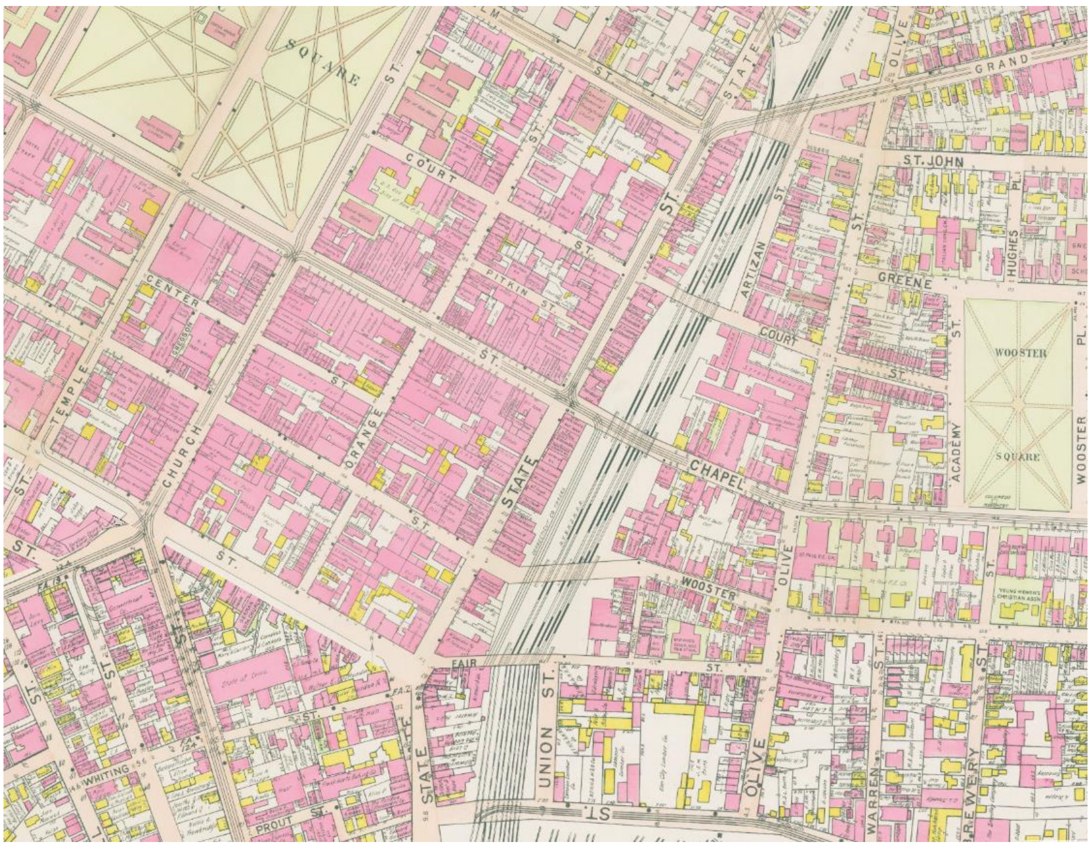
STATE STREET TRAFFIC ANALYSIS

FINAL REPORT



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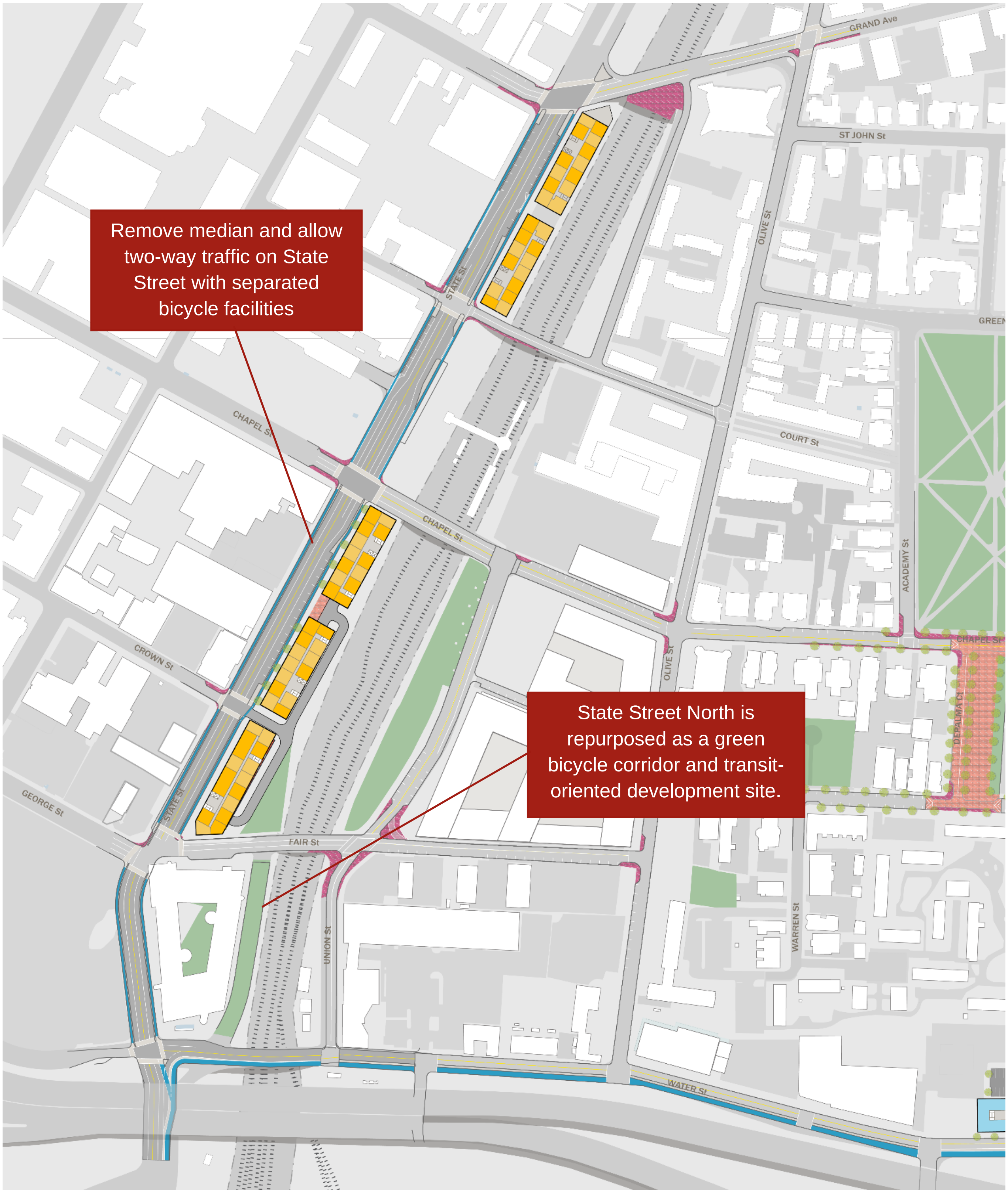
STATE STREET REDEVELOPMENT TRAFFIC ANALYSIS

