 2006, by STV Incorporated for NJ Transit performed a Bus Rapid Transit Alternatives Analysis for the central New Jersey route 1 corridor from the City of Trenton to the Township of South Brunswick, which included a connection to Princeton University. Five alternatives were selected for the Dinky corridor, of which two included BRT while the others called for rail. The two BRT alternative included Option 1 to replace the Dinky with a bi-directional bus way and Option 2 running a BRT system adjacent to the Dinky thus retaining the current dinky system and allow buses to make through movements between Lawrence and Southwick. The final recommendation of the study was to shift the Dinky, but to remain in service, and to operate BRT alongside it. This option allowed for future BRT expansion. It was estimated that this project would cost $668.3 million and would carry roughly 43,500 passengers daily. While this system has yet to materialize, New Jersey has implemented BRT systems. In Newark, New Jersey, the Go Bus 25 is operated as BRT along Springfield Avenue and has since expanded to include route 28 from Bloomfield to Newark Liberty International Airport. It was started in 2008 as a 4.8-mile long exclusive lane with service every 15 minutes during peak periods. Go Bus 25 travels between Irvington bus Terminal and Newark Penn Station.

[16] Levinson, Herbert and Zimmerman, Samuel, *"Bus Rapid Transit Planning, Features and Effectiveness,"* in American Planning Association, Transportation Planning Division, Transportation Planning, volume XXIX, number 1, March 2004.

Bus capacity can be increased with utilization of larger articulated buses, and even double-articulated buses with a capacity of over 200 passengers. However, a limitation of buses compared to all other options, is that they cannot be coupled into trains. Buses must be run more frequently than fixed guideway systems to achieve high PPHPD capacity. Available bus technologies that can be used by BRT include conventional diesel, articulated buses, CNG, LNG, fuel cells, hybrid diesel-electric, electric trolley, guided bus technology, and rubber tire fixed guideway systems.

Conventional Diesel Buses

Conventional or standard diesel buses are typically 35 or 40-feet in length. They are the predominant public transit vehicle in use in North America today, and operate extensively in the Princeton - Trenton area. Diesel buses operate on fixed routes and schedules over existing roadways, are designed for frequent stops, and usually have front and center doors. There are three size classes of buses, according to NTD. Class A buses offer more than 35 seats per vehicle; Class B, between 25 and 35 seats; and Class C, fewer than 25 seats (an accepted minimum number of seats is 16). Buses less than 25 feet in length are typically called mini-buses. The standard diesel bus utilizes a diesel-powered internal combustion engine. Most transit diesel buses operate within mixed city traffic, but are also capable of achieving highway speeds of 55 to 65 mph.

One significant issue with operation of conventional diesel buses is that they produce pollutant emissions, including Particulate Matter (PMs) and Nitrogen Oxides (NOx) that can cause a deterioration of air quality in a region. Diesel fuel combustion also produces carbon dioxide, considered a primary contributor to global warming. However, many transit agencies have switched from conventional diesel to ultra-low sulfur diesel (ULSFD) or a biodiesel blend, primarily in response to the 2010 new diesel engine emissions standards required by the Environmental Protection Agency. Princeton University operates a fleet 10, 30-foot El Dorado National EZ Rider IIs that run on B20 Biodiesel. Biodiesel reduces tail pipe emissions for PM, carbon monoxide, and unburned hydrocarbons and causes less damage to the environment if spilled. Drawbacks to biodiesel include higher fuel costs, increased NOx, and vehicle engine warranty issues. As for performance, a Purdue University study shows that there is no difference in vehicle performance and miles per gallon achieved between similar buses running on B20 biodiesel or ULFSD.

Figure 1-2. Princeton University's TigerTransit Bus

A vast improvement to the operation of the conventional diesel bus has resulted from the introduction of low-floor buses. The passage of the Americans with Disabilities Act (ADA) in 1990 prompted the development of low-floor buses, designed to improve bus transit access for the elderly, disabled and mobility-impaired. This was a significant enhancement to earlier conventional diesel buses, in that it not only improved access, but it also improved boarding times. Today almost all conventional transit vehicles are low floor buses with "kneeling" suspensions and step-free access, making it easier to board and eliminating hydraulic wheelchair lifts in favor of mechanically operated ramps. Federal law requires that, if a disabled person cannot board a bus due to lift malfunction and there is not another bus on the same route within 30 minutes then an alternative must be provided by the transit agency. Wheelchair-lift equipment on transit buses has led to significant increases in bus transit usage by wheelchair bound persons. New York City Transit, for example, experienced a 67 % increase in wheelchair bound passengers in the three years following their installation (1996-99). Since low-floor vehicles are generally 12-14 inches from the pavement, when they are at or near full capacity, issues arise with overhang when pulling into a bus bay or bottoming out on certain turns due to the geometry and grade of the roadway.

Transit signal priority and automatic vehicle location systems have also significantly improved transit bus operations. These technologies are described in more detail below.

Princeton University's TigerTransit 30' El Dorado National EZ Rider IIs bus equipped with low floors, flip-out ramps and GPS tracking software

Articulated Buses

Figure 1-3 Toronto Transit Commission's new articulated Nova Bus

Articulated buses are defined as buses, usually 55-60 feet in length, with two permanently connected passenger compartments that bend at the connecting point when the bus turns a corner. The driver sits in the front or forward section and the rear or trailer section is connected by an "articulation" joint covered by an "accordion-like" passageway between sections. Passengers move freely between the two sections (full interior passenger circulation). The primary advantage of the articulated bus is the ability to carry additional passengers (approximately 120 seated and standing) along regular bus routes with the ability to navigate tight turns and short blocks. Articulated buses can also achieve speeds capable of operating along highway routes (55-65mph). As with conventional buses, they can operate in mixed city traffic, along urban roadways, HOV lanes and on dedicated bus lanes.

Articulated buses are used by many transit agencies across the U.S., particularly those experiencing heavy passenger loadings. They are available in high and low floor configurations, and some buses have both high and low floor boarding on the same vehicle.

30' CNG Gillig low floor in service in downtown Houston, TX as part of the Greenlink program hosted by Houston First and Downtown District. This shuttle provides free circulator services downtown.

Alternative Fuels Buses - CNG/LNG and Fuel Cell

Alternative fuel buses powered by either Compressed Natural Gas (CNG) or Liquid Natural Gas (LNG) have been developed and put into service at a number of transit agencies nationwide, Including New Jersey Transit who recently purchased 76 DesignLine EcoCoach buses. The Natural Gas Vehicle Coalition (NGV) reports that the more than 12,000 natural gas buses in the U.S. today represent approximately 18.6% of all transit buses and 52% of all alternatively fueled transit buses. According to the American Public Transportation Association (APTA) 19% of all transit agencies operate a natural gas vehicle in their fleet. The majority, over 90% of these natural gas vehicles are CNG, with a smaller percent of LNG vehicles operating in California, Texas and Arizona.

Figure 1-4 30' CNG Gillig in Houston, TX

Given the large fuel consumption of the transit bus industry, the natural gas powered bus has gained in popularity because of the perceived advantages of its lower fuel emissions and clean burning operations. CNG and LNG buses, do however, have considerably higher emission levels of Total Hydrocarbons (THC) and Non-Methane Hydrocarbons (NMHC). Because of its properties as a gas, fuel must be stored on board in either a compressed gaseous state (CNG) or in a liquefied state (LNG). This does not impact the bus frames, as dimensions are essentially the same as conventional diesel powered buses. There are advantages and disadvantages of CNG/LNG buses, including but not limited to the following:

<u>Advantages</u>

- The primary environmental advantage of CNG buses compared to conventional diesel buses is the absence of diesel particulate matter emissions (PM). However, conventional diesel buses, through more advanced diesel after-treatment technology, are working to achieve the same PM levels as CNG/LNG buses.
- CNG bus engines produce less noise than diesel combustion engines.
- Natural gas costs between $1.50-$2.00 less per gallon than gasoline

Disadvantages

- CNG buses consume 20% to 30% more fuel than diesel buses
- Fueling facilities for CNG buses are significantly more costly than conventional diesel
- Due to safety considerations, gaseous fueled vehicles (CNG/LNG buses) are not allowed to operate in tunnels
- Vehicles cost more to procure

Future development of CNG engines is focused on a Direct Injection CNG engine, which could considerably improve its energy consumption and make CNG engines more competitive with diesel buses.

Fuel cell powered buses are relatively new technology. The first prototype in the U.S. was constructed in 2006 as a joint venture between ClearEdge Power, VanHool bus, and ISE Corporation. Fuel cell propulsion systems consist of the fuel cell, a battery, a control system and motors to drive the wheels. In theory, fuel cells can utilize diesel fuel, natural gas, ethanol or methanol, and chemically convert this fuel into hydrogen. The fuel cell combines hydrogen and air to produce direct current electricity to power the vehicle. Hydrogen fuel cell bus demonstration programs are under way at CTTransit in Connecticut and AC Transit in California as part of the FTA's fuel cell bus program. CTTransit has reported some issues with the hybrid drive batteries in the first generation of buses but it was resolved with lithium ion batteries in the second generation.

Hybrid Diesel-Electric Buses

Figure 1-5 Hybrid New Flyer

Hybrid diesel-electric buses that are similar in operation to hybrid automobiles such as Toyota's Prius and Honda's Civic have been developed. Electricity generated by a computer-managed diesel engine is stored for future use and reduces fuel consumption. Typically, hybrid design utilizes regenerative braking and sends normally wasted braking energy to recharge the system's battery. There are several architectures available for the powertrain configuration; the most common are a Series Hybrid-Electric Drive and Parallel Hybrid-Electric Drive. The diesel fuel hybrids burns are typically ultra-low sulfur diesel, and are usually equipped with diesel particulate filters for ultra-low PM emissions. The cost of hybrid diesel-electric buses typically runs about 55-60% more than conventional diesels. According to APTA, as of 2011, 8.8% of the bus fleet in the U.S. was hybrid, hybrids account for about 17% of new buses ordered by transit agencies and more than 60 agencies use diesel hybrid buses.

The Southwest Ohio Regional Transit Authority's New Flyer Hybrid bus went into service in 2012. A total of 14 vehicles were added to the fleet.

Advantages of hybrid diesel-electric buses are improved fuel efficiency, 90% reduction in exhaust emissions, quieter operations, and potentially lower operating costs. There are mixed reports on savings. While many transit agencies report fuel savings up to 40%, life cycle costs show that it is often not enough to make up the difference in vehicle capital and maintenance costs. Hybrid vehicles cost about $200,000 more than the traditional diesel vehicle. Major cities around the country such as Boston, New York, Seattle, and San Francisco run hybrid buses for part of their fleet and recently the Maryland Transit Authority ordered 53. Cities large and small are beginning to operate hybrid bus technology.

Electric Trolley Buses (ETBs)

Electric trolley buses (ETBs) have been in service for nearly a century around the world and utilize a well-known and applied technology. Essentially, ETBs use electric motors powered from overhead wires above the street, known as catenary. The ETB vehicles, sometimes called "trackless trolleys," have essentially the same size and appearance as conventional and articulated buses. Steering is similar to conventional buses, but ETB movement is limited by the reach of the trolley poles (also called pantographs on light rail vehicles). Typically the movement is restricted to one lane on either side of the centerline of the trolley wires (approx. 12 feet) to allow for flexibility en route. Typically, ETBs are powered with an automatic current collection system that will, upon the driver's command, raise the trolley poles to, and subsequently engage, the overhead catenary wires. Similarly, upon command from the driver, the same system lowers the trolley poles to their normal secured positions and signals when the poles have been locked.

Figure 1-6 San Francisco MUNI Electric Trolley Bus Yard

ETBs offer three major advantages over conventional diesel buses. First, there is no pollution from the vehicle exhaust due to the electric operation, which makes them particularly advantageous for travel in tunnels. Second, noise is reduced due to the quieter electric motors. And third, ETBs provide better acceleration rates and propulsion on hills. Five cities in the U.S. currently operate ETBs, including Boston (MBTA), San Francisco (MUNI), Dayton, Ohio, Philadelphia (SPETA), and Seattle, Washington.

One of the main drawbacks of ETBs is the lack of visual aesthetics of overhead catenary. While many attempts have been made to reduce the visibility of trolley overhead contact systems, the typical 16-foot overhead contact wire is considered by many to be a visual impairment to the urban landscape. The other disadvantage includes lack of versatility, the bus is confined to roads with catenary for service planning.

In addition to Electric Trolley Buses, there are also **Dual Power Diesel/Electric** buses (also known as dual-mode buses), which have both diesel and electric propulsion units. These buses can operate like an ETB where there is an overhead contact wire system, or like a conventional diesel bus on regular streets. Currently the city of Boston is the only one in the country to operate dual mode bus technology. The vehicles operate on the Silver Line with electric power in the tunnel between Fort point Channel and South Station and diesel elsewhere. Seattle had operated dual-mode buses for more than a decade, but in 2004 suspended their service in favor of hybrid diesel-electric buses.

Figure 1-7 MBTA's Silver Line Operating on Dual Power Diesel/Electric

Guided Bus Technology

There are several types of guided bus systems currently under testing, development and operation throughout the world, although only one is currently in operation in the U.S. For the purposes of this review, we have divided guided bus technology into two categories:

- Guided articulated buses
- Rubber tire fixed guideway trolley operations

Guided Busway

Guided busways use a dedicated track and are steered by curb guidance and small guide wheels attached to the side of the bus. Most vehicles can be retrofitted with the wheel guides allowing transit agencies to use a wide variety of buses including articulated, diesel, CNG/LNG, hybrids and others. The guided technology does aid in automatic docking at stations, steering and overall operation, but does not relieve the operator of responsibility for safety of passengers and pedestrians. The most well know system is the Cambridgeshire Guided Busway in the United Kingdom. Construction began in 2007 on the 16 miles of bi-directional guideway and it opened for service in 2011. The system is designed as a trunk so that vehicles can utilize both the bus way and local roads. Currently three routes service the 20 ft wide busway, reaching speeds of 55 mph. Operationally no issues have been reported but the final cost was $274 million, approximately $45 million more than the estimated cost.

Figure 1-8 The Busway in Cambridgeshire County, UK performing test runs before its opening in 2011

Magnetic Guidance

One example of a system under development that relies on magnets is the Phileas in Eindhoven, Netherlands near the Belgian border. This guided articulated bus rapid transit system utilizes magnets embedded into the pavement as guides along the route. The guidance system will be automated, such that as long as the computer controlled system is able to read the magnets, the vehicle can technically operate without the driver at select stations along the route. It is not intended, however, to actually operate driverless. The idea is to increase the number of passengers conventional buses carry and create the sense of a fixed route without the infrastructure investments (However, more than $150 million in infrastructure construction was projected in Eindhoven). With nothing showing that it is a fixed route, it is not certain it will have the attractiveness of traditional fixed-guideway light rail systems.

Double-articulated, diesel electric Phileas vehicle in Eindhoven, Netherlands. The guided bus used a computer-based routing system with magnets imbedded in the pavement to serve as points of reference for guidance. However, this aspect of the system was discontinued by the regional transit authority. The most prominent feature of the vehicle s is the ability to recharge the battery by means of electromagnetic induction, allowing for a lighter battery system.

Figure 1-9. Phileas Magnetic guidance bus

Guided Bus

Figure 1-10 Civis optically guided bus operated by RTC in Las Vegas

In Las Vegas, Nevada, the Civis was an optically guided bus that began operations in the summer of 2004 along the then newly redesigned BRT Route 113. Las Vegas's Metropolitan Area Express (MAX) is the first system of its kind in the U.S. Developed by the French, the articulated Civis bus operated with an optical guidance system that steers the bus so that it precisely lines up with the platform at the station for easy passenger access. The bus on-board computer system reads special stripes on the roadway in order to control its movement. However, issues with desert dust and sand resulted in the system being permanently removed from use. Surprisingly, drivers were manually able to achieve a high level of accuracy in aligning vehicles for low-level platform boardings very similar to that automated system.

operations for several years and offers level boarding along all four doors, features a hybrid diesel-electric engine, in vehicle bike racks, transit signal priority, AVL system, the driver positioned in a center console and has the sleek rail like appearance. Vehicle capacity is 120 passengers.

Rubber Tire Fixed Guideway Systems

Four rubber tire trolley systems, more commonly referred to as 'trams' (*see also under Streetcars under light rail section to follow*), have been developed in Europe, and two in China that utilize the concept of light rail (LRT) combined with the rubber tire guided bus concept, with the intention of creating a lower cost alternative to expensive LRT systems. The first system, developed by Bombardier in conjunction with Spie Batignolles, is a fixed-guideway, rubber tire trolley with the guideway system in the middle extending into the pavement with a small steel wheel serving as the guidance mechanism. There is one single rail for the steel wheel guidance, and power is drawn from a standardized overhead contact system at 750v dc (catenary). This first systems in operation were in Nancy and Caen, France, but not without start-up problems. The system allows vehicles to go off line and operate essentially as a bus on rubber tires where there is no rail. However, there are limited locations in the system where the vehicle can detach from the rail, and this operation is not accomplished seamlessly. Practical problems, including 'derailments' have occurred, and Nancy suspended off-line operations to avoid these problems.

Figure 1-11 Bombarier rubber tire system

The "Twisto" rubber tire system in Caen, Franc, developed by Bombardier and installed by Spie Batignolles. Note on lower right of photo concrete bumper, added after initial installation to prevent vehicle from bumping into platform during station docking. Vehicles can leave guideway in certain locations to service outlying communities, but such practice is limited and not seamless.

As a result, vehicles in both the Nancy and Caen systems primarily operate along the fixed guideway to avoid problems disengaging to bus mode. Initial service problems include premature wear of tires, issues of weight on the guidance system, uneven docking of vehicles at the stations, and problems of derailment.

A second rubber tire tram system, developed by Lohr Industries and known as Translohr, is similar to the Bombardier rubber tire tram system, except that it operates completely on a fixed-guideway utilizing a "V" guiding system running in the center of the route. Clermont-Ferrand, France and Shanghai, China are the two cities to currently utilize this technology. It was first implemented in France in 2005. The advantages include increased traction resulting in the ability to climb steeper grades, shorter turning radii then conventional rail transit. Disadvantages including rutting of the roadway requiring extensive road repairs and costs, proprietary system and lack of spare parts, and reported poor rider comfort.

Translohr rubber tire vehicle, which is bi-directional, Clermont-Ferrand France. System utilizes traditional catenary and traction power design. Vehicles are modular units and are designed to operate completely in a fixed-guideway.

Example of the Translohr rubber tire guidance system – a single rail with two angled wheels wedged in securely to prevent derailment. The wheels are buffered by rubberized flangeway filler that keeps debris out and reduces noise and wheel friction. The rubber filler is glued in and can be replaced easily as part of standard maintenance costs.

Figure 1-12 Translohr rubber tire vehicle

STREET OPERATIONS TECHNOLOGIES

Transit Signal Priority (TSP) technology facilitates the movement of transit vehicles (Bus or rail) through traffic-signal controlled intersections which improves schedule adherence, and reduces travel times, thereby reducing fleet requirements. Consistent with the National Intelligent Transportation Systems Architecture there are four components to a TSP system:

1) a road side detection system on the traffic signal
2) a vehicle module that sends the signal
3) a control center that decided whether to grant the request and how to process it
4) software to manage the system, collect data and generate reports.

As the vehicle approaches the intersection it sends a signal to a detector that interfaces with the traffic signal operation control box to either extend the green, truncate the red, or rotate the signal phases, all of which enable the vehicle quicker passage through the intersection. Often TSP is installed along an entire corridor. In New Jersey it was installed at key intersection along the Go Bus 28 BRT line. Several transit agencies have seen vast improvements to their service because of TSP. For example TriMet in Portland, Oregon experienced a 10% improvement in travel time and 19% reduction in travel time variability which allowed them to avoid having to add another bus to the route just to maintain the required headway.

Automatic vehicle location (AVL) technology, also referred to as web-based GPS real-time tracking provides real time travel information to passengers and aids in vehicle dispatch. Princeton University uses a software package called TransLoc to provide real time information, which they have dubbed the TigerTracker. Each vehicle is equipped with a GPS transponder that constantly sends a location signal, which is then processed and displayed on their website and mobile application. Refresh rates can be as short as a few seconds. Users can access the TigerTracker to see where the bus is, when the next bus will arrive at a stop or plan their trip. Dispatch and operations use the data to monitor on-time performance, coordinate transfers, and aid in incident and emergency response. NJ Transit piloted MyBus Now in early 2012 on select routes and has begun to install the technology on all its vehicles. Like TigerTracker it provides up to date vehicle locations and travel times.

RAIL TECHNOLOGIES

Rail has a rich history in the US and is one of the first forms of public transportation, beginning in 1832 in New York City with the first horse-drawn street railway line, cable cars in San Francisco in 1873, and the first electric powered streetcar in Richmond, Virginia in 1888. Since it was first established the definition of what constitutes rail transit has been redefined several times. The NTD defines rail modes as “transit modes whose vehicles travel along fixed rail – bars of rolled steel – forming a track. The vehicles are usually electrically propelled through motors onboard the vehicles, but motors may also be at a central location not onboard the vehicle to pull the vehicle cables, vehicles may be self-propelled or drawn by a locomotive”[17] Major innovations within rail technology that would be beneficial to Princeton include dual mode locomotives, in-street running, automatic vehicle locations with real-time information, low floor boarding, and traffic signal priority.

According to the NTD there has been a steady growth in rail ridership with over 4.1 billion passenger trips in 2011, of which 10% was streetcar or light rail technology. This is a significant increase, up from 3 billion in 2001. Rail vehicles travelled slightly over 1 billion miles in 2011, with 8% percent of these miles light rail, 0.4% streetcar and the rest heavy and commuter rail. While light rail and streetcars travel

[17] From the NTD Glossary, http://www.ntdprogram.gov/ntdprogram/Glossary.htm#R, accessed on 6/25/201113

fewer miles and carry fewer passengers annually, the percentages are increasing as more and more cities implement LRT and Streetcar systems.

Streetcars/Trams

Streetcars can be either vintage or modern designs. The modern streetcar is typically referred to in Europe as a 'tram' - an evolution of a light rail system that is lighter than the early generations of LRT systems, easier to construct and less reliant on exclusive rights of way. The vehicle is typically 8 feet high, approximately 8 feet wide, and 60 to 80 feet long with maximum speeds of 30 to 40 mph. and with the capability of very high rates of acceleration and deceleration. Streetcars are generally constrained by a minimum turning radius of 65 feet, although some have the ability to operate on 50 foot radius curves. Streetcars generally have the capability to operate on an exclusive right of way, or over roadways intermixed with vehicle traffic. They can be operated as consists, or as single units. Stops are typically closely spaced. Power is typically provided by overhead catenaries, but diesel, battery, hybrid and underground power distribution systems are available. Each type of power system is explored below. Salient features of the Streetcar can be summarized as:

- Low risk, proven system technology
- Street running operation
- Approximate per vehicle capacity – 100 - 150 passengers, depending on vehicle type
- Headway dependent upon automotive or truck traffic conditions if in mixed traffic
- Costs significantly less per mile than LRT and less disruptive to an urban environment.

Overhead Catenary

Traditionally streetcar systems use overhead electric power for propulsion but many find the overhead wires detract from the visual streetscape. Wires are typically suspended 18 feet above the street, with a shoe device connected to the end of the trolley pole collecting power. Examples of such a streetcar system include installations in Portland, Oregon, and historic installations in cities like Boston, Lowell and Memphis. Shown below is the Skoda vehicle, manufactured in the Czech Republic and in service in Portland.

Figure 1-13 Skoda Streetcar in service in Portland Oregon utilizes overhead contact system

Diesel Vehicles

Four diesel powered replica streetcar were constructed in 1988 for the city of Galveston, Texas by Miner Railcar out of Pennsylvania. Diesel was chosen over electric to minimize hurricane related damages, as Galveston is an island in the Gulf of Mexico. The disadvantages to on-board diesel motors include limitations in speed, fuel reliance and clean air concerns. Siemens has developed a hybrid system that is in operation in Nordhausen, Germany, which can be powered by electric overhead catenary or diesel.

Figure 1-14 Galveston, Texas diesel powered streetcar

Battery Powered

Kawasaki, Siemens, Electric Motors and others have developed battery powered streetcars. The Kawasaki system has been successfully tested in Sapporo, Japan and is scheduled to open in 2018 with 16km of track. The system claims to run 10 km on a five minute battery charge using nickel metal hydride batteries. The Siemens system has been deployed in Portugal and allows streetcars with hybrid energy capabilities to operate up to 2,500 meters without overhead catenary. Electric Motors paired with Supply in Altoona to develop the current traction system on Savanah's historic streetcar. Utilizing super capacitor technology along with batteries this car runs just over a mile before charging is needed at the end of the line. These systems all use wireless sections of track and charging stations, either along the route or at the route terminals.

Figure 1-15 Savannah's historic streetcar

Figure 1-16 Siemens Sitras HES streetcar

Underground Power

Underground power can be supplied by a buried third rail with a slot the streetcar accesses or by contactless technology. The Bordeaux, France tram system applies an innovative traction power system developed by INNORAIL that replaces the overhead contact system with a power supply imbedded in pavement. Pedestrians can walk on the contact rail as it is energized only when the tram vehicle passes over it. Problems include poor drainage, "teething" problems, and debris on the contact strips.

Figure 1-17 Bombardier's Primove contactless rail technology being tested in Germany

Historical underground power systems utilized a slot with retractable shoe to obtain power but more recently Bombardier began testing contactless technology, where the third rail is only energized when the train is above it. It relies on electromagnetic fields under the rail track and can operate in all weather and environmental conditions including sand, snow and ice. The pilot project is being carried out in Augsburg, Germany.

The Bordeaux, France tram system lacks overhead wires which interrupt the viewscape. Using ground-level power supply the rail is imbedded in the roadway.

Figure 1-18 Bordeaux tracks with imbedded traction power

Figure 1-19 Bordeaux tram system

Light Rail Transit (LRT)

This technology encompasses lightweight passenger rail cars operating singly or in short trains, on fixed rails in right-of-way that is generally separated from other roadway traffic. Light rail vehicles are similar to street cars in that they are typically driven electrically with power being drawn from an overhead electric line via a trolley or a pantograph. As with streetcars, alternate technologies for power collection, including underground power, batteries and hybrid technology are being designed and implemented. Although LRT can operate in mixed traffic on tracks embedded in the street, it most typically is found on an at-grade right-of-way with street and pedestrian crossings, or on fully segregated exclusive rights-of-way.

LRT is a flexible transportation mode, which can operate in a variety of physical settings. The most common and economical LRT alignment is at-grade, however, light rail can also operate on aerial structures and in subways or tunnels.

Figure 1-20 Hudson Bergen Light Rail System street running in Jersey City, New Jersey

Light Rail Transit technology includes a range of vehicles and passenger carrying capability. There are many manufacturers of LRT cars as single units and articulated units measuring between 80 and 160 feet long, and weighing between 80,000 to 100,000 pounds. LRT cars can also be operated in consists for train lengths of up to 6 cars. The carrying capacity for these vehicles is between 60 and 120 sitting passengers, with an equivalent number of standees.

A variety of entry/exit door configurations are available, and often vehicles are designed specifically for a given property. Typically a single vehicle will have 2 door openings each side, or 4 each side for an articulated unit. Door design is an important factor in boarding and exiting speed, and thus dwell time. Vehicles are usually built with floor height integrated with station platforms, eliminating the need for steps, and improving the rate of passenger boarding. Both low floor and high floor designs are available. This feature also promotes easy cross platform transferring between light rail trains and buses.

LRT operating speeds on exclusive right-of-way can approach the speed and service levels of heavy rail transit vehicles. Acceleration rates are generally quite good, although the larger, heavier vehicles do not typically match the acceleration of their streetcar counterparts. Higher operating speeds and slower deceleration produce the need for station stops to be set further apart than streetcars.

Light Rail Transit Systems vary in cost over a broad spectrum, depending upon factors such as number of vehicles, number of stations, and type of trackwork. Average capital costs range from $30 to $40 million per mile.

Salient features of the LRT system include:

- Low risk, proven vehicle technology.
- Available for shared or exclusive rights of way, requires turning radius of 85 to 200 feet.
- Carrying Capacity – 200 passengers (~ 100 seated).
- Headway can be as short as three (3) minutes.
- System Capacity - ranging from 15,000 to 30,000 pphpd, depending upon system configuration.

Some manufacturers of LRT vehicles include:

Bombardier Transportation

Bombardier Transportation offers an extensive menu of LRV designs, including the 100% low-floor *Flexity* Outlook trams, which can be found in a number of European cities. *Flexity* is the first 100% low-floor tram with a wheel-set initially designed for the transport authority of Linz (Austria). Since then, public transportation in Lodz (Poland), Eskisehir (Turkey) and Geneva (Switzerland) have also chosen this forward-looking tram concept.

Figure 1-21 Bombardier Flexity in Frankfurt Germany

Figure 1-22 Bombardier Flexity Swift for Melbourne, Australia

Kinki Sharyo

Kinki Sharyo provides a range of Light Rail products, with one of the strongest project histories in the United States. This manufacturer has built the vehicles for the Dallas LRT, the Seattle Light Rail, Hudson Bergen cars, Boston Type 7 Cars, and the Santa Clara cars. Kinki Sharyo typically will provide specialized designs for respective properties.

Figure 1-23 Seattle Sound Transit Central link Light Rail

Figure 1-24 Massachusetts Bay Transportation Authority (MBTA)

Siemens Transportation Systems

The Vehicle Division of Siemens Transportation Systems specializes in the design, systems integration, assembly, testing, and commissioning of light rail vehicles. Since 1975, more than 700 light rail vehicles have been ordered from Siemens' Vehicle Division, making Siemens the largest supplier of light rail vehicles in North America. Siemens offers both low floor and high floor vehicle designs, utilizing advanced AC and DC propulsion technology.

Figure 1-25 Siemens Light Rail s70 – Salt Lake City

AUTOMATED GUIDEWAY TRANSIT (AGT) AND PERSONAL RAPID TRANSIT (PRT)

These systems include several variations on automated transportation systems that move people on a relatively limited route to one or more alternate destinations. The two primary categories of systems are Automated Guideway Transit (AGT) Systems (also known as Group Rapid Transit, or GRT Systems), and Personal Rapid Transit (PRT) Systems.

Both systems use relatively small, automated vehicles to carry small numbers of people along a fixed guideway between specific locations. Characteristically, these vehicles operate without a driver, and are controlled by computers. They may be rubber tired or railed vehicles, and they do not typically mix with other traffic modes. They are provided with a variety of types of propulsion and power sources.

AGT (GRT) systems typically consist of vehicles carrying 20 or more people, and may be coupled into trains. Passengers, although in small groups, mix with other groups within a vehicle. The vehicles typically operate on a closed circuit and fixed headway, stopping at all stations on the circuit, where passengers may enter or exit the vehicle. Headway is largely controlled by boarding intervals. A typical application of this technology is an airport or College "people-mover".

PRT systems utilize smaller vehicles that typically hold fewer than 6 passengers, and are generally occupied by members of a single group. They normally operate as a single vehicle and utilize a more sophisticated automatic control system. PRT generally leaves a pick-up station and goes directly to the destination chosen by the occupants. It does not stop at intermediate stations if no occupants have requested a stop. It is demand responsive and does not operate on a fixed headway. Vehicles can often operate within one minute of each other. There are few PRT systems in operation anywhere in the world, and none in North America.

Salient features of GRT are:

- Costly infrastructure, and high per passenger cost
- Dedicated right of way
- Approximate per vehicle capacity – 20-25 passengers (can be several hundred in a train)
- Headway is fixed
- Makes all stops on fixed route

Salient features of PRT are:

- Costly infrastructure, and high per passenger cost
- Dedicated right of way
- Approximate per vehicle capacity – 4-6 passengers
- Headway varies by demand, but can be as short as 60 sec.
- Point-to point trip with no stops

Most of the research performed on PRT was conducted in the 1970's by Germany but was the technology was abandoned and never installed due to high capital costs. Today, PRT technology is being advanced by several companies, as follows:

Ultra

Ultra currently operates a PRT system at the Heathrow Airport in London, UK. The Ultra system runs on an elevated concrete guideway with rubber tires and laser guides. The vehicles are battery powered with rotary motors and can operate up to 25 MPH with capacities of 4-6 people. The London system consists of 2.4 miles of guideway between terminal 5 and the Business Car Park. The system, which includes 3 stations and 21 vehicles cost $46 million (2011 US dollars) to construct. Reports indicate that the average wait time is 10-15 seconds, with 99% reliability for approximately 1,000 passengers per day.

Figure 1-26 Heathrow Airport's Ultra PRT system in service

Vectus

Vectus Limited, a subsidiary of POSCO, is a Swedish company that operates a full prototype in Uppsala, Sweden and operated a system Suncheon, South Korea for the Suncheon City Garden expo to transport visitors from the expo site to the Coastal Wetlands Park. PRT was selected because of its minimal environmental footprint on the surrounding wetlands. The system is an open rail track guideway supported above grade. Linear induction motors on the track provide propulsion. The cars carry up to 8 seated passengers, have a peak capacity of 1,313 passengers per hour, and an average wait time of 5 seconds.

Figure 1-27 Vectus PRT Prototype. Uppsala Sweden on the left Suncheon Bay, South Korea Right

2getthere

The 2getthere vehicle technology is free ranging rubber tire vehicles on a magnetic controlled grid at grade but in a separated guideway. Masdar City, UEA began implementing these vehicles in 2010 as part of the zero-net energy campaign and constructed a mile of guideway between the train station and university, most of it is underground. Following the construction of the initial portion of the project, the project has been halted, reportedly due to the increasing capital costs. However, the 2 stations and 10 vehicles continue in service. The vehicles hold 4 passengers, use lithium batteries and travel up to 25MPH.

2getthere also implemented a GRT system at the Rivium business Park, Capelle aan den Ijssel, the Netherlands in 2008, with 2.2 miles of guideway, 5 stations and 6 twenty-passenger vehicles.

Figure 1-28 Masdar City's 2getthere PRT Cybercab

Appendix 2 – LRT or Streetcar Schedule

Princeton Junction to Nassau Street

Meeting All NJT Trains

Weekday

			SB		NORTHBOUND				SOUTHBOUND	
Train		Time	Pr Jct AR	Pr Jct Dep	Princeton Ar	Princeton Dep	Nassau Street Ar	Nassau Street Dep	Princeton AR	Princeton DEP
NJT 3892	NB	0:02		23:52	23:57	23:59	0:03	0:14	0:18	0:20
NJT 3895	SB	0:25	0:25	0:30	0:35	0:39	0:43	0:47	0:51	0:55
NJT 3800	NB	1:10	1:00							
NJT 3897	SB	1:11		1:16	1:21	1:25	1:29	2:26	2:30	2:34
NJT 3805	SB	2:39	2:39	2:44	2:49	2:53	2:57	3:36	3:40	3:44
NJT 3806	NB	3:58	3:49	3:54	3:59	4:03	4:07	4:15	4:19	4:23
NJT 3808	NB	4:33	4:28	4:31	4:36	4:40	4:44	4:47	4:51	4:55
NJT 3810	NB	5:07	5:00	5:03	5:08	5:10	5:14	5:16	5:20	5:23
								5:01	5:05	5:09
NJT 3910	NB	5:19	5:14	5:17	5:22	5:24	5:28	5:47	5:51	5:55
NJT 3812	NB	5:32	5:28	↓↓↓↓						
NJT 3809	SB	5:33		5:38	5:43	5:47	5:51	5:56	6:00	6:03
NJT 3801	SB	6:03	6:00	↓↓↓↓				6:00	6:04	6:06
NJT 3814	NB	6:05		6:09	6:14	6:16	6:20	6:22	6:26	6:31
NJT 3914	NB	6:15	6:08	↓↓↓↓		6:06	6:10	6:12	6:16	6:18
AmT 111	SB	6:16		6:21	6:26	6:30	6:34	6:39	6:43	6:48
NJT 3818	NB	6:23	6:23	6:27	6:32	6:35	6:39	6:41	6:45	6:55
NJT 3813	SB	6:32		6:37	6:42	6:46	6:50	6:54	6:58	7:01
NJT 3918	NB	6:35	6:31	↑↑↑↑		6:55	6:59	7:03	7:07	7:17
NJT 3920	NB	7:00	6:53	↓↓↓↓						
AmT 181	SB	7:00		7:03	7:08	7:11	7:15	7:18	7:22	7:25
NJT 3922	NB	7:11	7:06	↓↓↓↓						
NJT 3815	SB	7:17		7:20	7:25	7:28	7:32	7:37	7:41	7:46
NJT 3924	NB	7:27	7:22	7:29	7:34	7:37	7:41	7:46	7:50	7:58
NJT 3828	NB	7:34	7:30	↓↓↓↓						
NJT 3817	SB	7:36		7:41	7:46	7:48	7:52	7:57	8:01	8:04
NJT 3926	NB	7:45				7:58	8:02	8:07	8:11	8:14
NJT 3928	NB	8:02	7:51	8:00	8:05	8:10	8:14	8:19	8:23	8:28
AmT 641	SB	8:13		8:17	8:22	8:24	8:28	8:44	8:48	8:53
NJT 3830	NB	8:14	8:09	↑↑↑↑						
NJT 3930	NB	8:23	8:19	8:24	8:29	8:34	8:38	8:50	8:54	9:02
NJT 3821	SB	8:25	8:33	↓↓↓↓						
NJT 3932	NB	8:39		8:38	8:43	8:46	8:50	8:55	8:59	9:00
						8:53	8:57	9:02	9:06	9:11
						9:02	9:06	9:14	9:18	9:23
NJT 3823	SB	9:02		9:07	9:12	9:15	9:19	9:22	9:26	9:29
NJT 3934	NB	9:10	9:05	↑↑↑↑						
						9:29	9:33	9:36	9:40	9:43
NJT 3832	NB	9:23	9:16	↓↓↓↓						

NJT 3825	SB	9:27		9:32	9:37	9:40	9:44	9:47	9:51	9:54
NJT 3936	NB	9:32	9:28	↓↓↓↓						
NJT 3827	SB	9:35		9:40	9:45	9:50	9:54			
NJT 3915	SB	9:48	9:48	9:53	9:58	10:02	10:06	10:09	10:13	10:17
NJT 3917	SB	9:59		10:04	10:09	10:14	10:18	10:26	10:30	10:35
NJT 3834	NB	10:03	9:59	↑↑↑↑						
NJT 3829	SB	10:20		10:27	10:32	10:35	10:39	10:42	10:46	10:49
NJT 3836	NB	10:27	10:22	↑↑↑↑						
						10:49	10:53	11:13	11:17	11:20
NJT 3838	NB	10:52	10:40	↓↓↓↓						
NJT 3831	SB	10:52		10:56	11:01	11:04	11:08	11:11	11:15	11:18
						11:20	11:24	11:26	11:30	11:50
NJT 3833	SB	11:18		11:27	11:32	11:35	11:39	11:42	11:46	11:49
NJT 3840	NB	11:30	11:23	↑↑↑↑		11:50	11:54	11:58	12:02	
NJT 3835	SB	11:51		11:59	12:04	12:07	12:11	12:14	12:18	12:21
NJT 3842	NB	12:04	11:54	↑↑↑↑						
						12:22	12:26	12:30	12:34	
NJT 3837	SB	12:16		12:29	12:34	12:37	12:41	12:44	12:48	12:51
NJT 3844	NB	12:32	12:26	↑↑↑↑						
						12:52	12:56	13:00	13:04	
NJT 3839	SB	12:52		13:00	13:05	13:08	13:12	13:15	13:19	13:22
NJT 3846	NB	13:03	12:56	↑↑↑↑						
						13:22	13:26	13:30	13:34	
NJT 3841	SB	13:19		13:30	13:35	13:37	13:41	13:43	13:47	13:49
NJT 3848	NB	13:34	13:27	↑↑↑↑						
						13:51	13:55	14:03	14:07	14:11
NJT 3843	SB	13:52		13:57	14:02	14:04	14:08	14:22	14:26	14:28
NJT 3850	NB	13:58	13:54	↑↑↑↑						
								14:31	14:35	14:38
NJT 3845	SB	14:17	14:16	14:20	14:25	14:28	14:32	14:45	14:49	
NJT 3852	NB	14:38	14:33	14:35	14:40	14:43	14:47	14:58	15:02	
						14:54	14:58	15:10	15:14	
NJT 3954	NB	14:48	14:43	↓↓↓↓						
NJT 3847	SB	14:51		14:56	15:01	15:06	15:10	15:13	15:17	15:20
						15:14	15:18	15:21	15:25	15:28
						15:21	15:25	15:29	15:33	
NJT 3849	SB	15:21	15:25	15:28	15:33	15:37	15:41	15:44	15:48	15:51
NJT 3856	NB	15:38	15:33	15:37	15:42	15:45	15:49	15:57	16:01	16:04
						15:56	16:00	16:03	16:07	16:10
NJT 3937	SB	15:55	15:56	↓↓↓↓						
NJT 3858	NB	16:03		15:59	16:04	16:07	16:11	16:17	16:21	16:24
NJT 3860	NB	16:16	16:09	16:12	16:17	16:20	16:24	16:27	16:31	16:34
NJT 3853	SB	16:20	16:15	16:24	16:29	16:32	16:36	16:43	16:47	16:51
NJT 3960	NB	16:37	16:29	↓↓↓↓						
NJT 3855	SB	16:39		16:41	16:46	16:49	16:52	16:59	17:03	17:06
NJT 3862	NB	16:44	16:39	16:51	16:56	17:00	17:04			
NJT 3857	SB	16:58		17:02	17:07	17:10	17:14	17:18	17:22	17:25

NJT 3864	NB	17:02	16:56	↑↑↑↑						
								17:25	17:29	
NJT 3943	SB	17:07		17:14	17:19	17:22	17:25	17:33	17:37	17:40
NJT 3866	NB	17:16	17:11	↑↑↑↑						
						17:32	17:36	17:43	17:47	17:50
NJT 3947	SB	17:25		17:33	17:38	17:41	17:44	17:55	17:58	18:02
NJT 3898	NB	17:35	17:30	↑↑↑↑						
NJT 3861	SB	17:44		17:49	17:54	17:58	18:02	18:06	18:10	18:14
AmT 652	NB	17:52	17:45	↑↑↑↑						
NJT 3949	SB	17:55		17:58	18:03	18:06	18:10	18:12	18:16	18:19
NJT 3868	NB	18:00	17:55	↑↑↑↑						
NJT 3951	SB	18:09	18:07	18:11	18:16	18:19	18:23	18:26	18:30	18:33
NJT 3953	SB	18:20	18:19	18:23	18:28	18:31	18:35	18:40	18:44	18:48
NJT 3867	SB	18:28		18:31	18:36	18:39	18:43	18:46	18:50	18:53
NJT 3870	NB	18:29	18:24	↑↑↑↑						
NJT 3955	SB	18:36	18:38	18:40	18:45	18:48	18:52	18:55	18:59	19:02
NJT 3869	SB	18:45	18:53	18:55	19:00	19:02	19:06	19:08	19:12	19:15
NJT 3872	NB	18:49								
NJT 3957	SB	18:56	18:57	18:59	19:04	19:07	19:11	19:20	19:24	19:28
NJT 3959	SB	19:13	19:07	19:15	19:20	19:23	19:27			
NJT 3874	NB	19:25		19:28	19:33	19:36	19:40	19:42	19:46	19:50
NJT 3873	SB	19:25	19:20	↑↑↑↑						
NJT 3961	SB	19:35		19:38	19:43	19:46	19:50	19:53	19:57	20:01
AmT 196	NB	19:39	19:33	↑↑↑↑						
NJT 3875	SB	19:57		20:03	20:08	20:11	20:15	20:33	20:37	20:40
NJT 3876	NB	20:00	19:55	↑↑↑↑						
NJT 3963	SB	20:06	20:06	20:09	20:14	20:17	20:21	20:40	20:44	20:48
AmT 138	NB	20:38								
NJT 3965	SB	20:45		20:48	20:53	20:56	21:00	21:03	21:07	21:10
NJT 3880	NB	20:50	20:45	↑↑↑↑						
NJT 3881	SB	20:56	20:53	20:59	21:04	21:09	21:13	21:15	21:19	21:21
NJT 3969	SB	21:14	21:15	↓↓↓↓						
NJT 3882	NB	21:20		21:17	21:22	21:25	21:29	21:31	21:35	21:38
NJT 3883	SB	21:23	21:26	21:28	21:33	21:35	21:39	21:41	21:45	21:47
NJT 3885	SB	21:46	21:43	21:48	21:53	21:56	22:00			
NJT 3886	NB	22:04	21:52	21:54	21:59	22:01	22:05	22:07	22:11	22:13
NJT 3887	SB	22:15	22:18	22:20	22:25	22:27	22:31	22:33	22:37	22:39
NJT 3889	SB	22:47	22:44	22:48	22:53	22:55	22:59	23:06	23:10	23:12
NJT 3888	NB	23:22	23:17	↓↓↓↓						
NJT 3891	SB	23:22		23:24	23:29	23:31	23:35	23:37	23:41	23:43
NJT 3893	SB	23:48	23:48	↓↓↓↓						

Princeton Junction to Nassau Street

15 Minute Headway

Weekday

			SB	NORTHBOUND				SOUTHBOUND		
Train		Time	Pr Jct	Pr Jct	Princeton		Nassau Street		Princeton	
			AR	Dep	Ar	Dep	Ar	Dep	AR	DEP
NJT 3892	NB	0:02		23:52	23:57	23:59	0:03	0:14	0:18	0:20
NJT 3895	SB	0:25	0:25	0:30	0:35	0:39	0:43	0:47	0:51	0:55
NJT 3800	NB	1:10	1:00							
NJT 3897	SB	1:11		1:16	1:21	1:25	1:29	2:26	2:30	2:34
NJT 3805	SB	2:39	2:39	2:44	2:49	2:53	2:57	3:36	3:40	3:44
NJT 3806	NB	3:58	3:49	3:54	3:59	4:03	4:07	4:15	4:19	4:23
NJT 3808	NB	4:33	4:28	4:31	4:36	4:40	4:44	4:47	4:51	4:55
NJT 3810	NB	5:07	5:00	5:03	5:08	5:09	5:13	5:15	5:19	5:21
								5:00	5:04	5:06
NJT 3910	NB	5:19	5:11	5:12	5:17	5:18	5:22	5:30	5:34	5:36
NJT 3812	NB	5:32	5:26	5:28	5:33	5:35	5:39	5:45	5:49	5:51
NJT 3809	SB	5:33	5:41	5:43	5:48	5:50	5:54	6:00	6:04	6:06
NJT 3801	SB	6:03	5:56	5:58	6:03	6:05	6:09	6:15	6:19	6:21
NJT 3814	NB	6:05								
NJT 3914	NB	6:15	6:11	6:13	6:18	6:20	6:24	6:30	6:34	6:36
AmT 111	SB	6:16								
NJT 3818	NB	6:23	6:26	6:28	6:33	6:35	6:39	6:45	6:49	6:51
NJT 3813	SB	6:32								
NJT 3918	NB	6:35	6:41	6:43	6:48	6:50	6:54	7:00	7:04	7:06
NJT 3920	NB	7:00	6:56	6:58	7:03	7:05	7:09	7:15	7:19	7:21
AmT 181	SB	7:00								
NJT 3922	NB	7:11	7:11	7:13	7:18	7:20	7:24	7:30	7:34	7:36
NJT 3815	SB	7:17								
NJT 3924	NB	7:27	7:26	7:28	7:33	7:35	7:39	7:45	7:49	7:51
NJT 3828	NB	7:34								
NJT 3817	SB	7:36								
NJT 3926	NB	7:45	7:41	7:43	7:48	7:50	7:54	8:00	8:04	8:06
NJT 3928	NB	8:02	7:56	7:58	8:03	8:05	8:09	8:15	8:19	8:21
AmT 641	SB	8:13	8:11	8:13	8:18	8:20	8:24	8:30	8:34	8:36
NJT 3830	NB	8:14								
NJT 3930	NB	8:23								
NJT 3821	SB	8:25	8:26	8:28	8:33	8:35	8:39	8:45	8:49	8:51
NJT 3932	NB	8:39	8:41	8:43	8:48	8:50	8:54	9:00	9:04	9:06
			8:56	8:58	9:03	9:05	9:09	9:15	9:19	9:21
NJT 3823	SB	9:02								
NJT 3934	NB	9:10	9:11	9:13	9:18	9:20	9:24	9:30	9:34	9:36
NJT 3832	NB	9:23								