This report provides an analysis of existing and proposed future conditions on State Street through downtown New Haven in support of the City's application to the Connecticut DOT (CDOT) Local Transportation Capital Improvement Program (LOTCIP). The intent of this study is to explore how to modernize State Street's design to better address the City's current priorities and goals, building on a series of past planning efforts, which included ample public involvement and discussion:

- Move New Haven Transit Mobility Study (2019)
- State Street Redevelopment – Draft Traffic Study (2017)
- Wooster Square Planning Study (2016)
- New Haven Vision 2025 (2015)
- City of New Haven Two Way Conversion Study (2014)
- Elm City Cycling - Bicycle and Pedestrian Plan (2013)

In addition to changes on State Street, the City of New Haven is seeking to redevelop several parcels along the railroad into mixed use, walkable, transit-oriented development. One possible concept, developed by Utile in the Wooster Square Planning Study, is shown on the following page as Figure 1. The purpose of this study is to evaluate the proposed traffic circulation changes, in light of the past plans and studies that enjoy a high level of public support, and develop an engineering concept plan that can be implemented through the Connecticut Department of Transportation's LOTCIP (Local Transportation Capital Improvement Program). Multimodal mobility and circulation will be analyzed to determine the optimal lane configurations and right-of-way requirements for State Street.

Figure 1: State Street Redevelopment Concept



Source: Wooster Square Planning Study, Utile (2016)

PROJECT GOALS

The purpose of this study is to evaluate traffic circulation and operations changes for State Street that will support the City's vision for the corridor, as expressed in the prior planning efforts. This study includes a look at the existing and future traffic operations of State Street in its current configuration and analyzes conditions under two alternatives for State Street with the intent of creating a multimodal, safer, and more economically vibrant corridor.

The City's Vision 2025 document articulates the City's goals for transportation, which guided this project:

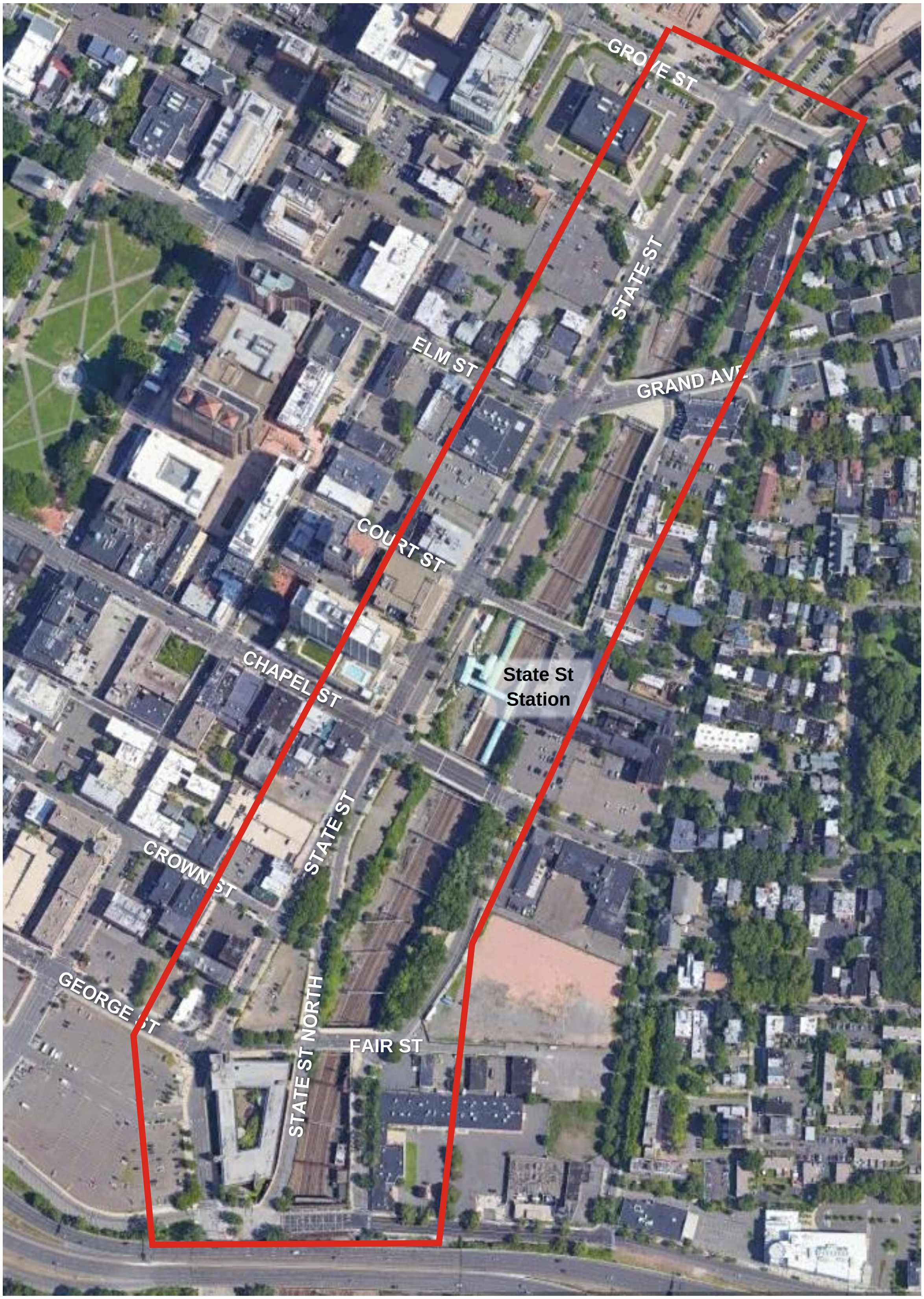
> *The primary transportation goal is to encourage a modal shift in the city, from a population largely dependent on single-occupant vehicles to a population with a wide range of options including public transit, bike, and pedestrian systems. In general, transit and bike/pedestrian improvements must complement each other and accommodate needs of people of all ages and abilities.*

The following summarize the project objectives for the State Street corridor:

- **Multimodal**. As a major corridor that provides access to New Haven's State Street Station and Downtown, this corridor should serve all modes of transportation. Its current configuration does not serve bicycles and transit well, and improvements to serve these modes are desired.
- **Efficient**. With limited public right-of-way, and a need to better accommodate more modes of transportation, State Street should be right-sized for vehicular traffic in order to provide more space for other important aspects of urban life: non-motorized transportation, streetscape and landscape elements, and placemaking.
- **Forward looking**. New Haven's goals for shifting the predominant modes of transportation away from single occupancy vehicles and towards walking, biking and transit and for urban infill redevelopment along the State Street corridor need to guide the design of State Street.

The study area includes State Street between Water Street (US Route 1) and Grove Street, outlined in red on the following page in Figure 2. State Street is under the jurisdiction of the City of New Haven and was constructed in its current configuration in the late 1980s.

Figure 2: Aerial of Study Area



EXISTING CONDITIONS

The following section review the current conditions for pedestrians, bicyclists, transit riders, and vehicular traffic. The design goals and objectives are also discussed.

PEDESTRIANS

Intersection counts conducted on Tuesday, June 25, 2019 during the AM and PM peak hours provide data on pedestrians, bicycles, and vehicular weekday volumes. The following table shows the total number of pedestrians at each of the study area intersections during the AM and PM peak periods.

Table 1: Peak period pedestrian counts (AM peak 7:00 to 9:00, PM peak 4:00 to 6:00)

Intersection	*AM peak Pedestrians*	*PM peak Pedestrians*
State & Grove	99	110
State & Elm & Grand	148	199
State & Court	338	411
State & Chapel	631	577
State & Crown	86	103
State N & Fair	27	44
State & Fair & George	121	158
State N & Water	42	44
State & Water	76	16

With the proximity to the State Street rail station, the intersections with Chapel and Court Streets have the highest pedestrian traffic, with many commuters walking between the State Street Station and other downtown locations. Most of the intersections currently have exclusive pedestrian phases, where all vehicular traffic stops during the pedestrian phase.

Table 2: Pedestrian Phasing and Crosswalk Length for State Street signalized intersections

Intersection	*Pedestrian Phasing*	*State Street crosswalk length (feet)*	*Peak Hour Cycle Length (sec)*
State/Grove	Exclusive	93	90
State/Elm/Grand	Exclusive	75	90
State/Court	Exclusive	75	90
State/Pitkin	No ped crossing	n/a	90
State/Chapel	Exclusive	75	90
State St/George/Fair	Exclusive	56	100
State St N/Fair	Concurrent	40	100
State St/Water	Exclusive	55	100

The crosswalks on State Street with the highest pedestrian volumes are mostly about 75 feet long, crossing up to 6 lanes of traffic. The exclusive pedestrian phase requires pedestrians to sometimes wait well over 60 seconds, leading many pedestrians to take risks and cross during the vehicle phase. Public input received during the Wooster Square Planning Study indicates that there is public support for reducing the crossing distances and waiting times at these intersections. Figure 3 shows the crosswalk conditions.

Figure 3: Google Streetview at State Street & Chapel Street

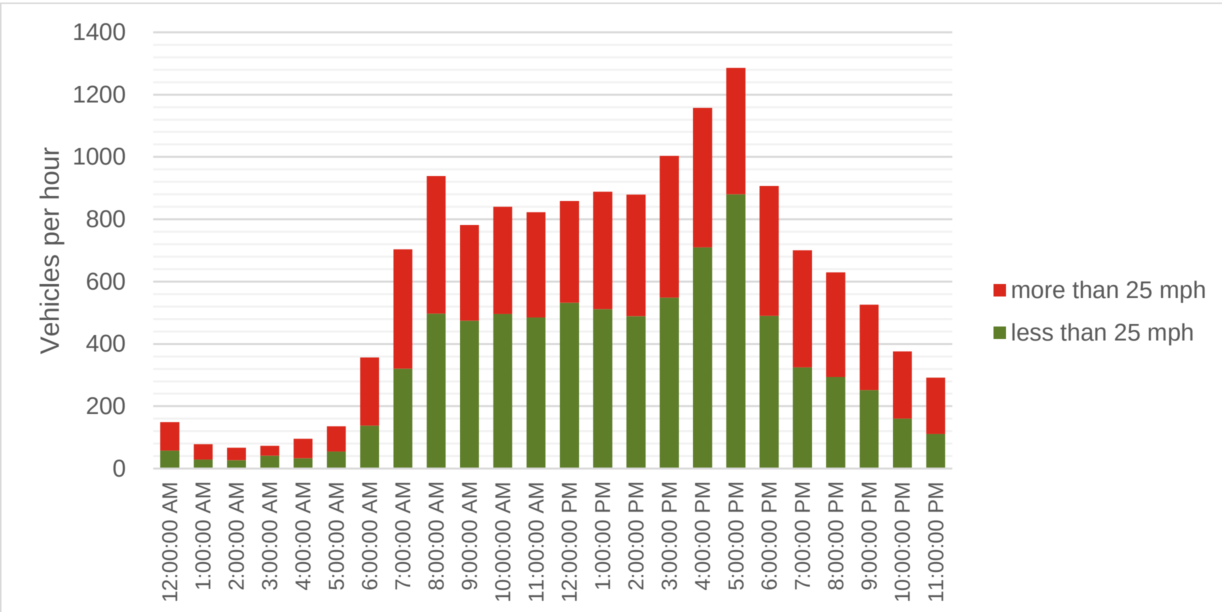
Pedestrian safety is highly influenced by traffic speeds, as shown in the following figure. The chances of a pedestrian surviving a crash with a motor vehicle depends heavily on the speed of the vehicle. To ensure pedestrian safety in a walkable downtown area, it is best to strive for a target operating speed of 20 mph.