NJT 3825	SB	9:27	9:26	9:28	9:33	9:35	9:39	9:45	9:49	9:51
NJT 3936	NB	9:32								
NJT 3827	SB	9:35								
NJT 3915	SB	9:48	9:41	9:43	9:48	9:50	9:54	10:00	10:04	10:06
NJT 3917	SB	9:59	9:56	9:58	10:03	10:05	10:09	10:15	10:19	10:21
NJT 3834	NB	10:03	10:11	10:13	10:18	10:20	10:24	10:30	10:34	10:36
NJT 3829	SB	10:20								
NJT 3836	NB	10:27	10:26	10:28	10:33	10:35	10:39	10:45	10:49	10:51
			10:41	10:43	10:48	10:50	10:54	11:00	11:04	11:06
NJT 3838	NB	10:52	10:56	10:58	11:03	11:05	11:09	11:15	11:19	11:21
NJT 3831	SB	10:52								
NJT 3833	SB	11:18	11:11	11:13	11:18	11:20	11:24	11:30	11:34	11:36
NJT 3840	NB	11:30	11:26	11:28	11:33	11:35	11:39	11:45	11:49	11:51
NJT 3835	SB	11:51	11:41	11:43	11:48	11:50	11:54	12:00	12:04	12:06
NJT 3842	NB	12:04	11:56	11:58	12:03	12:05	12:09	12:15	12:19	12:21
NJT 3837	SB	12:16	12:11	12:13	12:18	12:20	12:24	12:30	12:34	12:36
NJT 3844	NB	12:32	12:26	12:28	12:33	12:35	12:39	12:45	12:49	12:51
NJT 3839	SB	12:52	12:41	12:43	12:48	12:50	12:54	13:00	13:04	13:06
NJT 3846	NB	13:03	12:56	12:58	13:03	13:05	13:09	13:15	13:19	13:21
NJT 3841	SB	13:19	13:11	13:13	13:18	13:20	13:24	13:30	13:34	13:36
NJT 3848	NB	13:34	13:26	13:28	13:33	13:35	13:39	13:45	13:49	13:51
NJT 3843	SB	13:52	13:41	13:43	13:48	13:50	13:54	14:00	14:04	14:06
NJT 3850	NB	13:58	13:56	13:58	14:03	14:05	14:09	14:15	14:19	14:21
NJT 3845	SB	14:17	14:11	14:13	14:18	14:20	14:24	14:30	14:34	14:36
NJT 3852	NB	14:38	14:26	14:28	14:33	14:35	14:39	14:45	14:49	14:51
NJT 3954	NB	14:48	14:41	14:43	14:48	14:50	14:54	15:00	15:04	15:06
NJT 3847	SB	14:51	14:56	14:58	15:03	15:05	15:09	15:15	15:19	15:21
			15:11	15:13	15:18	15:20	15:24	15:30	15:34	15:36
NJT 3849	SB	15:21	15:26	15:28	15:33	15:35	15:39	15:45	15:49	15:51
NJT 3856	NB	15:38	15:41	15:43	15:48	15:50	15:54	16:00	16:04	16:06
NJT 3937	SB	15:55	15:56	15:58	16:03	16:05	16:09	16:15	16:19	16:21
NJT 3858	NB	16:03	16:11	16:13	16:18	16:20	16:24	16:30	16:34	16:36
NJT 3860	NB	16:16	16:26	16:28	16:33	16:35	16:39	16:45	16:49	16:51
NJT 3853	SB	16:20								
NJT 3960	NB	16:37								
NJT 3855	SB	16:39	16:41	16:43	16:48	16:50	16:54	17:00	17:04	17:06
NJT 3862	NB	16:44	16:56	16:58	17:03	17:05	17:09	17:15	17:19	17:21
NJT 3857	SB	16:58								

NJT 3864	NB	17:02								
NJT 3943	SB	17:07	17:11	17:13	17:18	17:20	17:24	17:30	17:34	17:36
NJT 3866	NB	17:16								
NJT 3947	SB	17:25	17:26	17:28	17:33	17:35	17:39	17:45	17:49	17:51
NJT 3898	NB	17:35	17:41	17:43	17:48	17:50	17:54	18:00	18:04	18:06
NJT 3861	SB	17:44								
AmT 652	NB	17:52								
NJT 3949	SB	17:55	17:56	17:58	18:03	18:05	18:09	18:15	18:19	18:21
NJT 3868	NB	18:00	18:11	18:13	18:18	18:20	18:24	18:30	18:34	18:36
NJT 3951	SB	18:09								
NJT 3953	SB	18:20								
NJT 3867	SB	18:28								
NJT 3870	NB	18:29	18:26	18:28	18:33	18:35	18:39	18:45	18:49	18:51
NJT 3955	SB	18:36	18:41	18:43	18:48	18:50	18:54	19:00	19:04	19:06
NJT 3869	SB	18:45								
NJT 3872	NB	18:49								
NJT 3957	SB	18:56	18:56	18:58	19:03	19:05	19:09	19:15	19:19	19:21
NJT 3959	SB	19:13	19:11	19:13	19:18	19:20	19:24	19:30	19:34	19:36
NJT 3874	NB	19:25	19:26	19:28	19:33	19:35	19:39	19:45	19:49	19:51
NJT 3873	SB	19:25								
NJT 3961	SB	19:35								
AmT 196	NB	19:39	19:41	19:43	19:48	19:50	19:54	20:00	20:04	20:06
NJT 3875	SB	19:57	19:56	19:58	20:03	20:05	20:09	20:15	20:19	20:21
NJT 3876	NB	20:00	20:11	20:13	20:18	20:20	20:24	20:30	20:34	20:36
NJT 3963	SB	20:06								
AmT 138	NB	20:38								
NJT 3965	SB	20:45	20:26	20:28	20:33	20:35	20:39	20:45	20:49	20:51
NJT 3880	NB	20:50	20:41	20:43	20:48	20:50	20:54	21:00	21:04	21:06
NJT 3881	SB	20:56	20:56	20:58	21:03	21:05	21:09	21:15	21:19	21:21
NJT 3969	SB	21:14	21:11	21:13	21:18	21:20	21:24	21:30	21:34	21:36
NJT 3882	NB	21:20	21:26	21:28	21:33	21:35	21:39	21:45	21:49	21:51
NJT 3883	SB	21:23								
NJT 3885	SB	21:46	21:41	21:43	21:48	21:50	21:54	22:00	22:04	22:06
NJT 3886	NB	22:04	21:56	21:58	22:03	22:05	22:09	22:15	22:19	22:21
NJT 3887	SB	22:15	22:11	22:13	22:18	22:20	22:24	22:30	22:34	22:36
NJT 3889	SB	22:47	22:41	22:43	22:48	22:50	22:54	23:00	23:04	23:06
NJT 3888	NB	23:22								
NJT 3891	SB	23:22	23:11	23:13	23:18	23:20	23:24	23:30	23:34	23:36
NJT 3893	SB	23:48	23:41							

Appendix 3 Cost Estimate

Princeton Transit Study

Alternative F - Single Track on Separate ROW

Summary Total	Track Miles	3.31	CostM	$ 13,677,949.87	All unit prices adjusted to Design year dollars			
Standard Cost Category (SCC)		**Quantity**	**Units**	**Unit Price**	**Subtotal**	**A. Con%**	**A. Con%**	**Summary Total**
10	GUIDEWAY & TRACK ELEMENTS							$2,508,440
10.10	**Track: Embedded**							$2,012,340
10.10.1	Embedded Trackwork - Construct Track Slab	3,670	TF	$ 359.02	$1,317,604	20%	$263,521	$1,581,124
10.10.2	Embedded Trackwork - Furnish Girder Rail	3,670	TF	$ 97.91	$359,346	20%	$71,869	$431,216
10.12	**Track: Special (switches, turnouts)**							$496,100
10.12.1	Embedded Turnout	2	EA	$ 206,708.51	$413,417	20%	$82,683	$496,100
10.12.2	Embedded Crossing Diamond	-	EA	$ 206,708.51	$0	20%	$0	$0
20	STATIONS, STOPS, TERMINALS, INTERMODAL							$215,412
20.01	**At-grade station, stop, shelter, mall, terminal, platform**							$215,412
20.01.1	Streetcar Stop Platforms - Standard		EA	$ 97,914.56	$0	20%	$0	$0
20.01.2	Streetcar Stop Platforms - Premium	1	EA	$ 179,510.03	$179,510	20%	$35,902	$215,412
30	SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS							$5,938,516
30.02	**Light Maintenance Facility**							$4,805,973
30.02.1	Building - Operations and maintenance Building	11,250	SF	$ 299.10	$3,385,813	20%	$673,163	$4,038,976
30.02.2	Building - Wash Facility	-	LS	$ 489,572.80	$0	20%	$0	$0
30.02.3	Equipment - Shop Equipment and Furnishings Allowance	1	LS	$ 707,160.71	$459,654	20%	$91,931	$551,585
30.02.4	Site Civil - Utility Connections and Services	1	LS	$ 59,036.60	$59,037	20%	$11,967	$71,604
30.02.5	Site Civil - Miscellaneous Allowance (i.e. Fences, sidewalk, etc.)	1	LS	$ 119,673.35	$119,673	20%	$23,935	$143,608
30.05	**Yard and Yard Track**							$1,132,546
30.05.1	Non-Revenue Track - Complete (includes OCS, track, rail, etc.)	-	TF	$ 2,393.47	$0	20%	$0	$0
30.05.3	Ballasted Yard Track	2,000	TF	$ 239.35	$478,693	20%	$95,739	$574,432
30.05.4	Yard Turnouts - Embedded	-	EA	$ 149,871.64	$0	20%	$0	$0
30.05.5	Yard Turnouts - Ballasted	6	EA	$ 54,396.98	$326,382	20%	$65,276	$391,658
30.05.6	Site Civil - Storage Yard Paving	4,500	SF	$ 16.32	$73,430	20%	$14,687	$88,123
30.05.7	TPSS - Yard	300	TF	$ 217.59	$65,276	20%	$13,055	$78,332
30.05.8	TPSS - Yard Substation	-	EA	$ 489,572.80	$0	20%	$0	$0
40	SITEWORK & SPECIAL CONDITIONS							$3,920,214
40.02	**Site Utilities, Utility Relocation**							$659,291
40.02.1	Utilities	1	LS	$ 163,190.93	$163,191	20%	$32,638	$195,829
40.02.4	Stormwater Drainage Allowance	3,500	TF	$ 32.64	$114,234	20%	$22,847	$137,080
40.02.5	Street Lighting Modification Allowance	1	LS	$ 271,984.89	$271,985	20%	$54,397	$326,382
40.06	**Pedestrian / bike access and accommodation, landscaping**							$626,653
40.06.1	Civil - Urban improvement allowance (sidewalks, driveways, etc)	24,000	SF	$ 21.76	$522,211	20%	$104,442	$626,653
40.06.2	Civil - Curb Ramp/ADA Upgrade Allowance (Per Intersection)	-	EA	$ 21,758.79	$0	20%	$0	$0
40.07	**Automobile, bus, van accessways including roads, parking lots**							$339,437
40.07.1	Civil - Roadway Pavement	13,000	SF	$ 24.78	$262,864	20%	$56,573	$339,437
40.07.2	Site Civil - Storage Yard/Parking	4,400	SF	$ 32.64	$143,608	20%	$28,722	$172,330
40.08	**Temporary Facilities and other indirect costs during construction**							$2,294,832
40.08.1	Maintenance of Traffic (percentage of direct costs)	17,577,818	$	4%	$764,944	0%	$0	$764,944
40.08.2	Contractor Indirects (mobilization, etc.; percentage of direct costs)	17,577,818	$	8%	$1,528,868	0%	$0	$1,528,888
50	SYSTEMS							$7,065,070
50.01	**Train Control and signals**							$2,611,055
50.01.1	Single-track signaling system	1	EA	$ 2,175,879.10	$2,175,879	20%	$435,176	$2,611,055
50.02	**Traffic signals and crossing protection**							$757,206
50.02.1	Traffic Signal - New (or Complete Rebuild)	1	EA	$ 261,105.49	$261,105	20%	$52,221	$313,327
50.02.3	Traffic Signal Modification	4	EA	$ 92,474.96	$369,899	20%	$73,980	$443,879
50.02.5	Traffic - Transit Signal Priority (TSP) Equipment upgrade allowance	-	TF	$ 27.20	$0	20%	$0	$0
50.03	**Traction power supply: substations**							$2,741,608
50.03.1	TPSS - Mainline Substation (incl charging station)	2	EA	$ 1,142,336.53	$2,284,673	20%	$456,935	$2,741,608
50.04	**Traction power supply: catenary and third rail**							$488,267
50.04.1	TPSS (Traction Power Supply System) - OCS - single track (trolley wire)	1,700	TF	$ 239.35	$406,889	20%	$81,378	$488,267
50.05	**Communications**	-	LS	$ 163,190.93	$0	20%	$0	$0
50.06	**Fare Collection system and equipment**	5	LS	$ 76,155.77	$380,779	20%	$76,156	$456,935
Construction Subtotal (10-50)								$19,637,665
70	VEHICLES							$14,902,500
70.01	**Light Rail**							$14,850,000
70.01.1	Streetcar Vehicle	3	EA	$ 4,500,000.00	$12,500,000	10%	$1,350,000	$14,850,000
70.07	**Spare Parts**	1	EA	$ 50,000.00	$50,000	5%	$2,500	$52,500
80	PROFESSIONAL SERVICES (applies to Cats. 10-50)							$4,846,211
80.01	Preliminary Engineering	19,384,842	$	2%	$387,697	0%	$0	$387,697
80.02	Final Design	19,384,842	$	6%	$1,163,091	0%	$0	$1,163,091
80.03	Project Management for Design and Construction	19,384,842	$	4%	$775,394	0%	$0	$775,394
80.04	Construction Administration & Management	19,384,842	$	5%	$969,242	0%	$0	$969,242
80.05	Professional Liability and other Non-Construction Insurance	19,384,842	$	2%	$387,697	0%	$0	$387,697
80.06	Legal; Permits; Review Fees by other agencies, cities, etc.	19,384,842	$	2%	$387,697	0%	$0	$387,697
80.07	Surveys, Testing, Investigation, Inspection	19,384,842	$	2%	$387,697	0%	$0	$387,697
80.08	Start up	19,384,842	$	2%	$387,697	0%	$0	$387,697
Subtotal (10-80)								$39,386,366
90	UNALLOCATED CONTINGENCY	39,133,553	$	15%				$5,870,033
Subtotal (10-90)								$45,256,399
100	FINANCE CHARGES	45,003,586	$	0%				$0
					Total Project Cost			$45,256,399

Princeton Transit Study

Alternative E - Dual Track (in street) North of Station

Summary Total		Track Miles 3.89	Cost/M	$ 12,779,734.25	All unit prices adjusted to Design year dollars			
Standard Cost Category (SCC)		**Quantity**	**Units**	**Unit Price**	**Subtotal**	**A. Con%**	**A. Con%**	**Summary Total**
10.04.1	Existing Structure Crossing	-	TF	$ 837.71	$0	20%	$0	$0
10.10	**Track: Embedded**							**$3,673,754**
10.10.1	Embedded Trackwork - Construct Track Slab	6,700	TF	$ 359.02	$2,405,434	20%	$481,087	$2,886,521
10.10.2	Embedded Trackwork - Furnish Girder Rail	6,700	TF	$ 97.91	$656,028	20%	$131,206	$787,233
10.12	**Track: Special (switches, turnouts)**							**$1,736,352**
10.12.1	Embedded Turnout	6	EA	$ 206,709.51	$1,240,251	20%	$248,050	$1,488,301
10.12.2	Embedded Crossing Diamond	1	EA	$ 206,709.51	$206,709	20%	$41,342	$248,050
20	**STATIONS, STOPS, TERMINALS, INTERMODAL**							**$215,412**
20.01	**At-grade station, stop, shelter, mall, terminal, platform**							**$215,412**
20.01.1	Streetcar Stop Platforms - Standard		EA	$ 97,914.56	$0	20%	$0	$0
20.01.2	Streetcar Stop Platforms - Premium	1	EA	$ 179,510.03	$179,510	20%	$35,902	$215,412
30	**SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS**							**$5,938,518**
30.02	**Light Maintenance Facility**							**$4,805,973**
30.02.1	Building - Operations and maintenance Building	11,250	SF	$ 299.18	$3,365,813	20%	$673,163	$4,038,976
30.02.2	Building - Wash Facility	-	LS	$ 489,572.80	$0	20%	$0	$0
30.02.3	Equipment - Shop Equipment and Furnishings Allowance	1	LS	$ 707,160.71	$459,654	20%	$91,931	$551,585
30.02.4	Site Civil - Utility Connections and Services	1	LS	$ 58,836.68	$59,837	20%	$11,967	$71,804
30.02.5	Site Civil - Miscellaneous Allowance (i.e. Fences, sidewalk, etc.)	1	LS	$ 119,673.35	$119,673	20%	$23,935	$143,608
30.05	**Yard and Yard Track**							**$1,132,545**
30.05.1	Non-Revenue Track - Complete (includes OCS, track, rail, etc.)	-	TF	$ 2,383.47	$0	20%	$0	$0
30.05.3	Ballasted Yard Track	2,000	TF	$ 239.35	$478,699	20%	$95,739	$574,432
30.05.4	Yard Turnouts - Embedded	-	EA	$ 146,871.84	$0	20%	$0	$0
30.05.5	Yard Turnouts - Ballasted	6	EA	$ 54,396.99	$326,382	20%	$65,276	$391,658
30.05.6	Site Civil - Storage Yard Paving	4,500	SF	$ 16.32	$73,436	20%	$14,687	$88,123
30.05.7	TPSS - Yard	300	TF	$ 217.59	$65,276	20%	$13,055	$78,332
30.05.8	TPSS - Yard Substation	-	EA	$ 489,572.80	$0	20%	$0	$0
40	**SITEWORK & SPECIAL CONDITIONS**							**$3,798,611**
40.02	**Site Utilities, Utility Relocation**							**$659,291**
40.02.1	Utilities	1	LS	$ 163,180.93	$163,181	20%	$32,636	$195,829
40.02.4	Stormwater Drainage Allowance	3,500	TF	$ 32.64	$114,234	20%	$22,847	$137,080
40.02.5	Street Lighting Modification Allowance	1	LS	$ 271,984.89	$271,985	20%	$54,397	$326,382
40.06	**Pedestrian / bike access and accommodation, landscaping**							**$292,438**
40.06.1	Civil - Urban improvement allowance (sidewalks, driveways, etc.)	11,200	SF	$ 21.76	$243,698	20%	$48,740	$292,438
40.06.2	Civil - Curb Ramp/ADA Upgrade Allowance (Per Intersection)	-	EA	$ 21,756.78	$0	20%	$0	$0
40.07	**Automobile, bus, van accessways including roads, parking lots**							**$182,774**
40.07.1	Civil - Roadway Pavement	7,000	SF	$ 21.75	$152,312	20%	$30,462	$182,774
40.07.2	Site Civil - Storage Yard/Parking	1,400	SF	$ 32.64	$45,693	20%	$9,139	$54,832
40.08	**Temporary Facilities and other indirect costs during construction**							**$2,664,108**
40.08.1	Maintenance of Traffic (percentage of direct costs)	20,406,373	$	4%	$888,036	0%	$0	$888,036
40.08.2	Contractor Indirects (mobilization, etc.; percentage of direct costs)	20,406,373	$	9%	$1,776,072	0%	$0	$1,776,072
50	**SYSTEMS**							**$7,237,844**
50.01	**Train Control and signals**							**$2,611,055**
50.01.1	Single track signaling system	1	EA	$ 2,175,879.10	$2,175,879	20%	$435,176	$2,611,055
50.02	**Traffic signals and crossing protection**							**$757,206**
50.02.1	Traffic Signal - New (or Complete Rebuild)	1	EA	$ 261,105.49	$261,105	20%	$52,221	$313,327
50.02.3	Traffic Signal Modification	4	EA	$ 92,474.96	$369,899	20%	$73,980	$443,879
50.02.5	Traffic - Transit Signal Priority (TSP) Equipment upgrade allowance	-	TF	$ 27.20	$0	20%	$0	$0
50.03	**Traction power supply: substations**							**$2,741,608**
50.03.1	TPSS - Mainline Substation (incl charging station)	2	EA	$ 1,142,336.53	$2,284,673	20%	$456,935	$2,741,608
50.04	**Traction power supply: catenary and third rail**							**$488,267**
50.04.1	TPSS (Traction Power Supply System) - OCS - single track (trolley wire)	1,700	TF	$ 239.35	$406,889	20%	$81,378	$488,267
50.05	**Communications**	-	**LS**	**$ 543,969.77**	**$0**	**20%**	**$0**	**$0**
50.06	**Fare Collection system and equipment**	7	**EA**	**$ 76,155.77**	**$533,090**	**20%**	**$106,618**	**$639,708**
Construction Subtotal (10-60)								**$22,800,492**
70	**VEHICLES**							**$14,902,500**
70.01	**Light Rail**							**$14,850,000**
70.01.1	Streetcar Vehicle	3	EA	$ 4,500,000.00	$13,500,000	10%	$1,350,000	$14,850,000
70.07	**Spare Parts**	1	**EA**	**$ 50,000.00**	**$50,000**	**5%**	**$2,500**	**$52,500**
80	**PROFESSIONAL SERVICES (applies to Cats. 10-60)**							**$6,645,868**
80.01	Preliminary Engineering	22,582,674	$	2%	$451,653	0%	$0	$451,653
80.02	Final Design	22,582,674	$	6%	$1,354,960	0%	$0	$1,354,960
80.03	Project Management for Design and Construction	22,582,674	$	4%	$903,307	0%	$0	$903,307
80.04	Construction Administration & Management	22,582,674	$	5%	$1,129,134	0%	$0	$1,129,134
80.05	Professional Liability and other Non-Construction Insurance	22,582,674	$	2%	$451,653	0%	$0	$451,653
80.06	Legal; Permits; Review Fees by other agencies, cities, etc.	22,582,674	$	2%	$451,653	0%	$0	$451,653
80.07	Surveys, Testing, Investigation, Inspection	22,582,674	$	2%	$451,653	0%	$0	$451,653
80.08	Start up	22,582,674	$	2%	$451,653	0%	$0	$451,653
Subtotal (10-80)								**$43,148,660**
90	**UNALLOCATED CONTINGENCY**	43,130,842	$	15%				**$6,469,626**
Subtotal (10-90)								**$49,618,286**
100	**FINANCE CHARGES**	49,600,469	$	0%				**$0**
					Total Project Cost			$49,618,286

2015-04-10 Cost Estimate Alt E

Princeton Transit Study

Alternative E1 - Dual Track (in street) North of Faculty Street

2014 – 11 07 Cost Estimate Alt 1

Summary Total		Track Miles 4.36	Cost/M	$ 13,011,112.35	All unit prices adjusted to Design year dollars			
Standard Cost Category (SCC)		**Quantity**	**Units**	**Unit Price**	**Subtotal**	**A. Con%**	**A. Con%**	**Summary Total**
10.04.1	Existing Structure Crossing	-	TF	$ 837.71	$0	20%	$0	$0
10.10	**Track: Embedded**							**$5,044,558**
10.10.1	Embedded Trackwork - Construct Track Slab	**9,200**	TF	$ 359.02	$3,302,984	20%	$660,597	$3,963,581
10.10.2	Embedded Trackwork - Furnish Girder Rail	**9,200**	TF	$ 97.91	$900,814	20%	$180,163	$1,080,977
10.12	**Track: Special (switches, turnouts)**							**$3,968,803**
10.12.1	Embedded Turnout	**13**	EA	$ 206,708.51	$2,687,211	20%	$537,442	$3,224,653
10.12.2	Embedded Crossing Diamond	**3**	EA	$ 206,708.51	$620,126	20%	$124,025	$744,151
20	**STATIONS, STOPS, TERMINALS, INTERMODAL**							**$900,814**
20.01	**At-grade station, stop, shelter, mall, terminal, platform**							**$900,814**
20.01.1	Streetcar Stop Platforms - Standard	**4**	EA	$ 97,914.56	$391,658	20%	$78,332	$469,990
20.01.2	Streetcar Stop Platforms - Premium	**2**	EA	$ 179,510.03	$359,020	20%	$71,804	$430,824
30	**ORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS**							**$5,737,467**
30.02	**Maintenance Facility**							**$4,805,973**
30.0	g - Operations and maintenance Building	**11,250**	SF	$ 299.18	$3,365,813	20%	$673,163	$4,038,976
30.0	g - Wash Facility	-	LS	$ 489,572.80	$0	20%	$0	$0
30.0	ent - Shop Equipment and Furnishings Allowance	**1**	LS	$ 707,160.71	$459,654	20%	$91,931	$551,585
30.0	vil - Utility Connections and Services	**1**	LS	$ 59,836.68	$59,837	20%	$11,967	$71,804
30.0	vil - Miscellaneous Allowance (i.e. Fences, sidewalk, etc.)	**1**	LS	$ 119,673.35	$119,673	20%	$23,935	$143,608
30.05	**nd Yard Track**							**$931,494**
30.0	evenue Track - Complete (includes OCS, track, rail, etc.)	-	TF	$ 2,393.47	$0	20%	$0	$0
30.0	ed Yard Track	**1,300**	TF	$ 239.35	$311,151	20%	$62,230	$373,381
30.0	urnouts - Embedded	-	EA	$ 146,871.84	$0	20%	$0	$0
30.0	urnouts - Ballasted	**6**	EA	$ 54,396.98	$326,382	20%	$65,276	$391,658
30.0	vil - Storage Yard Paving	**4,500**	SF	$ 16.32	$73,436	20%	$14,687	$88,123
30.0	- Yard	**300**	TF	$ 217.59	$65,276	20%	$13,055	$78,332
30.0	- Yard Substation	-	EA	$ 489,572.80	$0	20%	$0	$0
40	**ORK & SPECIAL CONDITIONS**							**$4,365,666**
40.02	**ilities, Utility Relocation**							**$659,291**
40.0	s	**1**	LS	$ 163,190.93	$163,191	20%	$32,638	$195,829
40.0	vater Drainage Allowance	**3,500**	TF	$ 32.64	$114,234	20%	$22,847	$137,080
40.0	Lighting Modification Allowance	**1**	LS	$ 271,984.89	$271,985	20%	$54,397	$326,382
40.06	**trian / bike access and accommodation, landscaping**							**$292,438**
40.0	Urban improvement allowance (sidewalks, driveways, etc)	**11,200**	SF	$ 21.76	$243,698	20%	$48,740	$292,438
40.0	Curb Ramp/ADA Upgrade Allowance (Per Intersection)	-	EA	$ 21,758.79	$0	20%	$0	$0
40.07	**obile, bus, van accessways including roads, parking lots**							**$182,774**
40.0	Roadway Pavement	**7,000**	SF	$ 21.76	$152,312	20%	$30,462	$182,774
40.0	vil - Storage Yard/Parking	**1,400**	SF	$ 32.64	$45,693	20%	$9,139	$54,832
40.08	**rary Facilities and other indirect costs during construction**							**$3,231,163**
40.0	nance of Traffic (percentage of direct costs)	**24,749,863**	$	4%	$1,077,054	0%	$0	$1,077,054
40.0	ctor Indirects (mobilization, etc., percentage of direct costs)	**24,749,863**	$	9%	$2,154,108	0%	$0	$2,154,108
50	**EMS**							**$7,493,728**
50.01	**Control and signals**							**$2,611,055**
50.0	track signalling system	**1**	EA	$ 2,175,879.10	$2,175,879	20%	$435,176	$2,611,055
50.02	**signals and crossing protection**							**$757,206**
50.0	Signal - New (or Complete Rebuild)	**1**	EA	$ 261,105.49	$261,105	20%	$52,221	$313,327
50.0	Signal Modification	**4**	EA	$ 92,474.86	$369,899	20%	$73,980	$443,879
50.0	- Transit Signal Priority (TSP) Equipment upgrade allowance	-	TF	$ 27.20	$0	20%	$0	$0
50.03	**on power supply: substations**							**$2,741,608**
50.0	- Mainline Substation (includes charging stations)	**2**	EA	$ 1,142,336.53	$2,284,673	20%	$456,935	$2,741,608
50.04	**on power supply: catenary and third rail**							**$287,216**
50.0	Traction Power Supply System) - OCS - single track (trolley wire)	**1,000**	TF	$ 239.35	$239,347	20%	$47,869	$287,216
50.05	**unications**	-	**LS**	**$ 163,190.93**	**$0**	**20%**	**$0**	**$0**
50.06	**ollection system and equipment**	**12**	**EA**	**$ 76,155.77**	**$913,869**	**20%**	**$182,774**	**$1,096,643**
Construction	**10-50)**							**$27,511,636**
70	**LES**							**$14,902,500**
70.01	**Rail**							**$14,850,000**
70.0	ar Vehicle	**3**	EA	$ 4,500,000.00	$13,500,000	10%	$1,350,000	$14,850,000
70.07	**Parts**	**1**	**EA**	**$ 50,000.00**	**$50,000**	**5%**	**$2,500**	**$52,500**
80	**ESSIONAL SERVICES (applies to Cats. 10-50)**							**$6,873,305**
80.01	nary Engineering	**27,493,218**	$	2%	$549,864	0%	$0	$549,864
80.02	Design	**27,493,218**	$	6%	$1,649,593	0%	$0	$1,649,593
80.03	Project Management for Design and Construction	**27,493,218**	$	4%	$1,099,729	0%	$0	$1,099,729
80.04	Construction Administration & Management	**27,493,218**	$	5%	$1,374,661	0%	$0	$1,374,661
80.05	Professional Liability and other Non-Construction Insurance	**27,493,218**	$	2%	$549,864	0%	$0	$549,864
80.06	Legal; Permits; Review Fees by other agencies, cities, etc.	**27,493,218**	$	2%	$549,864	0%	$0	$549,864
80.07	Surveys, Testing, Investigation, Inspection	**27,493,218**	$	2%	$549,864	0%	$0	$549,864
80.08	Start up	**27,493,218**	$	2%	$549,864	0%	$0	$549,864
Subtotal (10-80)								**$49,286,840**
90	**UNALLOCATED CONTINGENCY**	**49,269,023**	**$**	**15%**				**$7,390,353**
Subtotal (10-90)								**$56,677,194**
100	**FINANCE CHARGES**	**56,659,376**	**$**	**0%**				**$0**
					Total Project Cost			**$56,677,194**

2015-04-10 Cost Estimate Alt E1

Princeton Transit Study

Alternative E2 - Dual Track (in street) North of Restaurant

Summary	Total	Track Miles	4.96	Cost/M	$ 12,639,105.29	All unit prices adjusted to Design year dollars			
Standard Cost Category (SCC)		Quantity	Units	Unit Price	Subtotal	A. Con%	A. Con%	Summary Total	
10.04.1	Existing Structure Crossing	-	TF	$ 837.71	$0	20%	$0	$0	
10.10	**Track: Embedded**							**$6,799,187**	
10.10.1	Embedded Trackwork - Construct Track Slab	**12,400**	TF	$ 359.02	$4,451,849	20%	$890,370	$5,342,218	
10.10.2	Embedded Trackwork - Furnish Girder Rail	**12,400**	TF	$ 97.91	$1,214,141	20%	$242,828	$1,456,969	
10.12	**Track: Special (switches, turnouts)**							**$3,968,803**	
10.12.1	Embedded Turnout	**13**	EA	$ 206,708.51	$2,687,211	20%	$537,442	$3,224,653	
10.12.2	Embedded Crossing Diamond	**3**	EA	$ 206,708.51	$620,126	20%	$124,025	$744,151	
20	STATIONS, STOPS, TERMINALS, INTERMODAL							**$1,116,226**	
20.01	**At-grade station, stop, shelter, mall, terminal, platform**							**$1,116,226**	
20.01.1	Streetcar Stop Platforms - Standard	**4**	EA	$ 97,914.56	$391,658	20%	$78,332	$469,990	
20.01.2	Streetcar Stop Platforms - Premium	**3**	EA	$ 179,510.03	$538,530	20%	$107,706	$646,236	
30	SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS							**$5,737,467**	
30.02	**Light Maintenance Facility**							**$4,805,973**	
30.02.1	Building - Operations and maintenance Building	**11,250**	SF	$ 299.18	$3,365,813	20%	$673,163	$4,038,976	
30.02.2	Building - Wash Facility	-	LS	$ 489,572.80	$0	20%	$0	$0	
30.02.3	Equipment - Shop Equipment and Furnishings Allowance	**1**	LS	$ 707,160.71	$459,654	20%	$91,931	$551,585	
30.02.4	Site Civil - Utility Connections and Services	**1**	LS	$ 59,836.68	$59,837	20%	$11,967	$71,804	
30.02.5	Site Civil - Miscellaneous Allowance (i.e. Fences, sidewalk, etc.)	**1**	LS	$ 119,673.35	$119,673	20%	$23,935	$143,608	
30.05	**Yard and Yard Track**							**$931,494**	
30.05.1	Non-Revenue Track - Complete (includes OCS, track, rail, etc.)	-	TF	$ 2,393.47	$0	20%	$0	$0	
30.05.3	Ballasted Yard Track	**1,300**	TF	$ 239.35	$311,151	20%	$62,230	$373,381	
30.05.4	Yard Turnouts - Embedded	-	EA	$ 146,871.84	$0	20%	$0	$0	
30.05.5	Yard Turnouts - Ballasted	**6**	EA	$ 54,396.98	$326,382	20%	$65,276	$391,658	
30.05.6	Site Civil - Storage Yard Paving	**4,500**	SF	$ 16.32	$73,436	20%	$14,687	$88,123	
30.05.7	TPSS - Yard	**300**	TF	$ 217.59	$65,276	20%	$13,055	$78,332	
30.05.8	TPSS - Yard Substation	-	EA	$ 489,572.80	$0	20%	$0	$0	
40	SITEWORK & SPECIAL CONDITIONS							**$4,651,835**	
40.02	**Site Utilities, Utility Relocation**							**$659,291**	
40.02.1	Utilities	**1**	LS	$ 163,190.93	$163,191	20%	$32,638	$195,829	
40.02.4	Stormwater Drainage Allowance	**3,500**	TF	$ 32.64	$114,234	20%	$22,847	$137,080	
40.02.5	Street Lighting Modification Allowance	**1**	LS	$ 271,984.89	$271,985	20%	$54,397	$326,382	
40.06	**Pedestrian / bike access and accommodation, landscaping**							**$292,438**	
40.06.1	Civil - Urban improvement allowance (sidewalks, driveways, etc)	**11,200**	SF	$ 21.76	$243,698	20%	$48,740	$292,438	
40.06.2	Civil - Curb Ramp/ADA Upgrade Allowance (Per Intersection)	-	EA	$ 21,758.79	$0	20%	$0	$0	
40.07	**Automobile, bus, van accessways including roads, parking lots**							**$182,774**	
40.07.1	Civil - Roadway Pavement	**7,000**	SF	$ 21.76	$152,312	20%	$30,462	$182,774	
40.07.2	Site Civil - Storage Yard/Parking	**1,400**	SF	$ 32.64	$45,693	20%	$9,139	$54,832	
40.08	**Temporary Facilities and other indirect costs during construction**							**$3,517,332**	
40.08.1	Maintenance of Traffic (percentage of direct costs)	**26,941,844**	$	4%	$1,172,444	0%	$0	$1,172,444	
40.08.2	Contractor Indirects (mobilization, etc.; percentage of direct costs)	**26,941,844**	$	9%	$2,344,888	0%	$0	$2,344,888	
50	SYSTEMS							**$7,715,667**	
50.01	**Train Control and signals**							**$2,611,055**	
50.01.1	Single-track signalling system	**1**	EA	$ 2,175,879.10	$2,175,879	20%	$435,176	$2,611,055	
50.02	**Traffic signals and crossing protection**							**$757,206**	
50.02.1	Traffic Signal - New (or Complete Rebuild)	**1**	EA	$ 261,105.49	$261,105	20%	$52,221	$313,327	
50.02.3	Traffic Signal Modification	**4**	EA	$ 92,474.86	$369,899	20%	$73,980	$443,879	
50.02.5	Traffic - Transit Signal Priority (TSP) Equipment upgrade allowance	-	TF	$ 27.20	$0	20%	$0	$0	
50.03	**Traction power supply: substations**							**$2,872,160**	
50.03.1	TPSS - Mainline Substation (incl charging stations)	**2**	EA	$ 1,196,733.50	$2,393,467	20%	$478,693	$2,872,160	
50.04	**Traction power supply: catenary and third rail**							**$287,216**	
50.04.1	TPSS (Traction Power Supply System) - OCS - single track (trolley wire)	**1,000**	TF	$ 239.35	$239,347	20%	$47,869	$287,216	
50.05	**Communications**	**-**	**LS**	**$ 163,190.93**	**$0**	**20%**	**$0**	**$0**	
50.06	**Fare Collection system and equipment**	**13**	**EA**	**$ 76,155.77**	**$990,025**	**20%**	**$198,005**	**$1,188,030**	
Construction Subtotal (10-50)								**$29,989,186**	
70	VEHICLES							**$14,902,500**	
70.01	**Light Rail**							**$14,850,000**	
70.01.1	Streetcar Vehicle	**3**	EA	$ 4,500,000.00	$13,500,000	10%	$1,350,000	$14,850,000	
70.07	**Spare Parts**	**1**	**EA**	**$ 50,000.00**	**$50,000**	**5%**	**$2,500**	**$52,500**	
80	PROFESSIONAL SERVICES (applies to Cats. 10-50)							**$7,492,842**	
80.01	Preliminary Engineering	**29,971,368**	$	2%	$599,427	0%	$0	$599,427	
80.02	Final Design	**29,971,368**	$	6%	$1,798,282	0%	$0	$1,798,282	
80.03	Project Management for Design and Construction	**29,971,368**	$	4%	$1,198,855	0%	$0	$1,198,855	
80.04	Construction Administration & Management	**29,971,368**	$	5%	$1,498,568	0%	$0	$1,498,568	
80.05	Professional Liability and other Non-Construction Insurance	**29,971,368**	$	2%	$599,427	0%	$0	$599,427	
80.06	Legal; Permits; Review Fees by other agencies, cities, etc.	**29,971,368**	$	2%	$599,427	0%	$0	$599,427	
80.07	Surveys, Testing, Investigation, Inspection	**29,971,368**	$	2%	$599,427	0%	$0	$599,427	
80.08	Start up	**29,971,368**	$	2%	$599,427	0%	$0	$599,427	
Subtotal (10-80)								**$54,538,648**	
90	UNALLOCATED CONTINGENCY	**54,520,830**	**$**	**15%**				**$8,178,125**	
Subtotal (10-90)								**$62,716,772**	
100	FINANCE CHARGES	**62,698,955**	**$**	**0%**				**$0**	
					Total Project Cost			$62,716,772	

2015-04-10 Cost Estimate Alt E2

Appendix 4 – Memorandum of Understanding

Memorandum of Understanding
November 1, 2011

This memorandum outlines areas of agreement between Princeton University and the municipalities of Princeton Borough and Princeton Township in regard to the Arts and Transit proposal. The three entities have come together because of their common desire to assure continuing and improved transportation service along the NJ Transit Princeton Branch, known as the Dinky line. With the understanding that enhanced service will benefit all who travel to and from Princeton, the three parties agree to implement the following strategies as outlined in this Memorandum of Understanding.

Princeton University has proposed zoning that would establish a new Arts and Transit District that is situated within the municipal boundaries of both the Borough and the Township. The University has submitted conceptual zoning ordinances to the governing bodies of both municipalities, and those conceptual zoning ordinances will be subject to statutory public processes such as those set forth in the Municipal Land Use Law ("MLUL"), N.J.S.A. 40:55D-1 et seq., including public hearing(s) by the governing bodies of the municipalities and public hearing(s) by the Princeton Regional Planning Board ("Planning Board") concerning the governing bodies' referral of the ordinances and potential associated amendments to the Community Master Plan. If any zoning ordinances related to the University's Arts and Transit District are voted upon and approved in the aforementioned public forums, any subsequent development application made by Princeton University pursuant to such zoning ordinances would have to be reviewed by and voted upon in public hearings before the Planning Board pursuant to the requirements of the MLUL.

Since proper planning for future transportation service along the Dinky line is in the public interest, the parties wish to be prepared to move forward with appropriate transportation initiatives. This MOU is not being entered into with any representation by the municipalities that any conceptual zoning ordinances proposed by Princeton University will be adopted or that any future development application made by Princeton University pursuant to any zoning related to an Arts and Transit District will be granted by the Planning Board. Any conceptual zoning ordinances and any future development application are subject to public hearings before the governing bodies of the municipality and the Planning Board, and the execution of this MOU has no impact on those public hearings.

Except as expressly provided herein to the contrary, the provisions of this MOU will become effective if and when the Planning Board adopts a resolution granting final site plan approval to Princeton University for its Arts and Transit proposal, with said resolution containing conditions of approval that are acceptable to Princeton University.

Preserving and Enhancing the Dinky – Existing Heavy Rail Service

1. Upon approval of this agreement by the governing bodies of Princeton Borough and Princeton Township, the University, in conjunction with the Borough and the Township, will seek approval from New Jersey Transit to open the existing north station waiting room to the public. Upon receiving such approval, the University will open the station for a minimum of five hours each weekday, exact times to be mutually determined by an assessment of usage. The waiting room will be heated and lighted, with available restroom facilities for public use. The waiting room shall also include any other amenities and improvements that may be mutually agreed upon. All services, amenities, and improvements shall be at the sole cost of the University and/or New Jersey Transit. The north station building will remain open as a waiting room until the discontinuation of train service to the current location. Six months after the opening of the waiting room, the University may elect to terminate or modify this provision if the Planning Board has not adopted a resolution granting final site plan approval to Princeton University for its Arts and Transit project.

2. Upon approval of this agreement by the governing bodies of Princeton Borough and Princeton Township, the University will work together with Princeton Borough and Princeton Township to encourage New Jersey Transit to provide additional Dinky service, including during off-peak hours and weekend hours.

3. Upon approval of this agreement by the governing bodies of Princeton Borough and Princeton Township, the University will work with the municipalities and local merchants to develop a formal plan to promote Dinky ridership, including but not limited to train ticket receipts being utilized to obtain discounts at McCarter Theater, University athletic events and local stores and restaurants.

4. Upon approval of this agreement by the governing bodies of Princeton Borough and Princeton Township, the University shall continue to encourage additional use of the Dinky through the mass transit subsidy it provides to faculty, staff, and graduate students under its Transportation Demand Management (TDM) program.

5. The University agrees that if the present station terminus is moved to the proposed new location, it will take no action to move the station farther south as long as heavy rail service is in existence.

6. The Arts & Transit plan further proposes to increase Dinky ridership by:

    6.1 Providing an attractive new station (described below) and surrounding area, including easy access to parking, drop-off, taxis, and buses.

    6.2 Creating better bike access and shuttle connections, including TigerTransit scheduling as described below.

6.3 Adding new passenger destinations, including indoor arts programming, outdoor arts programming, community programming, and retail venues.

6.3.1 It is anticipated that expansion of the University's arts programming will result in more artists, students and audience members traveling between Princeton and New York or Philadelphia. It is further expected that there will be performers, performances and facilities in Princeton that will not be available in New York or Philadelphia.

6.3.2 It is anticipated that some of the outdoor programming in the area, apart from the arts programming, will attract interest outside of Princeton, e.g., outdoor chess tournaments, an outdoor summer movie series, etc. There will also be outdoor theater, music, and dance performances.

7. The University will schedule its TigerTransit shuttle system to meet all incoming Dinky trains and travel to Nassau St. during morning and evening peak commuter hours. During off-peak hours, TigerTransit shuttles also would stop regularly at the proposed new Dinky station. In addition, as it relates to this shuttle service, the University will:

7.1 Immediately develop a public relations program in conjunction with Princeton Borough and Princeton Township, including signage and other forms of promotion, to alert residents that this service is "free and open to the public" for both present and future stations. The metrics of the public relations program and its scheduling shall be determined by mutual agreement of the three parties.

7.2 The University will pay for and install an electronic route map and shuttle locator system for TigerTransit at the new station that would inform arriving passengers when the next shuttle will be arriving.

7.3 Recognizing a shared interest of the University and the municipalities in getting Transit riders to Nassau Street without excessive delays, the University will utilize Elm Drive, or other internal campus roads, as an alternative route for the TigerTransit shuttles from the new station to Nassau Street should traffic conditions along Alexander and or University Place cause repeated delays.

7.4 The University will work with the municipalities to design and help fund a collector transit system that will bring passengers from collection points in both municipalities to the new station.

7.5 Similar to the $10,000 contribution that the University made in 2011 to assist in launching the service, the University will provide an annual contribution of $10,000 to the municipalities' Community Transportation Coordination Initiative to help offset the costs of extending the FreeB shuttle service to mid day hours. This annual contribution will last for two years at a minimum from its initiation and it may be directed toward compliance with the goal stated in paragraph 7.4

above, in which case, it may be ongoing. Any extension past the initial two-year term will be solely at the discretion of the University.

8. Pursuant to its Arts & Transit proposal, the University shall construct a new rail station adjacent to a convenience store offering food that is open 24/7. The station proposed by the University would include:

   8.1 Heated/cooled waiting room
   8.2 Restrooms
   8.3 Ticket machines
   8.4 Electronic information kiosk
   8.5 Community bulletin board
   8.6 Electronic arrival and departure notification for the Dinky (pending NJT capability)
   8.7 Electronic arrival and departure notification for TigerTransit
   8.8 ATM
   8.9 Public library book drop off/pick up
   8.10.1 Secure/covered bike parking
   8.10.2 Changing areas
   8.10.3 Bike lockers
   8.10.4 Bike rental system
   8.10.5 Rider support (air for tires, tools for quick fixes)
   8.10.6 An enhanced bike path system to link campus and community bike routes to the station area.

9. Also pursuant to its Arts & Transit proposal, the University shall construct a new transit plaza and parking areas that provide easy access to the Dinky for riders who go to the station by car. Features of the plaza and parking areas in the University's proposal include:

   9.1 Convenient drop off and pickup area.

   9.2 The same number of on-site commuter and all-day parking spaces as currently exist in the vicinity of the current rail station, in both permit and metered spaces, with easy access to and from Alexander Street. The total number of short-term parking spaces provided in the University's Arts & Transit proposal exceeds the number of short-term spaces in the vicinity of the current station.

   9.3 Easy access to shuttles, jitneys and taxis.

10. The University's long-term development plan for its lands along south Alexander as a residential mixed-use neighborhood with well-designed bike and pedestrian connections would add several hundred residents to the immediate area and facilitate access to mass transit.

Next Generation Transit Service

11. Upon approval of this agreement by the governing bodies of Princeton Borough and Princeton Township, the University and the municipalities agree to form a joint task force ("The Alexander Street/University Place Transit Task Force") and commence the project described in section 12.1 below. The Task Force shall consist of six members, with no fewer than one appointed representative of Princeton Borough Council and no fewer than one appointed representative of Princeton Township Committee and with each town to have one additional appointed representative. There shall also be two representatives from Princeton University. Coincident with the filing of the Planning Board application for phase 1 of the Arts and Transit proposal, the Task Force shall commence the project described in section 12.2 below. Should the Borough and the Township consolidate, the new municipality will retain two thirds of the members of the Task Force.

12. The Task Force is charged as follows:

    12.1 To study, evaluate, and make recommendations concerning long-term transit needs of the Princeton community that may be affected by development of the Arts and Transit project, including an assessment of the potential benefits, including economic benefits, of implementing transportation service from the Northeast Corridor railroad line to Nassau Street. The Task Force shall study, among other transit concepts, a light rail system. Issues to be considered in connection with the light rail transit system shall include: vehicle type, routes and alternates, loop vs. single line, schedule, electrical distribution network, solar powered, peak load capacity, stations (number and location), parking (primary and alternative commuter locations), financing, public-private possibilities, cost, NJ Transit, development opportunities, potential ridership, operating authority, schedule, NE corridor connections, ticketing, pedestrian conflict issues, vehicular conflict issues, implementation strategies, staging strategies, participation by West Windsor Township, and other related issues as they arise.

    12.2 To study, evaluate, and make recommendations to manage the appropriate flow of traffic and transportation in the greater Princeton community as a result of the impact of this and other proposed developments in and near the Central Business District, including, but not limited to, the development of the Hulfish North site, the site presently occupied by the University Medical Center at Princeton, the Merwick/Stanworth site, the YM/YWCA site, and the Hibben-Magie graduate student housing complex, with a view that traffic impacts of proposed developments shall be coordinated in such manner as to minimize negative impact on the community.

    12.3 To produce reports on the projects described in sections 12.1 and 12.2 for presentation to and consideration by the governing bodies of Princeton Borough and Princeton Township and the University not later than eight (8) months after each project commences, with the goal that the Princeton Regional Planning Board would consider incorporating Task Force recommendations into the community Master Plan. The work of the Task Force shall be deemed complete upon acceptance of the reports by the municipalities.

12.4 As an initial step, the University, Borough and Township will provide funding to complete these studies with the University paying 50% and each municipality contributing 25%. The scope and the ultimate cost of the studies shall be determined by the Task Force, subject to the approval of the two governing bodies.

13. A mass transit trust fund will be established for studies, planning and implementation of improvements to transit needs of the Princeton community. Princeton University will provide $500,000 to establish the trust fund. Of that sum, $100,000 shall be provided upon approval of this agreement by the governing bodies of Princeton Borough and Princeton Township. Distributions from this fund will be made by majority vote of the trustees of the fund who will include equal numbers of representatives from the Borough, Township and University. (The membership or trustees of the trust fund shall not necessarily be the same as the membership of the Task Force established under section 11 of this memorandum.) There will be nine trustees of the fund. Three trustees will be appointed by the Mayor of the Borough with the consent of Borough Council; three trustees will be appointed by the Mayor of the Township with the consent of Township Committee; and three trustees will be appointed by Princeton University. The terms of the municipal trustees shall be decided by each respective governing body. Should the Borough and the Township consolidate, the new municipality will retain two thirds of the trustee membership.