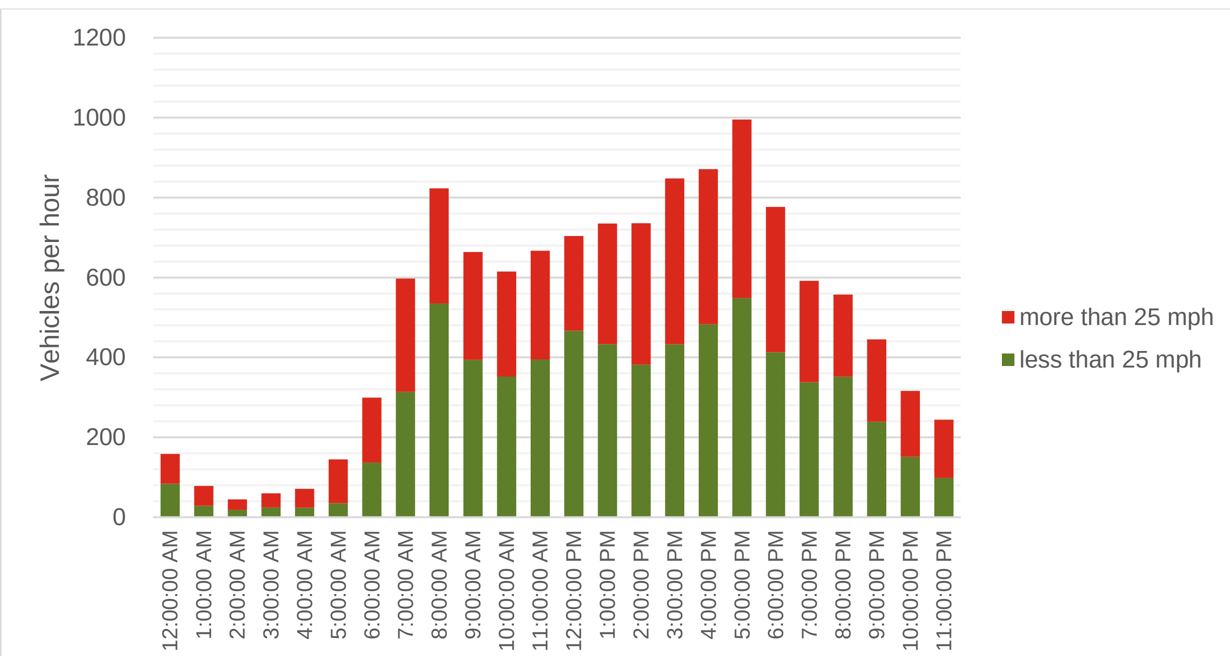
Figure 4: Relationship of Speed and Pedestrian Fatalities[1]

[1] U. S. Department of Transportation, National Highway Traffic Safety Administration, *Final Report - Literature Review on Vehicle Travel Speeds and Pedestrian Injuries*, DOT HS 809 021 October 1999.

Vehicular traffic volume and speed data were collected on State Street at four locations on the corridor on June 25, 2019. The charts below provide more detail on the daily volume and speeds, and show that nearly 40% of drivers exceed the posted speed limit of 25 mph.

Figure 5: Speed Data on State Street





The data presented above indicates that speeding is a problem on State Street. The high speeds likely arise from the configuration of State Street, which has two or more travel lanes in each direction, allowing motorist to easily pass.

The following strategies should be considered for the reconfiguration of State Street to reduce traffic speeds and increase safety:

- Reduce the number of lanes and distance that pedestrians need to cross at intersections.
- Reduce the prevalence of speeding on State Street by having only one travel lane in each direction wherever possible.

BICYCLE TRANSPORTATION

The City's overall bike network has several high comfort/low stress routes, including the Farmington Canal Heritage Trail and Brewery Street separated bicycle lanes. The State Street corridor can serve as a key connecting route between these two important facilities, as well as to several streets with existing bicycle lanes throughout downtown.

Bicycle Volumes

Intersection counts conducted on June 25, 2019 during the AM and PM peak periods also provide data on bicycle volumes, as presented in the following table.

Table 3: Peak hour bicycle counts (two-hour counts; AM peak 7:00 to 9:00, PM peak 4:00 to 6:00)

Intersection	*AM peak Bicycles*	*PM peak Bicycles*
State & Grove	42	47
State & Elm & Grand	35	43
State & Court	48	37
State & Chapel	60	43
State & Crown	29	20
State N & Fair	12	13
State & Fair & George	25	30
State N & Water	12	20
State & Water	26	26

The counts show slightly higher bicycle usage on the portion of State Street north of Chapel Street. In the southern portion of the corridor, the data show that there are greater numbers of southbound bicycles on State Street compared to northbound bicycles on State Street North.

Bicycle Level of Traffic Stress

Bicycle Level of Traffic Stress (BTLS) is an indicator of bicycle safety and comfort, and is determined by the presence or lack of bicycle infrastructure, vehicular traffic volume, posted speed limit, on-street parking, and the presence of other conditions that can exacerbate curbside conflict (bus stops, valets, pick-up/drop-off zones, etc.). The stress levels range from 1 to 4, with 1 being conditions that are conducive to riding by all ages and abilities, and 4 being a high stress condition that typically only very confident bicyclists are willing to ride in, as shown in the Figure 6 on the following page. State Street, the BTLS for the entire corridor through downtown is 4, indicating high stress conditions, making the corridor unappealing to most people who may be willing to bike.

Figure 6: Bicycle Level of Traffic Stress Chart

				Posted Speed			Conflict Factors*	All Ages & Abilities Treatments		
				20	25	30+		Protected Bike Lane	Shared Street**	Neighborhood Greenway***
If ADT available										
Vehicle Volumes	< 1500	Bike lane	No Parking	LTS 1	LTS 1	LTS 2	add 1 up to LTS 4	LTS 1	LTS 1	LTS 1
			Parking	LTS 1	LTS 1	LTS 3				
		No bike lane		LTS 1	LTS 2	LTS 3				
	1500 - 3k	Bike lane	No Parking	LTS 2	LTS 2	LTS 2		LTS 1	LTS 1	LTS 2
			Parking	LTS 2	LTS 2	LTS 3				
		No bike lane		LTS 2	LTS 2	LTS 3				
	3k - 6k	Bike lane	No Parking	LTS 2	LTS 2	LTS 2				
			Parking	LTS 2	LTS 2	LTS 3				
		No bike lane		LTS 3	LTS 3	LTS 4				
	> 6k	Bike lane	No Parking	LTS 3	LTS 3	LTS 4		LTS 1	n/a	n/a
			Parking	LTS 3	LTS 4	LTS 4				
		No bike lane		LTS 3	LTS 4	LTS 4				

Existing Conditions on State Street

* If any of the following conflict factors are present, add 1 to the LTS score: industrial, commercial, or hotel uses; key bus route; valet zone; pick-up/drop-off zone; cab stand; or school.
** For shared streets to meet all ages and abilities criteria, prevailing vehicle speeds should not exceed 10 mph.
*** For neighborhood greenways to meet all ages and abilities criteria, horizontal and/or vertical deflection measures should be used to keep prevailing vehicle speeds under 20 mph.

In order to meet the City's goal of increasing the mode share for bicycling, a design goal for State Street is to achieve a BTLS of 1 by providing separated bicycle lanes, which will make the corridor comfortable and attractive for riders of all ages and abilities. An example of an appropriate bicycle facility to connect the existing bicycle facilities in downtown New Haven is shown in the following figure.

Figure 7: Example of a Separated Bicycle Lane (Toole Design)

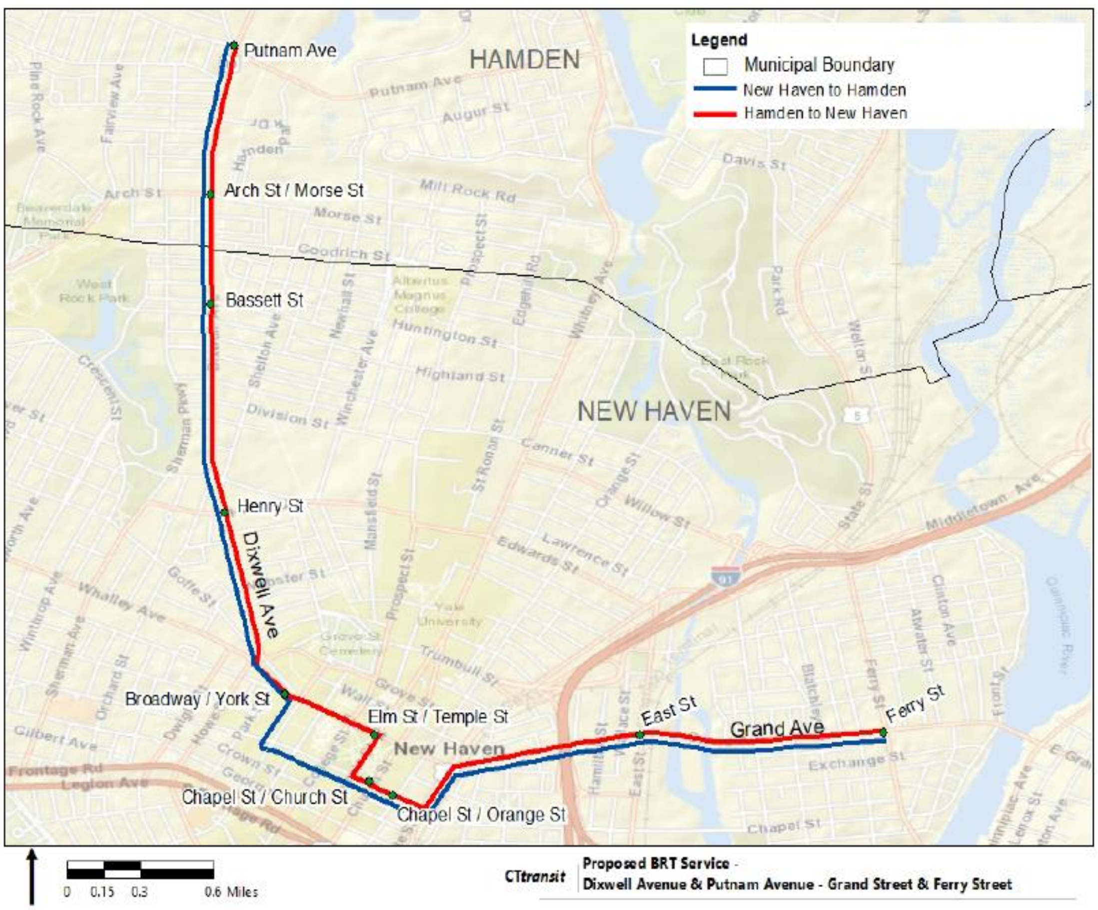
PUBLIC TRANSIT

The *Move New Haven* plan provides a comprehensive review of New Haven's transit operations and constraints. The following issues are of concern in the study area:

- Numerous bus transit routes enter State Street via Chapel Street. The routes that turn north on State Street are particularly challenged by maneuvering from the curbside stop on Chapel to turn left at the traffic signal.
- Travel times on the high ridership cross town routes, including along Grand Avenue, experience delays and slow travel times. One option to consider are transit priority features such as queue jump lanes, transit signal priority, or bus lanes.

The plan includes a recommendation to develop a BRT (Bus Rapid Transit) Overlay route along State Street between Chapel and Elm Streets, which will reduce the delays experienced by bus riders on several high ridership routes.

Figure 8: Potential BRT Overlay Route (MOVE New Haven)



The BRT Overlay could be implemented by incorporating transit priority and queue jump lanes at the Chapel/State and Elm/Grand/State intersections to reduce bus delays. Another option to address bus delays would be to convert Elm Street to a two-way street. This would greatly simplify bus circulation to and from the transit hub at Orange and Church Streets while allowing for more direct routing.