14. Upon receipt by the Borough of necessary approvals from the New Jersey Department of Transportation and the Princeton Regional Planning Board, Princeton University agrees to provide up to $150,000 each for the installation of three (3) automatic illuminated cross-walks across Nassau Street at Palmer Square, Tulane Street and in the vicinity of 185 Nassau Street, comparable to that already installed on University Place by McCarter Theater. One cross-walk will be installed per year over a three-year period. In the event that NJDOT fails to approve the installation of such cross-walks, then the Borough and the Township, in consultation with the University, will undertake other pedestrian safety measures of comparable scope and purpose to be paid for by the University. In any event, Princeton University will have no financial obligation with respect to these safety measures in excess of $450,000. These initiatives will serve the interests of Princeton University and the greater Princeton resident community.

15. Subject to the conditions stated below, Princeton University hereby commits to provide a deed of easement for a permanent, perpetual right of way exclusively to permit and sufficient to accommodate light rail service or other mass transit service, as described below. In addition, the two municipalities agree to provide a necessary right of way in public owned property, as needed. The easements shall not be granted and recorded until such time when the mass transit service operator and/or the municipalities and the University are prepared to apply for the requisite approvals and permits to establish light rail service or other mass transit service, as described below. The easement shall terminate if the light rail service or other mass transit service use is abandoned for a

period of three years or if either municipality fails to deliver, or later terminates, a right of way for the service link to Nassau Street. It is understood that the light rail or mass transit service provider shall be fully responsible for any maintenance and operation of mass transit service across the University-provided right of way. The University-provided right of way will be established from the existing NJ Transit right of way connecting to Alexander Street either at the proposed new station location or at a point to be mutually agreed farther south. The University will enter into agreements with the municipalities that preserve a right of way from future development. The right of way shall be adequate for vehicle width and clearance and shall be legally enforceable. No party to this agreement will seek compensation in connection with the use of any right of way identified herein. The Borough's legal counsel has prepared a memorandum that opines that the right of way is adequately defined herein so as to be legally enforceable, a copy of which is attached hereto as Exhibit A. The University has had an opportunity to review this memorandum with its counsel and concurs that the right of way is adequately defined herein so as to be legally enforceable and agrees to waive any right to contest the enforceability of its commitment to provide the right of way agreed upon herein. If not used for transit purposes within 65 years from the date of the commencement of train service from the new station location, the commitment for the right of way set forth in this memorandum will expire.

<u>Miscellaneous</u>

16. Any waiver, modification, consent, or acquiescence with respect to any provision of this MOU shall be set forth in writing and duly executed by or on behalf of the party to be bound thereby. No waiver by any party of any breach hereunder shall be deemed a waiver of any other or subsequent breach.

17. In the event that any provision of this MOU should be breached by any party and thereafter waived by the other party, such waiver shall be limited to the particular breach so waived and shall not be deemed to waive any other breach.

18. This MOU shall be construed and enforced under the laws of the State of New Jersey without regard to Conflicts of Laws rules.

19. This MOU shall be binding upon and shall inure to the benefit of the parties and their respective successors and permitted assigns.

20. Wherever possible, each provision of this MOU shall be interpreted in such a manner as to be valid under applicable law, but, if any provision of this MOU shall be invalid or prohibited thereunder, such invalidity or prohibition shall be construed as if such invalid or prohibited provision had not been inserted herein and shall not affect the remainder of such provision or the remaining provisions of this MOU.

21. This MOU may be executed in any number of counterparts, each of which shall be deemed an original, but all of which, when taken together, shall constitute one and the same instrument. The signature page of any counterpart may be detached therefrom

without impairing the legal effect of the signature(s) thereon provided such signature page is attached to any other counterpart identical thereto except having additional signature pages executed by other parties to this MOU attached thereto.

22. Each entity executing this MOU hereby represents and warrants that he, she, or it has the capacity set forth on the signature pages hereof with full power and authority to bind the party on whose behalf he, she, or it is executing this MOU to the terms hereof.

23. Notwithstanding anything to the contrary contained herein, this MOU shall not be deemed or construed to make the parties hereto partners or joint venturers, or to render any party liable for any of the debts or obligations of another, except as specifically contemplated herein.

IN WITNESS WHEREOF, the Borough of Princeton, the Township of Princeton and Princeton University have caused this MOU to be executed in their respective names by their duly authorized officers, as of the date first above written.

WITNESS ______________________	Borough of Princeton ______________________ By: Mayor Mildred Trotman Dated:
WITNESS ______________________	Township of Princeton ______________________ By: Mayor Chad Goerner Dated:
WITNESS ______________________	Princeton University ______________________ By: President Shirley Tilghman Dated:

EXHIBIT A

HILL WALLACK LLP
ATTORNEYS AT LAW

Princeton, NJ / Atlantic City, NJ / Yardley, PA
WWW.HILLWALLACK.COM

To: Princeton Borough Council

From: Henry T. Chou, Esq.

Date: September 28, 2011

Re: MOU provision on future easement for rail right of way – "EXHIBIT A"

QUESTION PRESENTED

Is the provision of the Memorandum of Understanding ("MOU") between Princeton Borough, Princeton Township and Princeton University concerning the parties' commitment to provide a right of way for future rail uses (Paragraph 15) adequately defined and legally enforceable?

ANALYSIS

Yes. In New Jersey, the courts routinely enforce MOUs as legally binding contracts if they impose cognizable obligations upon the parties based upon mutual consideration and are signed by the parties. See, e.g., Livingston Builders, Inc. v. Township of Livingston, 309 N.J. Super. 370, 377 (App. Div. 1998); Flores v. Murray, 2007 WL 3034512 (N.J. Super. App. Div.); Anderson v. Ludeking, 2008 WL 4630697 (N.J. Super. App. Div.); Mitchell v. Mitchell, 2010 WL 289096 (N.J. Super. App. Div.).

The MOU at issue imposes cognizable obligations upon all of the parties and mutual consideration is present. Through the MOU, residents of both municipalities will receive the benefit of improved rail transportation services associated with Princeton University's development activities, and Princeton University will receive the benefit of the municipalities' cooperation in the development of a formal plan to promote increased patronage of the McCarter Theater and Princeton University athletic events. Additionally, the MOU will be signed by duly authorized representatives of all parties.

Although Paragraph 15 concerning the commitment of the parties to provide deeds of easement for a right of way to accommodate future rail service is not specifically defined, i.e., with a metes and bounds description, it describes the right of way with a fair degree of detail, as follows:

> "Subject to the conditions stated below, Princeton University hereby commits to provide a deed of easement for a permanent, perpetual right of way exclusively to permit and sufficient to accommodate light rail service or other mass transit service, as described below. In addition, the two municipalities agree to provide a necessary right of way in public owned property, as needed. The easements shall not be granted and recorded until such time when the mass transit service operator and/or the municipalities and the University are prepared to apply for the requisite approvals and permits to establish light rail service or other mass transit service, as described below. The easement shall terminate if the light rail service or other mass transit service use is abandoned for a period of three years or if either municipality fails to deliver, or later terminates, a right of way for the service link to Nassau Street. It is understood that the light rail or mass transit service provider shall be fully responsible for any maintenance and operation of mass transit service across the University-provided right of way. The University-provided right of way will be established from the existing NJ Transit right of way connecting to Alexander Street either at the proposed new station location or at a point to be mutually agreed farther south. The University will enter into agreements with the municipalities that preserve a right of way from future development. The right of way shall be adequate for vehicle width and clearance and shall be legally enforceable. No party to this agreement will seek compensation in connection with the use of any right of way identified herein. The Borough's legal counsel has prepared a memorandum that opines that the right of way is adequately defined herein so as to be legally enforceable, a copy of which is attached hereto as Exhibit A. The University has had an opportunity to review this memorandum with its counsel and concurs that the right of way is adequately defined herein so as to be legally enforceable and agrees to waive any right to contest the enforceability of its commitment to provide the right of way

> agreed upon herein. If not used for transit purposes within 65 years from the date of the commencement of train service from the new station location, the commitment for the right of way set forth in this memorandum will expire."

In New Jersey, a contract is unenforceable for vagueness when its terms are too indefinite to allow a court to ascertain with reasonable certainty what each party has promised to do. Weichert Co. Realtors v. Ryan, 128 N.J. 427, 435 (1992). The courts focus on the performance promised in testing an agreement for vagueness. See Malaker Corp. Stockholders Protective Comm. v. First Jersey Nat'l Bank, 163 N.J. Super. 463, 474, (App.Div.1978) ("An agreement so deficient in the specification of its essential terms that the performance by each party cannot be ascertained with reasonable certainty is not a contract, and clearly is not an enforceable one.") (citing Friedman v. Tappan Dev. Corp., 22 N.J. 523, 531 (1956)), certif. denied, 79 N.J. 488 (1979). This does not mean that each term must be exactly spelled out. Where the court can determine the contract's "essential terms" to which the parties manifested an intent to be bound, the contract is enforceable. Ryan, 128 N.J. at 435. The Court notes by analogy New Jersey law providing that a contract for the sale of goods will not fail if the parties intended to agree and there is a "reasonably certain basis" for crafting a remedy even though some terms are left open. N.J.S.A. 12A:2-204; Truex v. Ocean Dodge, Inc., 219 N.J. Super. 44, 50 (App.Div.1987).

The law generally and in New Jersey does not favor voiding a contract for vagueness. See E. Allen Farnsworth, Contracts § 3.27 at 208-09 (2d ed. 1990); Paley v. Barton Savs. & Loan Ass'n, 82 N.J. Super. 75, 83 (App. Div.), certif. denied, 41 N.J. 602 (1964). The courts will not scruple at filling gaps or interpreting ambiguous terms where there is evidence of a manifestation of assent to enter into a bargain. See Paley, 82 N.J. Super. at 83; Heim v. Shore, 56 N.J. Super. 62, 73 (App.Div.1959); 4 Samuel Williston, Williston on Contracts, § 4:18 at 421-22 (4th ed. 1990). Thus, a promise to provide "the usual sponsorship fees" for a bowling team was sufficient. Leitner v. Braen, 51 N.J. Super. 31, 39-40 (App. Div. 1958). Likewise, an agreement by a savings and loan association to hold $100,000 available to buy mortgages that a real estate developer hoped to obtain from the future buyers of unbuilt houses was sufficiently definite. Paley, 82 N.J. Super. at 82-84.

A contract may be sufficiently certain even though one party has discretion to choose between material terms. Kleckner v. Mutual Life Ins. Co., 822 F.2d 1316, 1319 (3d Cir.1987). Partial performance by one side of the bargain may, by the specifics of that performance, cure an indefinite term of the agreement. Merrick v. United States, 846 F.2d 725, 726 (Fed. Cir.1988); Restatement (Second) of Contracts, § 34(2) (1979); Joseph M. Perillo, Corbin on Contracts, § 4.7 at 606-08 & n. 2 (rev. ed. 1993). Likewise, even if uncertainty remains, where one party has acted in reliance on an indefinite agreement the courts will act to protect that reliance whether through a contractual or non-contractual remedy. Restatement, supra § 34(3); see also Heim, 56 N.J. Super. at 73.

Paragraph 15 of the MOU concerning the parties' commitment to provide deeds of easement for a right of way to accommodate future rail service is not likely to be interpreted by the courts as void for vagueness. It provides that a "right of way will be established from the existing NJ Transit right of way connecting to Alexander Street either at the proposed new station location or at a point to be mutually agreed farther south." Although this provision does not set forth the exact path of the right of way with a metes and bounds description, it describes a potential path in easily cognizable terms to all parties and leaves no doubt as to the general route by which a future rail line would reach Nassau Street.

Pursuant to the case law cited above, a court would likely interpret Paragraph 14 as legally binding and enforceable, especially, e.g., in scenario where two of the parties perform their obligations by providing deeds of easement for a right of way, but one party refuses to provide a deed of easement even though the route contemplated by the other two parties is consistent with the general description of the route in Paragraph 15.

Appendix 5 – Presentations, Public Outreach and Survey Comments

Princeton Transit Study

Princeton Traffic and Transit Task Force Meeting

June 26, 2013

URS

Project Goals

Project Goals

1. Improve Transit Mobility, Connectivity, and Accessibility
2. Provide Cost Effective and Efficient Transportation Services
3. Encourage Sustainable Economic Development
4. Maintain/Enhance Livability and Quality of life

Improve Transit Mobility, Connectivity and Accessibility

- Provide connections to existing and future transit services.
- Increase transit demand.
- Accommodate future transit demand.
- Maintain existing commuter level of service.
- Maintain existing comfort of service.
- Minimize transfers within the transportation system.
- Improve operating speed.
- Maintain bicycle friendly atmosphere.

Provide Cost Effective & Efficient Transportation Services

- Implement within a reasonable time frame.
- Implement at a reasonable capital cost.
- Minimize operating and maintenance costs per passenger mile.
- Consistent with NJT or Princeton University operating technologies.
- Maintain emergency vehicles access to system.
- Maintain access to arterial roadways.
- Maintain access to existing and future users.
- Minimize property acquisition.
- Ability to phase construction.
- Minimize turning radii that meet current alignments.

Encourage Sustainable Economic Development

- Stimulate economic development
- Improve connection between residential/commercial/educational destinations.

Maintain/Enhance Livability and Quality of Life

- Minimize/avoid impacts on historic resources.
- Minimize encroachment on view corridors.
- Minimize construction impacts.
- Reduce vehicle congestion emissions and noise.
- Reduce system congestion emissions and noise.
- Improve energy efficiency.

URS

LRT (Light Rail Transit)

LRT

- Single Cars/Short Trains
- Generally in Exclusive or Separated Right of Way
- Occasionally in Streets
- Higher Capacity and Speeds (up to 60 mph)
- Larger Curves (min 82 feet)


27
Nassau St
University


27
Nassau St
University Pl


Forbes
Green
Forbes
Fence
University Place
Green
Lewis Center
For the Arts

URS

Streetcar

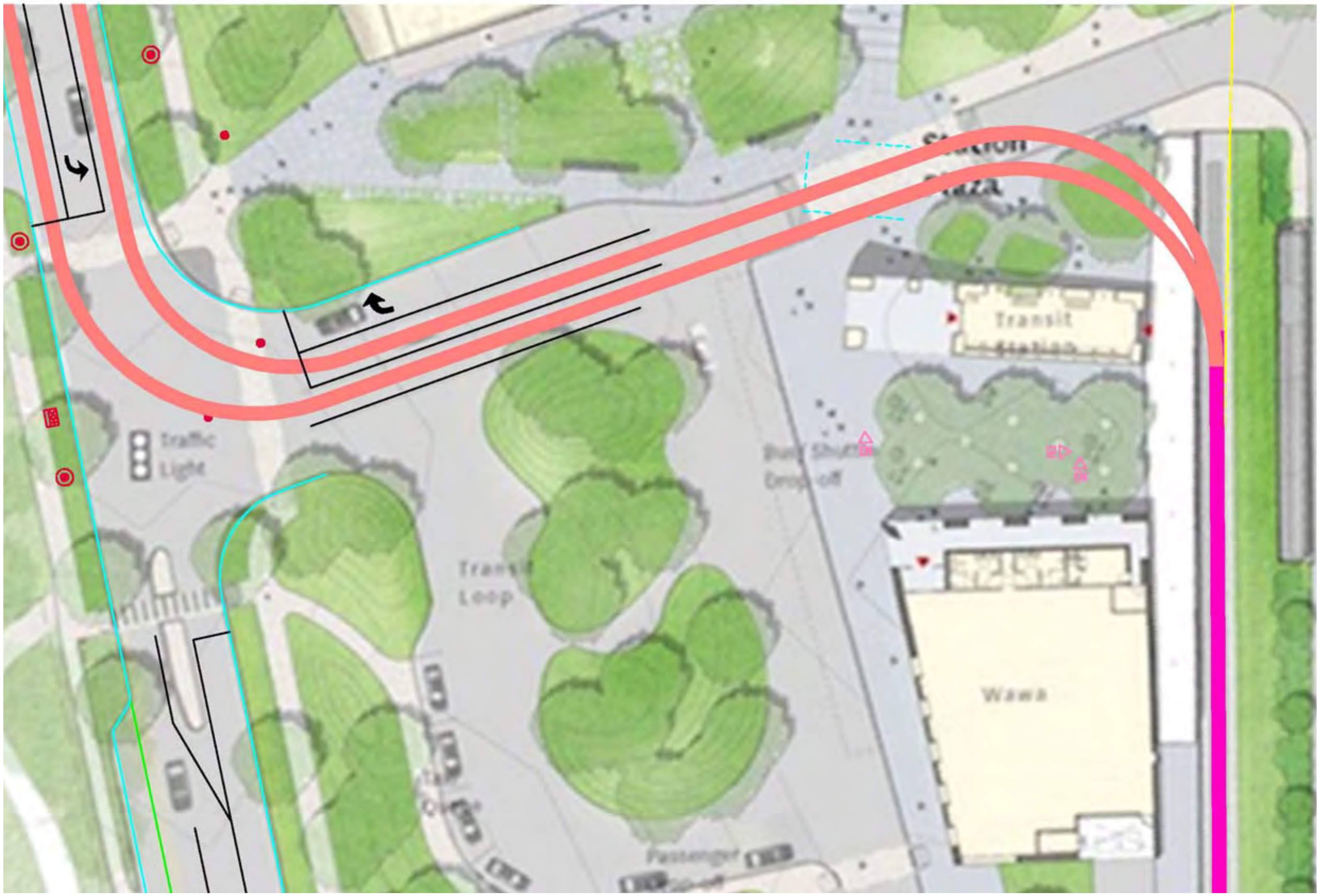
Streetcar

- Single Cars
- Generally in Streets with traffic
- Moderate Capacity
- Speeds up to 40/45 mph
- Tight Curves possible (min 50 feet)
- Rolling Stock available includes:
  - Modern Cars
  - Heritage Cars
  - New Replica Cars


Nassau St
27

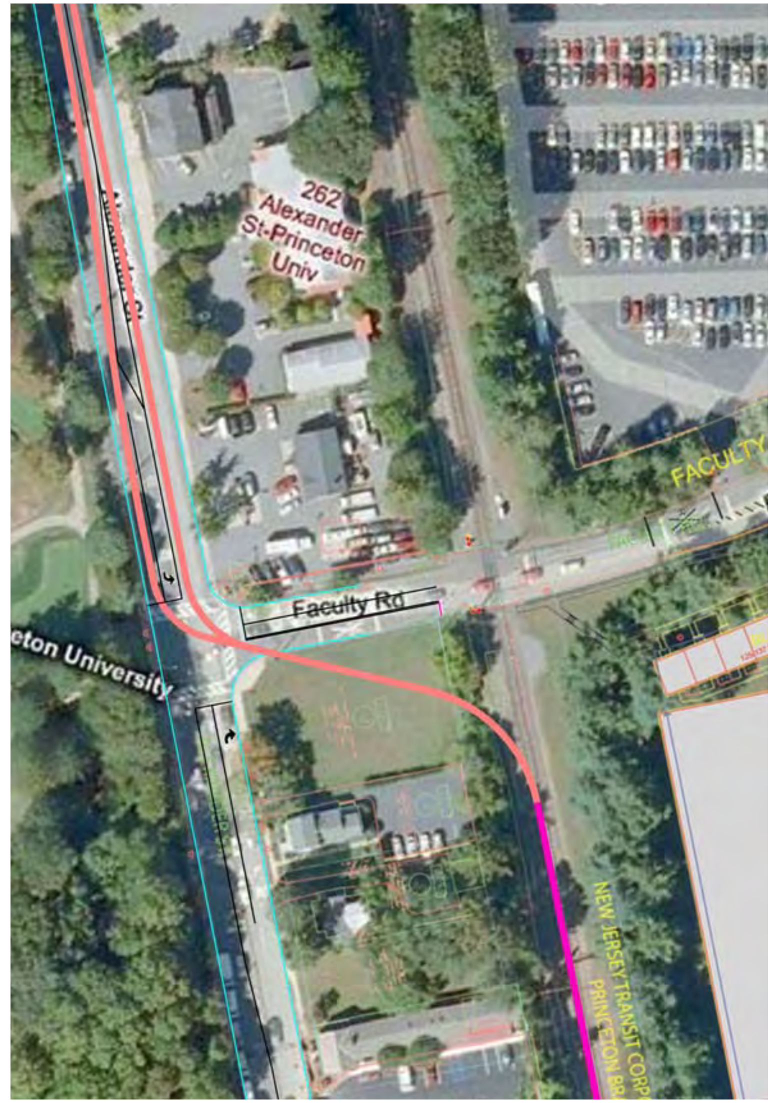

Forbes
Fence


Forbes



Traffic Light
Transit Loop
Transit Station
Wawa
Drop-off


Alexander

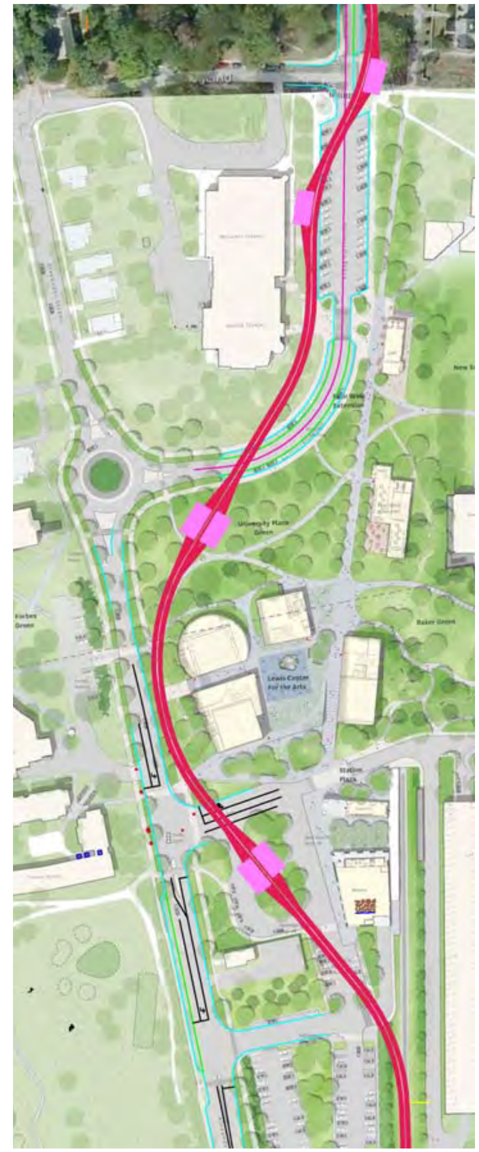

262 Alexander St-Princeton Univ
Faculty Rd
eton University
FACULTY
NEW JERSEY TRANSIT CORP
PRINCETON BR

URS

PRT (Personal Rapid Transit)

PRT

- Single Cars
- Separated Guideway Required
- Low Capacity:
  - 4-6 Persons (PRT)
  - 20+ Persons (GRT)
- Speeds up to 25 mph
- Generally Demand Responsive
- Broad Curves needed at speed; Tight Turns possible for Maneuvering



URS | Princeton Transit Study

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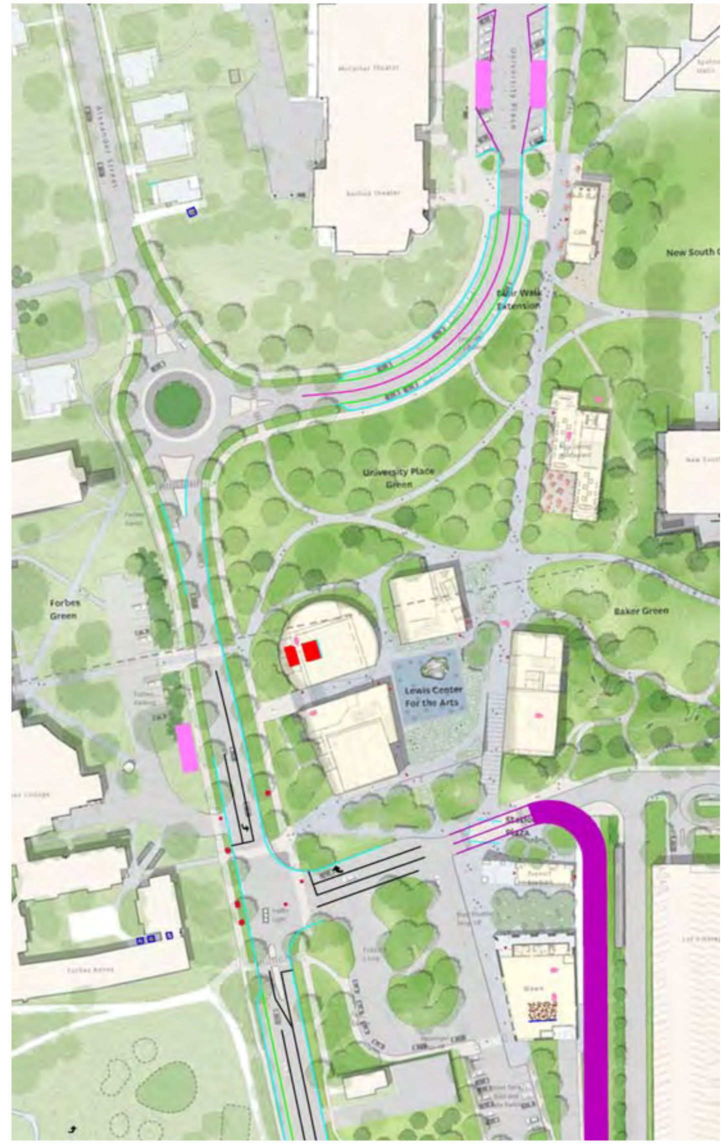
BRT (Bus Rapid Transit)

BRT

- Standard Bus or special vehicles available
- Separated Guideway Typical, but Street operations possible
- Moderate Capacity
- Highway Speeds
- Normal street geometry acceptable


Nassau St
Mercer St
University Pl
Edwards Pl
Madison Hall-Princeton University
Holder Hall-Princeton Univ
Hamilton Hall-Princeton University
Joline Hall-Princeton University
Campbell Hall-Princeton University
Blair Hall-Princeton University
U-Store-Princeton University
Lockhart Hall-Princeton University
Foulke Hall-Princeton


New South
Blair Walk Extension
University Place Green
Forbes Green
Baker Green
Lewis Center For the Arts

Preliminary

Table
Evaluation of Mode Alternatives

Objectives and Evaluation Criteria	LRT	Streetcar	PRT - above grade	PRT- at grade	BRT
Improve Transit Mobility, Connectivity, and Accessibility	130	120	100	90	130
Provide connections to existing and future transit services.	10	10	0	10	15
Increase transit demand.	15	15	20	15	15
Accommodate future transit demand.	20	15	5	5	15
Maintain existing commuter level of service.	20	20	20	20	20
Maintain existing comfort of service	20	20	20	15	10
Minimize transfers within the transportation system.	20	20	15	15	20
Improve operating speed.	20	15	5	5	15
Maintain bicycle friendly atmosphere.	5	5	15	5	20
Provide Cost Effective and Efficient Transportation Services	130	130	70	35	150
Implement within a reasonable time frame.	15	15	0	0	15
Implement at a reasonable capital cost.	15	15	0	0	15
Minimize operating and maintenance costs per passenger mile	10	10	20	20	15
Consistent with NJT or Princeton University operating technologies.	15	10	0	0	15
Maintain emergency vehicles access to system.	15	15	5	10	20
Maintain access to arterial roadways.	20	20	20	0	20
Maintain access to existing and future users.	15	15	10	5	20
Minimize property acquisition.	15	20	15	0	15
Ability to phase construction.	10	10	0	0	15
Minimizing turning radii that meets current alignments	5	10	20	20	15
Encourage Sustainable Economic Development	35	40	10	20	35
Stimulate economic development	15	20	5	5	15
Improve connection between residential/commercial/educational destinations.	20	20	5	15	20
Maintain/Enhance Livability and Quality of Life	75	75	60	85	80
Minimize/avoid impacts on historic resources.	15	15	0	10	15
Minimize encroachment on view corridors.	15	15	0	15	15
Minimize construction impacts.	10	10	0	10	10
Reduce vehicle congestion emissions and noise.	15	15	20	15	15
Reduce system congestion emissions and noise.	15	15	20	15	15
Improve energy efficiency.	5	5	20	20	10
TOTAL	370	365	240	230	395

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Princeton Transit Study

Princeton Traffic and Transit Task Force Meeting

May 14, 2014

URS

Project Goals

Project Goals

1. Improve Transit Mobility, Connectivity, and Accessibility
   - Enhance connections to existing and future transit services.
   - Accommodate/Increase transit demand.
   - Maintain existing commuter level of comfort and service.
   - Minimize transfers and Improve operating speed.
   - Maintain bicycle friendly atmosphere.
2. Provide Cost Effective and Efficient Transportation Services
   - Time frame, capital cost operating cost, technology.
   - Maintain access
   - Minimize property acquisition.
3. Encourage Sustainable Economic Development
   - Stimulate economic development and Improve connections
4. Maintain/Enhance Livability and Quality of life
   - Minimize impact on historic resources, on views and from construction.
   - Reduce vehicle congestion emissions and noise.
   - Improve energy efficiency.

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Streetcar/LRT

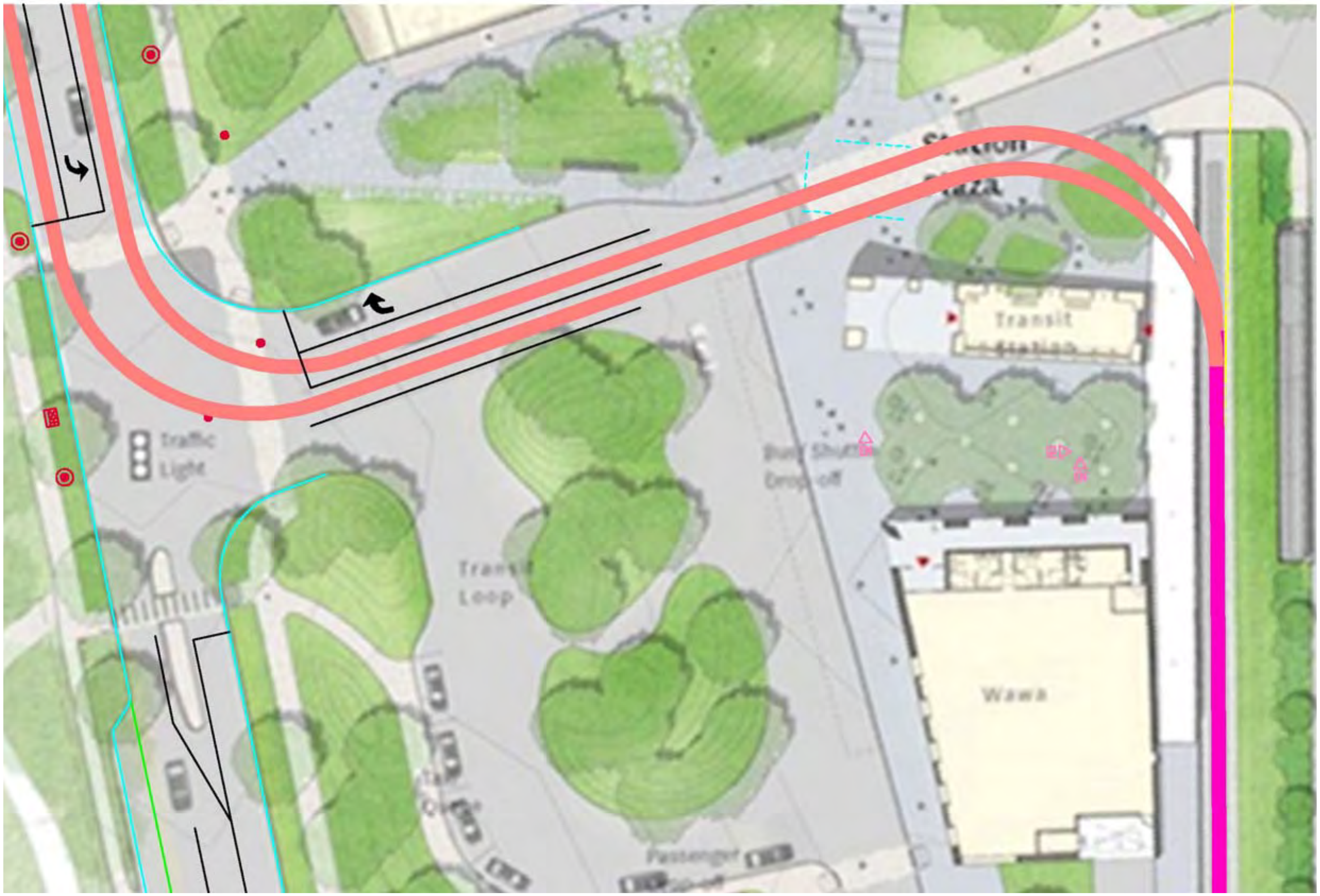
Streetcar

- Single Cars
- Generally in Streets with traffic
- Moderate Capacity
- Speeds up to 40/45 mph
- Tight Curves possible (min 50 feet)
- Rolling Stock available includes:
  - Modern Cars
  - Heritage Cars
  - New Replica Cars

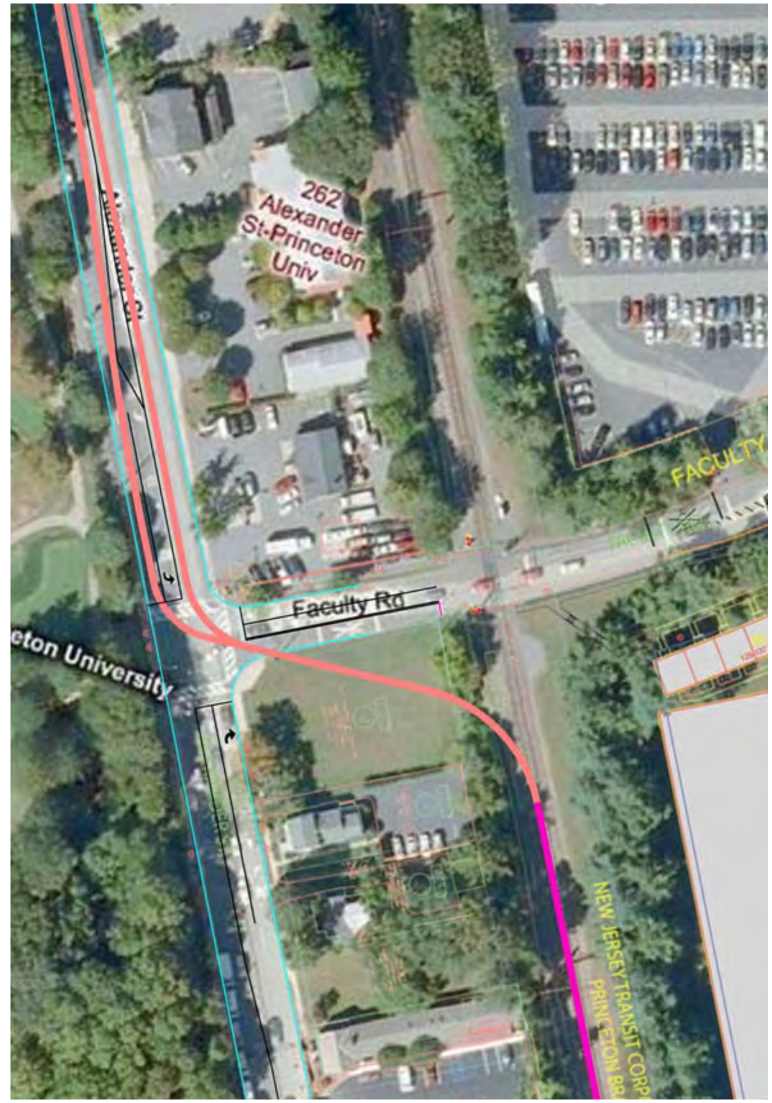

Nassau St
27


Forbes
Fence


Forbes


Transit Station
Traffic Light
Transit Loop
Wawa


Alexander


262 Alexander St-Princeton Univ
Faculty Rd
FACULTY
eton University
NEW JERSEY TRANSIT CORP
PRINCETON BR

URS

BRT (Bus Rapid Transit)

BRT

- Standard Bus or special vehicles available
- Separated Guideway Typical, but Street operations possible
- Moderate Capacity
- Highway Speeds
- Normal street geometry acceptable


Nassau St
Mercer St
University Pl
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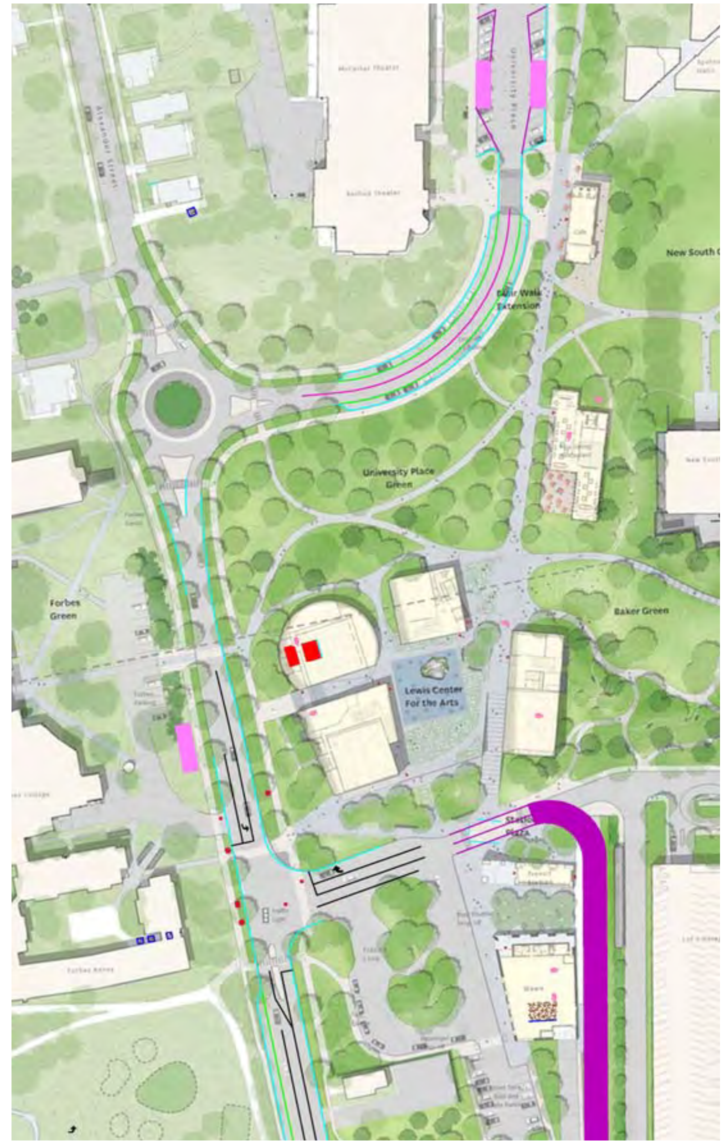
U-Store-Princeton University
Lockhart Hall-Princeton University


University Place Green
Forbes Green
Baker Green
Lewis Center For the Arts

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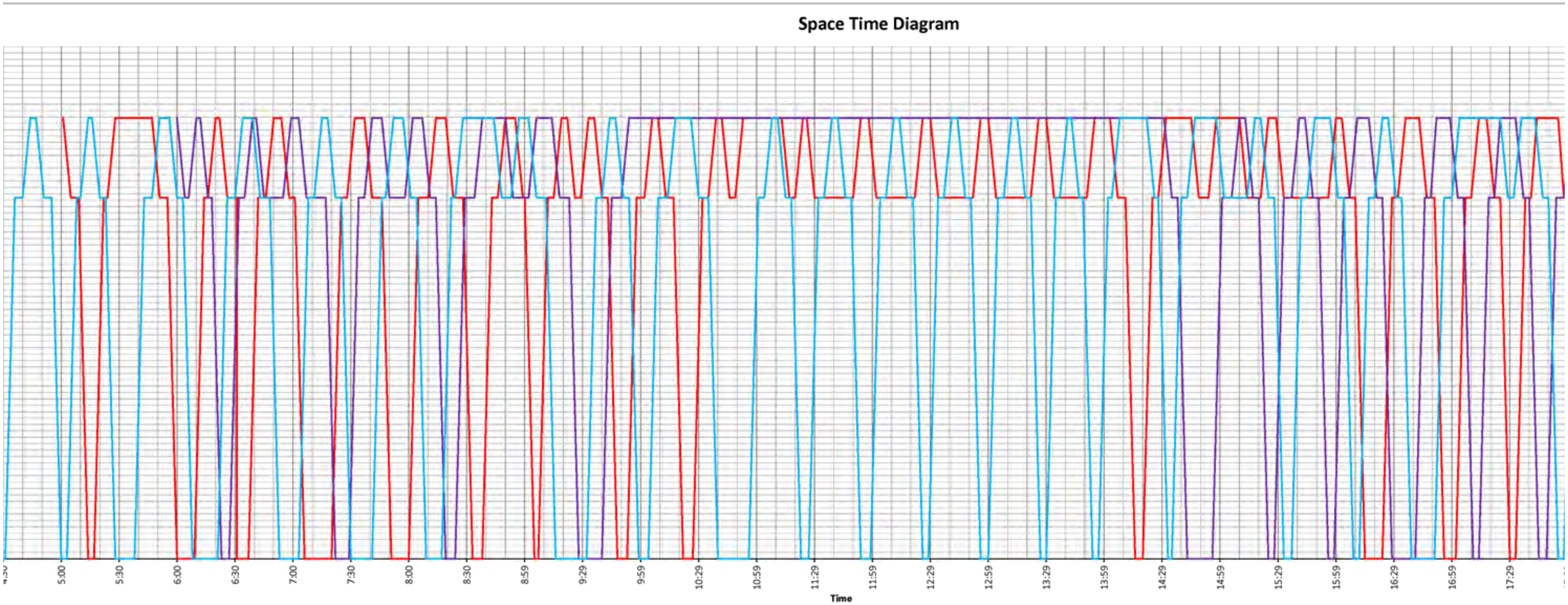
Frequency

Dinkey 1														
Weekday			**Princeton Junction**		Main Line Headway									
	NB		Princeton				SOUTHBD	NORTHBOUND				SOUTHBOUND		
Train		Time	Dinkey Connect		(min)		Pr Jct	Pr Jct	Princeton		Nassau Street		Princeton	
							AR	Dep	Ar	Dep	Ar	Dep	AR	DEP
NJT 3892	NB	0:02	2351	**2356**	0:14			23:52	23:57	23:59	0:03	0:14	0:18	0:20
NJT 3895	SB	0:25	**30**	35	0:23	1	0:25	0:30	0:35	0:39	0:43	0:47	0:51	0:55
NJT 3800	NB	1:10	58	**103**	0:45	2	1:00							
NJT 3897	SB	1:11	**117**	122	0:01	3		1:16	1:21	1:25	1:29	2:26	2:30	2:34
NJT 3805	SB	2:39			1:28	4	2:39	2:44	2:49	2:53	2:57	3:36	3:40	3:44
NJT 3806	NB	3:58			1:19	5	3:49	3:54	3:59	4:03	4:07	4:15	4:19	4:23
NJT 3808	NB	4:33			0:35	6	4:28	4:31	4:36	4:40	4:44	4:47	4:51	4:55
NJT 3810	NB	5:07	456	**501**	0:34	7	5:00	5:03	5:08	5:10	5:14	5:16	5:20	5:23
												5:01	5:05	5:09
NJT 3910	NB	5:19			0:12	8	5:14	5:17	5:22	5:24	5:28	5:47	5:51	5:55
NJT 3812	NB	5:32	521	**526**	0:13	9	5:28	↓↓↓↓						
NJT 3809	SB	5:33	**539**	544	0:01	10		5:38	5:43	5:47	5:51	5:56	6:00	6:03
NJT 3801	SB	6:03	**608**	613	0:30	11	6:00	↓↓↓↓				6:00	6:04	6:06
NJT 3814	NB	6:05	552	**557**	0:02	12		6:09	6:14	6:16	6:20	6:22	6:26	6:31
NJT 3914	NB	6:15			0:10	13	6:08	↓↓↓↓		6:06	6:10	6:12	6:16	6:18
AmT 111	SB	6:16			0:01	14		6:21	6:26	6:30	6:34	6:39	6:43	6:48
NJT 3818	NB	6:23			0:07	15	6:23	6:27	6:32	6:35	6:39	6:41	6:45	6:55
NJT 3813	SB	6:32	**638**	643	0:09	16		6:37	6:42	6:46	6:50	6:54	6:58	7:01
NJT 3918	NB	6:35	624	**629**	0:03	17	6:31	↑↑↑↑		6:55	6:59	7:03	7:07	7:17
NJT 3920	NB	7:00	649	**654**	0:25	18	6:53	↓↓↓↓						
AmT 181	SB	7:00			0:00	19		7:03	7:08	7:11	7:15	7:18	7:22	7:25
NJT 3922	NB	7:11			0:11	20	7:06	↓↓↓↓						
NJT 3815	SB	7:17	**740**	745	0:06	21		7:20	7:25	7:28	7:32	7:37	7:41	7:46
NJT 3924	NB	7:27	716	**721**	0:10	22	7:22	7:29	7:34	7:37	7:41	7:46	7:50	7:58
NJT 3828	NB	7:34			0:07	23	7:30	↓↓↓↓						
NJT 3817	SB	7:36	**800**	805	0:02	24		7:41	7:46	7:48	7:52	7:57	8:01	8:04
NJT 3926	NB	7:45	731	**738**	0:09	25				7:58	8:02	8:07	8:11	8:14
NJT 3928	NB	8:02	750	**755**	0:17	26	7:51	8:00	8:05	8:10	8:14	8:19	8:23	8:28
AmT 641	SB	8:13			0:11	27		8:17	8:22	8:24	8:28	8:44	8:48	8:53
NJT 3830	NB	8:14			0:01	28	8:09	↑↑↑↑						
NJT 3930	NB	8:23	811	**816**	0:09	29	8:19	8:24	8:29	8:34	8:38	8:50	8:54	9:02
NJT 3821	SB	8:25	**835**	840	0:02	30	8:33	↓↓↓↓						
NJT 3932	NB	8:39			0:14	31		8:38	8:43	8:46	8:50	8:55	8:59	9:00


Space Time Diagram
5:00
5:30
6:00
6:30
7:00
7:30
8:00
8:30
8:59
9:29
9:59
10:29
10:59
11:29
11:59
12:29
12:59
13:29
13:59
14:29
14:59
15:29
15:59
16:29
16:59
17:29
Time

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Alternative Track Configurations

Preliminary

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Reduce system congestion emissions and noise.	15	15	20	15	15
Improve energy efficiency.	5	5	20	20	10
TOTAL	370	365	240	230	395

LRT (Light Rail Transit)

LRT

- Single Cars/Short Trains
- Generally in Exclusive or Separated Right of Way
- Occasionally in Streets
- Higher Capacity and Speeds (up to 60 mph)
- Larger Curves (min 82 feet)


27
Nassau St
University


27
Nassau St
University Pl

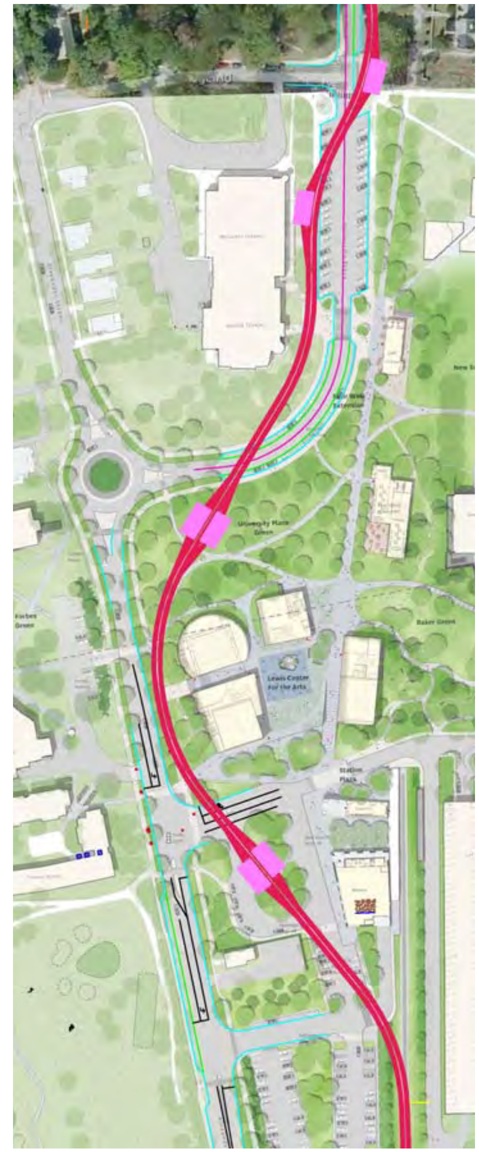

Forbes Green
Forbes Fence
University Place Green
Lewis Center For the Arts
Forbes Parking

PRT (Personal Rapid Transit)

PRT

- Single Cars
- Separated Guideway Required
- Low Capacity:
  - 4-6 Persons (PRT)
  - 20+ Persons (GRT)
- Speeds up to 25 mph
- Generally Demand Responsive
- Broad Curves needed at speed; Tight Turns possible for Maneuvering


Nassau St
Nassau St
University Pl
Madison Hall-Princeton University
Hamilton Hall-Princeton University
Joline Hall-Princeton University
U-Store-Prin University
Edwards Pl
University Pl



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Princeton Transit Study

Progress and Preliminary Findings

Public Meeting

Carl Fields Center, Princeton University

Saturday, November 9, 2013 9:00 AM to 12:30 PM

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Presentation Outline

Princeton Transit Study - Presentation Outline

- Introduction
- Project's Goals
- Previous study work
- Who uses public transportation in Princeton?
- What specific problem are we focusing on?
- What transit alternatives were examined?
- What works best?
  - Bus Rapid Transit or Enhanced Bus options
  - Light Rail options
  - Streetcar options
- Next Steps
- What do you think?