VEHICULAR TRAFFIC

State Street has been in its current configuration since a major reconstruction project was implemented around 1989. At the southern end of the study area, State Street operates as two, one-way couplets between Water and Chapel Streets, with State Street North providing the northbound flow. North of Chapel Street, State Street is a two-way street with a median. There is more detailed discussion of the lane configurations at each intersection later in this report.

Existing Traffic Volumes

The following table provides Average Daily Traffic (ADT) on State Street, which were collected on June 25, 2019.

Table 4: Average Daily Traffic (ADT) on State Street

Segment	*2020 Average Daily Traffic*
Between Grove and Wall	14,950
Between Court and Elm	15,350
Between Chapel and Crown	12,480
Between George and Water	13,580

Table 15. Signalized highway generalized service volume table.

Number Lanes	% Green Time	Speed Limit	Level of Service—B Service Volume	Level of Service—C Service Volume	Level of Service—D Service Volume	Level of Service—E Service Volume
2	40	35	12,800	14,900	16,400	18,700
2	40	40	12,600	14,400	15,900	17,700
2	40	45	12,000	14,200	15,500	17,400
2	40	50	11,800	13,800	15,200	16,700
2	40	55	12,300	14,100	15,400	16,900
2	40	60	12,700	14,300	15,500	17,100
2	45	35	14,600	16,900	18,500	21,100
2	45	40	14,400	16,300	18,000	20,000
2	45	45	13,900	16,100	17,600	19,700
2	45	50	13,600	15,700	17,200	18,900
2	45	55	14,200	16,000	17,400	19,100
2	45	60	14,600	16,200	17,600	19,300
2	50	35	16,500	18,900	20,700	23,600
2	50	40	16,300	18,300	20,100	22,300
2	50	45	15,700	18,100	19,600	22,000
2	50	50	15,500	17,700	19,200	21,100
2	50	55	16,100	17,900	19,500	21,400
2	50	60	16,400	18,100	19,600	21,500
2	55	35	18,400	20,900	22,900	26,000
2	55	40	18,100	20,300	22,200	24,700
2	55	45	17,600	20,000	21,700	24,300
2	55	50	17,400	19,600	21,300	23,400
2	55	55	17,900	19,900	21,500	23,600
2	55	60	18,300	20,100	21,700	23,800

The volumes shown above are well within the range that can be adequately served with one travel lane in each direction, with left turn lanes provided where warranted by turning volumes[2], even when considering the potential for future traffic growth. Vehicular turning movement counts were also conducted on June 25, 2019 and are included in Appendix 1. The peak hour turning movements are shown in Figures 9 and 10.

Future Traffic Scenario Development

A year 2040 future traffic scenario was developed using the CTDOT and LOTCIP guidance to determine traffic operations for a twenty-year design year. While the City's goals include increasing travel by walking, biking and public transit, the future traffic analysis scenario incorporates the Connecticut DOT's conventional practice of assuming 0.5% annual traffic growth in an urban area, resulting in 10% growth in traffic over 20 years. In addition to the annual growth, traffic from the following planned developments was also included in the future traffic volumes:

- 87 Union Street
- Audubon Square

Worksheets documenting the details on the future traffic scenario development are included in Appendix 2. It should be noted that the 2040 traffic scenario is not a forecast, but rather a planning scenario that shows what the traffic operations would be under the above assumptions.

The most recent available data on the commute patterns for the City of New Haven indicate that, since 2010, there has been a trend of reduced automobile commuting mode share and increasing mode shares for bicycling and public transit, as shown in Figure 11. This desirable trend is consistent with the City's goals of increasing walking, biking and public transit, and should be a strong consideration in the future design of the State Street corridor through downtown. If the City continues the desired trends of mode shifts from auto to walk, bike and transit, the 2040 peak hour vehicular traffic would be lower than the volumes used in this traffic analysis.

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[2] https://www.fhwa.dot.gov/policyinformation/pubs/pl18003/chap04.cfm; https://safety.fhwa.dot.gov/road_diets/guidance/info_guide/ch3.cfm#s335

Figure 9: Vehicular Turning Movement Counts on State Street: Grove Street to Elm Street

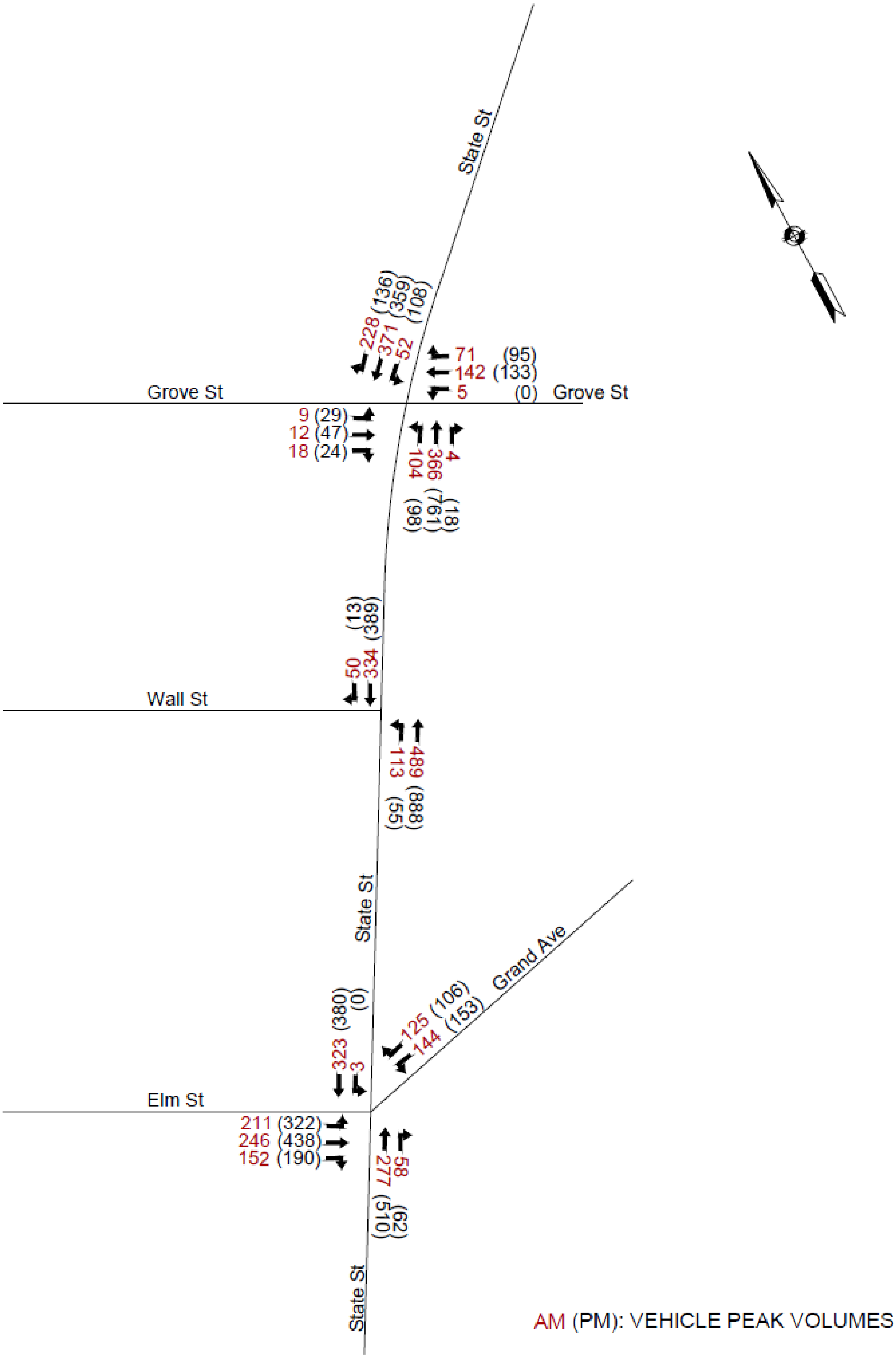
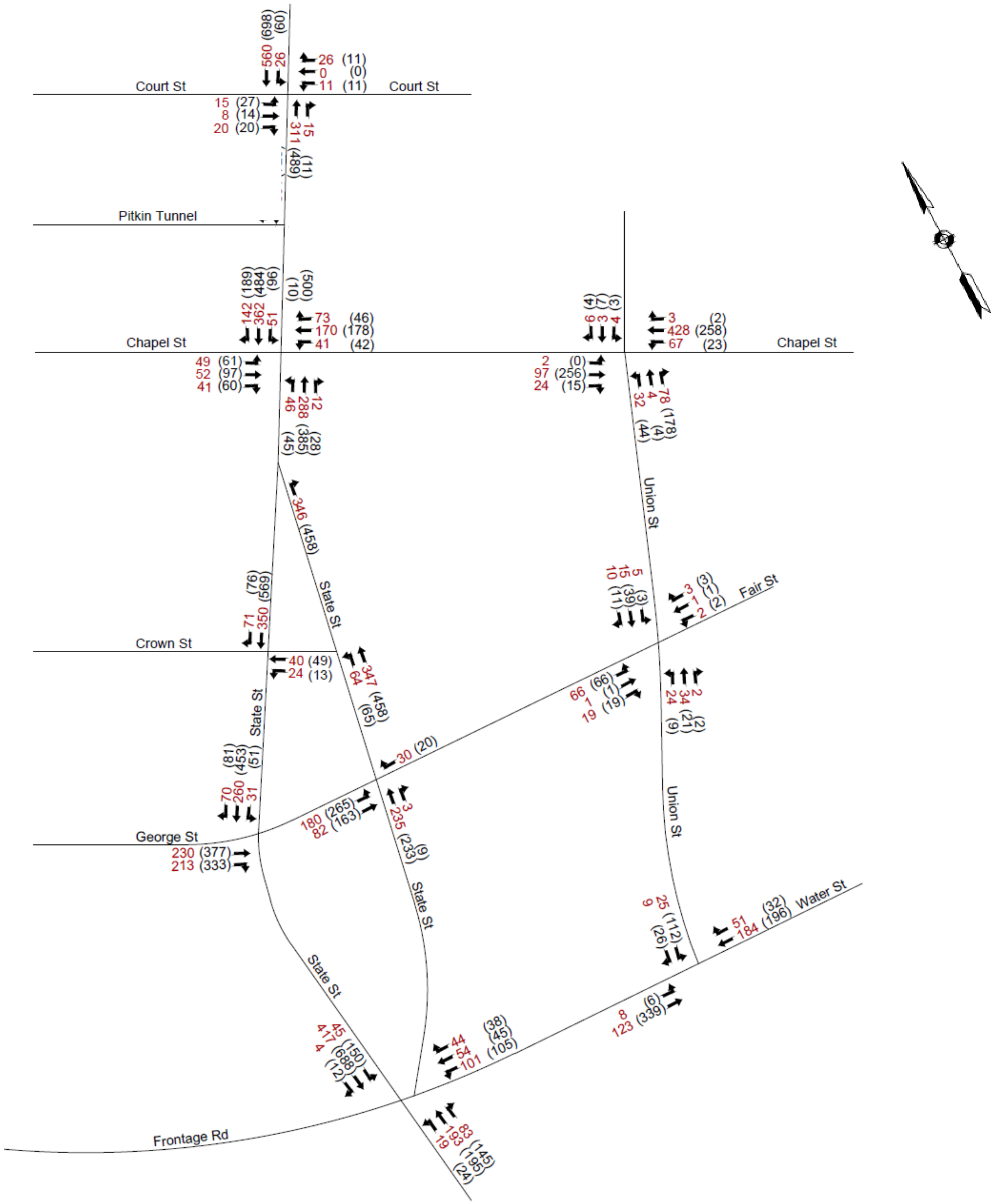
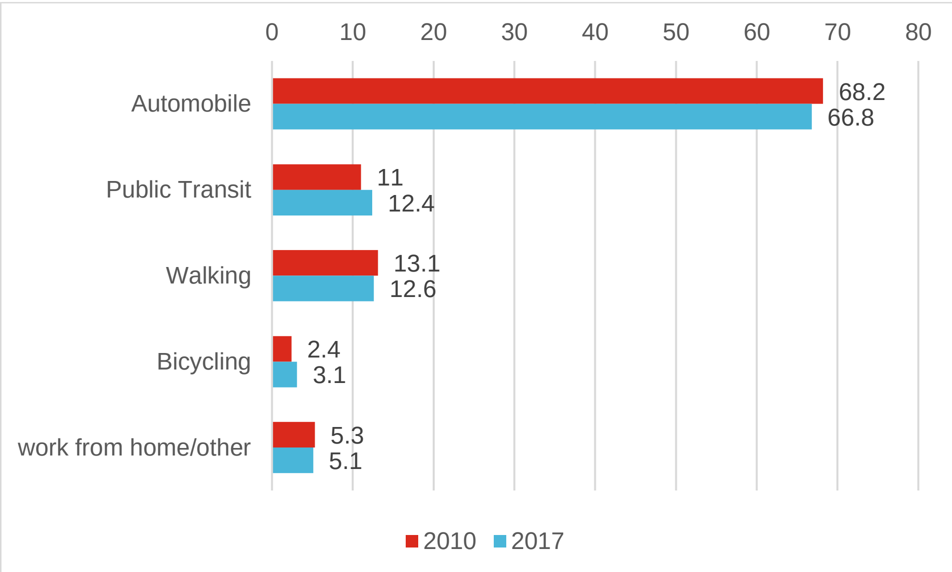