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Project Goals

Project Goals

1. Improve Transit Mobility, Connectivity, and Accessibility
2. Provide Cost Effective and Efficient Transportation Services
3. Encourage Sustainable Economic Development
4. Maintain/Enhance Livability and Quality of life

1. Improve Transit Mobility, Connectivity and Accessibility

- Provide connections to existing and future transit services.
- Increase transit demand.
- Accommodate future transit demand.
- Maintain existing commuter level of service.
- Maintain existing comfort of service.
- Minimize transfers within the transportation system.
- Improve operating speed.
- Maintain bicycle friendly atmosphere.

2. Provide Cost Effective & Efficient Transportation Services

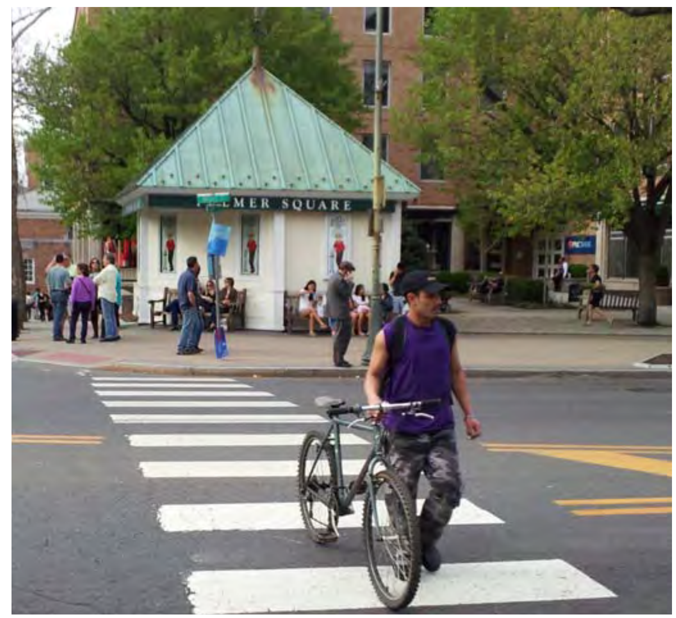
- Implement within a reasonable time frame.
- Implement at a reasonable capital cost.
- Minimize operating and maintenance costs per passenger mile.
- Consistent with NJT or Princeton University operating technologies.
- Maintain emergency vehicles access to system.
- Maintain access to arterial roadways.
- Maintain access to existing and future users.
- Minimize property acquisition.
- Ability to phase construction.
- Minimize turning radii that meet current alignments.

3. Encourage Sustainable Economic Development

- Improve connection between residential/commercial/educational destinations.
- Stimulate economic development

4. Maintain/Enhance Livability and Quality of Life

- Minimize/avoid impacts on historic resources.
- Minimize encroachment on view corridors.
- Minimize construction impacts.
- Reduce vehicle congestion emissions and noise.
- Reduce system congestion emissions and noise.
- Improve energy efficiency.



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Previous Study Work

Previous Studies

- Draft Princeton Residential Mixed Use (RMU) Zoning Code
- Princeton Community Master Plan
- Community Transportation Coordination Initiative
- Princeton University Campus Plan
- Viability of Personal Rapid Transit in New Jersey
- Penns Neck Area Environmental Impact Statement
- Princeton University Arts and Transit Neighborhood Plan
- Redevelopment Plan for Hibben-Magie Site
- Others

Summary of previous study findings

- Numerous efforts to address transportation needs in the Princeton area have been put forward
- Traffic congestion continues to grow in the community and circuitous transit routes tend not to work
- Multi-modal solutions should be considered
- Need to coordinate transit connections with existing transit and rail services
- Public is divided about future of development in the community
- Relocation of Princeton Station for the Dinky is an opportunity to explore improving connectivity to downtown

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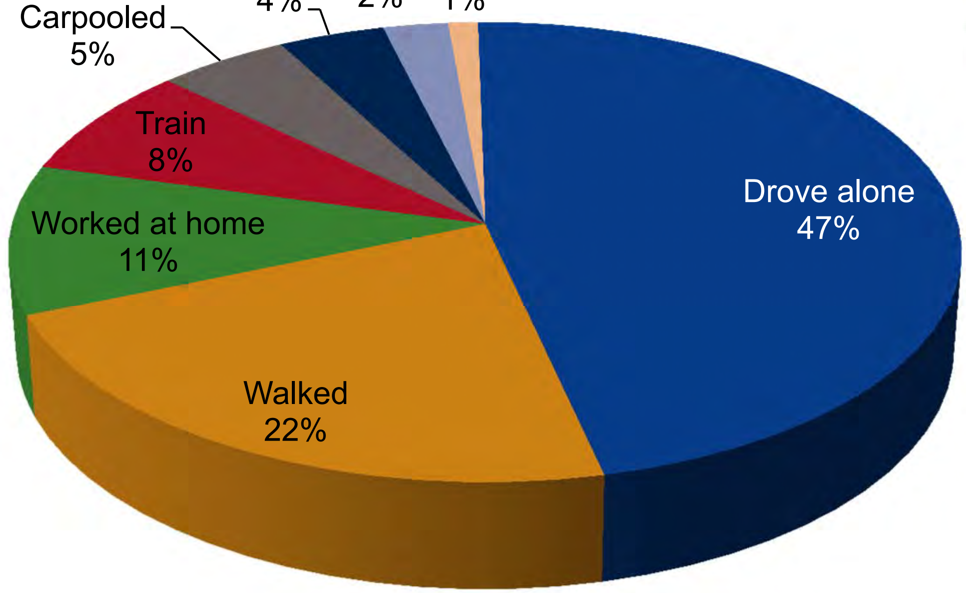
Who uses public transportation in Princeton?

Ways people commute within Princeton

Total Population = 28,717

Commute to Work Mode Split - Princeton



Source: 2011 American Community Survey 5-Yr. estimates including Township and Borough

Dinky - Ridership

TOTAL DAILY EASTBOUND RIDERSHIP: 1050

NORTHEAST CORRIDOR LINE
PRINCETON BRANCH
WEEKDAY SURVEY - APRIL 26th 2012

EASTBOUND					WESTBOUND				
TRAIN NO.	PRINCE. TIME	PRIN. JCT. TIME	PSGRS COUNT		TRAIN NO.	PRIN. JCT. TIME	PRINCE. TIME	PSGRS COUNT	
4106	5:00AM	5:05AM	10		4105	4:50 AM	4:55 AM	1	
4108	5:25AM	5:30AM	4		4107	5:12 AM	5:17 AM	1	
4110	5:55 AM	6:00 AM	16		4109	5:39AM	5:44AM	1	
4112	6:27AM	6:32AM	21		4111	6:09 AM	6:14 AM	2	
4114	6:52 AM	6:57 AM	31		4113	6:42 AM	6:47 AM	4	
4116	7:17AM	7:22AM	69		4115	7:07AM	7:12AM	4	
4118	7:47AM	7:52AM	37		4117	7:27AM	7:32AM	9	
4120	8:12 AM	8:17 AM	55		4119	7:57AM	8:02AM	18	
4122	8:53AM	8:58AM	36		4121	8:33AM	8:38AM	71	
4124	9:19AM	9:24AM	25		4123	9:09AM	9:14AM	56	
4126	9:52AM	9:57AM	17		4125	9:32AM	9:37AM	26	
4128	10:17 AM	10:22 AM	34		4127	10:06 AM	10:11AM	94	
4132	11:15AM	11:20AM	18		4131	11:04 AM	11:09AM	44	
4134	11:50AM	11:55AM	26		4133	11:27AM	11:32AM	77	
4136	12:17PM	12:22PM	15		4135	12:00PM	12:05PM	66	
4138	12:46PM	12:51PM	18		4137	12:27PM	12:32PM	53	
4140	1:14PM	1:19PM	30		4139	12:59PM	1:04PM	32	
4142	1:47 PM	1:52 PM	23		4141	1:26PM	1:31PM	24	
4144	2:16PM	2:21PM	20		4143	2:02PM	2:07PM	37	
4146	2:45PM	2:50PM	46		4145	2:26PM	2:31PM	39	
4148	3:18 PM	3:23 PM	26		4147	2:56PM	3:01PM	12	
4150	3:44PM	3:49PM	32		4149	3:28 PM	3:33 PM	16	
4152	4:13PM	4:18PM	39		4151	4:00PM	4:05PM	2	MISSED NY CONNECTION
4154	4:37PM	4:42PM	58		4153	4:25PM	4:30PM	52	
4156	5:05PM	5:10PM	69		4155	4:47PM	4:52PM	20	
4158	5:42PM	5:47PM	44		4157	5:18PM	5:23PM	44	
4160	6:09PM	6:14PM	58		4159	5:57PM	6:02PM	56	
4162	6:31 PM	6:36 PM	20		4161	6:21 PM	6:26 PM	44	
4164	6:51 PM	6:56 PM	13		4163	6:41 PM	6:46 PM	38	
4166	7:13PM	7:18PM	17		4165	7:03PM	7:08PM	50	
4168	7:35 PM	7:40 PM	24		4167	7:25PM	7:30PM	29	
4170	7:56 PM	8:01 PM	3		4169	7:45 PM	7:50 PM	38	
4172	8:25 PM	8:30 PM	14		4171	8:15PM	8:20PM	20	
4174	8:52PM	8:57PM	12		4173	8:40PM	8:45PM	28	
4176	9:55 PM	10:00 PM	40		4175	9:45 PM	9:50 PM	16	
4178	10:35PM	10:40PM	1		4177	10:20PM	10:25PM	13	
4180	11:05 PM	11:10 PM	4		4179	10:52PM	10:57PM	10	
4182	11:50PM	11:55PM	4		4181	11:28PM	11:33PM	20	
4100	12:16AM	12:21AM	2		4183	12:06AM	12:11AM	14	
4102	12:58AM	1:03AM	12		4101	12:32AM	12:37AM	2	
4104	1:27AM	1:32AM	7		4103	1:17AM	1:22AM	2	
TOTAL			1,050		TOTAL			1185	

TOTAL DAILY WESTBOUND RIDERSHIP: 1185

Based on April 26, 2012 NJT Ridership survey

Princeton Junction Rail Station Boardings

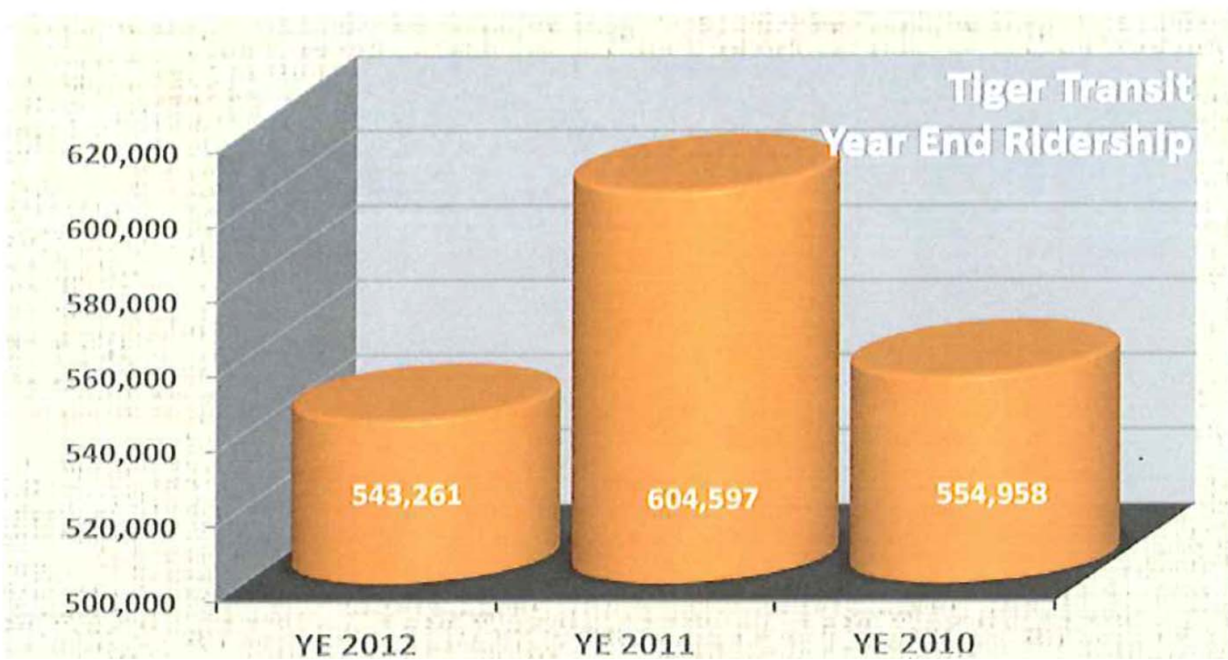
NJTransit Stations with the Highest Boarding Levels

Avg. Weekday Boardings	
Penn Station New York (Rail)	79,616
Port Authority Bus Terminal (Bus)	72,200
Newark Penn Station (Rail)	27,189
Hoboken Terminal (Rail)	16,297
Metropark Station (Rail)	7,447
Princeton Junction (Rail)	**6,816**

Approximately 15% of those boarding at Princeton Junction arrived by the Dinky.

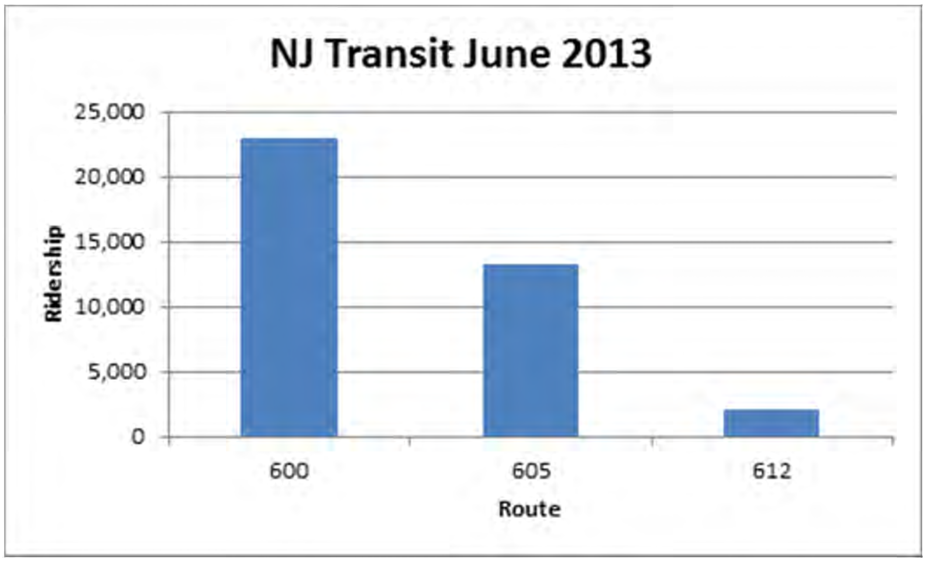
Based on data in *NJT Transit Facts at a Glance,* March 2013, and NJT Ridership survey, April 26, 2012

Other Princeton Ridership Data – Tiger Transit



567,605 average annual ridership, over past three years

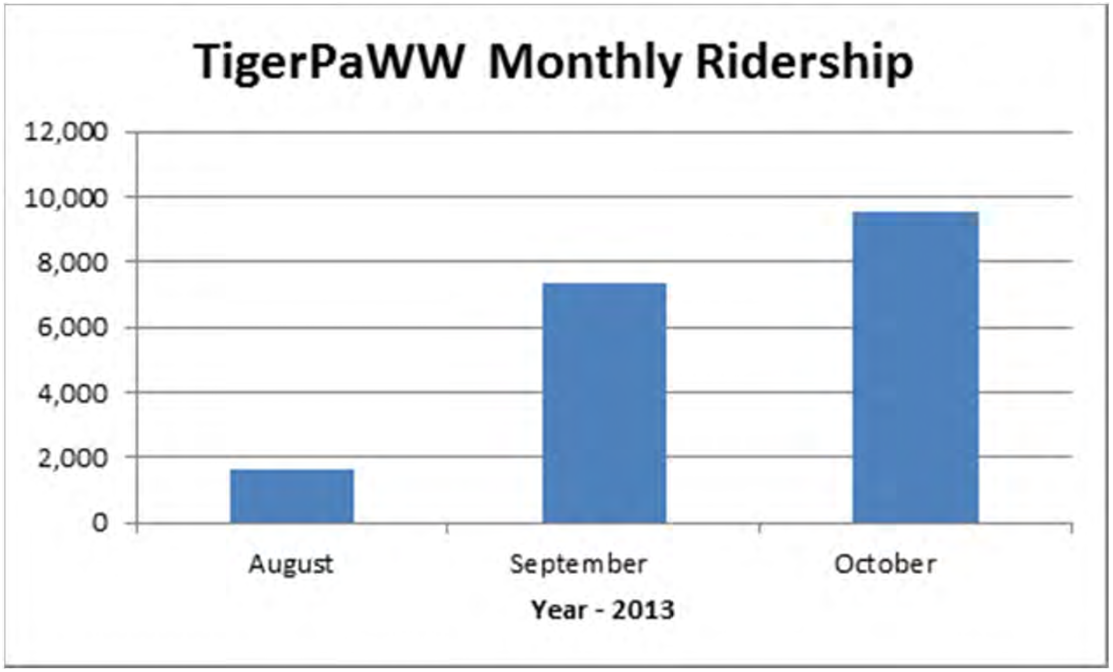
Other Princeton Ridership Data



Ridership on three NJ Transit but routes serving Princeton (not all data available)

Source:
NJ Transit rider survey 2012.

Other Princeton Ridership Data



Tiger PaWW service began in August 2013

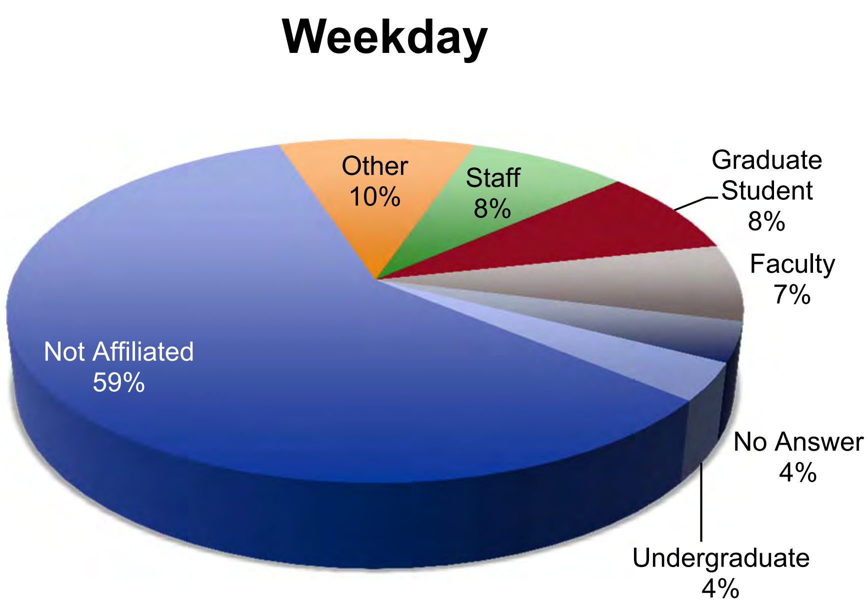
New TigerPaWW service

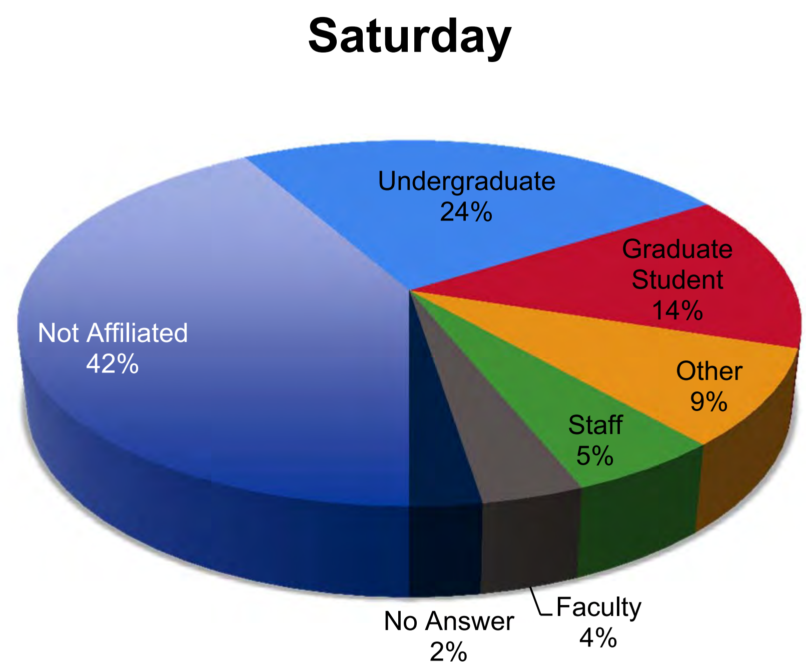
Temporary service provided during construction of the Arts and Transit Neighborhood. Mirrors the Dinky schedule "arrival at" and "departure from" times for Princeton Junction Station. Stops at:

- **Princeton Junction**
- **Princeton Station**
- **University Place (Former "Dinky" Station)**

Source:
Princeton University
Tiger Transit 2013

Dinky - Passenger Mix



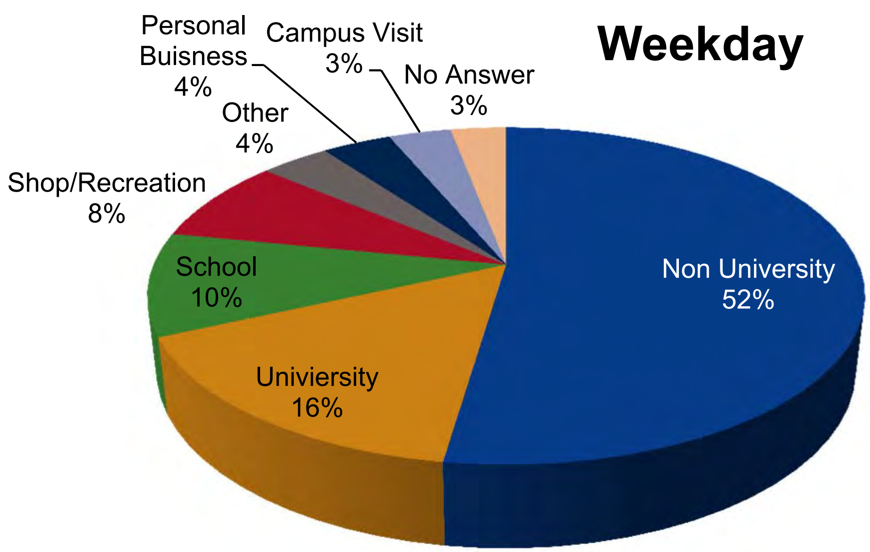


Overall, Dinky passengers close to 50% university based and 50% other.

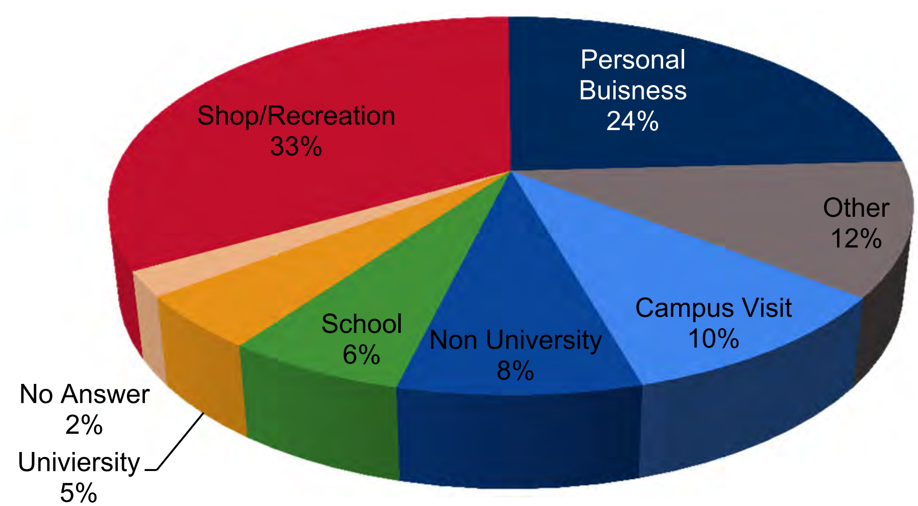
Based on Dinky Survey results, 2007

Dinky – Trip Purpose

Weekday

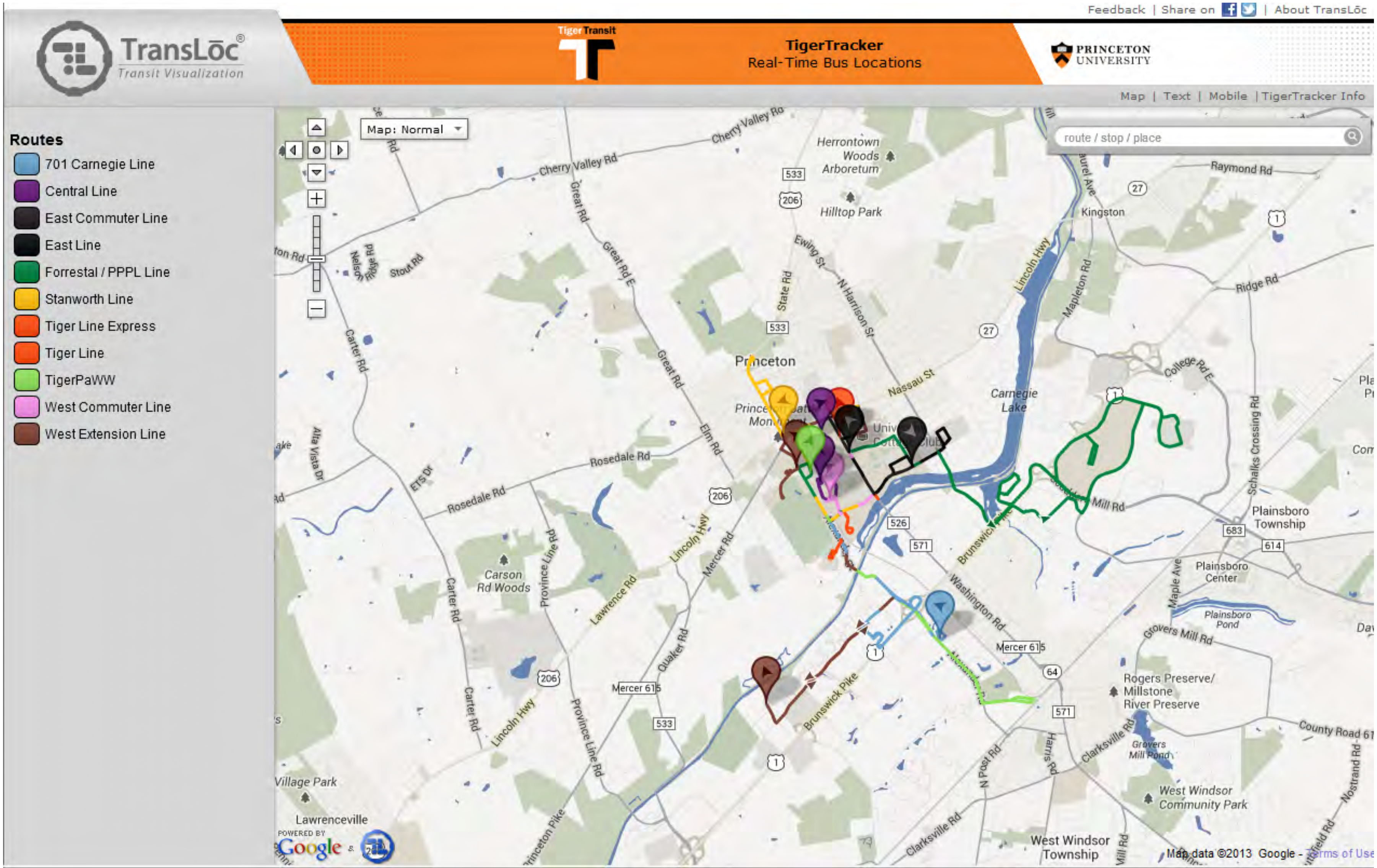


Saturday



Based on Dinky Survey results, 2007

Random look at Tiger Tracker – concentration of service



What specific problem are we focusing on?

What were we tasked to do

Specific focus: Improve transit connection between Princeton Junction and Nassau Street (Downtown Princeton).

Evaluate:

- One Seat Ride from Princeton Junction to Nassau Street (rail or bus)
- Option for circulator service to supplement the Dinky – two seat or three seat ride from Princeton Junction to Nassau Street

Study area


Princeton Transit Study
Nassau Street
University Place
Princeton Station
Alexander Rd
Princeton Junction
0 0.2 0.4 0.8 Miles
Legend
Bus
Rail
Study Area
Rail Station
Copyright: ©2013 Esri, DeLorme, NAVTEQ

URS

What transit alternatives were examined?

Options Considered to achieve transit goals

Many transit mode options were considered including:

- Commuter Rail extension
- Rapid Transit
- Bus Rapid Transit
- Light Rail Transit
- Personal Rapid Transit
- Enhanced Bus Operations
- Streetcar
- Others

URS

What works best?

URS

Bus Rapid Transit or Enhanced Bus options

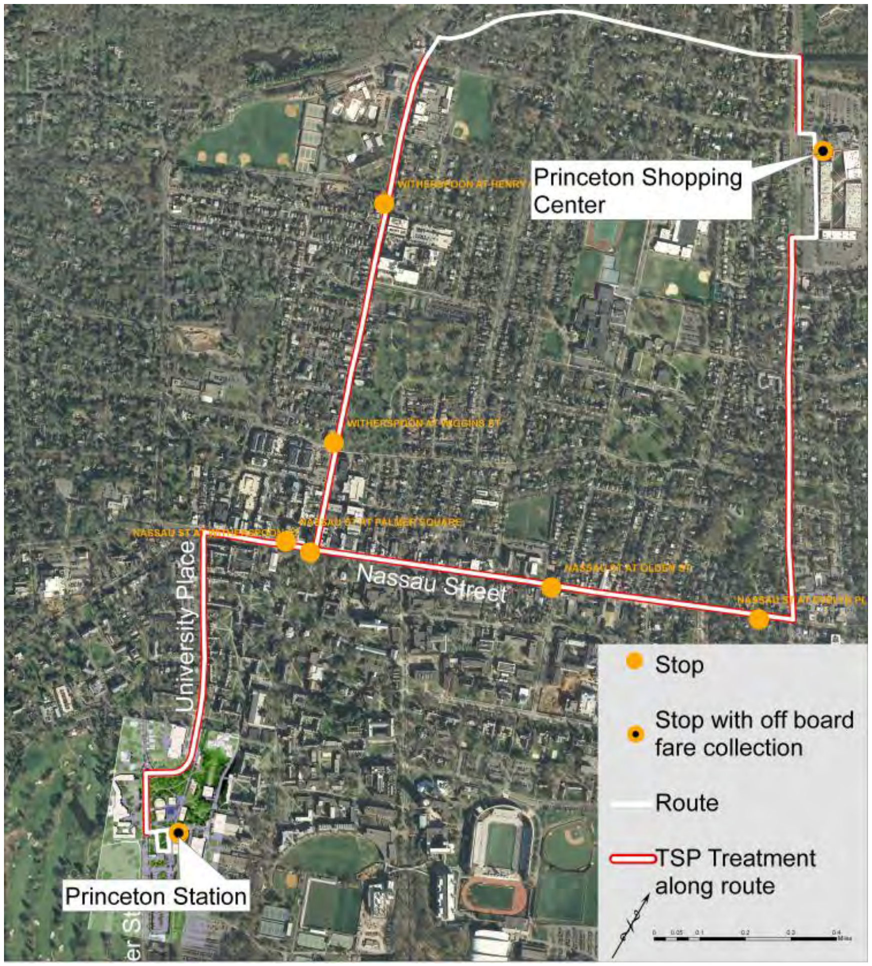
Bus Rapid Transit or Enhanced Bus

Buses (conventional, hybrid and state-of-the art) operating on exclusive roadway, or busway, that is access-controlled.

- Standard Bus or special vehicles available
- Separated Guideway Typical, but Street operations possible
- Moderate Capacity
- Highway Speeds
- Normal street geometry acceptable

BRT

Option 2A

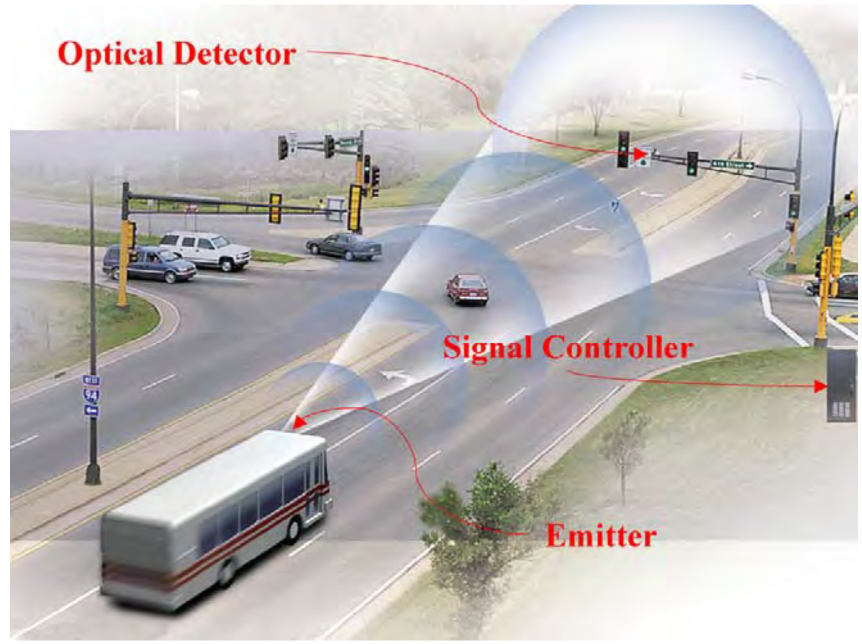


Option 2B

BRT Elements

Off Board Fare Collection and Level Boarding

Transit Signal Priority



Source: sustainabletransportationholland.org

URS

Light Rail Transit (LRT) options

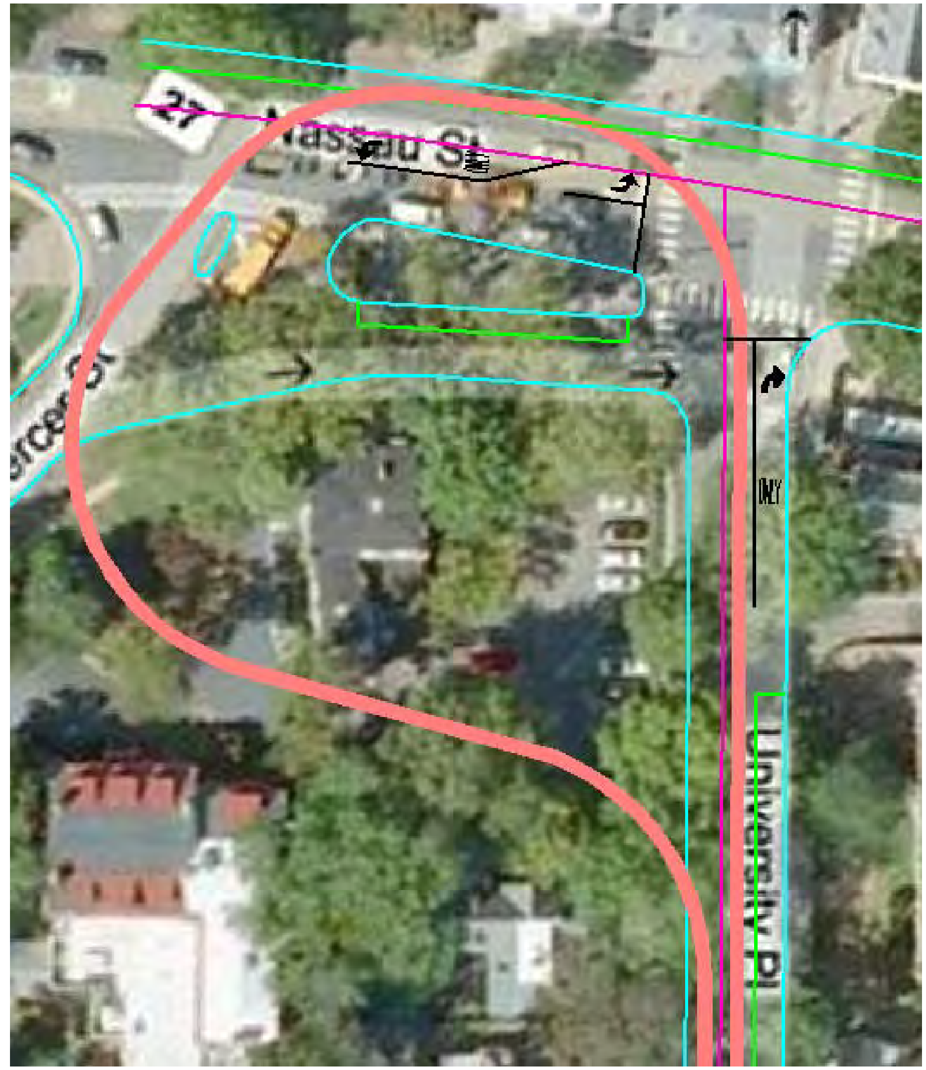
Light Rail Transit (LRT)

Light Rail Transit is a primarily at-grade rail mode, usually in an exclusive right of way, with electric powered vehicles receiving current from an overhead wire (catenary). Can also operate with other traffic along existing roadways.

- Single Cars/Short Trains
- Generally in Exclusive or Separated Right of Way
- Occasionally in Streets
- Higher Capacity and Speeds (up to 60 mph)
- Larger Curves (min 82 feet)
- Station spacing one-half to one mile apart

Overview of Potential LRT route

Issues with turning radii at University Pl and Nassau



New Traffic Circle on Alexander

URS

Streetcar options

Modern Streetcar

Modern streetcars run on an at-grade fixed track with mixed traffic along existing roadways. The modern streetcar uses a low-floor vehicle design that is basically a smaller version of a light rail car.

- Single Cars
- Generally in Streets with traffic
- Speeds up to 40/50 mph
- Tight Curves possible (min 50 feet)
- Rolling Stock available includes:
  - Modern Cars
  - Heritage Cars
  - New Replica Cars
  - Hybrid

Route Options

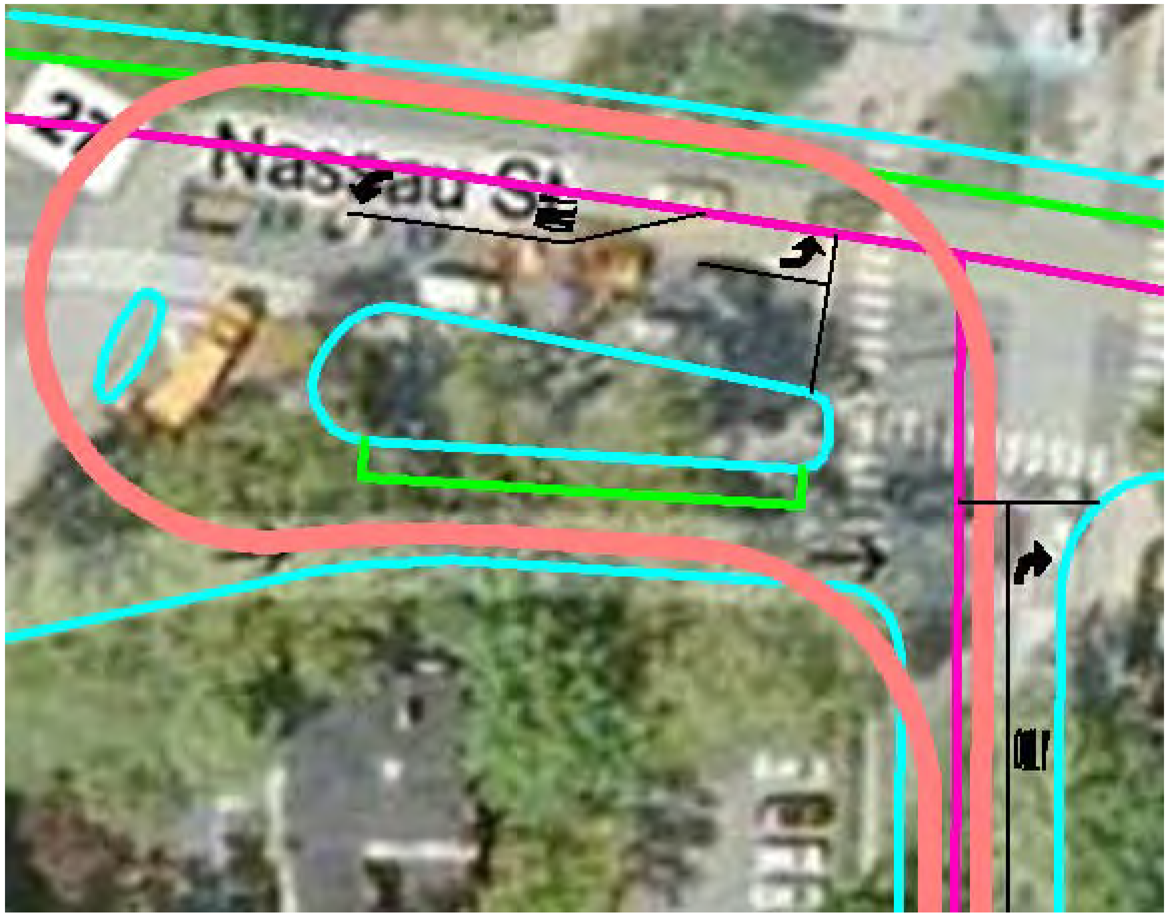
Streetcar – Southern Alignment

Streetcar – Basic Route

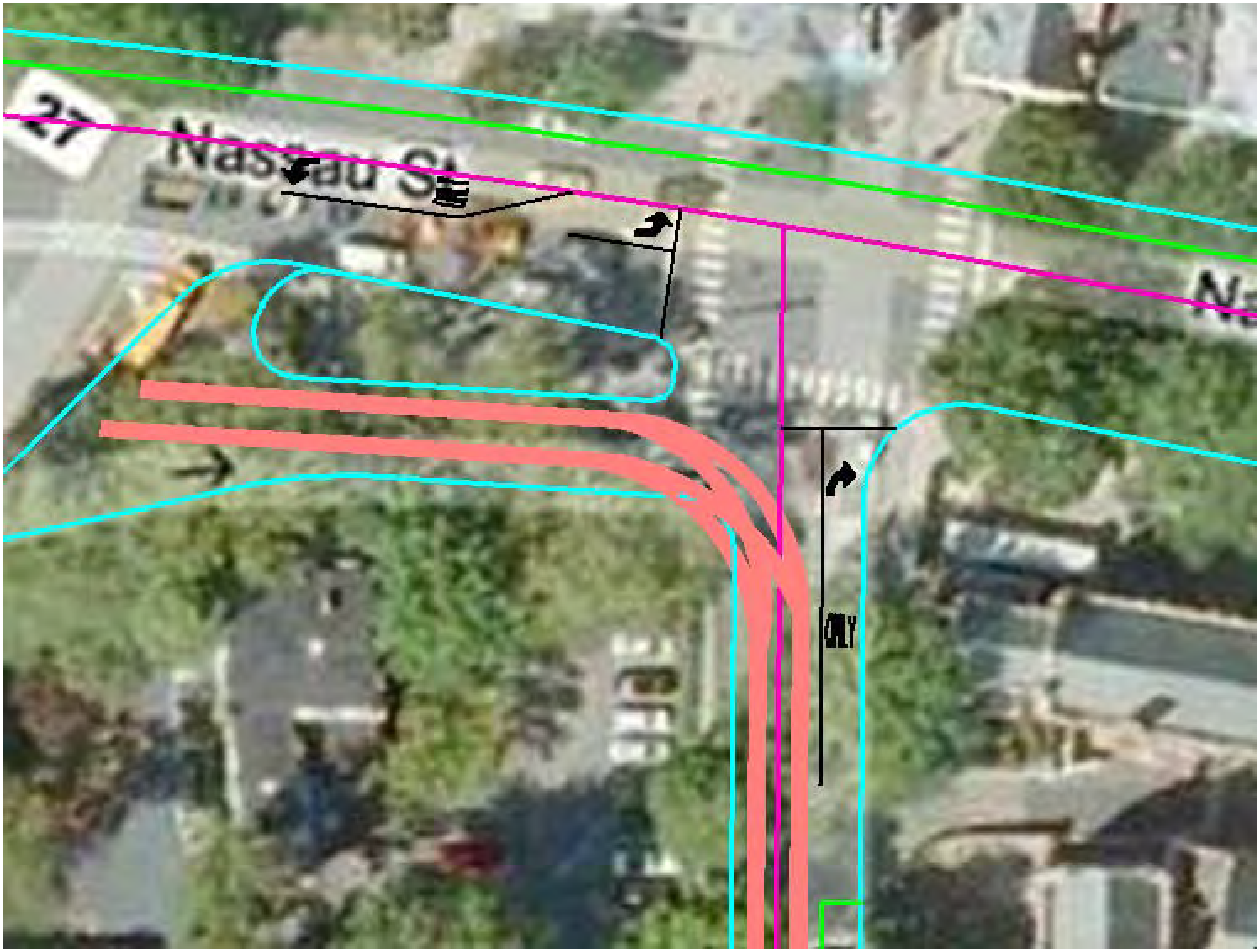
Streetcar – Faculty Road Alignment

Streetcar in one way loop – University Pl – Nassau – Mercer - Alexander

Potential Loop at Nassau Street

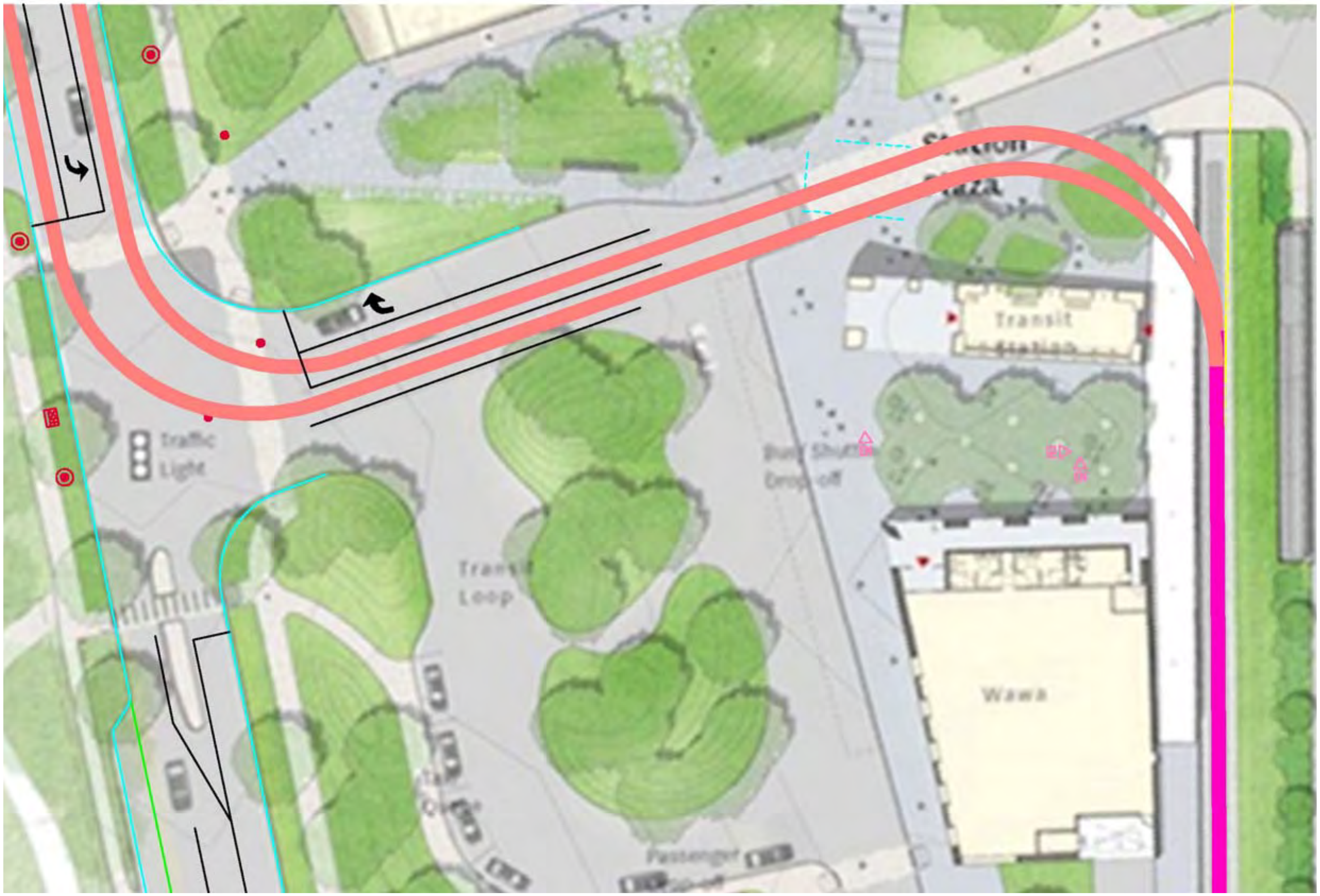


Potential bi-directional service at Nassau

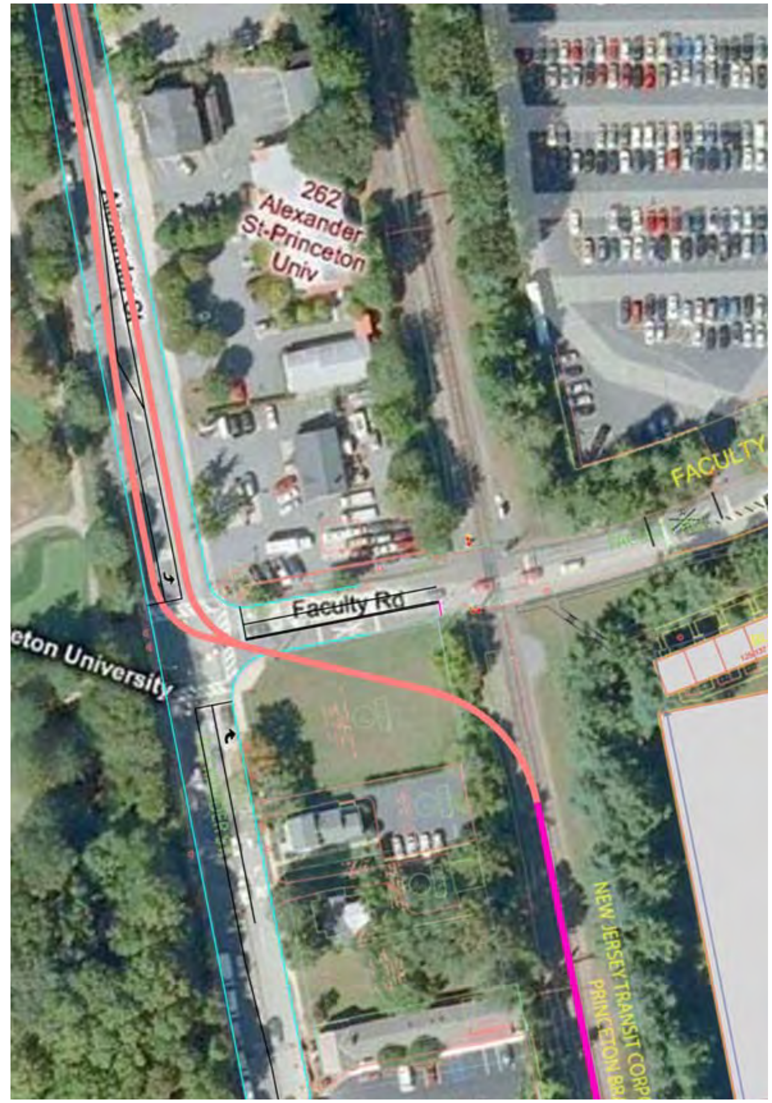


Streetcar at new roundabout on Alexander

Princeton Station transition



Alternatives to get on Alexander Street sooner



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Conversion of Dinky line to streetcar/LRT

- New substation required
- Separation from Northeast Corridor at Princeton Junction
- Same wire may be kept
- Speeds would be similar to existing Dinky
- Voltage differences (12.5kV vs. 650 vDC)
- Separate maintenance facility required for streetcar or LRT.

University Place - 2013

University Place – with visualization of streetcar operating on it

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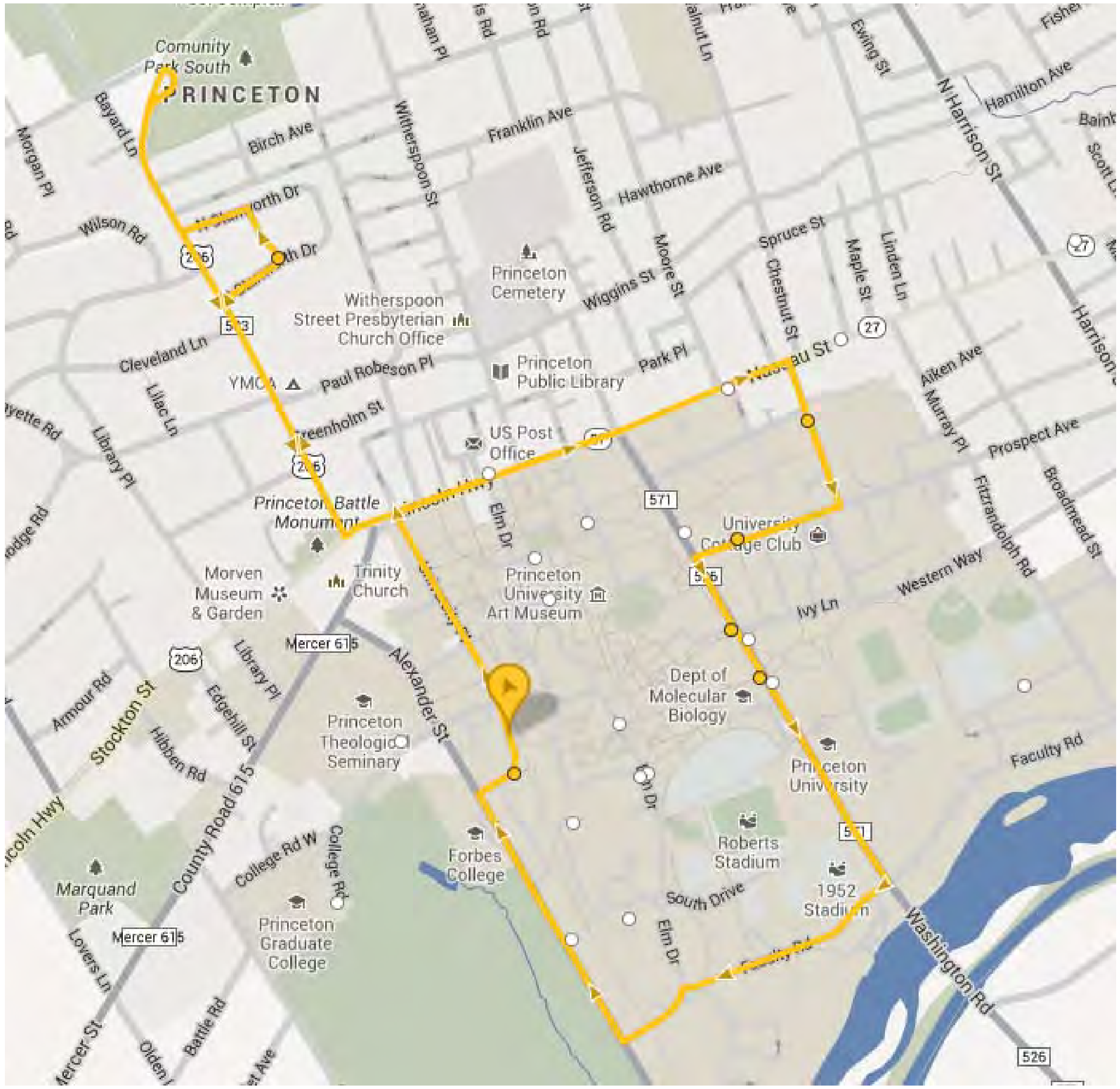
Two-seat ride options

Existing circulator service operated by Tiger Transit



Potential Circulator service

Potential ‘figure 8’ circulator connecting with Princeton station, serving center of University campus, Nassau Street and points North.

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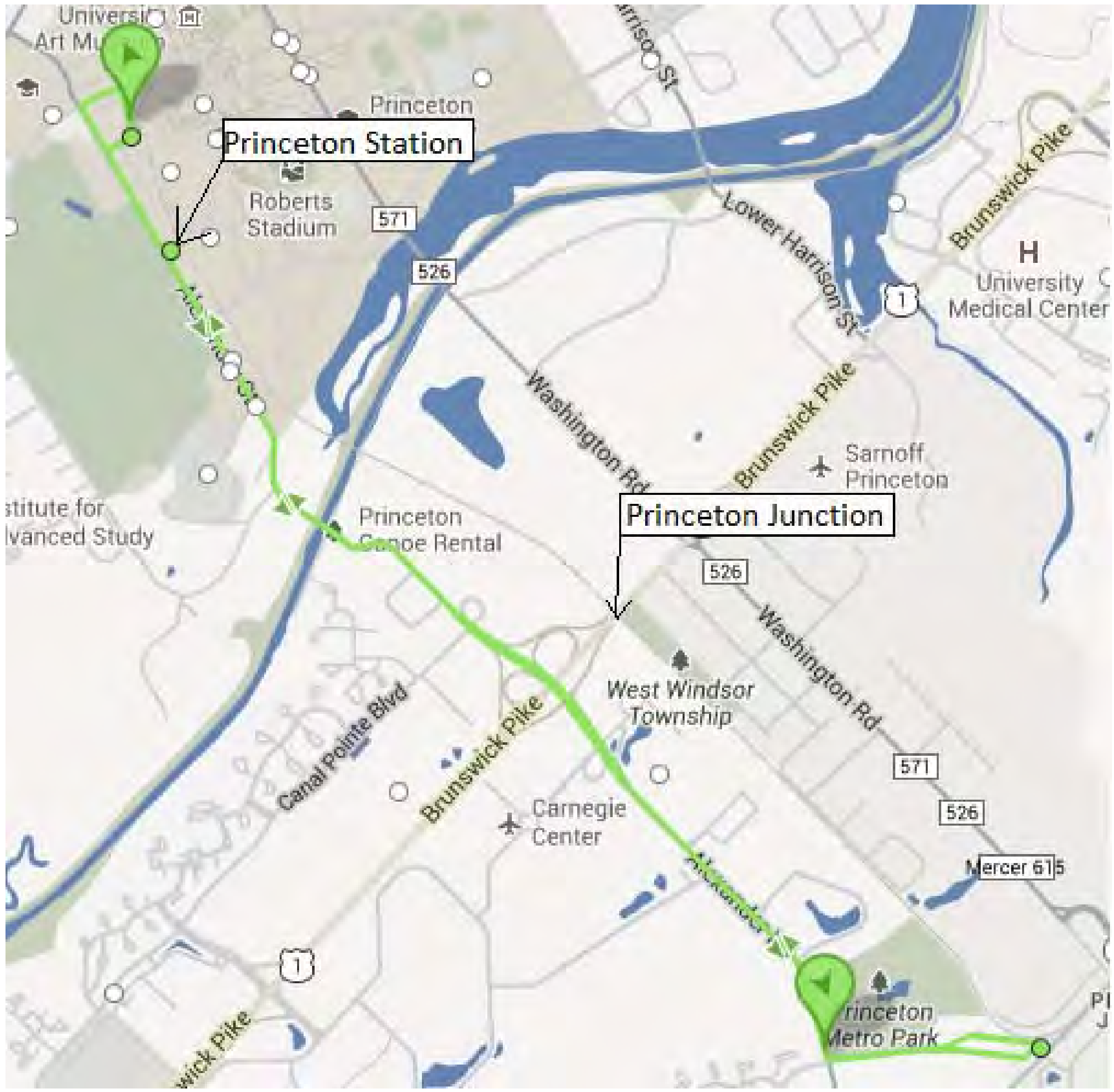
New Tiger PaWW service – W. Windsor - Princeton



URS | Princeton Transit Study

URS

Next Steps

Next Steps

- Invite, Involve the Public; Review public input
- Estimate ridership for each alternative
- Estimate costs
- Prepare preliminary schedules and operating plan
- Evaluate integration with other modes like bicycle and pedestrian
- Prepare evaluation matrix of options

URS

What do you think?

Notes from public meeting held Saturday, November 9, 2013 at Princeton University

Meeting went from 9 am to noon. About 35-40 persons attended (including task force and staff). There were not many students , though there was a rep from the Princeton University paper. Most of the crowd represented LRT and streetcar proponents, Princeton Future, PRT, anti-development folks, people interested in technical aspects of the project and some retirees. A photo of the meeting is also attached. The meeting was videotaped so it would be interesting to review some of the questions.

Following the meeting URS conducted a brief site inspection of key project locations - the Princeton station was closed, and a new temporary station was put up further away from downtown, but with a lot of parking.

In addition, there was a vote at the Planning Board Thursday night (November 7) to eliminate BRT from future options in any transit plans but the vote was not directly tied to the study. BRT was not mentioned at the public meeting on November 9. A key comment was that those who are "Save the Dinky" proponents want to make sure that if we change the mode to LRT or streetcar, the short, non-stop ride from Princeton Junction to Princeton Station is preserved (they don't want to see interim stops on the route). The Task Force will follow-up with URS after a discussion they will have at their next meeting.

Comment sheets were also distributed at the meeting and are attached.

COMMENT FORM

PRINCETON TRANSIT STUDY

Thank you for your interest in the Princeton Transit Study!

One of the main purposes of the Princeton Transit Study is to review potential transit options to determine the best way to get from Princeton Junction to Downtown Princeton (Nassau Street) by transit. Many alternatives are available, but what makes the most sense for Princeton? We'd like to hear your thoughts and incorporate what we learn from you into the decision-making process.

Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: Princeton

Town of Employment: Princeton / New York

How did you hear about this public meeting? email from Princeton Future / last minute

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☐ Light Rail Transit (LRT)
- ☐ Streetcar
- ☐ No Change (Existing Dinky Service)
- ☐ Other ______

If you have any additional comments, please write them in the space provided below and on the back of this form.

Why pulling all trafic into center of town?
getting Eastern parts of town to NYC / Airport
By existing bus speed up
People western section to NYC without
coming into town

Why not working to enhance Suburban Transit Ride – too many stops in town.
Express dropping people off Jersey Avenue –
why nothing on Washington.
nothing on Harrison.
have Hospil Route not stop @ Junction ?
long term parking to get to Air Park
multi day leaving town.

protection from weather @ stops.

look @ areas with low income & provide more public transit.

More public input

Tiger Transit include stops Junction

THANK YOU FOR YOUR INPUT!

COMMENT FORM

PRINCETON TRANSIT STUDY

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: Lawrence

Town of Employment: L - P - W retired

How did you hear about this public meeting? e mail was sent to me

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☐ Light Rail Transit (LRT)
- ☐ Streetcar
- ☐ No Change (Existing Dinky Service)
- ☐ Other ~~[illegible]~~ see comments below

Part II

If you have any additional comments, please write them in the space provided below and on the back of this form.

It seems to me that the planning studies are top loaded.

I don't know if Future Use

sent out Questionnaire to the residents of Princeton to get their input.
A mailer can develop and sent to their homes along with other township mail.

Regarding solutions
Has any consideration been given to sky-walk scenarios.
There are some models I've seen that caught my attention. (This would be for the big future out.)
This second segment attracted some good questions from your participants

THANK YOU FOR YOUR INPUT!

COMMENT FORM

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: Lawrence

Town of Employment: L – P – W triad

How did you hear about this public meeting? notice was e-mailed to me

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service } these two would be good for Rt. One
- ☐ Light Rail Transit (LRT) } or tributaries in P'ton.
- ☒ Streetcar —
- ☐ No Change (Existing Dinky Service)
- ☐ Other ~~for right away~~

If you have any additional comments, please write them in the space provided below and on the back of this form.

I am ~~still on~~ still trying to get a picture image in my mind as to how a pedestrian plaza in Princeton (Bayard/Nassau to Spring/Nassau →

would look - if a ~~sim~~ CAD simulated model could be developed. Also what is the distance between these 2 points (N/Bayard to Spring St)

If it is 1-mi, that is generally too great a distance for a senior population to walk. People age differently - some would do the distance, others may not.

But most would probably choose a mid-point and walk to one end or another (which would make their walk about 1/2 mi. One-half mi. is doable. Studies have been done that identify that 1/2 mi is the upper limit people would walk to catch a bus or such.

And how ~~you~~ would you re-connect the traffic that has been diverted from Princeton proper?

THANK YOU FOR YOUR INPUT!

COMMENT FORM

PRINCETON TRANSIT STUDY

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: Princeton

Town of Employment: writer/consultant in NYC + Princeton

How did you hear about this public meeting? Facebook / Walkable Princeton

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☐ Light Rail Transit (LRT) – if one seat / dedicated corridor
- ☐ Streetcar maybe
- ☑ No Change (Existing Dinky Service) preserved at original (location/station)
- ☐ Other

If you have any additional comments, please write them in the space provided below and on the back of this form.

"Two seat" solution would likely discourage some commuters

I have so much more to say!

COMMENT FORM

PRINCETON TRANSIT STUDY

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: Princeton

Town of Employment: Retired

How did you hear about this public meeting? Traffic + Transportation Committee

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☐ Light Rail Transit (LRT)
- ☐ Streetcar
- ☐ No Change (Existing Dinky Service)
- ☐ Other Open-minded at moment.

If you have any additional comments, please write them in the space provided below and on the back of this form.

If the objective (AECOM Study) is to shift as much car traffic as possible to transit a point-to-point downtown to PJ transit system will - at best - yield only modest increases in transit use. Can the system be designed to serve a more diverse area ridership (shoppers, hospital visitors, employees at area job sites) so that we get an actual reduction in car traffic.

COMMENT FORM

PRINCETON TRANSIT STUDY

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: Princeton

Town of Employment: Princeton (N 206)

How did you hear about this public meeting? ad / announcements / PF email

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☐ Light Rail Transit (LRT)
- ☐ Streetcar
- ☒ No Change (Existing Dinky Service)
- ☐ Other DINKY PLUS (NEED GOOD 1 seat w/ complementary two seat)

If you have any additional comments, please write them in the space provided below and on the back of this form.

We need more public Input
A variety of input
Capture commuters / students / residents from various neighborhoods

COMMENT FORM

PRINCETON TRANSIT STUDY

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: Princeton

Town of Employment: work from home | semi-retired

How did you hear about this public meeting? Princeton email list

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☐ Light Rail Transit (LRT)
- ☐ Streetcar
- ☐ No Change (Existing Dinky Service)
- ☒ Other whichever provides the most reliable & frequent service - more important than type of vehicle

If you have any additional comments, please write them in the space provided below and on the back of this form.

If we want people to get out of their car, there must be an alternative that offers comparable convenience & reliability & gets them where they want to go.

COMMENT FORM

PRINCETON TRANSIT STUDY

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: Pennington

Town of Employment: West Windsor

How did you hear about this public meeting? email / contact / PF

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☐ Light Rail Transit (LRT)
- ☒ Streetcar
- ☐ No Change (Existing Dinky Service)
- ☐ Other

If you have any additional comments, please write them in the space provided below and on the back of this form.

streetcar appears to be a "no brainer"; can extend further into town and better impact traffic.

COMMENT FORM

PRINCETON TRANSIT STUDY

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: PRINCETON

Town of Employment: PRINCETON

How did you hear about this public meeting? SAVE THE DINKY (PRINCETON DINKY) INVITE

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☐ Light Rail Transit (LRT)
- ☐ Streetcar
- ☐ No Change (Existing Dinky Service)
- ☐ Other PRIVATE / PUBLIC MASS TRANSPORTATION

If you have any additional comments, please write them in the space provided below and on the back of this form.

GOAL (1) DEVELOP A WAY TO FILL THE FOOTBALL STADIUM WITHOUT BUILDING A SINGLE NEW PARKING SPACE

COMMENT FORM

PRINCETON TRANSIT STUDY

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: PRINCETON

Town of Employment: PRINCETON

How did you hear about this public meeting? PRINCETON FUTURE

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☐ Light Rail Transit (LRT)
- ☑ Streetcar
- ☐ No Change (Existing Dinky Service)
- ☐ Other

If you have any additional comments, please write them in the space provided below and on the back of this form.

USE A "COMPLETE STREETS" PERSPECTIVE TO ANALYZE ANY TRAFFIC IMPROVEMENT – THE STREET SPACE SHOULD FAVOR PED/BIKE/TRANSIT MODES TRANSIT

COMMENT FORM

PRINCETON TRANSIT STUDY

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: PRINCETON

Town of Employment: (AM RETIRED)

How did you hear about this public meeting? I FOLLOW THE ISSUE BY ALL SYSTEMS

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☐ Light Rail Transit (LRT)
- ☐ Streetcar
- ☒ No Change (Existing Dinky Service) EXPANDED, ...
- ☐ Other

If you have any additional comments, please write them in the space provided below and on the back of this form.

COMMENT FORM

PRINCETON TRANSIT STUDY

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Town of Residence: WEST WINDSOR

Town of Employment: PRINCETON

How did you hear about this public meeting? WALKABLE PRINCETON BLOG

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☒ Light Rail Transit (LRT)
- ☒ Streetcar
- ☐ No Change (Existing Dinky Service)
- ☐ Other LRT + STREETCAR EXTENDS RAIL CONNECTIONS — INTO TOWN — VERY DESRABLE

If you have any additional comments, please write them in the space provided below and on the back of this form.

— BRT — SILVER LINE IN BOSTON IS AWFUL!!

→ ONE WAY TRAFFIC GIVES OPPORTUNTIES — BUT CAN INCREASE SPEEDS!

→ [illegible] ITS IN TRAFFIC — NOT AN OPTION!!

COMMENT FORM

PRINCETON TRANSIT STUDY

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: Princeton

Town of Employment: Plainsboro

How did you hear about this public meeting? email for neighborhood group (Yahoo)

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☑ Light Rail Transit (LRT)
- ☐ Streetcar
- ☑ No Change (Existing Dinky Service)
- ☐ Other

If you have any additional comments, please write them in the space provided below and on the back of this form. = A LARGE PARKING LOT @ PRINCETON STATION:

I started to use the Princeton station more since the move as the parking is better now. If you want to expand Dinky use - have a LARGE parking lot there for commuters. I go to the city often & there rarely are parking places at Princeton Junction - it would be good to have spots in Princeton.

COMMENT FORM

PRINCETON TRANSIT STUDY

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Please write your comments in the space provided on this form and drop it off at the sign in table before you leave. Thanks for your interest and participation!

Town of Residence: [illegible]

Town of Employment: [illegible]

How did you hear about this public meeting? [illegible]

Of the alternatives being considered as a part of this study, what is your preference?

- ☐ Bus Rapid Transit (BRT) / Enhanced Bus Service
- ☒ Light Rail Transit (LRT)
- ☒ Streetcar
- ☐ No Change (Existing Dinky Service)
- ☒ Other [illegible]

If you have any additional comments, please write them in the space provided below and on the back of this form.

[illegible]

[illegible]

Appendix 6 – Review of Previous Studies

Review of Previous Studies

As a first step in the process, the Consultant Team reviewed all prior studies to gain a baseline understanding of Princeton's Dinky service, the University's plans for future growth, and existing data on rail and transit usage within the Princeton area.

The Consultant Team reviewed studies, plans, and planning documents that have been prepared by various agencies to identify and address transportation needs within the study corridor of the Princeton Transit Study. These reviews provide a summary of these reports in reverse chronological order of publication, highlighting their relationship to the Princeton Transit Study.

The following studies have been reviewed:

1. Princeton Residential Mixed Use (RMU) Zoning Code (Proposed), 1968 (amended 2012, DRAFT)
2. Princeton Community Master Plan, 1996 (Amendments through November 2012)
3. Community Transportation Coordination Initiative, 2010
4. Princeton University Campus Plan, 2008
5. Viability of Personal Rapid Transit in New Jersey, 2007
6. Penns Neck Area Environmental Impact Statement, 2004

Additionally, this report includes review of two websites that chronicle construction projects by Princeton University that were ongoing or near completion:

7. Princeton University Arts and Transit Neighborhood Plan
8. Redevelopment Plan for Hibben-Magie Site

1. PRINCETON RESIDENTIAL MIXED USE (RMU) ZONING CODE (PROPOSED)

Completed by: Township of Princeton, 1968 (Draft amendments through 2012)

Document Purpose

The purpose of this amendment to Princeton's zoning code is to introduce a new zoning district designated as Residential Mixed Use ("RMU"). At this point, the code amendment is only in its draft form.

Summary of Relevant Findings

Based on this code amendment, a wide variety of residential, office, retail, service, transit, and accessory uses would be allowed within the RMU zone. The ordinance also outlines guidelines for landscaping, parking, signage, streetscape, and design aesthetics. Through these guidelines, the RMU zone encourages mixed-use development that is consistent with the principles of Smart Growth and transit-oriented development (TOD).

osite street combining all the design
ne elements that follow.

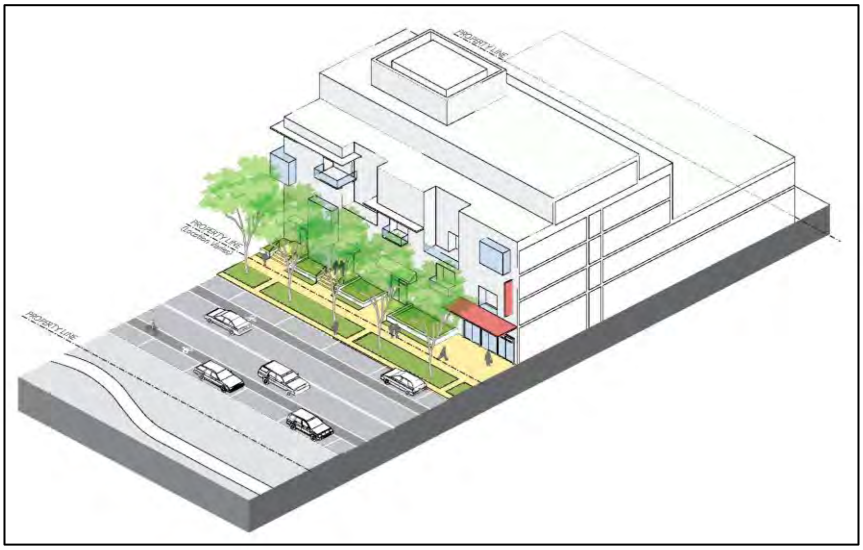


Figure 6-1: Overall Intent of RMU Design Guidelines

It can be assumed that the RMU zone will be sited south of the existing Dinky station and in areas of Princeton that have the potential to support transit and associated development. With the institution of the RMU zone, it will be possible to propose TOD sites around the proposed transit improvements within the Princeton Transit Study. By removing the need for special zoning variances, it makes the potential for such development more realistic and gives clearer expectations for the type of development desired within the area.

2. PRINCETON COMMUNITY MASTER PLAN

Completed by: Planning Board of Princeton, 1996 (amendments through 2012)

Study Purpose

The Princeton Community Master Plan (the Master Plan) was originally adopted in 1996. Since then, there have been fourteen amendments made to the document. The most recent came in June 2012. The amended version of the document was adopted by the Planning Board of Princeton in February 2013. The Master Plan is centered on the following vision statement:

> *Princeton has a special sense of place and community. It is an educational, cultural and commercial center as well as the site of such world-renowned institutions as Princeton University and the Institute for Advanced Study. It is also home to a leading center for theological studies, two nationally acclaimed schools of music, and numerous prestigious public and private schools at the elementary and secondary level. It combines a rich mixture of educational, cultural and historic resources. Princeton is a lively college town with attractive shops and restaurants, as well as businesses and residences. Surrounding the town center are architecturally diverse, residential neighborhoods on tree-lined streets linked by bike paths and/or sidewalks to small scale suburban offices, shopping and service centers. Within these urban and suburban neighborhoods, residents vary widely in age, socio-economic and ethnic backgrounds. Princeton is remarkable for its scenic open spaces, parks, recreational facilities and rural settings. Tree lined two-lane roadways lead to surrounding residential areas, extensive new office centers, shopping malls, and major transportation arteries.*

Summary of Relevant Findings

While the Master Plan also outlines the goals and ideals for development in Princeton in terms of housing, land use, open space, community facilities, utilities, conservation, and historic preservation, the section of the Master Plan most directly related to the Princeton Transit Study is the "Circulation Element." Within that chapter, the portions relating to transit and bicycle/pedestrian improvements are most applicable. For these items, the Master Plan identifies the following goals:

- Encourage the further development, extension, and use of both public and private mass transit
- Provide better information on available transit service using print and electronic media
- Provide a pedestrian and bicycle path network for maximum recreational and circulation use between neighborhoods, recreational areas, schools, and shopping areas
- Improve parking opportunities for mass transit facilities.

In order to meet these goals, the Master Plan identifies the following potential strategies:

- Encourage convenient peripheral parking for CBD employees and locate parking garages and larger parking lots so that they are integrated into the circulation plan.
- Reduce auto dependency by providing traditional public bus and rail transportation as well as minibus and van services.
- Provide better information on transit routes through the use of newspapers, cable television and other communication media.
- Maintain and create bicycle and pedestrian linkages that reduce auto dependency
- Develop, in conjunction with major corporations and institutions, an overall pedestrian, bicycle and vehicular circulation and parking plan.
- Develop a continuous pedestrian and bicycle circulation system throughout the community and encourage neighboring communities and corporations to become a part of this network.
- Investigate the integration of bicycle lanes on existing roadways.

3. COMMUNITY TRANSPORTATION COORDINATION INITIATIVE

Completed by: Gannett Fleming, April 2010

Study Purpose

The purpose of the Community Transportation Coordination Initiative was to analyze the current transit services in the Princeton area, identify existing gaps in service, and recommend any improved transit services that would increase transit coverage, improve mobility options of residents, and/or increase connectivity between the area's existing transit services. To achieve this goal, Princeton Borough and Princeton Township, in conjunction with Princeton University, created a working group to address opportunities for improved transit in the area.

The goals of this initiative were to identify transportation improvement that would create a coordinated and integrated transit system to:

- Increase ridership and reduce dependence on motor vehicles;
- Reduce redundant services and improve connections between existing transit systems;
- Provide increased and timely service to underserved population centers;
- Support community businesses; and
- Preserve flexibility to integrate with future NJ Transit service enhancements and potential Bus Rapid Transit.

To respond to these goals, the current transit systems were analyzed and remedies to address current deficiencies and to leverage opportunities for the future were identified. This process included developing several shuttle service route options that would provide expanded coverage in both Princeton Borough and Princeton Township via expanded routes and hours of service.

Summary of Relevant Findings

Ten proposals were created for consideration, and they were developed to serve as many of the area's trip generators as possible. These initial proposals were reduced to the four most promising alternatives. In turn, these alternatives were further analyzed in terms of their strengths and weaknesses, and reduced to a single recommended shuttle alternative. This selected alternative was then refined to more fully meet specific goals created at the start of the project and the needs of the Princeton area.

Alternative D was recognized as the original preferred alternative, and it had the following advantages:

- Serves many of the area's housing options, including Elm Court/Harriet Bryan House, the Princeton Community Village/Holly House, Spruce Circle and Princeton Senior Resource Center.
- Provides service to the John Witherspoon Middle School and Princeton High School, as well as to both the Princeton Borough Hall and the Princeton Township Building.
- Offers bi-directional service on Nassau Street and through most of the route.
- Provide service on Bayard Lanes, including the Merwick/Stanworth site.

At the same time, the following disadvantages were identified:

- Somewhat circuitous routing through Princeton Borough, with a few difficult turns
- Large loop on the western portion of the route.
- Would not provide service to the housing units at Redding Terrace.

Alternative D was further evaluated using a field test. The test resulted in slight modifications to the route and the creation of the Recommended Alternative.

The Community Transportation Coordination Initiative recommended hourly service that would be timed to offer connections to existing transit service. Service would be offered between 10:00 AM and 4:00 PM on weekdays. Given this schedule, it is anticipated that the shuttle would carry 30 passengers per day and have an annual ridership of 7,590 persons. It was estimated that the first year operating costs for this level of service would be approximately $113,380. In addition to these operating costs, the new shuttle service would also require various capital investments including vehicle, bus stops, information kiosks, and passenger waiting shelters Depending on whether or not existing vehicles and infrastructure were utilized, these capital costs were estimated to be between $35,000 and $118,500.

Figure 6-2: Recommended Alternative, Community Transportation Coordination Initiative

The Community Transportation Coordination Initiative also identified various grants from local, state and federal governments, as well as from non-profit and private organizations that could be used to fund the proposed shuttle service. Another possible source of funds would be contributions from area merchants and other interested businesses that would benefit from the new service. The Community Transportation Coordination Initiative Identified the following potential funding sources, which are discussed in more detail in the initiative's Final Report:

- Congestion Mitigation Air Quality (CMAQ)
- Job Access Reverse Commute (Section 5316 or JARC)
- SAFETEA-LU Section 5307 and
- Federal Earmarks
- New Jersey Transit
- Princeton Borough and Princeton Township
- Local Sponsorship

The Community Transportation Coordination Initiative also noted that a strong marketing campaign would be critical to the success of a new shuttle service. A number of marketing elements were suggested for the proposed service, including:

- Shuttle service logo
- Unique Vehicle Appearance

- Bus Stop Signs
- Brochure/Timetable
- Publicity
- Website
- Posters

4. PRINCETON UNIVERSITY CAMPUS PLAN

Completed by: Princeton University, 2008

Study Purpose

The Princeton University Campus Plan is the result of the university's most comprehensive campus planning initiative ever. The University needed to determine how it could accommodate significant academic expansion while preserving the historic beauty and walkability of the campus. The Plan defined Princeton's campus as a web of interconnected systems, and as such it considered policy, architecture, infrastructure, landscape, and environment, along with implications and opportunities for the surrounding community. Overall, the Plan sought to identify a way for the university to use its diminishing available land for development on campus in an effective and meaningful way.

Summary of Relevant Findings

A core component of the Princeton University Campus Plan (the Plan) is to create a multi-modal transportation hub alongside a new arts complex to create a clear and welcoming point of entry to both the University and the township and borough of Princeton. This effort is known as the *Arts and Transit Project*. As part of this project, the Plan envisions a pedestrian-oriented transit plaza that would include a new station, retail stores, and connections to other modes (buses, jitneys, campus shuttles, taxis, parking, and bike facilities). New pathways, signage, and maps will direct visitors to destinations across campus and in the community.

The Plan notes that the Dinky is an important link for University students, faculty, staff, and visitors. While the University determined it was necessary to move the existing station, through consultation with New Jersey Transit they sought to handle this relocation in a way that would meet neighborhood parking needs and accommodate the potential addition of bus rapid transit service while plan minimizing the distance of this move and creating am improved transportation facility for all users.

The Plan recognized that before the vision for a mixed-use arts neighborhood could be implemented, transportation infrastructure in the area would need to be reconfigured. While the arts and Transit Project is not anticipated to generate new traffic, the roads and transit facilities in the area are already over their designed capacities. The redesign of the roadway network is intended to alleviate existing congestion by reducing peak-hour traffic-generating land uses and by eliminating the concentration of conflicting traffic movements at the intersection of Alexander Street and University Place. A new roundabout would remove a traffic light and encourage the natural flow of traffic toward University Place, while also providing an arrival point to both the campus and community when approaching from the south.

Figure 6-3: Rendering of the Transit Plaza in the Arts and Transit Neighborhood

The design of the Arts and Transit Neighborhood also includes the reduction of University-related parking will be reduced at the site. This change will result in less vehicular traffic during peak periods, making the site more accessible and attractive to commuters, visitors, and pedestrians.

Princeton University has created a website (http://www.princeton.edu/artsandtransit) dedicated to the ongoing progress of the Arts and Transit Project. A review of the website and its content can be found in this report under *Princeton University Arts and Transit Neighborhood Plan* below.

The Plan also discusses the renovations being planned for the Hibben and Magie apartments. This project will create mid-rise graduate student housing neighborhood in the western area of campus near the Graduate College and the Lawrence Apartments. Residents of these apartments will benefit from this area's proximity to the new Arts and Transit Neighborhood; the Dinky and the campus shuttles; and the recreational pathways and woodlands along Lake Carnegie. The Plan also recognizes the potential for a bus rapid transit stop at the intersection of Faculty Road and Alexander Street near these apartments in the future. Princeton University has created a website (http://www.princeton.edu/campusplan/buildings/hm-site) dedicated to the ongoing progress of the renovation of the Hibben and Magie apartments. A review of the website and its content can be found in this report under *Redevelopment Plan for Hibben-Magie Site* below.

5. VIABILITY OF PERSONAL RAPID TRANSIT IN NEW JERSEY

Completed by: Jon A. Carnegie, AICP/PP (Alan M. Voorhees Transportation Center at Rutgers, The State University of New Jersey) and Paul S. Hoffman (Booz Allen Hamilton, Inc.), 2007

Study Purpose

The purpose of this study was to demonstrate the current state of Personal Rapid Transit (PRT) development and implementation and to examine the potential viability of implementing PRT in New Jersey. The study was a response to the New Jersey Legislature's P.L. 2004, Chapter 160, which directed the Commissioner of Transportation, in consultation with the Executive Director of NJTRANSIT, to prepare a report evaluating the viability of PRT in New Jersey.

The goals of this study were to:

- Provide a complete and thorough description of the key elements of PRT technology and identify PRT components that have been demonstrated successfully and those that are conceptual in nature;
- Identify potential PRT system developers and assess the current status of PRT relative to implementation readiness;
- Compare and evaluate the potential benefits and costs of PRT to other modes of transportation, in terms of: capital costs, operations and maintenance costs, energy use, ability to reduce congestion, right-of-way needs, and potential environmental, land use, utility and visual impacts; and
- Evaluate the viability of integrating PRT as a supplement to NJ TRANSIT's current and future transportation networks and services.

Summary of Relevant Findings

In addition to reviewing the technical components of PRT, a key component of this study was to identify potential scenarios where PRT could be appropriate in New Jersey. Rather than siting specific locations for PRT systems, the study considered the types of New Jersey locations that might be appropriate for future PRT applications given the theoretical service characteristics of PRT found in the literature. Using this approach, the study identified urbanized areas, suburban employment centers, activity centers, and university campuses as potential areas where PRT could be implemented.

The study also identified the following local needs that PRT could potentially address:

- **Areas with high demand for local circulation**
    - PRT could work in areas where there is a high demand for local circulation among many origins and many destinations derived from a mix of land uses such as residential, retail, employment, and entertainment.
    - Such a system would be most effective where the origins and destinations have travel demand throughout the day in addition to a peak commuter travel demand.
- **Areas with the potential to extend the reach of nearby conventional transit**
    - PRT could offer an intermodal connection to conventional fixed-guideway or fixed-route transit services and create an extension of the conventional transit system by connecting nearby areas and neighborhoods to the station or terminal.
    - PRT could serve as a parking management tool by providing an alternative to auto access and the ability to connect to remote/satellite parking facilities.

- **Areas with constrained access and/or congested local circulation**
  - Individuals often make their mode choice decisions based on travel time comparisons between transit and the private automobile. Thus, PRT could be an attractive option in areas with congested travel conditions on local roadways.
- **Areas with constrained and/or expensive parking**
  - Areas with limited and/or expensive parking would be expected to generate higher demand for PRT service, as PRT could provide connections to/from less expensive remote parking facilities.

- **Areas requiring connectivity between high activity centers**
  - PRT could be a viable connector between other PRT systems, providing an integrated transit network across a region, eliminating the need to transfer between modes or within the mode.
  - As a scalable network, PRT could initially be used to support the locations with the highest need and then expand to connect these initial systems as demand and economic conditions allow.

The study seems to suggest that a location such as Princeton and Princeton University could potentially be a location where PRT could be implemented. At the same time, however, the Study notes that there are significant technical, financial, and institutional challenges that would need to be overcome in order to institute PRT service.

6. PENNS NECK AREA ENVIRONMENTAL IMPACT STATEMENT

Completed by: US Department of Transportation Federal Highway Administration and New Jersey Department of Transportation, 2004

Study Purpose

The purpose of the Penns Neck Area Environmental Impact Statement (EIS) was to address traffic congestion, mobility constraints, and safety concerns on US Route 1 and the east-west cross streets in the Penns Neck Area. Princeton Borough and Princeton Township were included in the primary study area (PSA).

The transportation-related goals of the Penns Neck Area EIS were as follows:

- Improve access, mobility, and safety while reducing congestion for all modes
- Maintain the viability of institutional and business communities
- Recognize the interrelationships between land use and transportation

Summary of Relevant Findings

The Penns Neck Area EIS analyzed a variety of potential alternatives to address the project purpose and goals. In addition to the required consideration of no-build and Transportation Demand Management alternatives, the Penns Neck Area EIS included various roadway and transit actions. These transit actions included the creation of a light rail or bus rapid transit system; changes to the existing New Jersey Transit Rail Service; and modifications to the existing bus system and the creation of a comprehensive jitney/shuttle system.

As explained in the following table, however, the light rail, bus rapid transit, and rail actions of the Penns Neck Area EIS were quickly removed from the scope of the Study due to the findings of concurrent studies. As a result, the Penns Neck Area EIS proceeded to analyze a series of 19 roadway modifications. The components of these alternatives are summarized in the second table, below..

Table 6-1: Actions Considered in Penns Neck Area EIS

Action Considered	Disposition
No-Action	As required by the National Environmental Policy Act (NEPA), the Penns Neck Area EIS includes consideration of a No-Action Alternative. This "do-nothing alternative" is included as the benchmark alternative against which all "action" alternatives will be compared.
Travel Demand Management	A variety of TDM strategies were advanced as complementary strategies included in the proposed EIS Commute Options package incorporated as a part of each action alternative (see Chapter 2, Section 2.4).
Transit – Creation of a Light Rail Transit or Bus Rapid Transit system	This action was examined as part of a concurrent planning study conducted by the Delaware Valley Regional Planning Commission for the Central Jersey Transportation Forum (CJTF) and in partnership with NJ TRANSIT. The study determined that construction of a LRT/BRT system would not significantly improve traffic congestion in the Penns Neck area. This action was eliminated from further analysis in the Penns Neck Area EIS, but study of a BRT system has been advanced separately.
Transit – Changes to the NJ TRANSIT rail service	A variety of rail service changes were considered, including more frequent reverse peak service to Princeton Junction station; new rail stations in Plainsboro and/or South Brunswick; additional Amtrak commuter rail service to the Hamilton station; and changes to the Dinky service between Princeton Junction and Princeton Borough. Based on input from NJ TRANSIT, it was determined that these actions were either under investigation as part of other concurrent studies or the project purpose could be more efficiently addressed through enhanced/expanded use of shuttles/jitneys.
Transit – Modification to existing bus services and the creation of a comprehensive jitney/shuttle system	These actions were advanced as complementary strategies included in the proposed EIS Commute Options package incorporated as a part of each action alternative.
Various road-based capacity improvements	A variety of road-based actions were advanced for further consideration in the alternatives development process. In most cases, individual road-based actions were combined into the alternatives considered in the EIS. Chapter 2 provides a complete description of the alternatives development process.

Table6- 2: Components of Alternatives in Penns Neck Area EIS

Table ES-3
Components of Alternatives

	Route 1 in-a-cut	Route 1 at-grade	Eastern frontage road	Western frontage road	East-side connector road	West-side connector road to Harrison St (Direct)	West-side connector road to Harrison St (Indirect)	West-side connector road to Washington Rd	West-side connector road between Alex. Rd and Washington Rd	Loop-type interchange (vicinity of Harrison)	Diamond interchange (vicinity of Harrison)	Diamond interchange (just north of Fisher Pl)	Vaughn Drive connector road
Alternative A	■				ESC1	■				■			■
A.1	■		■	■	ESC1	■				■			■
A.2	■			■	ESC1	■				■			■
A.3	■		■	■	ESC1	■					■		■
A.4	■		■	■	ESC1	■					■		■
Alternative B		■			ESC1		■	■		■			
B.1		■			ESC1		■	■		■			■
B.2		■			ESC1		■	■	■	■			■
Alternative C		■		2-way			■		■		■		■
C.1		■		2-way			■				■		■
Alternative D	■		■	■	ESC2	■					■		■
D.1	■		■	■	ESC2		■				■		■
D.2	■		■	■		■					■		■
Alternative E	■		■	■	ESC3		■					■	■
Alternative F	■				ESC1	■				■			■
F.1	■		■	■	ESC1	■				■			■
Alternative G		■											■
G.1		■											■
G.2		■											

Key: 2-way – frontage road accommodates two-way traffic.
ESC1 – northern alignment of the east-side connector road adjacent to Millstone River
ESC2 – central alignment of the east-side connector road
ESC3 – southern alignment of the east-side connector road adjacent to Penns Neck neighborhood

Following analysis of data and consideration of public input, the conclusion of the Penns Neck Area EIS was that the best potential alternatives were Alternatives D and D.2. These alternatives were combined into the preferred alternative, D.2.A.

Alternative D.2.A included the following improvements:

- Route 1 in-a-cut at Washington Road with Washington Road crossing over Route 1 at its existing grade and a new single-point interchange at Washington Road
- A new grade-separated single-point interchange in the vicinity of Harrison Street
- A new west-side connector road running parallel to Lower Harrison Street, connecting the new Harrison Street interchange with existing Harrison Street
- A one-way frontage road system on both sides of Route 1 between Washington Road and the new Harrison Road interchange, with two roads in each direction

- A Vaughn Drive connector road location west of existing Station Drive, connecting Washington Road and existing Vaughn Drive

Alternative D.2.A was selected as the preferred alternative because it provides a reasonable level of transportation benefit, while avoiding and minimizing environmental impacts. Specifically, this alternative would:

- Provide system-wide congestion relief;
- Improve the flow of traffic on Route 1, resulting in shorter travel times;
- Improve the flow of traffic on east-west routes crossing Route 1;
- Maintain an equitable balance of traffic on east-west routes, on both sides of Route 1;
- Reduce traffic on residential streets in most parts of the core study area; and
- Enhance vehicular, bicycle and pedestrian access and safety.

These improvements have the potential to improve the roadway system within the Princeton Transit Study's focus area.

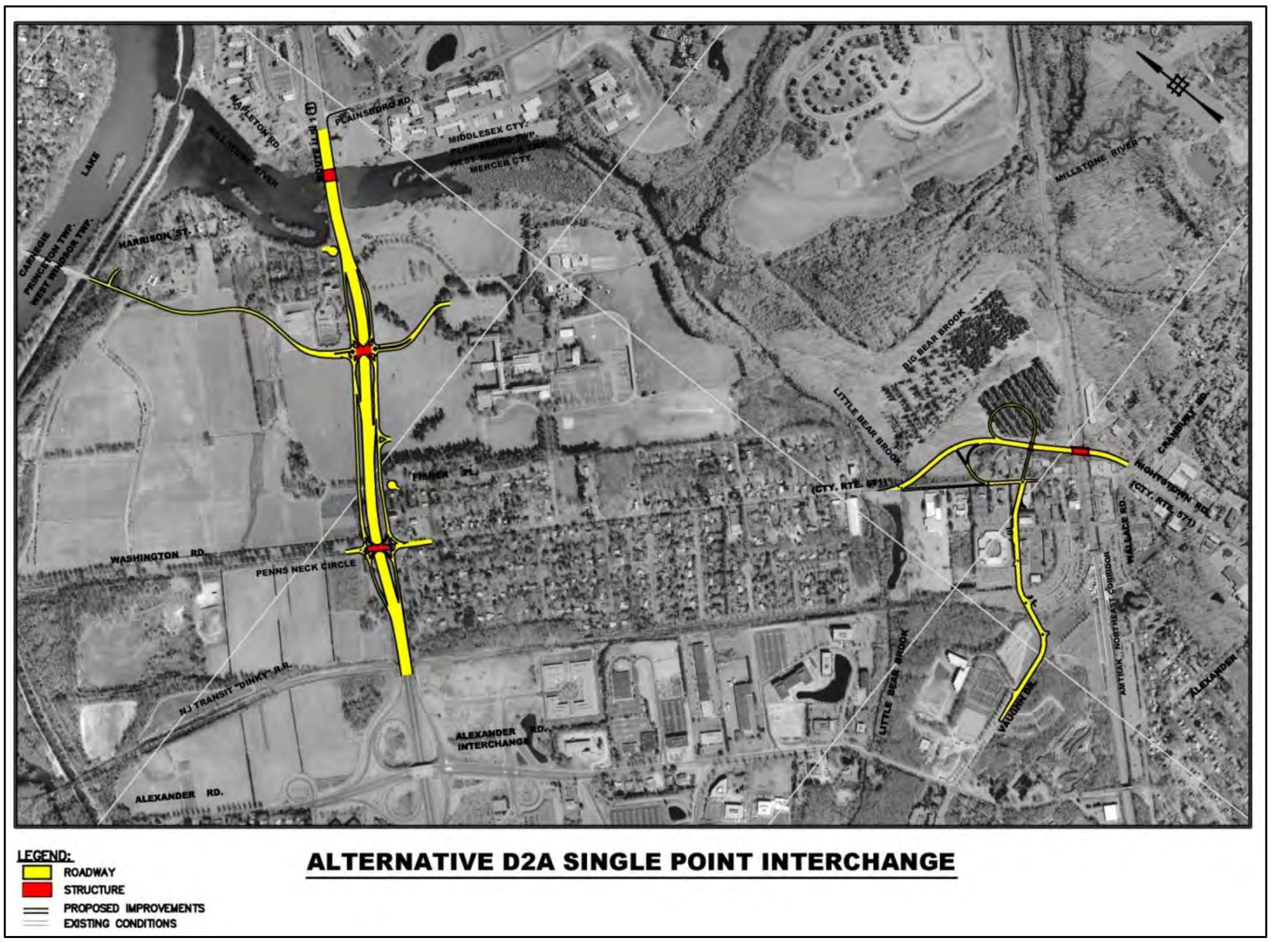


Figure 6-4: Preferred Alternative, Penns Neck Area EIS

7. PRINCETON UNIVERSITY ARTS AND TRANSIT NEIGHBORHOOD PLAN

Completed by: Princeton University

Website Purpose

Princeton University created a website (http://www.princeton.edu/artsandtransit) dedicated to its Arts and Transit Project, which was previously discussed in this report in the section on the *Princton University Campus Plan.* The purpose of the website is to provide information about the project's history, design and construction. The site also includes pages dedicated to recent news, frequently asked questions, and contact information for the project team. The new Dinky station was slated to be opened on November 17, 2014.

Summary of Relevant Findings

The website summarizes the transportation-related Arts and Transit Project improvements as follows:

- Improvements to public roadways including construction of a new roundabout at the intersection of University Place and Alexander Street and construction of an access road from Alexander Street to the University's West Garage (Lot 7) for University as well as public use;
- New Princeton train station complex with an indoor waiting room, outdoor waiting area, platform, 24-hour restrooms, and Wawa;
- Transit plaza for multi-modal connections, including spaces for drop-off and pick-up;
- New commuter parking lot;
- Public plaza;
- A new restaurant and café in the former train station buildings; and
- Extensive landscaping and site lighting improvements.

These improvements are important to the Princeton Transit Study because they deal with the areas surrounding the Dinky station. While alternative options for the area could be proposed, it is likely that the University is fully committed to this new station site. The new station was scheduled to open November 17, 2014.

This website also offers the most up-to-date information regarding the construction of Princeton University's Arts and Transit Neighborhood. Interested individuals can sign up to receive email alerts when new information is added to the website.

Figure 6-5 – Arts and Transit Neighborhood

8. REDEVELOPMENT PLAN FOR HIBBEN-MAGIE SITE (LAKESIDE GRADUATE STUDENT HOUSING)

Completed by: Princeton University

Website Purpose

Princeton University created a website (http://www.princeton.edu/campusplan/buildings/hm-site) dedicated to the renovation of Hibben and Magie apartments, which was previously discussed in this report in in the section on the *Princton University Campus Plan.* The purpose of the website is to provide information about the project's design, purpose, and construction progress.

Summary of Relevant Findings

The renovation of Hibben and Magie apartments will begin with the removal of the existing undergraduate housing located on the site. In its place will be built 13 structures with 329 units and a capacity for 715 graduate students and their families. The housing will include a mixture of one- to four-bedroom townhomes as well as apartments. In addition to the housing, the Hibben-Magie site will include a commons facility with a fitness center, social lounge, multi-function room, computer cluster, children's playroom, and outdoor social and recreation areas. The site will be served by the university shuttle.

The site is located less than one mile from the Arts and Transit Neighborhood and thus its residents represent potential transit users. The University has also identified the potential for a bus rapid transit stop at the intersection of Faculty Road and Alexander Street near these apartments in the future. The Lakeside Graduate Housing project (at the Hibben and Magie site) is shown below. The project is slated for completion by the end of 2014.

Figure 6-6: Hibben and Magie Apartments

Appendix 7 - ENVIRONMENTAL AND ECONOMIC CONSIDERATIONS

ENVIRONMENTAL AND ECONOMIC CONSIDERATIONS

A detailed environmental impacts evaluation for this study was not part of the scope of work. However, based on the Consultant Team's experience with the construction of streetcar systems around the country, there are typically short-term environmental consequences that could result from construction activities of a future Princeton streetcar system, particularly along Alexander Street, University Place and Nassau Street. Construction impacts would need to be further analyzed if the Princeton project progresses and an environmental review is formally prepared. The potential short-term environmental consequences would include the following categories:

- Transit – Princeton would need to coordinate with NJ Transit and Tiger Transit to notify riders of detours and closed/temporary bus stops related to construction. This would be similar to services provided during the relocation of the Dinky station.
- Traffic – at least one travel lane would be maintained in each direction at all times, and truck routes would not be eliminated during construction, but could be maintained temporarily on alternate routes (truck detour signs would be provided as necessary).
- Land Use and Socio-economic – typical construction best management practices would be employed to avoid or minimize adverse economic consequences to occupants, such as avoiding full access closures, providing temporary alternate access and signage, and timely communications with business owners.
- Neighborhoods and Community – construction would utilize standard industry practices to avoid or minimize increasing noise, the creation of dust, establishing construction zones and signage, altering or reducing access and establishing detours, and temporarily disrupting utilities as they are relocated or reinforced. This would be similar to that which is employed for the Arts and Transit project.
- Noise – construction would comply with the State of New Jersey's model noise ordinance and that which is set by Princeton, which defines hours for construction related noise.
- Air Quality – construction contractors would be required to use reasonable measures to control fugitive dust.
- Visual and Aesthetic Resources – due to their temporary nature, visual impacts related to a future Princeton streetcar would be classified as low to moderate. However, the long term impact of trolley or catenary overhead wire would need to be fully reviewed prior to final design selection.
- Historic, Archaeological and Cultural Resources – unknown archaeological or cultural resources potentially encountered during construction would be protected from any adverse effect by

taking some or all of the following actions, in compliance with Federal and state regulations: notification to and consultations with regulatory agencies and/or tribes; temporary work stoppage at the site; additional surveying and/or documentation; removal and preservation; other actions as appropriate.

- Parklands and Recreation Areas – temporary noise and dust related to streetcar construction is not expected to negatively affect use of nearby parks and recreation areas during the construction period. Controls similar to those implemented for the Arts and Transit project would need to be considered.
- Hazardous Materials – prior to construction of a future Princeton streetcar, a Phase I (and potentially Phase II) Environmental Site Assessment (ESA) would be prepared and remedial actions would be identified, if necessary.
- Biological Resources and Endangered Species – no effect to listed aquatic species and their designated critical habitat would be expected because project activities would implement construction containment plans and BMPs.
- Water Resources – construction effects on water quality from a future Princeton streetcar would be negligible, as construction would follow New Jersey and Princeton regulations.

FUNDING OPTIONS

Funding for streetcar projects is typically derived from a variety of sources often including a combination of federal, state, local and private financing. The following are typical examples:

Federal Sources of Funds

Section 5309 Small Starts Funding: The primary source of federal funding for new streetcar projects has been Section 5309 Federal Transit Administration (FTA) Funding, until recently commonly referred to as Small Starts grants. A word of note regarding FTA funding: grant programs typically change and are modified over time. This program originated in the Safe, Accountable, Flexible, Efficient, Transportation Equity Act – A Legacy of Users (SAFETEA-LU). This funding sources was started to support small capital projects (up to $75 of federal funds available for eligible projects of up to $250 million). It should be noted that changes to this program and many other available federal grant programs frequently occur, and up to date options, regulations and requirements need to be vetted with FTA prior to proceeding. The most important lesson learned from team members involved in the federal funding of streetcar projects is to involve the FTA as early as possible to be certain to meet all FTA requirements and enhance prospects of success.

Federal TIGER grants: This discretionary grant program was started in 2009 as a competitive grants process providing up to $25 million for individual eligible projects. TIGER grants have benefitted a number of streetcar projects, including Charlotte, NC and most recently Providence, RI.

Federal Housing and Urban Development (HUD) Funds: Typically not the most common source of federal transit funding, HUD funds have been used to support planning and design efforts for streetcar projects and can be a useful source early in the process.

Value Capture: Since well-planned transportation investments can increase people's access to desirable destinations, locations near these investments reflect higher land values, benefiting land owners and developers. Value capture mechanisms are a type of public financing where increases in the private land values generated by public transportation investments are "captured" to repay the cost of the public investment. Using value capture mechanisms to finance new or existing transportation infrastructure connects the cost to provide the service with the benefit of the infrastructure investment.

Federal Transportation Finance and Innovation Act (TIFIA) money is a potential source for funding debt for the years between streetcar construction and the redevelopment return on the public's investment. TIFIA provides credit assistance for qualified projects including transit projects over $50 million. Qualified projects are evaluated against eight criteria, including among others, impact on the environment, significance to the national transportation system, and the extent to which they generate economic benefits, leverage private capital, and promote innovative technologies.

State Funding: State funding can come from a variety of sources, including the state's transportation department program, economic development programs and miscellaneous programs, including the state's lottery funds.

Tax Increment Financing (TIF): Another value capture method, TIF is a public financing tool that can be used as a subsidy for redevelopment, infrastructure, and other community-improvement projects and has been used for streetcar projects. Future projected gains in taxes are used to subsidize the streetcar project as an improvement based on the gains in taxes that would be realized beyond what would happen with no improvements.

Local Funding Sources: A number of streetcar projects have bypassed federal funding due to the length of time and the restrictions imposed on the project. Instead, a variety of local sources are used to finance the construction. The first Modern streetcar project in the U.S., was in Portland, OR and was financed entirely from non-federal sources. One common technique is to set up a Business or Local Improvement District, which essentially taxes itself to help pay for the system. See next item.

Special Improvement District: Another potential source of funding is through a one-time assessment on properties within a specified number of blocks of the streetcar line, with properties closest to the proposed streetcar having a higher assessment than those further away. Pursuit of a special assessment for streetcar construction would need to be evaluated in advance within the Princeton community with regard to level of support for specific project elements and assessment level.

General Obligation Bonds: These can also be used as a means of helping to finance a streetcar project at the local level. Sources of support can include parking meter and parking lot revenues, as example. Princeton could issue such bonds upon voter approval to levy an assessment on real property, payable by property owners.

Private Funding: Financial participation by private entities such as major employers could be sought to fund some portion of the capital project. There is precedent in other cities where major private employers and institutions have chosen to fund the capital costs:

In Seattle, a major employer funded the cost of a streetcar vehicle to allow for higher frequency service.

In Tucson, a private developer contributed $3.2 million towards the streetcar project as part of a joint development agreement.

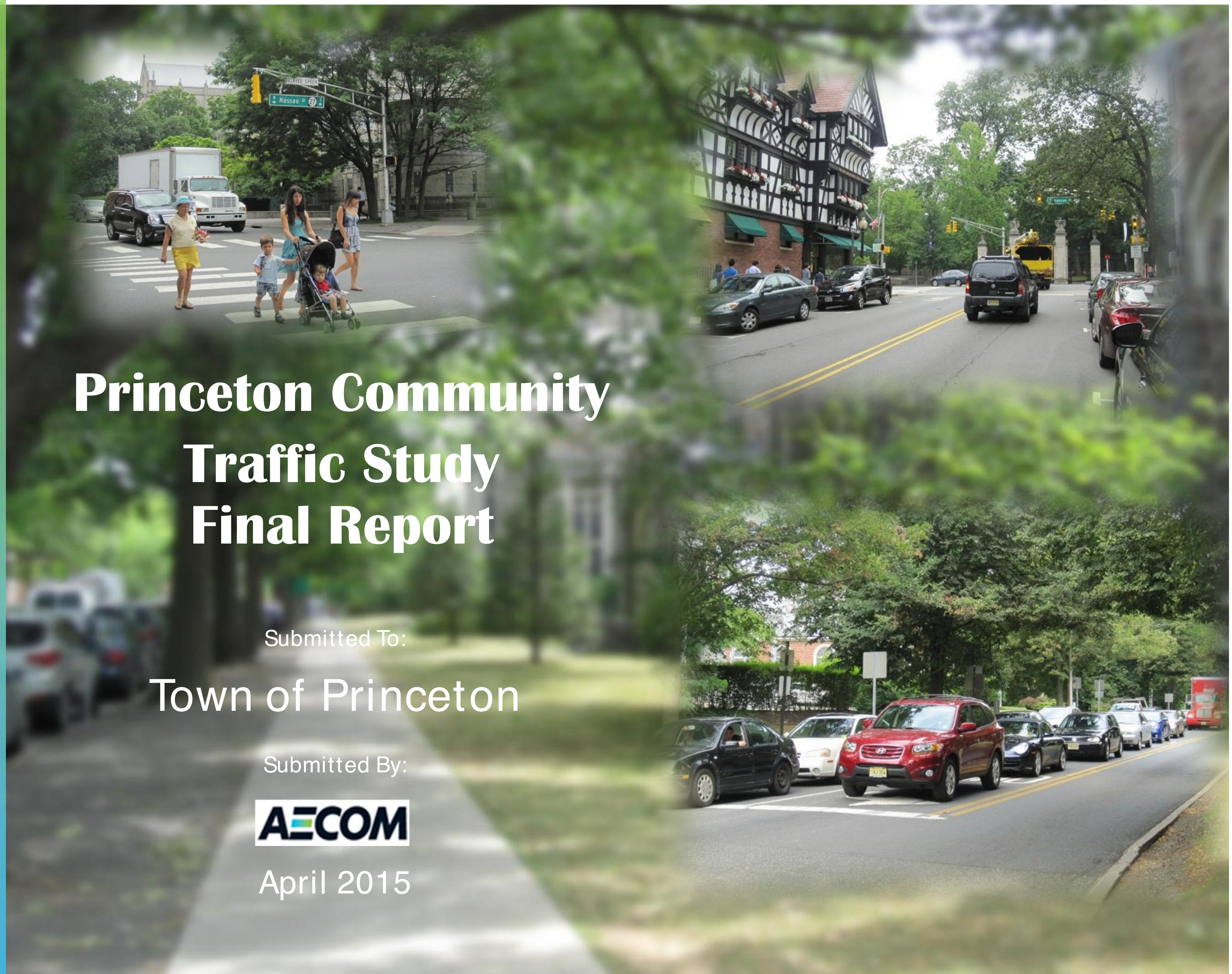
In Detroit, a group of private investors and philanthropists has led an effort to secure over $81.9 million in private and philanthropic commitments to pay for streetcar capital and operations costs. So far, sources of money for M-1 Rail are the Kresge Foundation, which pledged $49.6 million. Additional sources include Quicken Loans ($10 million pledge), Penske Corp. ($7 million) and Ilitch Holdings ($6 million). The Ford Foundation is participating ($4 million) and an additional $3 million in donations pledged by General Motors, Ford, the Chrysler Foundation, Detroit Medical Center, Blue Cross Blue Shield of Michigan, Wayne State University and Wayne County. Compuware and JPMorgan Chase put up $1.5 million each and the Hudson-Webber Foundation $1 million.

Property value impact: Proximity to a transit service improves the accessibility of a site, particularly in an urban setting. This additional level of accessibility and convenience for travelers translates into higher property values for adjacent properties. The general result from a review of recent research into the property value impacts of LRT/Streetcar systems is that the property values increased for commercial and residential parcels adjacent to transit, although they demonstrate that the situation in each individual locality will be dependent on the local market, geography, type(s) of use, and distance from the rail station. Based on existing research conducted by URS for other streetcar projects, it is reasonable to estimate up to a 10% - 15% increase in property values for commercial and residential parcels near the transit line.

Economic development impact: The increased accessibility and convenience of sites located near transit not only drives up the value of those properties, but also makes them more attractive as development sites, particularly for dense, transit-supportive uses such as office buildings and mixed-use residential. Examples from Portland, Denver, Dallas, and even smaller communities like Kenosha, Wisconsin have shown an accelerated pace and density of development near their new transit lines. All cases show the scale of private investment along the transit lines, and the Portland example in particular demonstrates how development density increases as one gets nearer the transit line. Each represents a major change from the areas before and after the investment in the transit facility.

Experience from other communities indicates that a transit line will not, by itself, create new development in a market without current demand, but instead can concentrate and accelerate existing development trends in an area. For Princeton, the primary impact of the transit line is likely to be that it will help to accelerate the development pipeline.

Overall, Princeton as a community needs to determine if economic development is a desired trait, as during the course of this study positions both in favor of economic development and against additional development were expressed. Research sponsored by the Federal Transit Administration has identified the primary factors for economic development related in areas adjacent to transit. Three of these factors – the strength of the underlying real estate market, the presence of transit density-supporting land use plans and policies, and the regional economic climate would need to come together for Princeton to benefit from the positive economic potential of a new streetcar line.



Princeton Community Traffic Study Final Report

Submitted To:

Town of Princeton

Submitted By:

AECOM

April 2015

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I. INTRODUCTION

A. Background

Princeton is strategically located at the nexus of north-south and east-west traffic flows in Central New Jersey. Reflecting this geographic situation, the Circulation Element of the Master Plan has goals that seek to reduce or limit the volume of through traffic on Princeton streets in favor of a peripheral road system that would better serve through traffic. The Circulation Element also seeks to balance land use with the capacity of the circulation system to ensure that proposed land uses do not overload the system.

Through this circulation planning process Princeton elected to not expand street system capacity, instead working to manage existing cartway widths for optimal performance with intersection and traffic signal improvements; operational improvements such as turn lanes; roundabouts; traffic calming; and sustainable, safe pedestrian / bicycle and transit networks. The overarching theme of the Master Plan is of balance and scale, and this approach to street management is consistent with and supports that theme.

B. Purpose of the Study

The purpose of this traffic planning study was to:

1. Assess issues, constraints and opportunities related to current traffic condition within the study area,
2. Estimate the extent of future traffic growth based on both the upcoming development projects within Princeton and development potential in greater Princeton area,

3. Determine impacts due to local and regional growth,
4. Identify context sensitive and multimodal improvement concepts based on the identified traffic issues; and
5. Involve all stakeholders including general public through a collaborative process to build consensus in order to improve quality of life.

C. ASUP Task Force

Recognizing the study background and purpose, Princeton formed the Alexander Street / University Place (ASUP) Task Force with a goal to advance a study to “evaluate and make recommendations to manage the appropriate flow of traffic and transportation in the Princeton community as a result of increased development”.

The ASUP Task Force included the following stakeholders:

1. Selected representatives of the general public
2. Princeton University
3. Municipality of Princeton representatives - planning and engineering divisions
4. Elected officials

II. BASIC STUDY PARAMETERS

A. Study Focus Area

The study focus area was concentrated on the key corridors and intersections within the Princeton downtown as shown in **Figure 1** below. These corridors included:

Group 1: Bayard Lane Corridor

Group 2: Princeton Core (Nassau Street between Bayard Lane and University Place)

Group 3: Alexander Street Corridor

Group 4: Witherspoon Street Corridor

Group 5: Washington Road Corridor

Group 6: Harrison Street Corridor

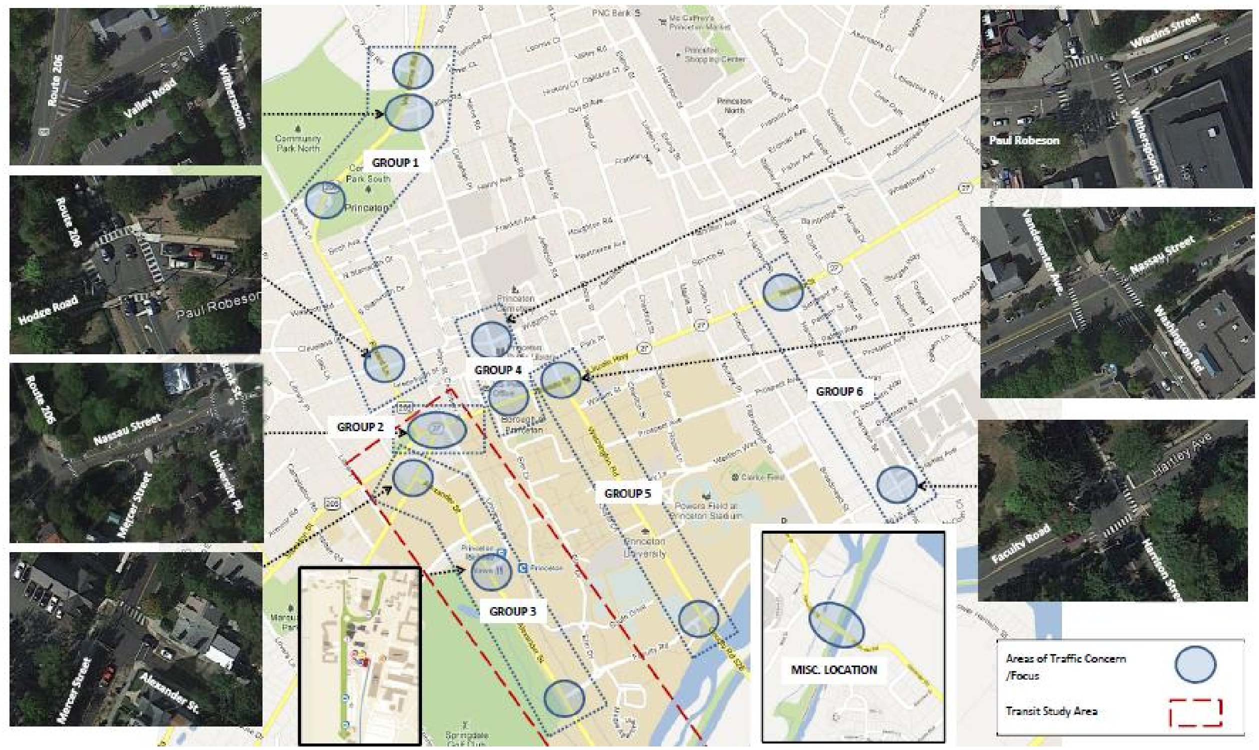


Figure 1: Traffic Focus Areas

The figure illustrates areas of concern from a traffic operations and performance perspective. These areas were identified based on the previous studies conducted in this area by AECOM and others, feedback from the Municipality of Princeton and the ASUP Task Force.

B. Traffic Data Compilation

The study did not involve any new traffic data collection efforts. For the purpose of this study the approach was to compile available traffic data from the recent studies within and near the study area. With the help of the Municipality of Princeton, AECOM compiled traffic count data from various sources including previous Princeton area studies conducted by AECOM and others, recent traffic studies including the Princeton Arts and Transit District Study and other NJDOT studies in the vicinity. **Appendix 1** provides intersection turning movement traffic counts during weekday AM and PM peak hours and **Appendix 2** provides ATR count information based on this traffic data compilation effort. These counts were used to refine the greater Princeton area travel demand model.

It should be noted that the available peak hour traffic counts at the beginning of this study (from the recent studies including the Princeton Arts and Transit District Study) were found to be somewhat lower in some areas of the Alexander Street corridor when data from some other resources was made available. However, even with the lower existing counts in such areas the projected impacts of future growth were significant. Thus, this only highlights the fact that with higher existing counts the extent of impacts related to projected future growth will be even worse, as such further highlighting the need to identify appropriate context sensitive solutions.

III. CURRENT TRAFFIC CONCERNS AND CONSTRAINTS

The following current traffic concerns and constraints were identified for each of the focus corridors:

Bayard Lane Corridor (Figure 2)

This corridor extends from the intersection of Cherry Hill Road to the north to the intersection of Paul Robeson Place and Hodge Road to the south. This is a 2-lane corridor with one lane in each direction with a narrow shoulder on either side.

Concerns	Constraints
• Heavy vehicle traffic impacts • Vehicular speeding • Narrow lanes • Lack of bicycle opportunities • Traffic congestion along Route 206 • Pedestrian crossing issues	• Proximity to historic structures/ monument • Varying nature of Route 206 Transect: In-town residential to civic park to rural residential

Figure 2: Bayard Lane Corridor

Nassau Street and Bayard Lane Core (Figure 3)

This small Nassau Street segment between the Bayard Lane intersection and the University Place intersection is key to the traffic operational performance during peak hours. Traffic backups from this segment spill back on other key corridors in the Princeton Downtown.

Concerns	Constraints
• Peak period traffic congestion • Confusing intersection geometry • Closely spaced intersections • Lack of signal coordination opportunities • Pedestrian safety • Extent of through traffic • Heavy vehicle/truck traffic - turning radii	• Proximity to historic structures/ monument - no room for expansion and/or for acquiring additional ROW

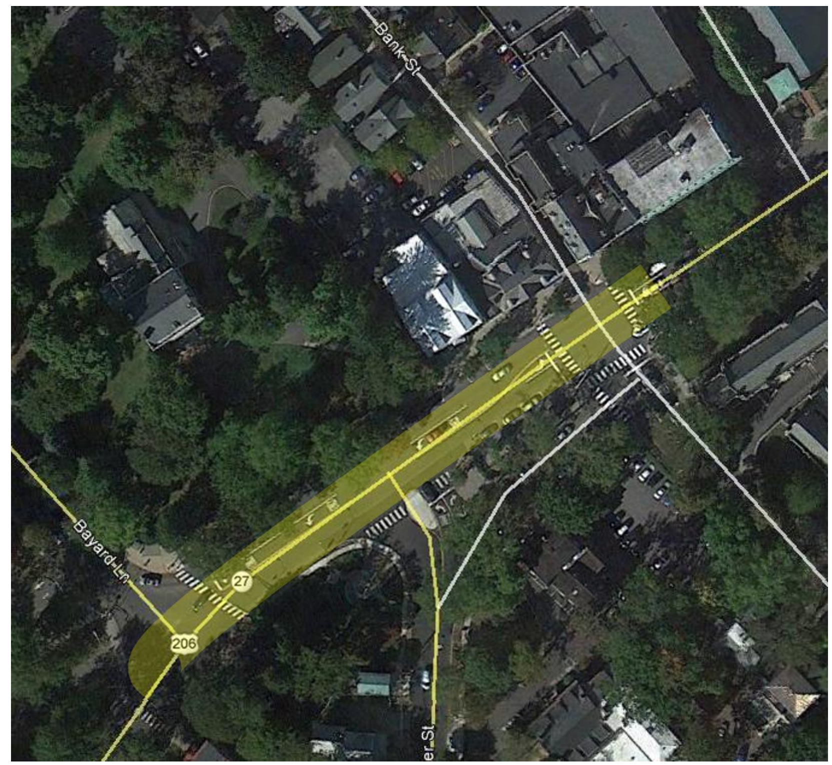


Figure 3: Nassau Street and Bayard Lane Core

Alexander Street Corridor (Figure 4)

This corridor extends from the intersection of Mercer Street to the north to the intersection of Faculty Road to the south. This is a 2-lane corridor with one lane in each direction. The corridor has various intersection controls including the newly built roundabout (University Place and Alexander Street), a signalized intersection (Faculty Rd. and Alexander Rd.) and stop-control (Mercer Street and Alexander Street). This corridor provides access to the newly relocated Princeton Station. On-street parking is available on one side along almost entire length of this corridor.

Concerns	Constraints
• Increased levels of traffic • Possible Route 1 traffic actions may further impact traffic • Vehicular speeding	• Potential ROW impacts • Proximity to historic district

Figure 4: Alexander Street Corridor

Witherspoon Street Corridor (Figure 5)

This corridor extends from the intersection of Paul Robeson Place to the north to the intersection of Nassau Street to the south. This is a 2-lane corridor with one lane in each direction and has on-street parking on both sides.

Concerns	Constraints
• Peak hour traffic congestion • Pedestrian safety issues • Vehicular-pedestrian conflicts and impacts on intersection operation	• Proximity to historic structures • On-street parking maneuvers impact traffic flow performance

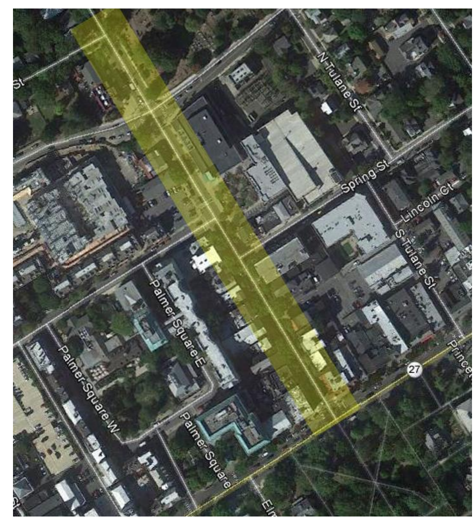


Figure 5: Witherspoon Street Corridor

Washington Road Corridor (Figure 6)

This corridor extends from the intersection of Nassau Street to the north to the D&R Canal to the south. This is a 2-lane corridor with one lane in each direction and has significant pedestrian activity in the northern section of the corridor related to the Princeton University.

Concerns	Constraints
• Peak hour traffic congestion • Vehicular speeding • Pedestrian safety issues • Nassau St. & Washington Road intersection alignment • Impacts of potential Route 1 traffic actions on Washington Rd corridor	• Proximity to historic structures • Proximity to environmentally sensitive area

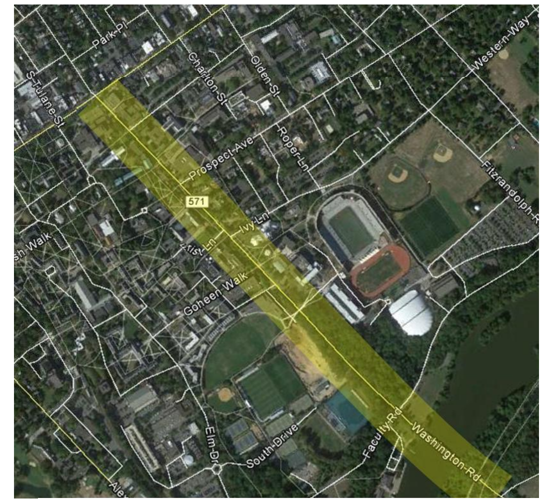


Figure 6: Washington Road Corridor

Harrison Street Corridor (Figure 7)

This corridor extends from the intersection of Nassau Street to the north to the intersection of Faculty Road to the south. This is a 2-lane corridor with one lane in each direction and is sometimes used as a corridor to bypass Princeton Downtown.

Concerns	Constraints
• Vehicular speeding • Increasing peak hour traffic volumes • Pedestrian safety issues	• No room for expansion and/or for acquiring additional ROW

Figure 7: Harrison Street Corridor

IV. FUTURE DEVELOPMENT IMPACT ASSESSMENT

Local and regional developments and/or redevelopments have a direct relationship with the extent of additional traffic generated and assigned to the area roadway network. Thus, in turn, land use development/redevelopment activities have direct impact on the traffic operational performance of the transportation system.

In order to estimate future condition traffic volumes, AECOM used the greater Princeton area travel demand model. This model covers Princeton, West Windsor, and portions of Plainsboro, Lawrence and Montgomery Townships. A comprehensive land use and development inventory is maintained for this model on an ongoing basis and this modeling tool is applied to determine roadway assessments for Princeton and West Windsor. In addition, this modeling tool has also been used for various planning studies in the area including the NJDOT Penns Neck Study and West Windsor/Princeton Junction Redevelopment Planning Study. **Figure 8** shows a screenshot of this travel demand model network.

Figure 8: Greater Princeton Area Travel Demand Model Network

A. Travel Demand Modeling Process

The following describes a typical 3-step traffic modeling process for an auto travel demand model (See **Figure 9**).

Trip Generation: Based on the assumed land use data, vehicular trips are generated in this step related to these land uses.

Trip Distribution: This step determines the origin and destination for each generated trip based on socioeconomic characteristics like population, employment etc.

Trip Assignment: The generated trips are assigned to the roadway network along one or more path(s) between their origin and destination.

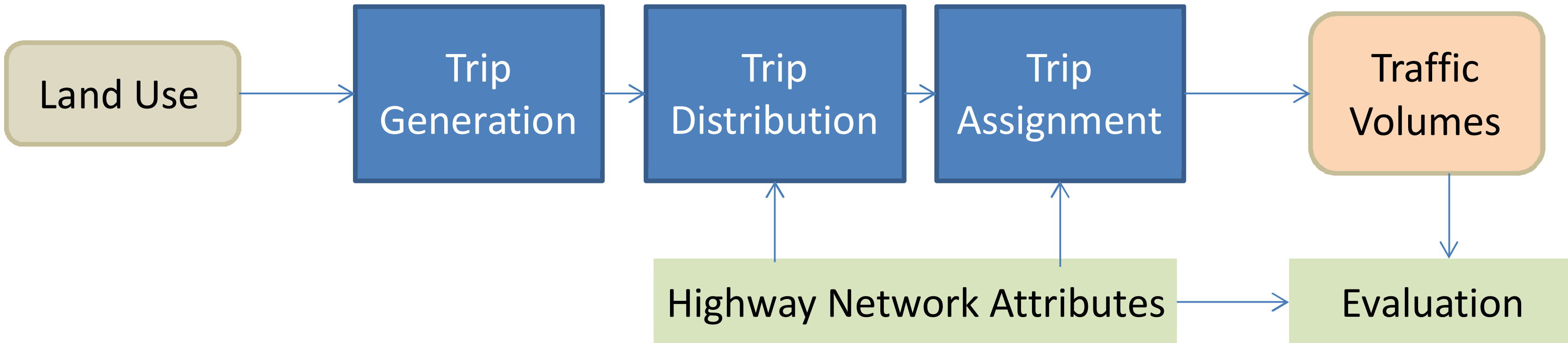


Figure 9: Travel Demand Modeling Process

B. Model Refinement

Based on the available existing condition traffic volume data, the model was calibrated for the existing condition. This calibration process ensures that the traffic volume outputs provided by the model under existing condition generally match observed traffic count data on the ground. This process validates the usefulness of the model for future condition volume projections.

Once the existing condition calibration was completed, future development/redevelopment information as well as upcoming roadway improvement projects were applied to the model before the model was used to project future condition traffic volumes.

C. Local and Regional Land Use Assumptions

The following is a list of proposed study area (local) developments/redevelopments (See **Figure 10** for location and **Appendix 3** for new trip generation estimates):

1. Reconstruction of Hibben Magie graduate student housing
2. Princeton University Arts and Transit Project

3. Hulfish North (Palmer Square)
4. Redevelopment of YM/YWCA
5. Redevelopment of Merwick and Stanworth
6. Redevelopment of Princeton Medical Center

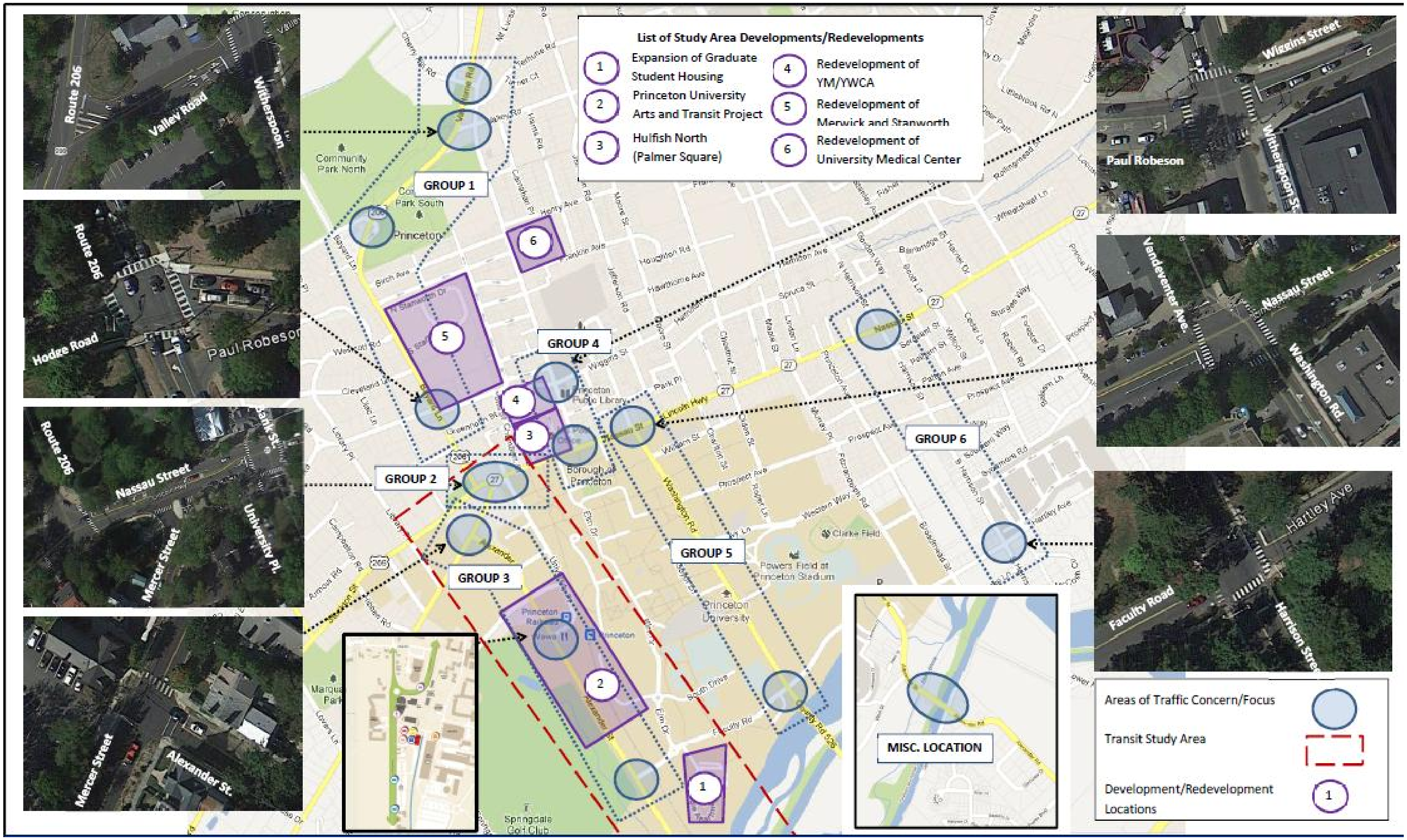


Figure 10: Study Area Developments/Redevelopments

In addition to the local or study area development/redevelopment projects, the following regional development/redevelopment potential was also considered in the model in order to determine impacts associated with these projects on Princeton roadways (See **Figure 11**) :

- A Princeton/Plainsboro Medical Center
- B Carnegie Center (East)
- C Carnegie Center (West)
- D Princeton Junction Redevelopment
- E Wyeth
- F Sarnoff
- G Greenview

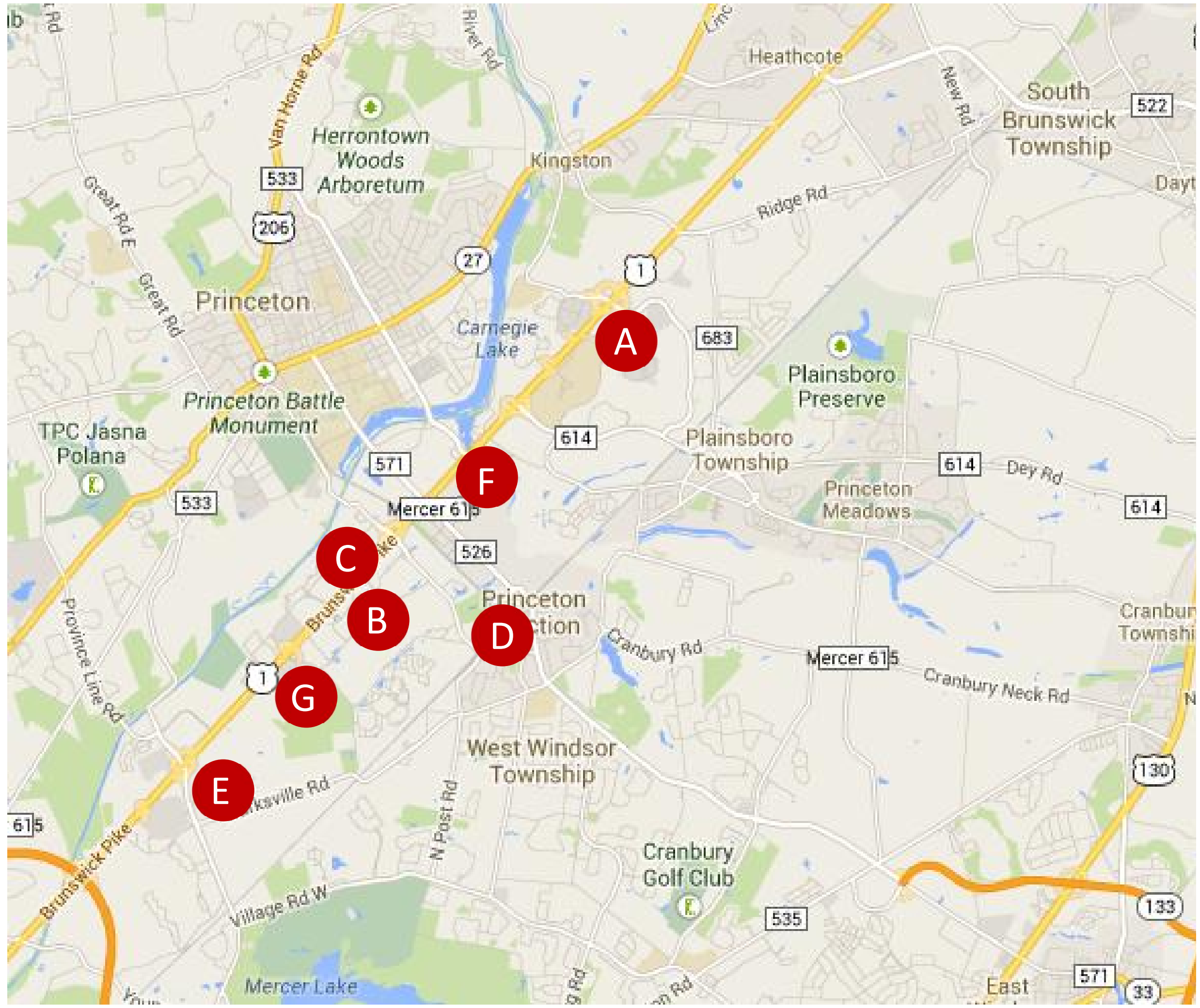


Figure 11: Regional Developments/Redevelopments

D. Travel Demand Model Outputs

The calibrated travel demand model provided projected roadway link volumes under the future condition (see **Figure 12** for a sample). For the purpose of this study the future year was 2027 (15 years in the future from the base analysis year of 2012).

These projected volumes were then compared to the existing condition volumes to determine the extent of absolute and percentile traffic volume change as well as to understand likely traffic volume shift patterns during both the AM and PM peak hours.

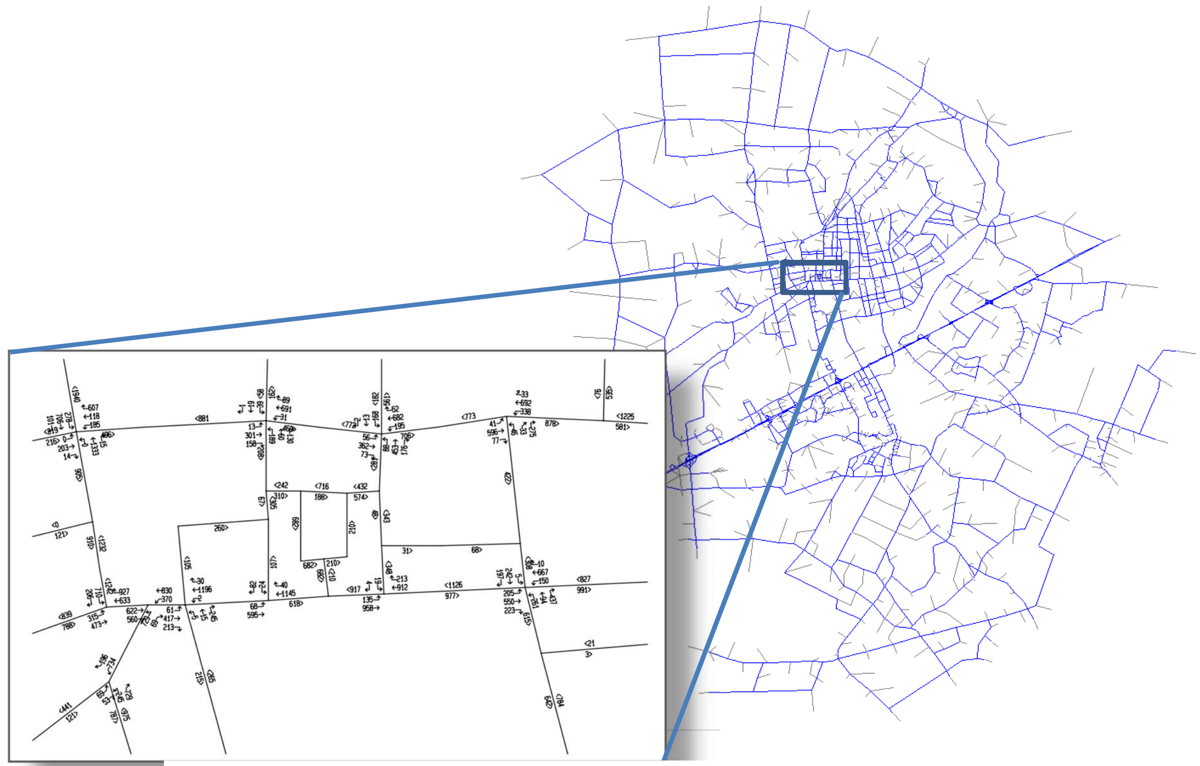


Figure 12: Future Condition Traffic Volume Projection Sample

Separate model runs were also conducted once the improvement packages were identified (discussed later in the report) with the help of the ASUP Task Force to determine how each of the improvement packages would help to improve study area traffic performance.

Figure 13 shows as an example the difference in the roadway network bi-directional volumes between the 2012 Existing Condition PM peak hour and 2027 Future No-Build Condition PM peak hour. This type of analysis can help to determine the overall impacts that can be anticipated if the anticipated regional development happens within the next 25 years. In addition, this change in anticipated traffic volumes can be linked to specific generators to determine what portion of this traffic volume change is related to local developments vs. regional developments.

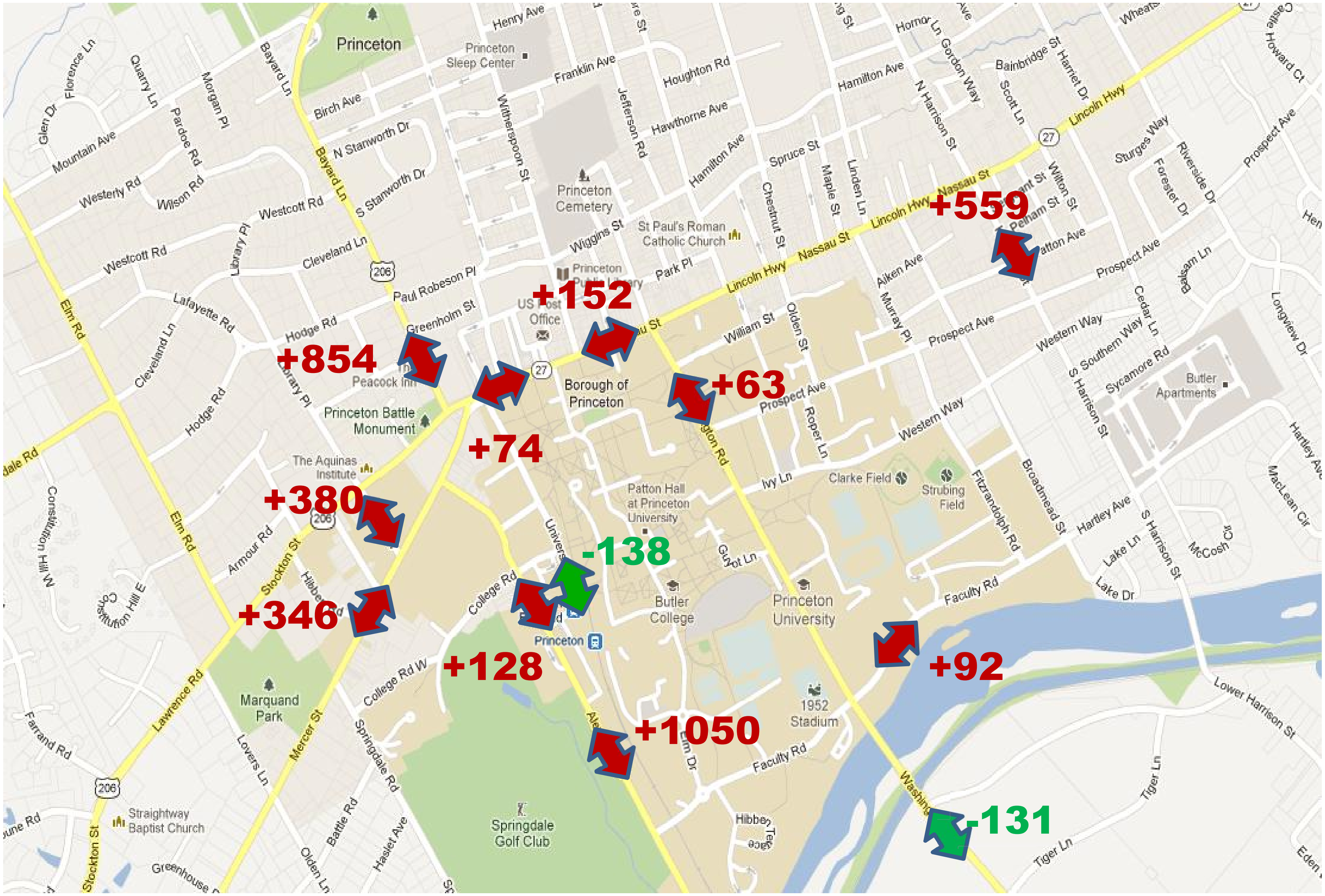


Figure 13: Projected Change in Bi-Directional Link Volumes (PM Peak Hour) between 2012 Existing Condition and 2027 Future No-Build Condition

For example, **Figure 14** breaks down the projected increase in Alexander Street traffic just north of the Faculty Road intersection. It shows that a 110% traffic volume growth (additional 1050 vehicles) can be anticipated by the 2027 Future Condition PM peak hour compared to the 2012 Existing Condition PM peak hour bi-directional volume (948 vehicles). Of these additional vehicles, almost 2/3 are associated with regional growth whereas 1/3 can be linked to local Princeton area growth.

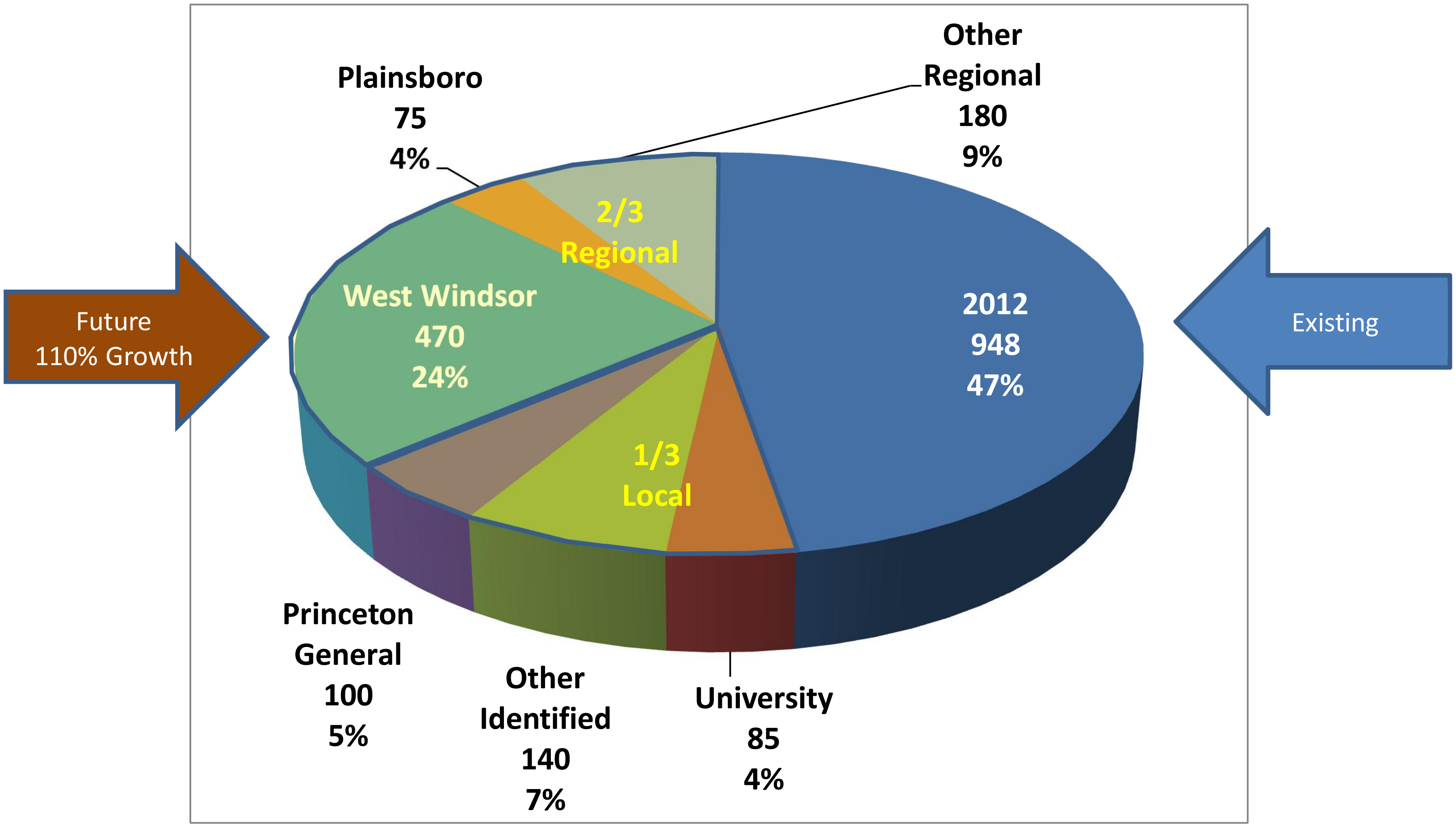


Figure 14: Example of Roadway Link Volume Growth and Contributing Components for Alexander Street Roadway Segment

(Bi-Directional Volumes during PM Peak Hour)

V. IMPROVEMENT CONCEPT DEVELOPMENT

A. Concept Development Process

As discussed earlier, through this circulation planning process of the Master Plan Princeton has elected to not expand street system capacity, instead working to manage existing cartway widths for optimal performance with intersection and traffic signal improvements; operational improvements such as turn lanes; roundabouts; traffic calming; and sustainable, safe pedestrian / bicycle and transit networks. Considering this AECOM developed and presented several improvement concepts to the ASUP Task Force. A framework was provided to the ASUP Task Force to evaluate these various improvement concepts as below:

1. Concept Evaluation Criteria

Traffic Evaluation Criteria

- Potential to reduce vehicular conflict points and improve traffic flow
- Potential to reduce congestion
- Extent of likely change in through traffic levels
- Traffic calming potential

Multimodal Evaluation Criteria

- Transit friendliness
- Bicycle friendliness
- Pedestrian friendliness

Socioeconomic/Quality of Life Evaluation Criteria

- Residential neighborhoods impacts
- Business impacts

<u>Other Evaluation Criteria</u>

- Ease of implementation
- Potential for ROW impacts
- Consistency with prior plans

2. Consideration for Concurrent Transit Study

Considering the concurrent Princeton Transit Study that was also underway to assess various transit options to connect Princeton Dinky Station with the Nassau Street corridor, AECOM also incorporated provisions for multimodal choices in its concept development process. The ASUP Task Force was presented with information on the potential of each improvement concept to support transit alternatives along the University Place and/or Alexander Street corridors.

B. Concept 1: Turn Restrictions

This easy to implement and low cost improvement concept was developed for the Nassau Street core area between Bayard Lane and University Place. As identified before, this core area experiences significant congestion and backups during existing condition peak hours. This congestion in turn propagates along the other key corridors in the Princeton downtown.

As a part of this improvement concept, left turns into and out of Mercer Street will be prohibited at the intersection with Nassau Street. In addition, left turn from Nassau Street onto Bank Street will also be prohibited. This will result in a significant reduction in vehicular conflict points in the core area and will help streamline traffic operation, which will result in reduced congestion and backups. This concept is illustrated in **Figure 15**.

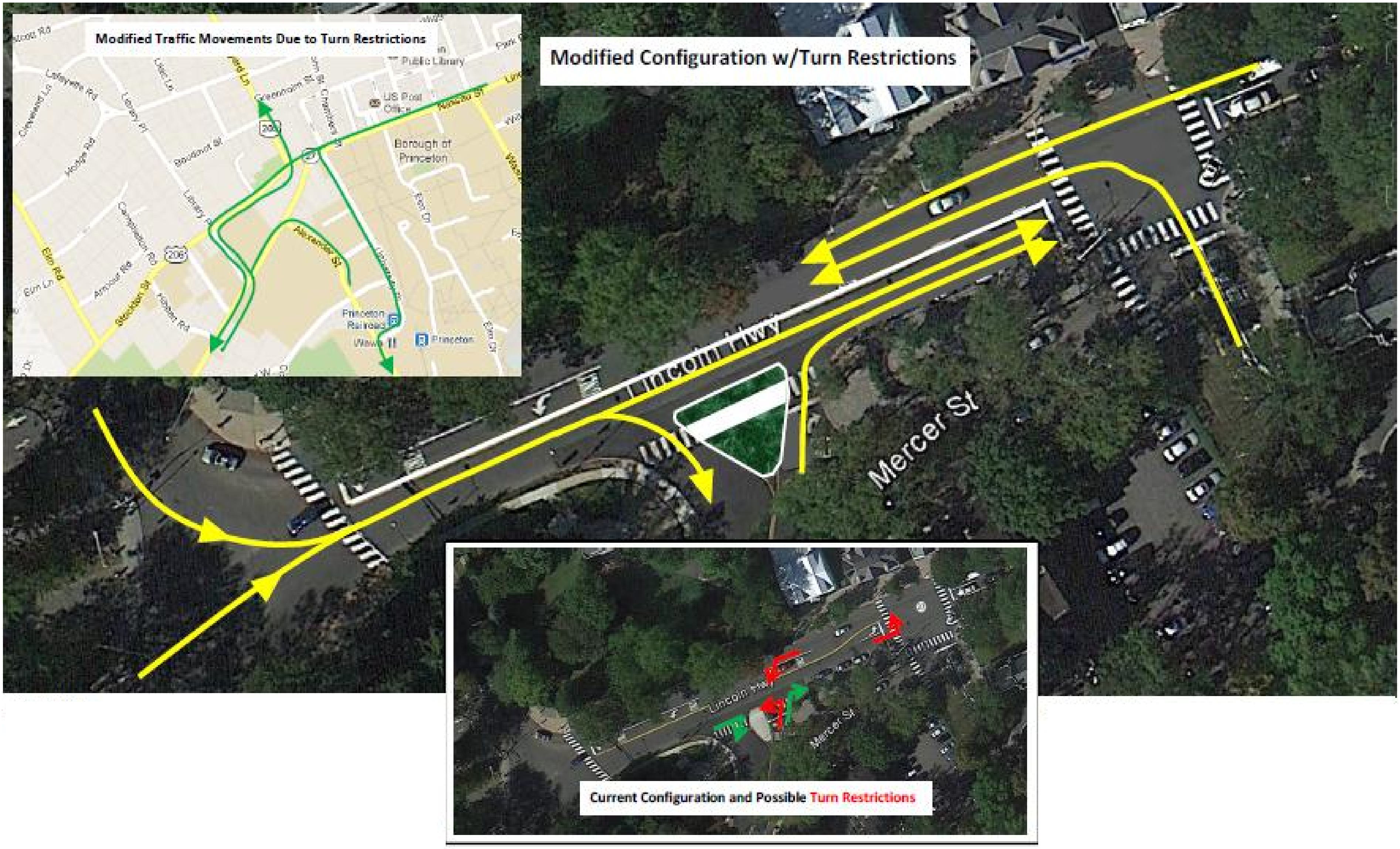


Figure 15: Concept 1: Left Turn Restrictions for Nassau Street Core Area

The following are the advantages and disadvantages of the Turn Restriction Concept:

Advantages	Disadvantages
• Fewer vehicular conflicts and improved traffic flow • Better signal coordination opportunity and reduced congestion • Fewer backups impacting closely spaced intersections • Well defined traffic movements • Wider island at Mercer Street for pedestrian crossing convenience • Easy to implement	• Modified (and slightly longer) routing for some vehicles • Elimination of a few on-street parking spaces • May have some impacts on the intersection of Route 206 & Library Place

C. Concept 2: Street Closures

This improvement concept was developed to achieve two aspects. First, by closing a roadway segment several turning movements could be eliminated, which will result in traffic performance improvement at the termini intersection of this closed segment. Second, this area can be converted into a pedestrian only plaza to further enhance the pedestrian friendly character of Princeton downtown. One of the key candidate locations for this concept is the Mercer Street segment between Alexander Street and Nassau Street. **Figure 16** illustrates the street segment closure concept for the Mercer Street segment.

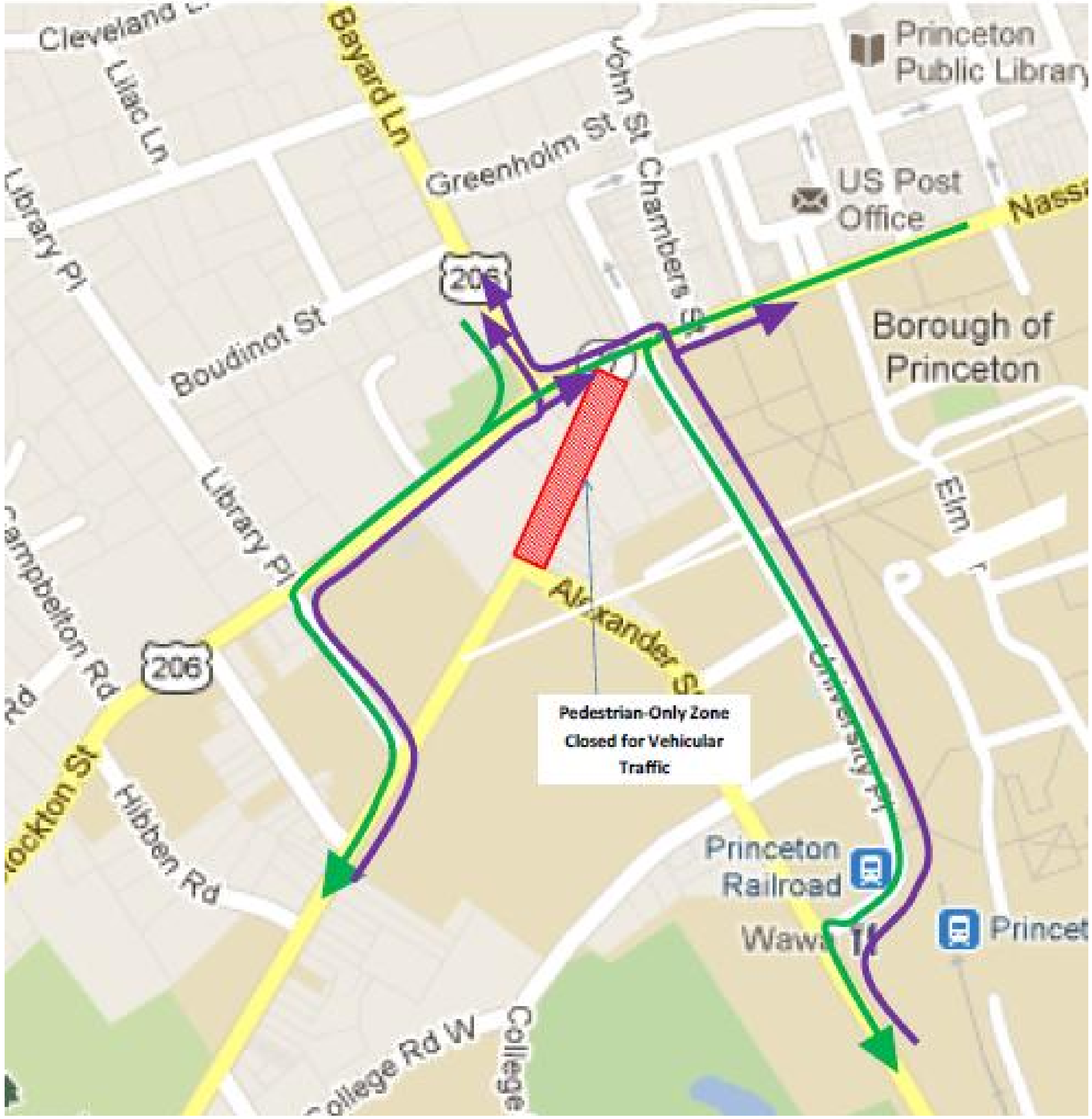


Figure 16: Concept 2: Mercer Street Closure

The following are the advantages and disadvantages of the Street Closure Concept for Mercer Street:

Advantages	Disadvantages
• Fewer vehicular conflicts and improved traffic flow on Nassau St. • Elimination of many vehicular conflict points - fewer spillback impacts at closely spaced intersections on Nassau Street • Eastbound on-street parking (3 spaces) on Nassau Street between Mercer St. and University Pl. can be replaced by a travel lane facilitating further circulation improvements • Better signal coordination opportunity for Bayard/Nassau and Nassau/University intersections and reduced congestion • Alexander St. and Mercer St. intersection becomes a control-free intersection • Minimal routing impacts for key destinations • Improved pedestrian experience along Nassau Street • Opportunity to create a pedestrian-only zone for variety of uses	• Modified routing for some vehicles • Elimination of few on-street parking spaces • May have some impacts on the intersection of Route 206 & Library Place • Access to properties along the closed section of Mercer Street needs to be resolved

D. Concept 3: One-Way Loops

These improvement concepts consider one-way pair operation with University Place and Alexander Street. The one-way loop can be in either a clockwise direction or a counterclockwise direction. The one-way loop concept can provide performance improvements for key intersections in this area. It will also have the potential for preserving a dedicated right-of-way for the transit option along University Place. Also, it can promote other multimodal choices such as provision of a bicycle lane. **Figure 17** illustrates these one-way loop concepts.

Counter Clockwise One-Way Loop

Clockwise One-Way Loop

Figure 17: Concept 3: One-Way Loops

The following are the advantages and disadvantages of the clockwise one-way loop improvement concept:

Advantages	Disadvantages
• Significant traffic performance improvement potential for the core area (Nassau Street between Bayard Lane and University Place) • Potential for multimodal opportunities • Opportunity for dedicated transit lane • All right turn movements – easier from circulation point of view • Better circulation benefits during PM peak vs. AM peak	• Significant performance deterioration likely at the proposed new roundabout at University & Alexander • Reduces redundancy (conversion of 2 two-way streets into single one-way loop)

The following are the advantages and disadvantages of the counter-clockwise one-way loop improvement concept:

Advantages	Disadvantages
• Significant traffic performance improvement at the proposed new roundabout at University Place and Alexander Street • Potential for multimodal opportunities • Opportunity for dedicated transit lane • Better circulation benefits during AM peak vs. PM peak	• All left turn movements – need to yield to major opposing flows on Nassau Street • Significant performance impact on Nassau Street core area (between Bayard Lane and University Place) • Reduces redundancy (conversion of 2 two-way streets into single one-way loop)

E. Recommended Improvement Packages for Further Study

The various concepts described in the earlier section were presented to the ASUP Task Force. The Task Force reviewed them closely with a detailed discussion of pros and cons related to each of the concepts. The Task Force then recommended packaging these concepts as follows for conducting further analysis using travel demand modeling. **Appendix 4** provides roadway network and land use details of the above scenarios.

1. Improvement Package 1: Street Closures

- Mercer Street closed between Alexander Street and Nassau Street
- Witherspoon Street closed between Nassau Street and Spring Street
- Left turn from Nassau Street onto Bank Street prohibited

2. Improvement Package 2: Clockwise One-way Loop (University Place-Alexander Street) with one-way Witherspoon Street

- Mercer Street one-way in eastbound direction from Alexander Street to Nassau Street
- University Place one-way in southbound direction from Nassau Street to Alexander Street
- Alexander Street one-way in northbound direction from University Place to Mercer Street
- Left turns from Nassau Street onto Bank Street prohibited
- Witherspoon Street one-way in northbound direction from Nassau Street to Spring Street
- Signal at Nassau Street and Witherspoon Street converted to pedestrian signal only

3. Improvement Package 3: Counterclockwise One-way Loop (University Place-Alexander Street) with one-way Witherspoon Street

- Mercer Street one-way in westbound direction from Nassau Street to Alexander Street
- University Place one-way in northbound direction from Alexander Street to Nassau Street
- Alexander Street one-way in southbound direction from Mercer Street to University Place
- Left turns from Nassau Street on to Bank Street prohibited

- Witherspoon Street one-way in northbound direction from Nassau Street to Spring Street
- Signal at Nassau Street and Witherspoon Street converted to pedestrian signal only

4. **Improvement Package 4: Standalone One-way Loop option for University Place and Alexander Street**
    - Standalone one-way loop without any other improvement (better option between clockwise or counter-clockwise based on assessment of packages 2 and 3)

F. Travel Demand Model Key Observations

The travel demand modeling analysis conducted the following comparisons:

1. Existing 2012 Condition to 2027 No-Build Condition – this comparison was done to understand the potential impacts of future land use on Princeton roadways if no roadway improvement projects are done (see earlier Section IV. D and Figure 13 for this comparison).
2. 2027 No-Build Condition to 2027 Build Condition (individual comparison with improvement packages 1 through 4 as described earlier) – this comparison was done to understand the potential performance improvement that could be achieved through each of these improvement packages (see **Appendix 5** for the estimated change in bi-directional traffic volumes during PM peak hour between the 2027 No-Build Condition and the 2027 Build Condition packages)

The following are the key observations from the travel demand modeling analysis:

1. Forecasted peak hour traffic growth is likely to be concentrated along the Alexander Street corridor (based on the comparison between 2012 Existing Condition and 2027 No-Build Condition)
2. All proposed improvement packages will help redistribute future traffic from the Alexander Street corridor to other access corridors.
3. All proposed improvement packages have more or less similar traffic volume redistribution potential from Alexander Street corridor to other corridors.

4. Closing Witherspoon Street between Nassau Street and Spring Street or converting it to northbound one-way operation will have significant impacts on the operation of Nassau Street intersections with Chambers Street and Vandeventer Avenue.

Figure 18 shows PM peak hour two-way traffic volumes on North-South corridors in the study area. It can be seen that a significant projected increase between the Base (2012 Existing) and the No-Build (2027) scenarios can be attributed to the Alexander Street corridor. All four improvement packages will reduce the projected demands on the north-south corridors compared to the No-Build scenario.

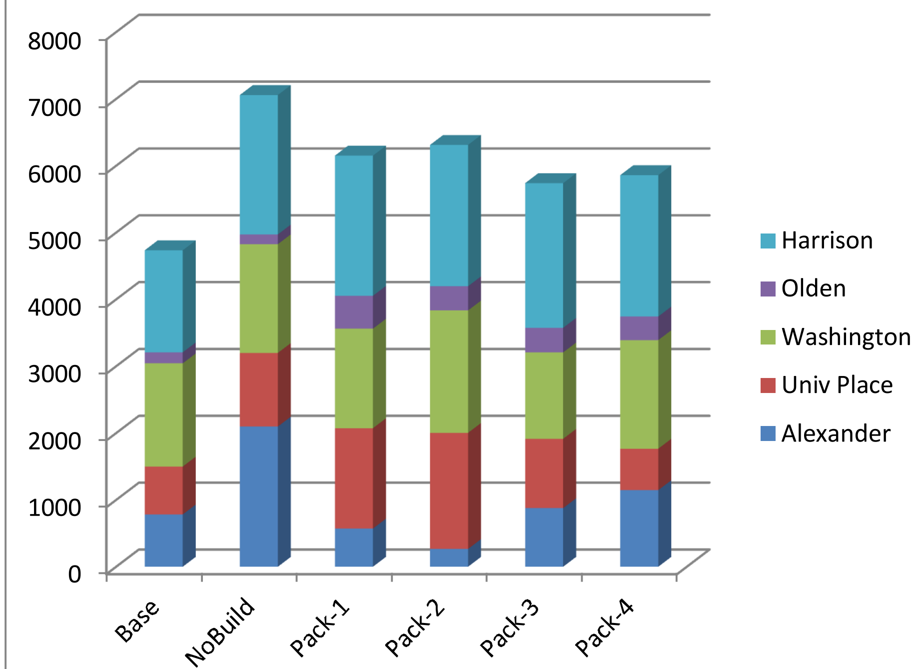


Figure 18: Projected PM Peak Hour Bi-Direction Volumes along North-South Corridors

While all the improvement packages showed potential for traffic volume redistribution helping to reduce impacts on Alexander Street corridor, it is important to note:

1. The proposed one-way loop systems lack redundancy. Under the existing condition both Alexander Street and University Place are two-way streets with collectively two travel lanes in each direction. With the proposed one-way systems, there will be one lane in each direction with the remaining cartway reserved for either on-street parking and a bicycle lane or for a dedicated transit lane.
2. Since the proposed improvement packages are not improving capacity, there will be some impacts on other locations outside of the study area boundary for this study. These impacts will need to be assessed before implementing any of the proposed improvement packages.

VI. PRELIMINARY TRAFFIC OPERATIONAL ANALYSIS

While travel demand analysis provided estimates of potential traffic volume growth and/or shifts during the weekday peak hours, it is important to understand how these projected volumes will impact operational performance for the key study area intersections. Thus, while AECOM was not scoped to conduct an operational analysis as a part of this study, AECOM undertook such analysis at the request of the ASUP Task Force and the Town of Princeton.

A. Operational Modeling Process

AECOM conducted intersection operational performance analysis using the Synchro + SimTraffic software platform. Operational performance indicators for the key study area intersections were Level of Service (LOS) and average intersection delay per vehicle. Based on the industry approved Highway Capacity Methods (HCM), the Level of Service for signalized and unsignalized intersections relates to the following ranges of control delays:

Level of Service (LOS)	Average Control Delay per Vehicle (in Sec.)	
	Signalized	Unsignalized
A (Excellent - Free Flow)	<=10	<=10
B (Very Good - Minor Adjustments)	>10 and <=20	>10 and <=15
C (Good - Stable Flow of Traffic)	>20 and <=35	>15 and <=25
D (Satisfactory Flow - Occasional Delays)	>35 and <=55	>25 and <=35
E (Capacity Flow - Significant Delays)	>55 and <=80	>35 and <=50
F (Failing - Significant Delays and Queuing)	>80	>50

B. Use of Princeton Arts and Transit Study Operational Model

AECOM used the traffic volumes from the 2017 Build Condition Synchro model from the Princeton Arts and Transit Study for establishing the Base No-Build Condition intersection operational performance without implementing any of the improvement packages described earlier in the report. While the future year assumed for travel demand analysis was 2027, for the purpose of operational analysis a near-term future year (2017) was deemed acceptable to understand impacts of various improvement packages on intersection performance. AECOM then created multiple Synchro models to determine intersection operational performance related to the various improvement packages.

Based on the specifics associated with the proposed roadway network for each improvement package, AECOM conducted traffic volume reassignment prior to conducting the intersection performance analysis for the improvement package models. The traffic volume reassignment process did not consider any reduction/shifts in traffic away from the immediate corridor, in order to conduct a worse case analysis. The following scenarios were tested during both weekday AM and PM peak hours:

1. 2017 baseline analysis
2. 2017 Improvement Package 1 analysis (Mercer Street segment closed)
3. 2017 Improvement Package 2 analysis (clockwise one-way loop for University Place and Alexander Street)
4. 2017 Updated Improvement Package 2 analysis (same as Improvement Package 2 except for traffic signal at the intersection of Nassau Street and University Place shifted to the intersection of Nassau Street and Mercer Street)
5. 2017 Improvement Package 3 (counter-clockwise one-way loop for University Place and Alexander Street)
6. 2017 Updated Improvement Package 3 (same as Improvement Package 3 except University Place to Mercer Street traffic flows bypass Nassau Street using the street parallel to and located just south of Nassau Street)

C. Intersection Performance Assessment

The following table shows results of the intersection performance assessment during the weekday AM peak hour.

AM Peak Hour Intersection Performance Assessment

Intersection	Control	AM Peak Hour: 2017 Baseline Analysis		2017 Mercer Closed Analysis		2017 Updated Clockwise One-way Loop Analysis		2017 Updated Counterclockwise One-way Loop Analysis	
		LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)
NASSAU CORE AREA									
Nassau & Bayard	Signal	D	49.6	C	27.1	C	29.0	D	39.5
Nassau & Mercer	Stop	**F**	**80.5**	-	-	C	24.9	C	15.5
Nassau & University	Signal	C	21.7	B	14.5	C	24.6	B	12.8
ALEXANDER CORRIDOR									
Alexander & Mercer	Stop	**F**	**434.9**	A	-	D	34.4	A	-
Alexander & College	Stop	D	34.6	C	17.8	B	11.8	E	39.9
Alexander & University	Roundabout	C	-	D	-	**F**	**-**	A	-

It can be seen that by 2017 without any improvements, the stop controlled intersections of Nassau Street and Mercer Street as well as Alexander Street and Mercer Street will perform at a failing level of service with significant delays. With the Improvement Package 1 (Mercer Street Segment between Alexander Street and Nassau Street closed), intersection performance can be improved to an acceptable level of service. Similarly with the counter-clockwise one-way loop options, 2017 baseline intersection performance for the intersections with failing LOS can be improved to an acceptable LOS.

The following table shows results of the intersection performance assessment during the weekday PM peak hour. It can be seen that for the 2017 baseline condition, PM peak hour delays are worse for the stop-controlled intersections of Nassau Street and Mercer Street as well as Alexander Street and Mercer Street. Each vehicle at the stop-controlled approach of Mercer Street at Nassau Street will experience an average of 17-minute delay before it can turn onto Nassau Street. Similarly, each vehicle at the stop-controlled approach of Alexander Street at Mercer Street will experience an average of 10-minute delay before it can turn onto Mercer Street. These significant delays and associated backups will also impact performance of other intersections in the vicinity as well.

However with the proposed improvement packages, these excessive delays can be eliminated and these intersections will perform at an acceptable level of service.

It should be noted that while the improvement packages help improve the study area intersection performance to an acceptable level of service in 2017, some other intersections outside of the study area can be impacted due to changes in the traffic pattern related to these improvements. These impacts will need to be assessed before implementing any of the proposed improvement packages.

PM Peak Hour Intersection Performance Assessment

Intersection	Control	PM Peak Hour 2017 Baseline Analysis		2017 Mercer Closed Analysis		2017 Updated Clockwise One-way Loop Analysis		2017 Updated Counterclockwise One-way Loop Analysis	
		LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)
NASSAU CORE AREA									
Nassau & Bayard	Signal	C	28.2	C	28.8	B	17.6	C	32.0
Nassau & Mercer	Stop	**F**	**1031**	-	-	B	14.0	C	16.3
Nassau & University	Signal	B	15.4	B	18.4	B	12.5	C	28.1
ALEXANDER CORRIDOR									
Alexander & Mercer	Stop	**F**	**600.4**	A	-	C	16.4	A	-
Alexander & College	Stop	E	36.6	C	22.9	E	45.7	D	30.5
Alexander & University	Roundabout	B	-	C	-	D	-	A	-

VII. PATH FORWARD

The ASUP Task Force has also been overseeing the Princeton Transit Study, which looks into various options for providing continuation of transit service from the recently relocated Princeton Dinky Station to the Nassau Street corridor. This transit study has developed several options. The following two options have been the leading contenders and it is important to understand the traffic implications associated with these options:

Option 1[1] : Widening University Place to Accommodate 2-way In-street[2] Transit Tracks with Parking:

This option will maintain the existing number of travel lanes, two-way traffic operation and intersection controls along the University Place corridor. Thus, this transit option in its present form cannot support the one-way loop improvement packages (Packages 2, 3 and 4) of the Princeton Traffic Study. With the proposed in-street operation of transit vehicles under this option, vehicular performance along the University Place corridor will be slightly impacted compared to the existing conditions. Improvement Package 1 of the traffic study (closure of Mercer Street segment between Alexander Street and Nassau Street) can still be implemented to eliminate traffic issues in the Nassau Street core area (between University Place and Bayard Lane) as well as to improve failing intersection performance at the intersections of Mercer Street/Nassau Street and Mercer Street/Alexander Street.

If it is not suitable to implement the Traffic Study's Improvement Package 1 with this transit option, then performance of the Nassau Street core area as well as the performance of the intersection of Nassau Street and Mercer Street can still be improved by implementing the "Turn Restrictions" concept described earlier in Section V - Subsection B of this report. For improving performance of the Mercer Street and Alexander Street intersection, a signal warrants analysis should be undertaken to determine if this intersection can be signalized to improve intersection performance.

[1] Labeled as Option E in the Princeton Transit Study
[2] Shared with regular traffic lane

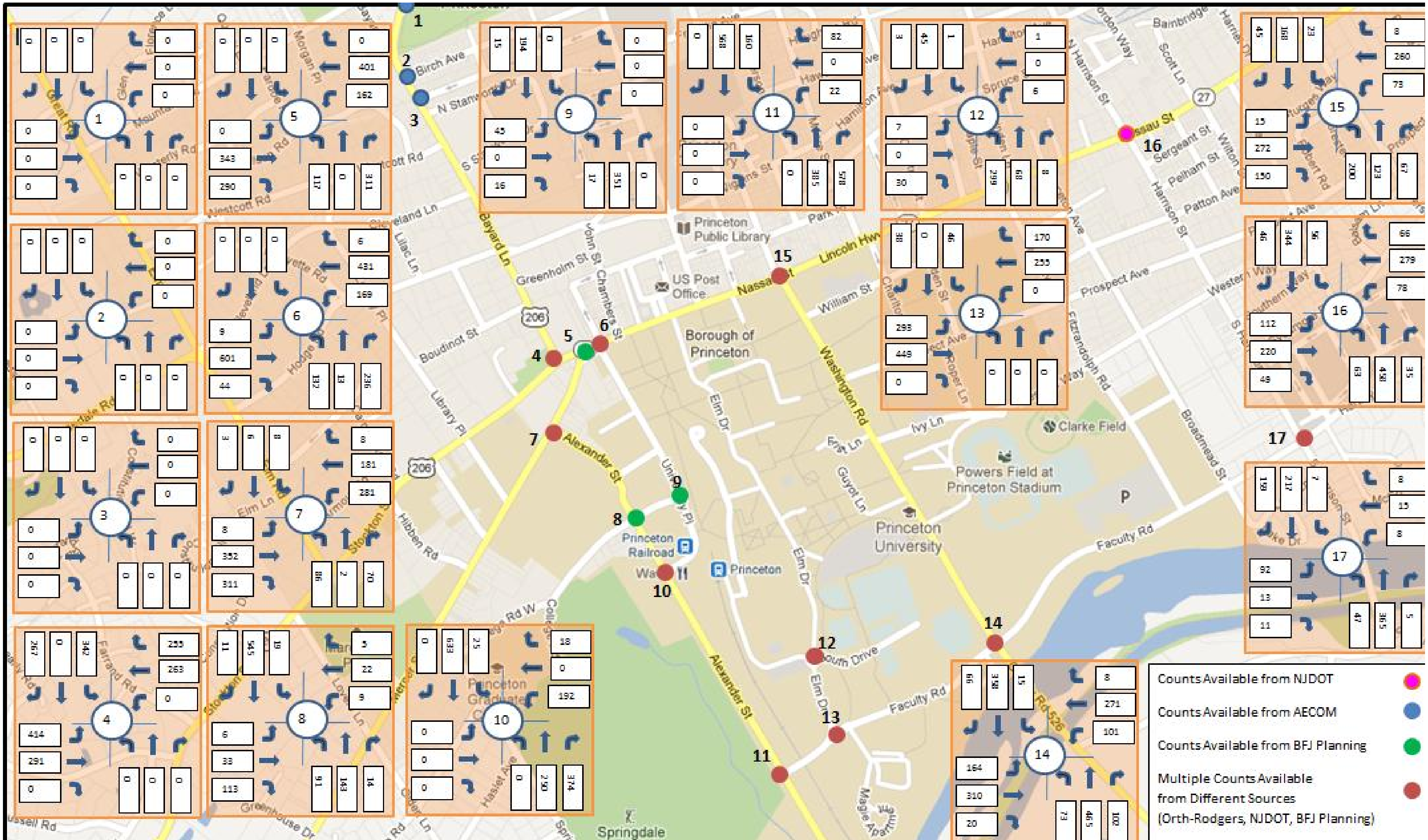
Option 2[3]: Widening University Place to accommodate dedicated transit track with two-way traffic operation:

From a traffic operations point of view this option is similar to Option 1 above except that the provision of a dedicated track for the proposed transit service will cause University Place corridor traffic operation to remain similar to the existing condition. The Traffic performance improvement options suggested above under the discussion of Option 1 apply to this option as well.

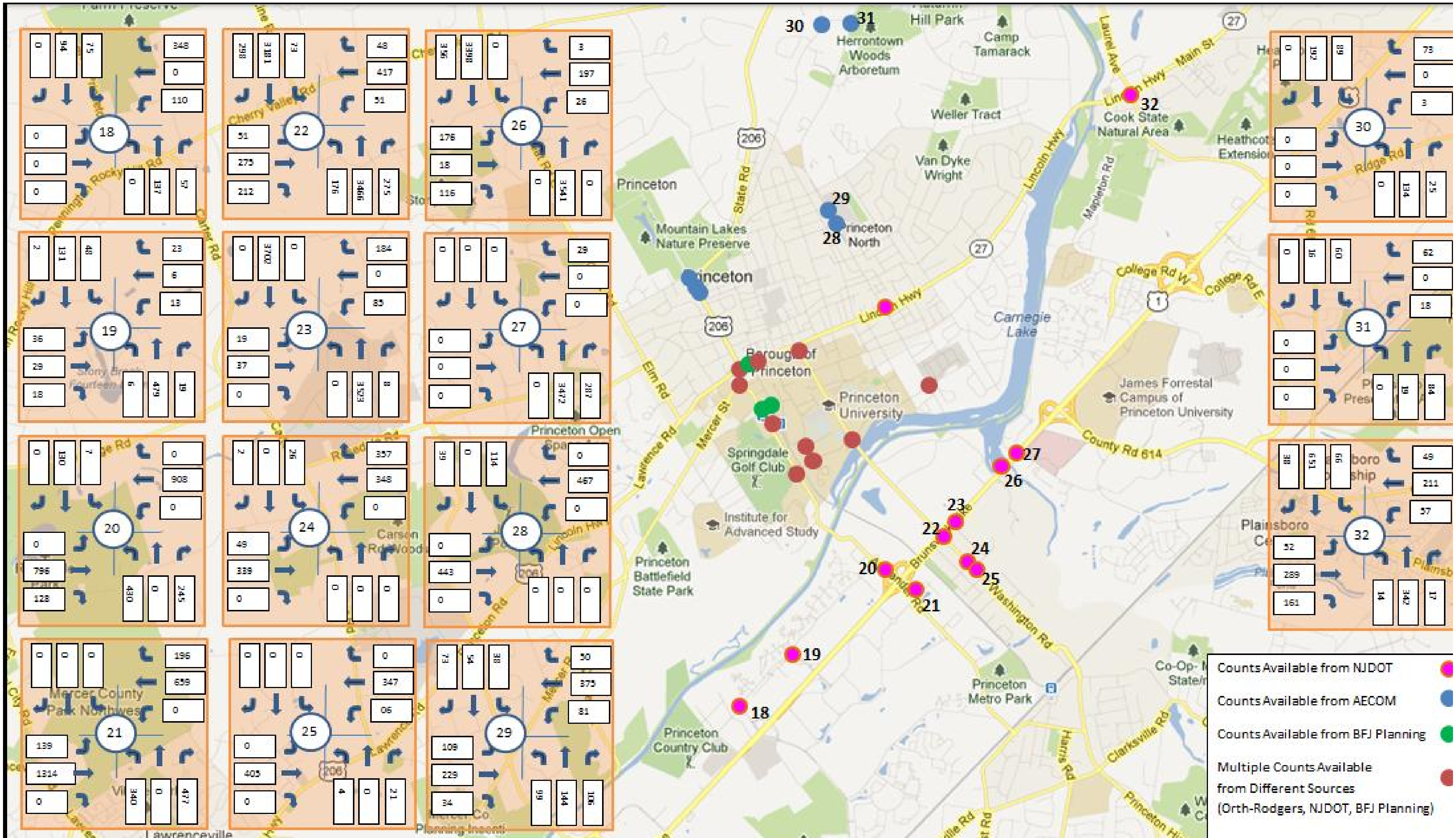
[3] Labeled as Option F in the Princeton Transit Study

APPENDIX 1

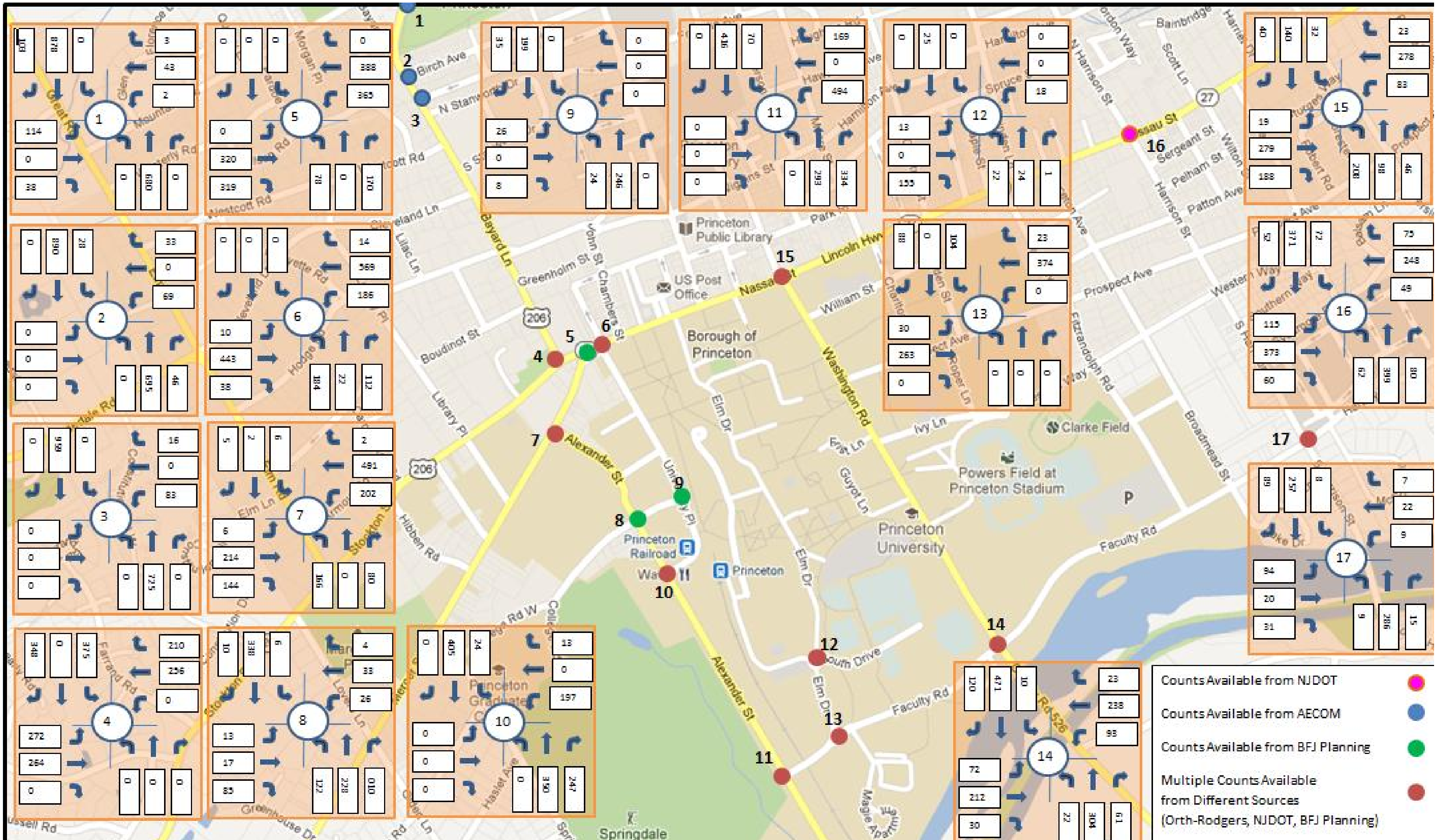
Compiled Intersection Turning Movement Traffic Counts – Weekday AM and PM Peak Hours



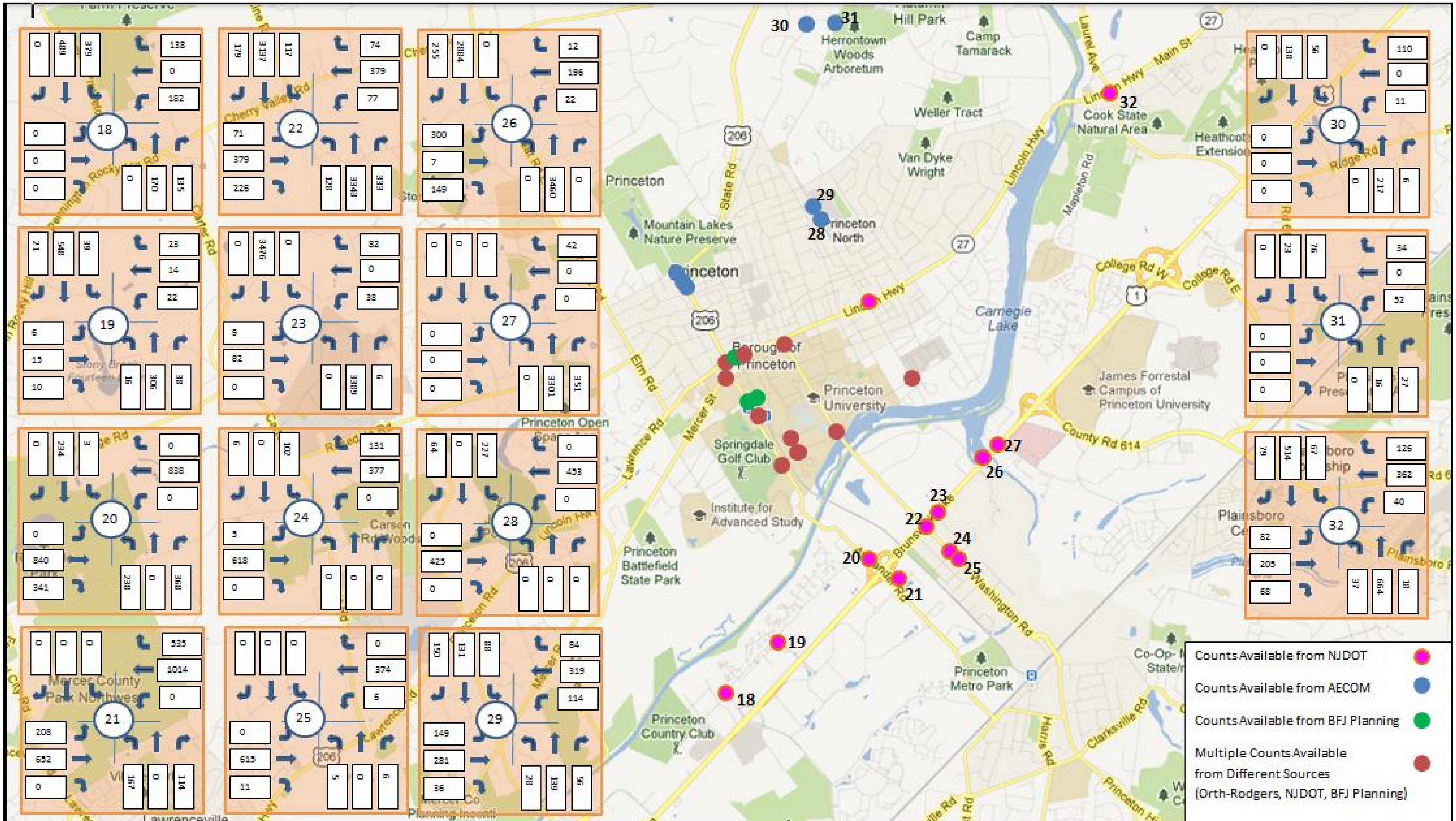
2012 AM Peak Hour Intersection Turning Movement Traffic Counts



2012 AM Peak Hour Intersection Turning Movement Traffic Counts



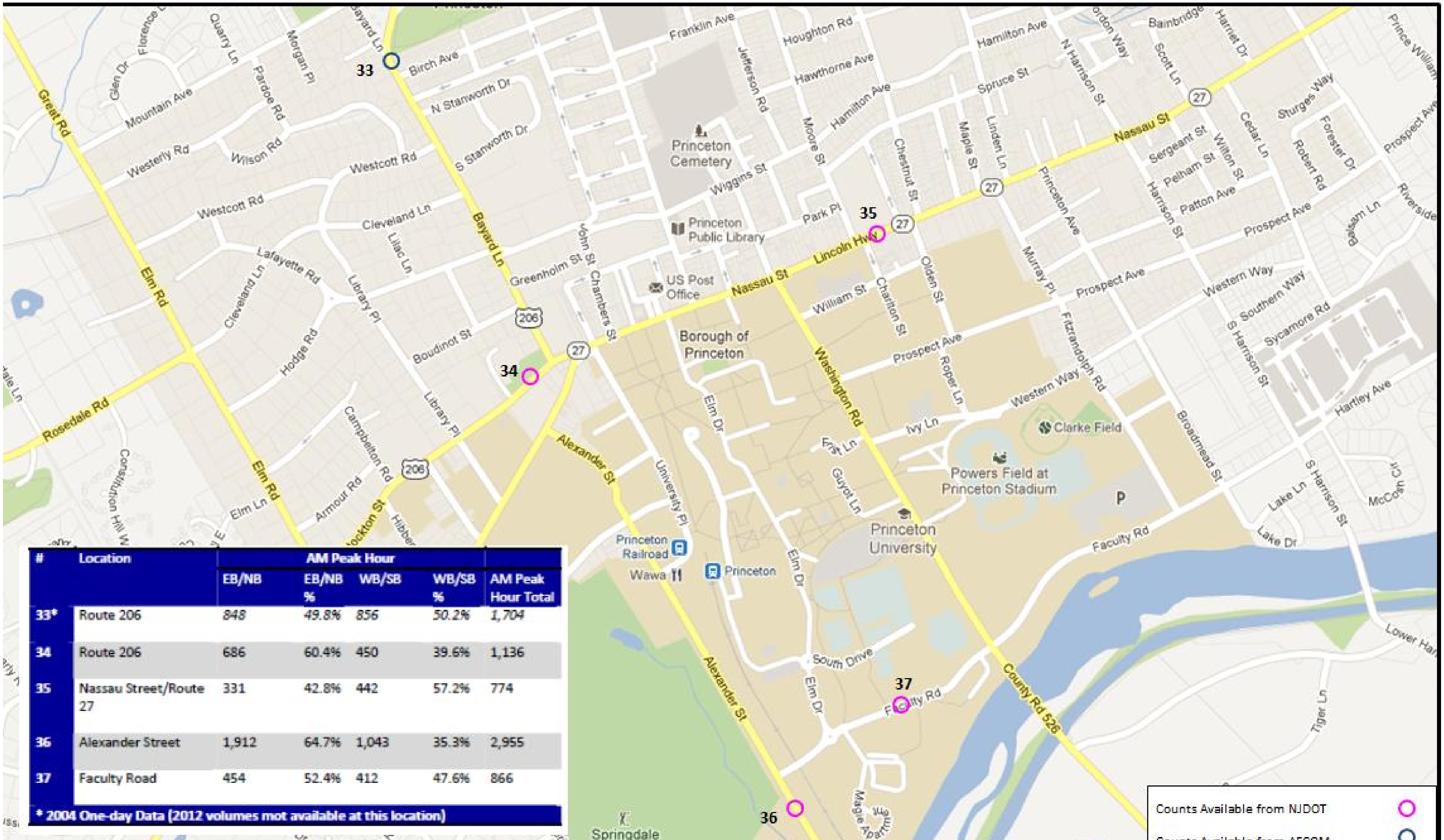
2012 PM Peak Hour Intersection Turning Movement Traffic Counts



2012 PM Peak Hour Intersection Turning Movement Traffic Counts

APPENDIX 2

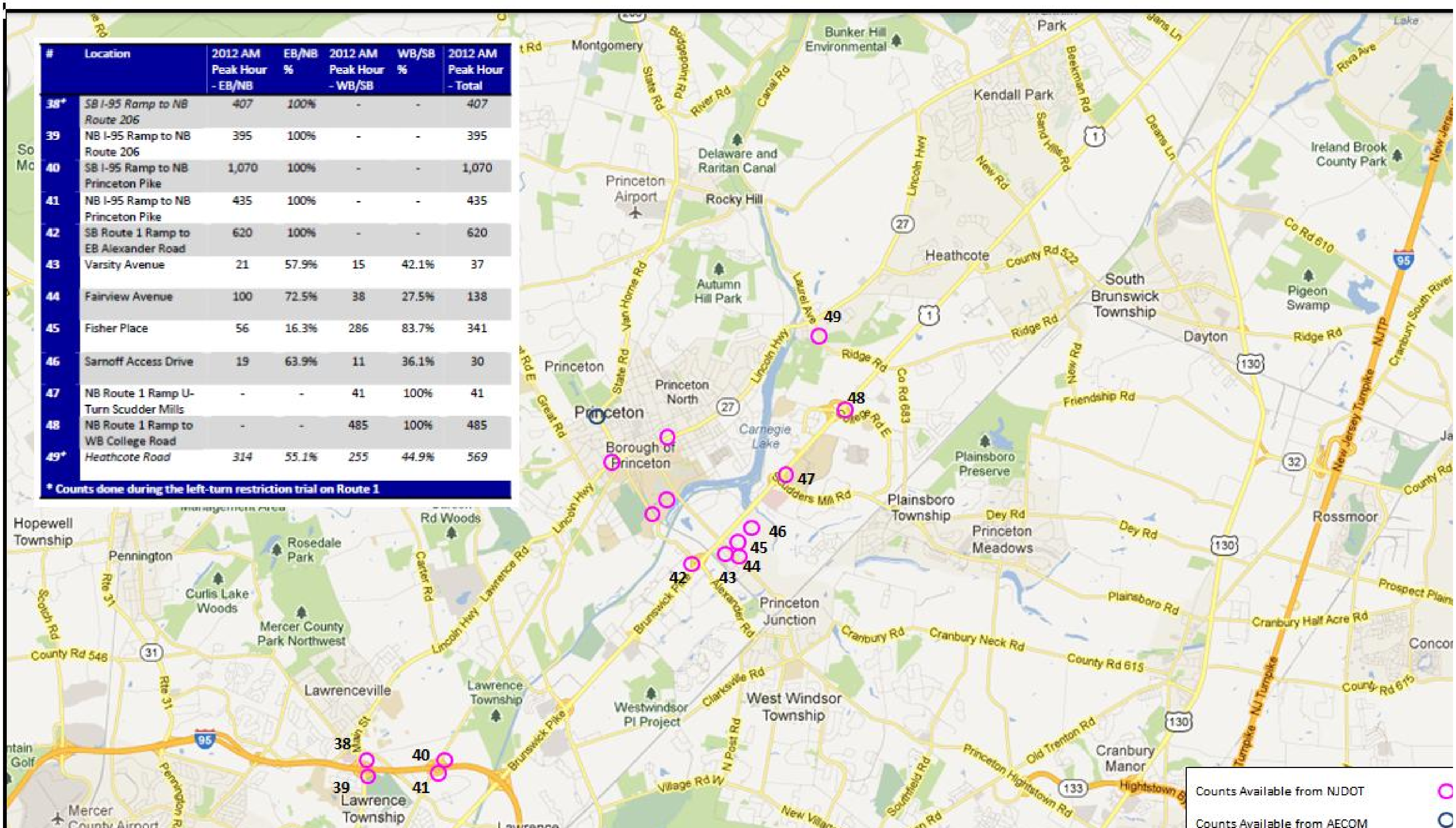
Compiled Automatic Traffic Recorder (ATR) Counts



#	Location	AM Peak Hour EB/NB	EB/NB %	WB/SB	WB/SB %	AM Peak Hour Total
33*	Route 206	848	49.8%	856	50.2%	1,704
34	Route 206	686	60.4%	450	39.6%	1,136
35	Nassau Street/Route 27	331	42.8%	442	57.2%	774
36	Alexander Street	1,912	64.7%	1,043	35.3%	2,955
37	Faculty Road	454	52.4%	412	47.6%	866

* 2004 One-day Data (2012 volumes mot available at this location)

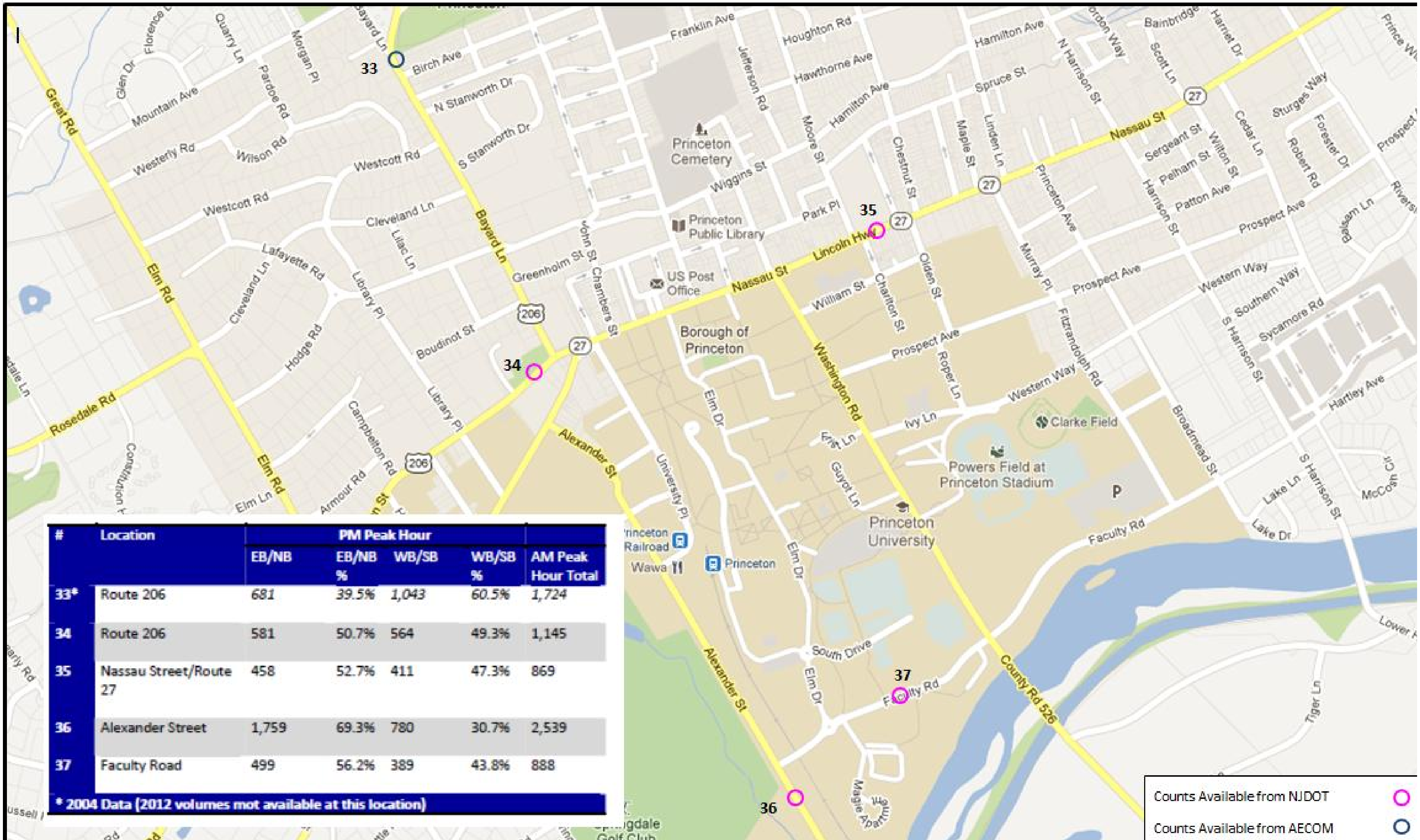
2012 AM Peak Hour ATR Counts



#	Location	2012 AM Peak Hour - EB/NB	EB/NB %	2012 AM Peak Hour - WB/SB	WB/SB %	2012 AM Peak Hour - Total
38*	*SB I-95 Ramp to NB Route 206*	*407*	*100%*	-	-	*407*
39	NB I-95 Ramp to NB Route 206	395	100%	-	-	395
40	SB I-95 Ramp to NB Princeton Pike	1,070	100%	-	-	1,070
41	NB I-95 Ramp to NB Princeton Pike	435	100%	-	-	435
42	SB Route 1 Ramp to EB Alexander Road	620	100%	-	-	620
43	Varsity Avenue	21	57.9%	15	42.1%	37
44	Fairview Avenue	100	72.5%	38	27.5%	138
45	Fisher Place	56	16.3%	286	83.7%	341
46	Sarnoff Access Drive	19	63.9%	11	36.1%	30
47	NB Route 1 Ramp U-Turn Scudder Mills	-	-	41	100%	41
48	NB Route 1 Ramp to WB College Road	-	-	485	100%	485
49*	*Heathcote Road*	*314*	*55.1%*	*255*	*44.9%*	*569*

* Counts done during the left-turn restriction trial on Route 1

2012 AM Peak Hour ATR Counts



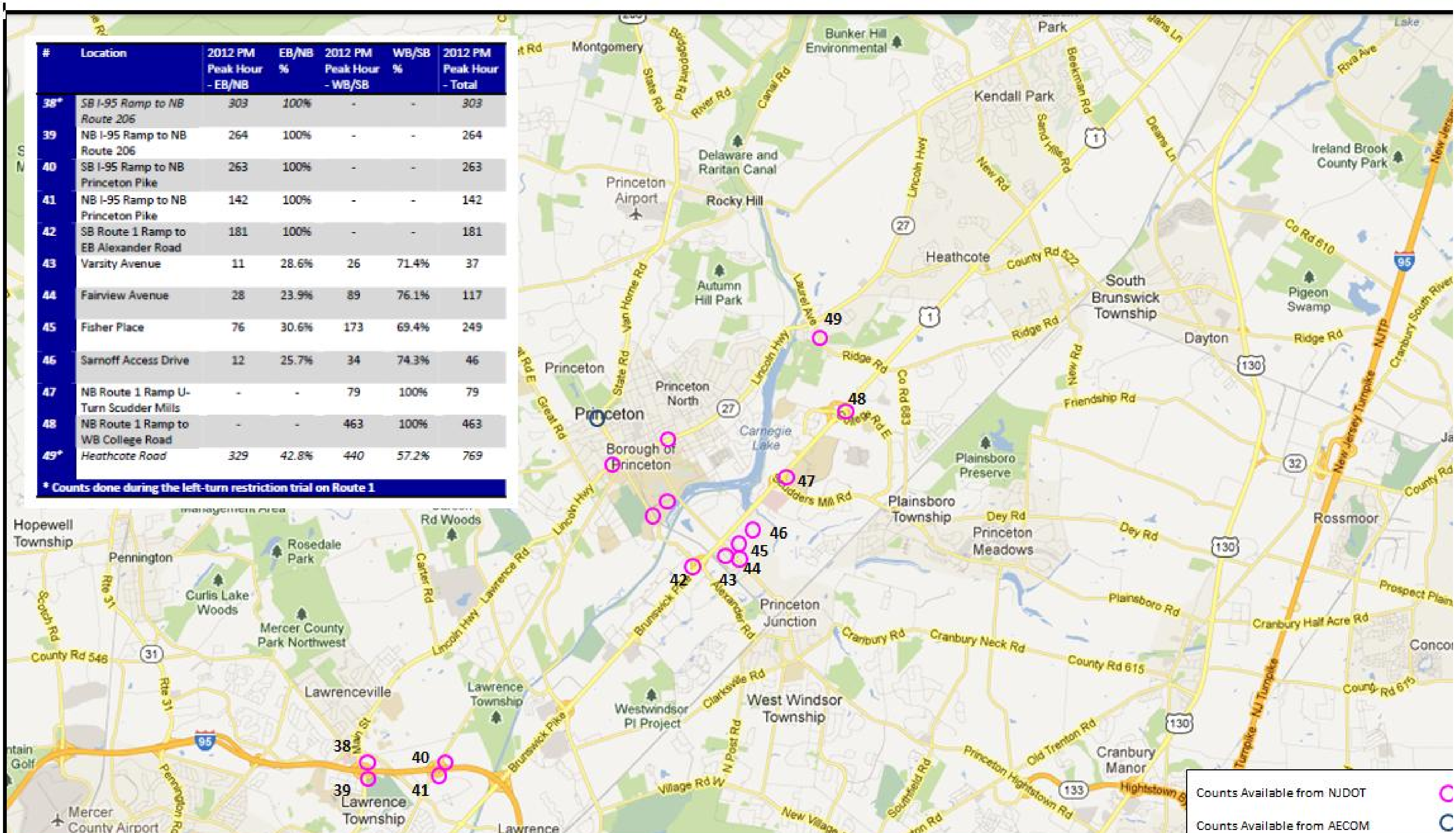
#	Location	PM Peak Hour				AM Peak Hour Total
		EB/NB	EB/NB %	WB/SB	WB/SB %	
33*	Route 206	681	39.5%	1,043	60.5%	1,724
34	Route 206	581	50.7%	564	49.3%	1,145
35	Nassau Street/Route 27	458	52.7%	411	47.3%	869
36	Alexander Street	1,759	69.3%	780	30.7%	2,539
37	Faculty Road	499	56.2%	389	43.8%	888

* 2004 Data (2012 volumes mot available at this location)

2012 PM Peak Hour ATR Counts

#	Location	2012 PM Peak Hour - EB/NB	EB/NB %	2012 PM Peak Hour - WB/SB	WB/SB %	2012 PM Peak Hour - Total
38*	*SB I-95 Ramp to NB Route 206*	*303*	*100%*	-	-	*303*
39	NB I-95 Ramp to NB Route 206	264	100%	-	-	264
40	SB I-95 Ramp to NB Princeton Pike	263	100%	-	-	263
41	NB I-95 Ramp to NB Princeton Pike	142	100%	-	-	142
42	SB Route 1 Ramp to EB Alexander Road	181	100%	-	-	181
43	Varsity Avenue	11	28.6%	26	71.4%	37
44	Fairview Avenue	28	23.9%	89	76.1%	117
45	Fisher Place	76	30.6%	173	69.4%	249
46	Sarnoff Access Drive	12	25.7%	34	74.3%	46
47	NB Route 1 Ramp U-Turn Scudder Mills	-	-	79	100%	79
48	NB Route 1 Ramp to WB College Road	-	-	463	100%	463
49*	*Heathcote Road*	*329*	*42.8%*	*440*	*57.2%*	*769*

*** Counts done during the left-turn restriction trial on Route 1**



2012 PM Peak Hour ATR Counts

APPENDIX 3

Study Area Development/Redevelopment – New Trip Generation

FUTURE LOCAL DEVELOPMENT NEW TRIP GENERATION

				Peak Hour New Trip Generation			
				AM		PM	
	TAZ	NUMBER	TYPE	In	Out	In	Out
Hulfish North (Palmer Square)	747	97	Townhouses	9	41	41	22
University Med Center Redevelopment	716	280	Apartments	26	118	118	64
YM/YWCA Redevelopment	749						
- Additional Residential @ 14 du/ac @ 10 a		140	Townhouses	13	59	59	32
Merewick / Stanworth Graduate Housing							
- Additional units	706	172	Apartments	16	73	73	39
Hibben Magie Graduate Housing	610	329	Dwelling Units	23	12	21	21
University Arts & Transit							
Relocated Employees (West Garage)	600			24	0	0	20
New Employees (Lots 32, 33)	694	55	Spaces	25	2	2	23
Restaurant / Café	601	10	Thousand Sq. Ft.	79	82	31	31
Total Trips				215	387	345	251

APPENDIX 4

Travel Demand Modeling Scenario Details

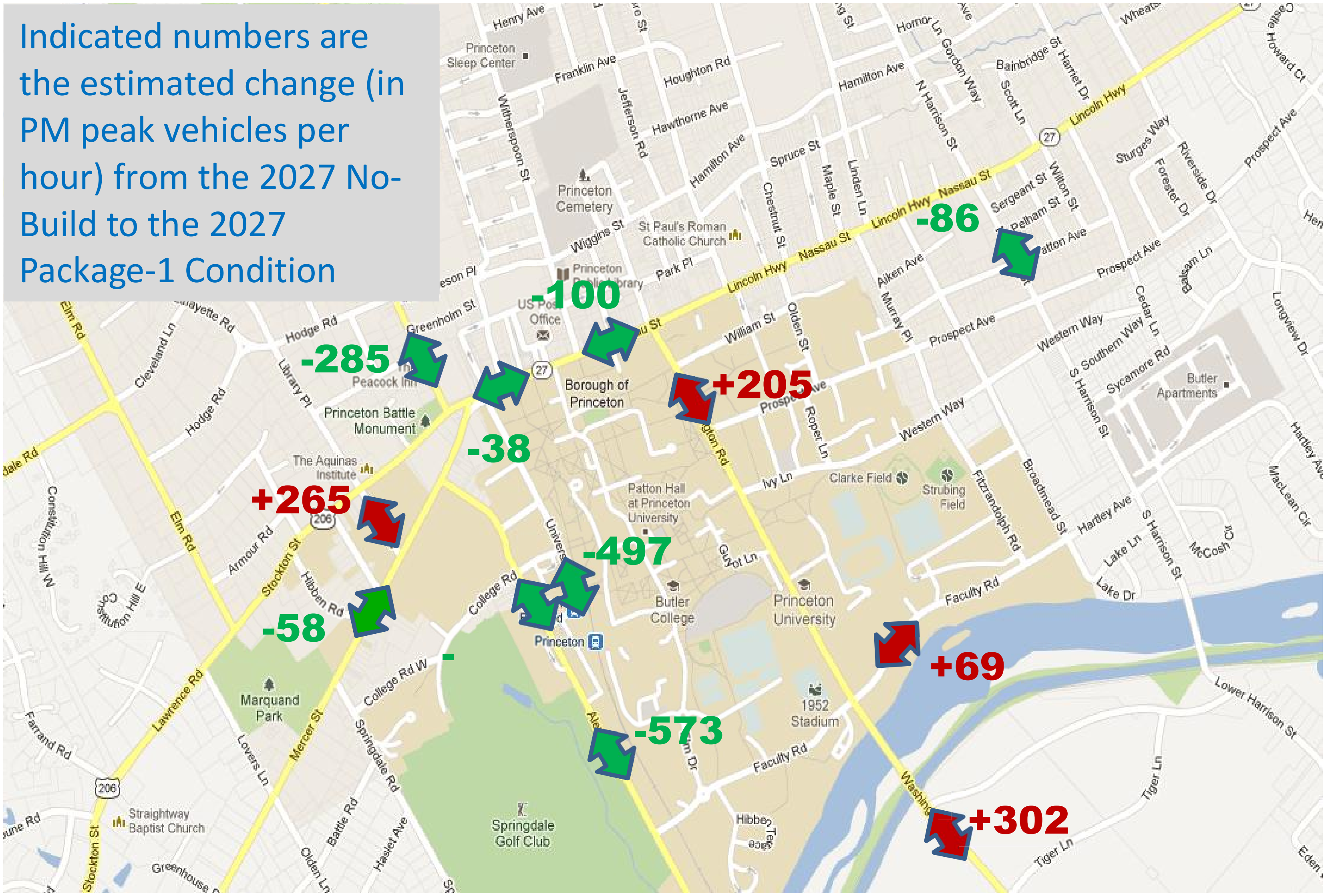
Modeled Scenario	Base Model	Network Updates	Land Use Updates
1. **2012 Base Condition**	2006 Base Model	• Available 2012 Traffic Count Data • Any roadway improvement projects completed since 2006	• Relocation of the University Medical Center
2. **2027 No-Build Condition**	2012 Base Condition	• Roadway improvements related to the Princeton University Arts and Transit Project	• All new developments/redevelopments identified in RFP o Expansion of Graduate Hosing (Hibben-Magi o Princeton University Arts and Transit Project o Hulfish North (Palmer Square) Redevelopme o Redevelopment of YM/YWCA o Redevelopment of Merwick and Stanworth o Redevelopment of University Medical Cente
3. **Improvement Package 1: Street Closures**	2027 No-Build Condition	• Mercer Street closed in both directions between Alexander Street and Nassau Street • Witherspoon Street closed in both directions between Nassau Street and Spring Street • Left turn from Nassau Street onto Bank Street prohibited	• None: same as in 2027 No-Build Condition
4. **Improvement Package 2: One-way Loop in Clockwise Direction**	2027 No-Build Condition	• Mercer Street one-way in eastbound direction from Alexander Street to Nassau Street • University Place one-way in southbound direction from Nassau Street to Alexander Street • Alexander Street one-way in northbound direction from University Place to Mercer Street • Left turns from Nassau Street on to Bank Street prohibited • Witherspoon Street one-way in northbound direction from Nassau Street to Spring Street • Signal at Nassau Street and Witherspoon Street converted to pedestrian signal only	• None: same as in 2027 No-Build Condition
5. **Improvement Package 3: One-way Loop in Counterclockwise Direction**	2027 No-Build Condition	• Mercer Street one-way in westbound direction from Nassau Street to Alexander Street • University Place one-way in northbound direction from Alexander Street to Nassau Street • Alexander Street one-way in southbound direction from Mercer Street to University Place • Left turns from Nassau Street on to Bank Street prohibited • Witherspoon Street one-way in northbound direction from Nassau Street to Spring Street • Signal at Nassau Street and Witherspoon Street converted to pedestrian signal only	• None: same as in 2027 No-Build Condition
6. **Stand-alone Improvement Run: Either Clockwise or Counterclockwise One-Way Loop**	Either Improvement Package 2 or Improvement Package 3	• Same actions as in either Package 2 or Package 3 except: o Replace Witherspoon Street one-way conversion with current two-way operation o Fully functional traffic signal at Nassau Street and Witherspoon Street intersection	• None: same as in 2027 No-Build Condition

APPENDIX 5

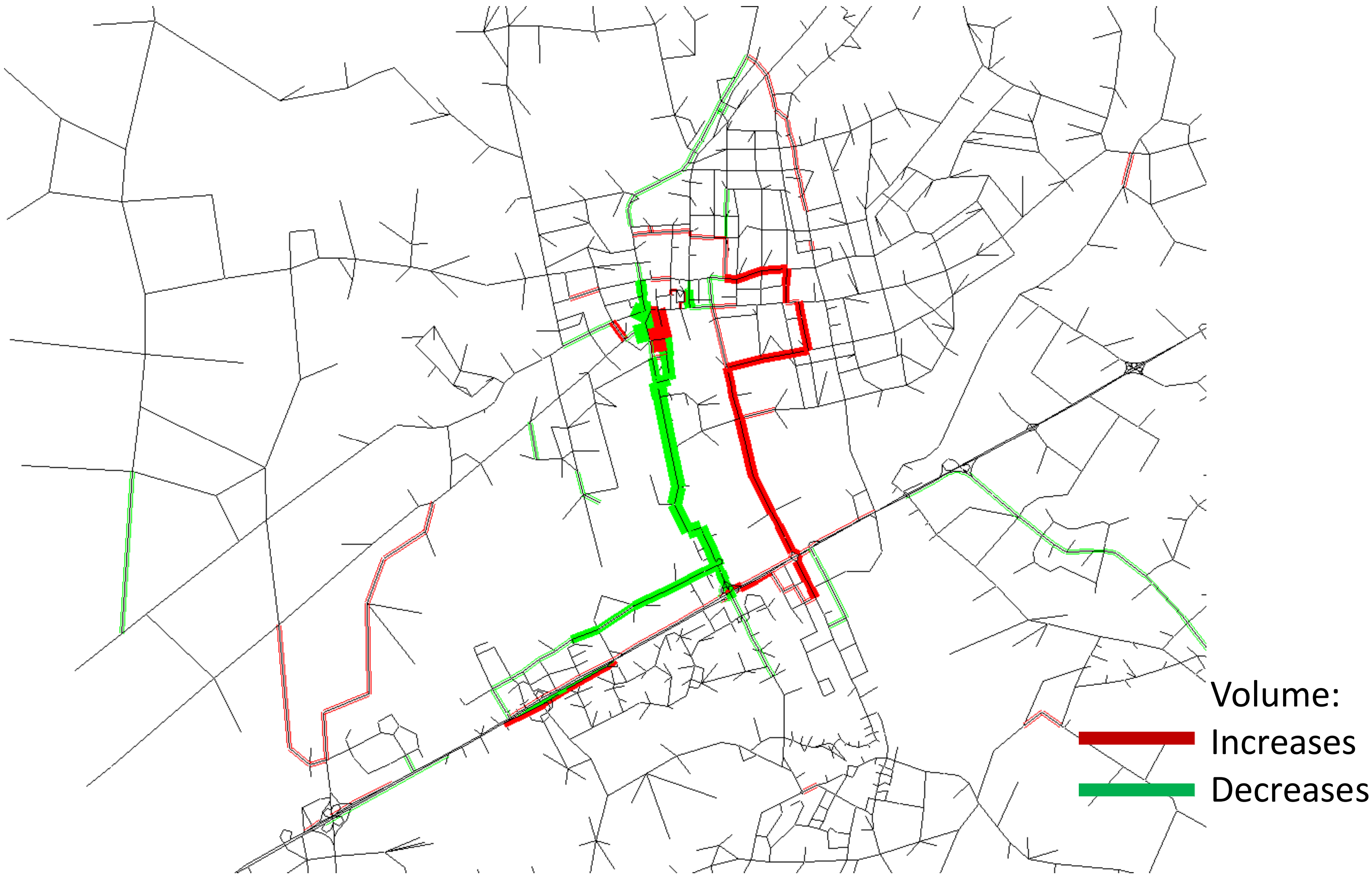
Travel Demand Modeling Analysis for Improvement Packages

Traffic Volume Changes

Projected PM Peak Hour Traffic Volume Change: 2027 No-Build to 2027 Improvement Package 1

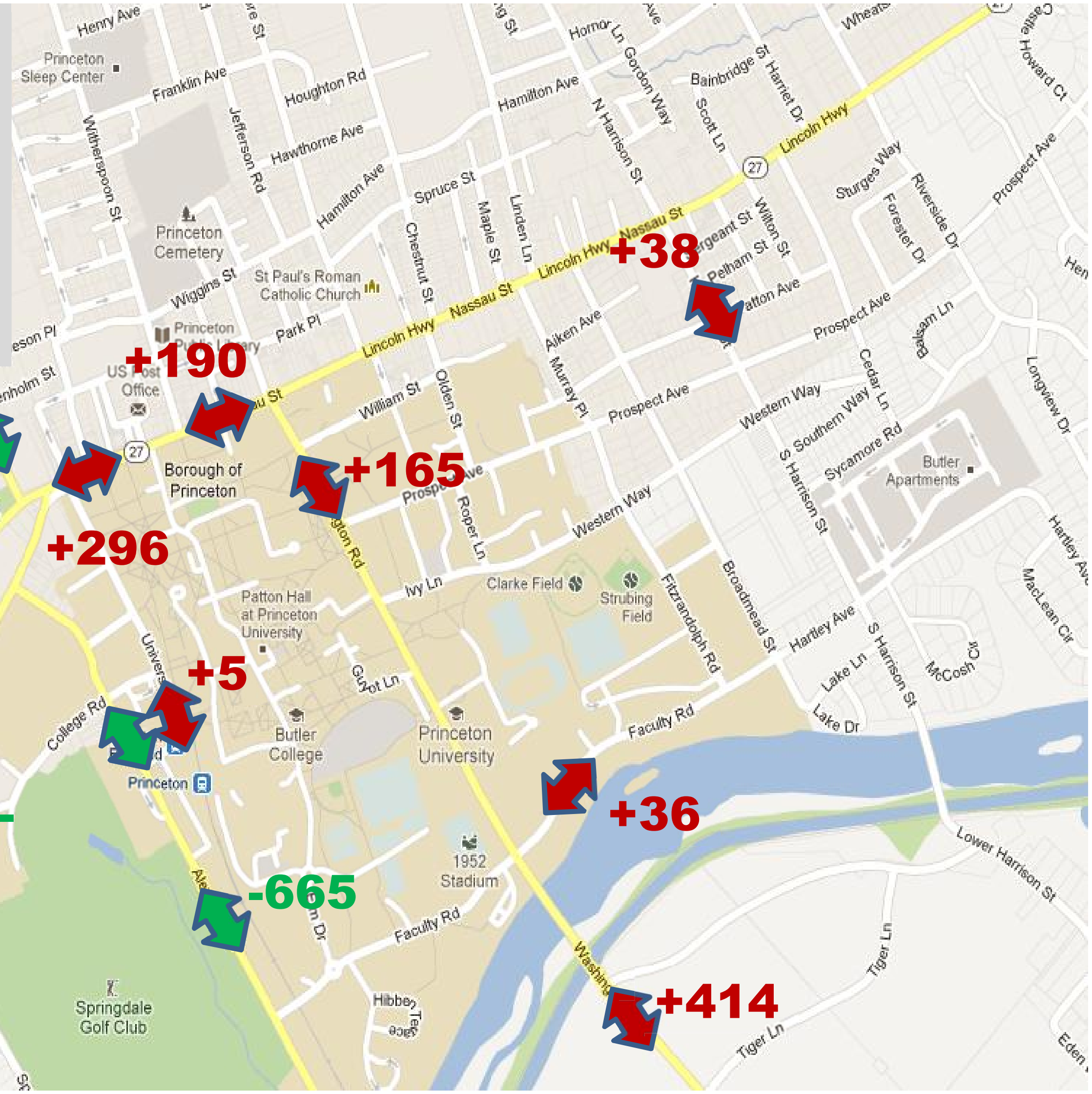


Projected PM Peak Hour Traffic Volume Shifts: 2027 No-Build to 2027 Improvement Package 1

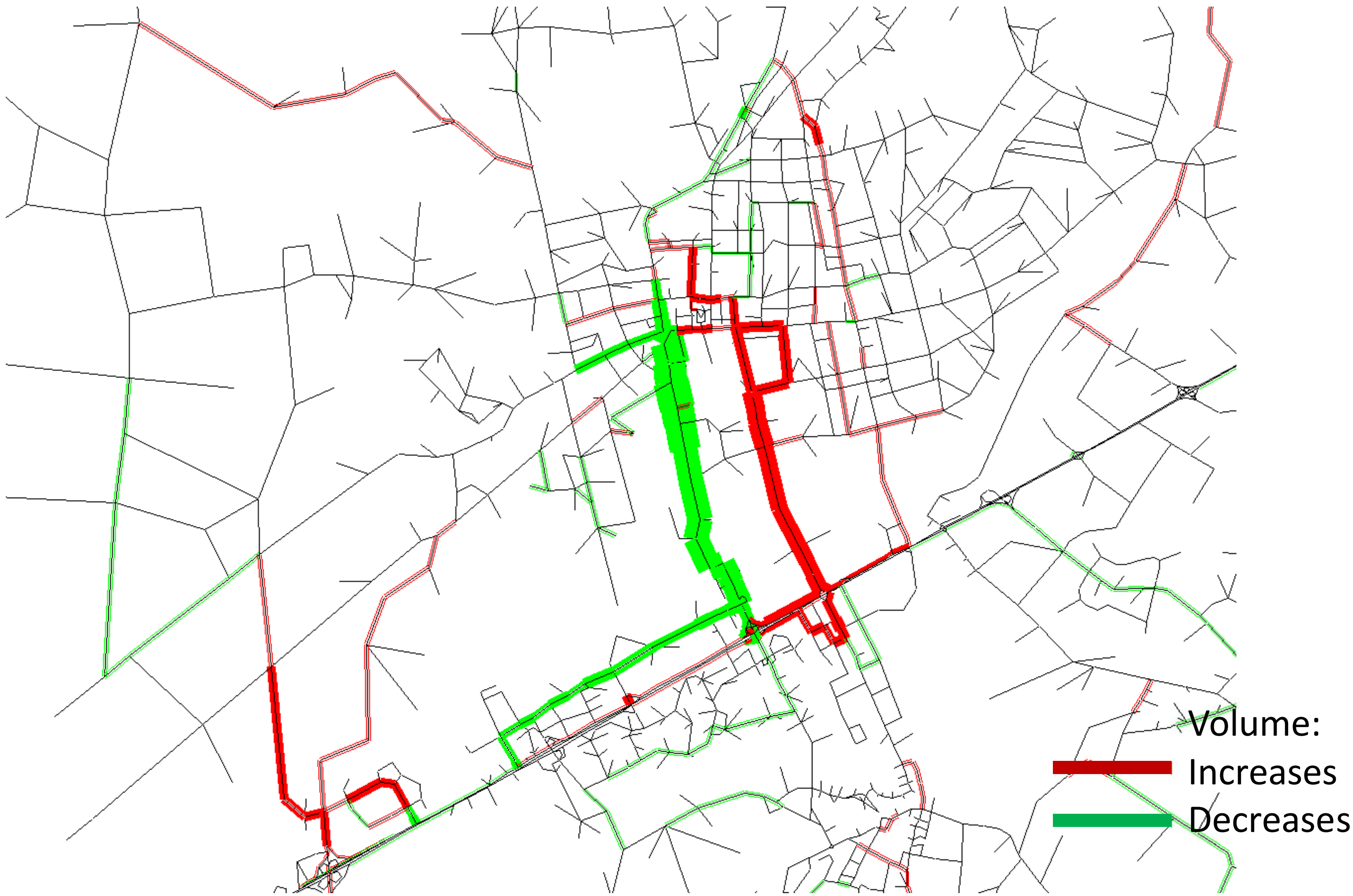


Projected PM Peak Hour Traffic Volume Change: 2027 No-Build to 2027 Improvement Package 2

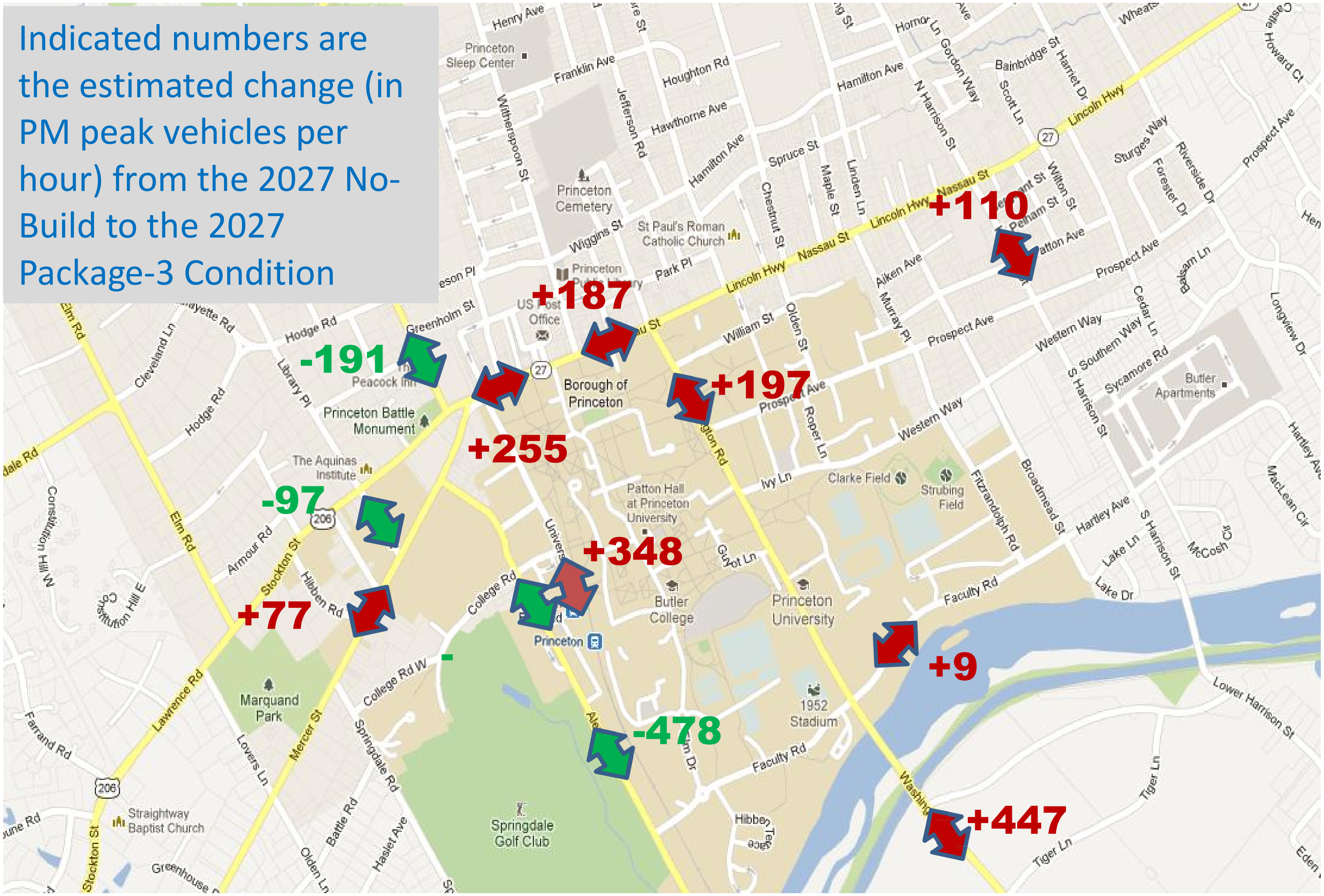
Indicated numbers are the estimated change (in PM peak vehicles per hour) from the 2027 No-Build to the 2027 Package-2 Condition



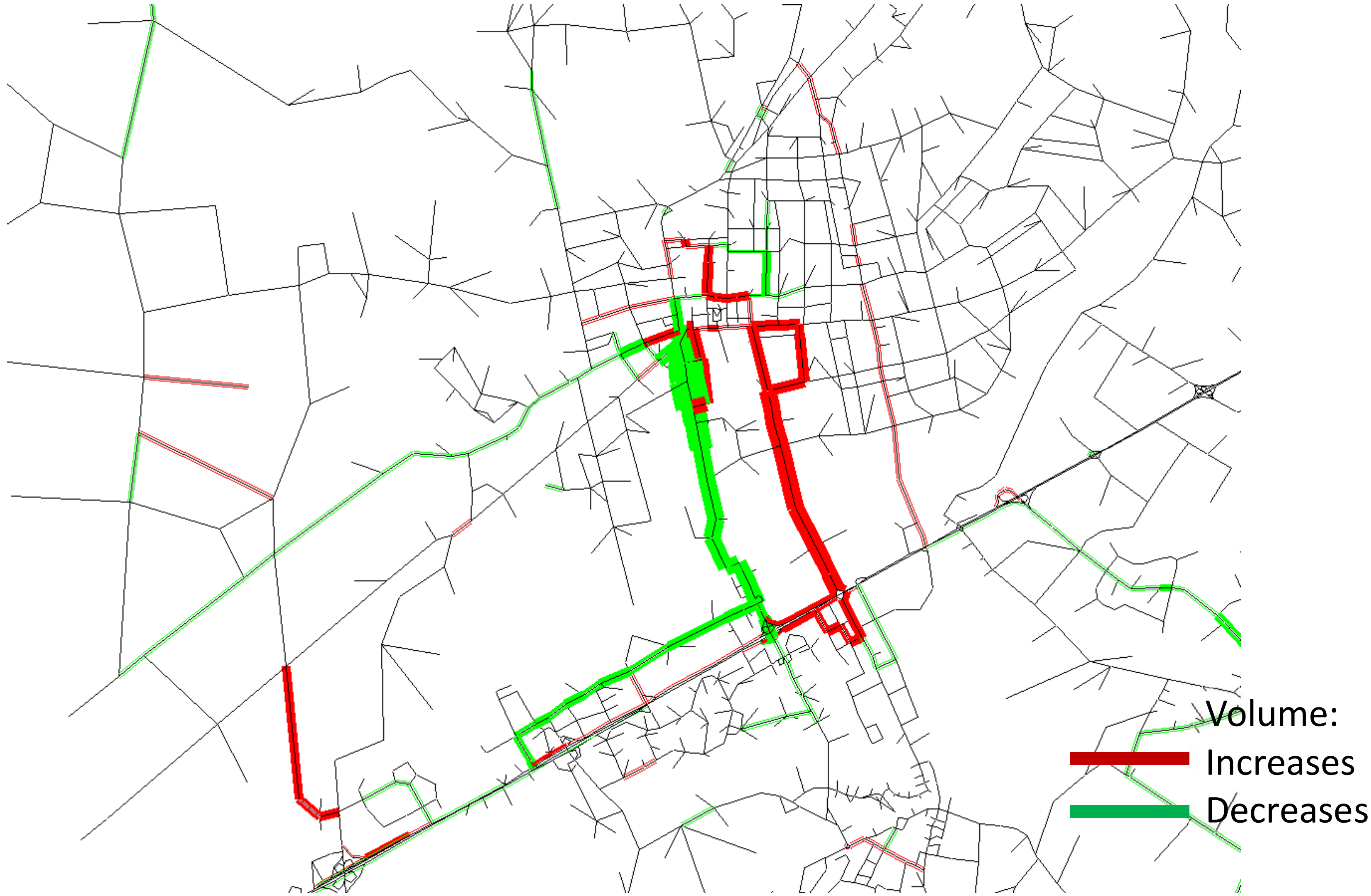
Projected PM Peak Hour Traffic Volume Shifts: 2027 No-Build to 2027 Improvement Package 2



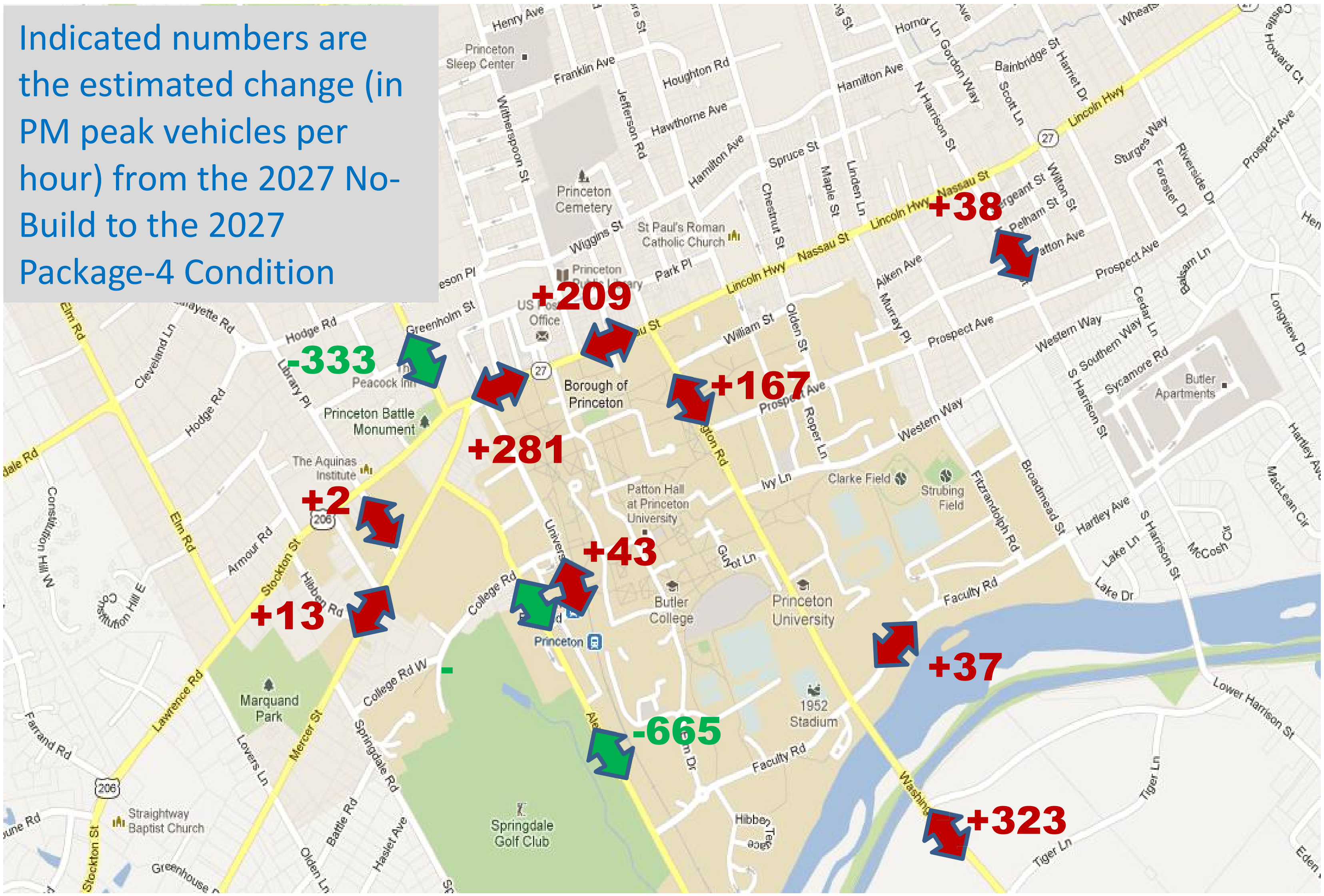
Projected PM Peak Hour Traffic Volume Change: 2027 No-Build to 2027 Improvement Package 3



Projected PM Peak Hour Traffic Volume Shifts: 2027 No-Build to 2027 Improvement Package 3



Projected PM Peak Hour Traffic Volume Change: 2027 No-Build to 2027 Improvement Package 4



Projected PM Peak Hour Traffic Volume Shifts: 2027 No-Build to 2027 Improvement Package 4