Figure 10: Vehicular Turning Movement Counts on State Street: Court Street to Water Street



AM (PM): VEHICLE PEAK VOLUMES

Figure 11: Commute Mode Share (%) for the City of New Haven (US Census Journey to Work data)



Existing and Future No Build Traffic Operations

The traffic operations analysis is focused on the signalized intersections from Grove Street in the north to Water Street in the south. At each intersection, the number and type of vehicle lanes, traffic signal timings and turning movement counts are used to determine the vehicular Level of Service (LOS), which is a qualitative measure of traffic congestion based on the average delay for a motorist. LOS A defines minimum traffic delay and is an indication that there is underutilized roadway capacity during the peak hour. LOS F represents high levels of traffic delay. The table below, excerpted from the Highway Capacity Manual, provides LOS criteria for signalized and unsignalized intersections.

Table 5: Level of Service Average Stopped Delay (seconds/vehicle)

Level of Service	Average Stopped Delay (seconds/vehicle)	
	Signalized Intersection	Unsignalized Intersection
A	0.0–10.0	0.0–10.0
B	10.1–20.0	10.1–15.0
C	20.1–35.0	15.1–25.0
D	35.1–55.0	25.1–35.0
E	55.1–80.0	35.1–50.0
F	>80.0	>50.0

Source: Highway Capacity Manual, 2000. Transportation Research Board.

One weakness of using vehicular level of service as a primary measure of traffic operations is that the use of a letter grade scale implies that “A” is the best condition. LOS A or B means that there is excess vehicle capacity, which has negative consequences like speeding, endangering people walking or biking. There are no national standards for LOS, and cities or states have discretion to adopt LOS targets that reflect their unique constraints and their tolerance for traffic congestion. The Connecticut Department of Transportation design standard for urban arterials is LOS D.

Synchro software was used to evaluate the peak hour traffic operations in the study area, including signalized and unsignalized LOS, as well as corridor-wide performance. The table below shows the current and future no build AM and PM LOS for the signalized intersections in the study area for the current and future conditions, assuming the same configuration and signal operations are still in place in 2040.

Table 6: Signalized Intersection Operations Summary – Existing (2020) and Future (2040) No Build Conditions

Intersection	*2020 AM LOS*	*2020 PM LOS*	*2040 AM LOS*	*2040 PM LOS*
State/Grove	C	C	C	C
State/Elm/Grand	C	C	C	C
State/Court	B	C	B	C
State/Pitkin	A	B	A	B
State/Chapel	D	D	D	D
State St/George/Fair	C	C	C	D
State St N/Fair	A	A	A	B
State St/Water	C	C	C	C

Most of the intersections have peak hour LOS is C or better, except for Chapel and George/Fair in the 2040 PM peak hour.

Another aspect of traffic operations that affects one's perception of congestion is traffic signal coordination. Currently, the signal cycle lengths change along the corridor vary between 60 seconds and 100 seconds, depending on the time of day, as shown in the table below, making full coordination impossible. A uniform signal cycle length for the entire State Street corridor would improve signal coordination and reduce driver frustration.

Table 7: Existing Signal Cycle Lengths

Intersection	*AM Peak*	*Mid-day*	*PM Peak*	*Other (night, weekend)*
State/Grove	90	80	90	60
State/Elm/Grand	90	80	90	60
State/Court	90	90	90	80
State/Pitkin	90	90	90	80
State/Chapel	90	90	90	80
State St/George/Fair	100	100	100	100
State St N/Fair	100	100	100	100
State St/Water	100	100	100	100

Synchro software considers signal coordination and provides arterial corridor measures of average travel time and speed for each direction, which provide an indicator the combined effects of signal coordination and delay at signalized intersections. Arterial performance measures are shown in Table 8 for 2020 and 2040 conditions.

Table 8: Arterial Performance Measures for State Street from Grove Street to Water Street

Period	**Direction**	**2020 Travel Time (sec)**	**2020 Average Speed (mph)**	**2040 Travel Time (sec)**	**2040 Average Speed (mph)**
AM	Northbound	158	9.0	146	9.8
	Southbound	262	9.1	242	9.8
PM	Northbound	288	8.3	251	6.4
	Southbound	241	6.7	302	7.9

More detail on intersection and corridor operations is provided in the Synchro reports, included in Appendix 3.

PROPOSED CONDITIONS

The process that yielded this report involved working closely with several City Departments to develop a future street configuration that will allow the advancement of several goals, including a safer and more multimodal street, and allow room for transit-oriented development on several adjacent parcels, as shown in Figure 1.

DESIGN OBJECTIVES

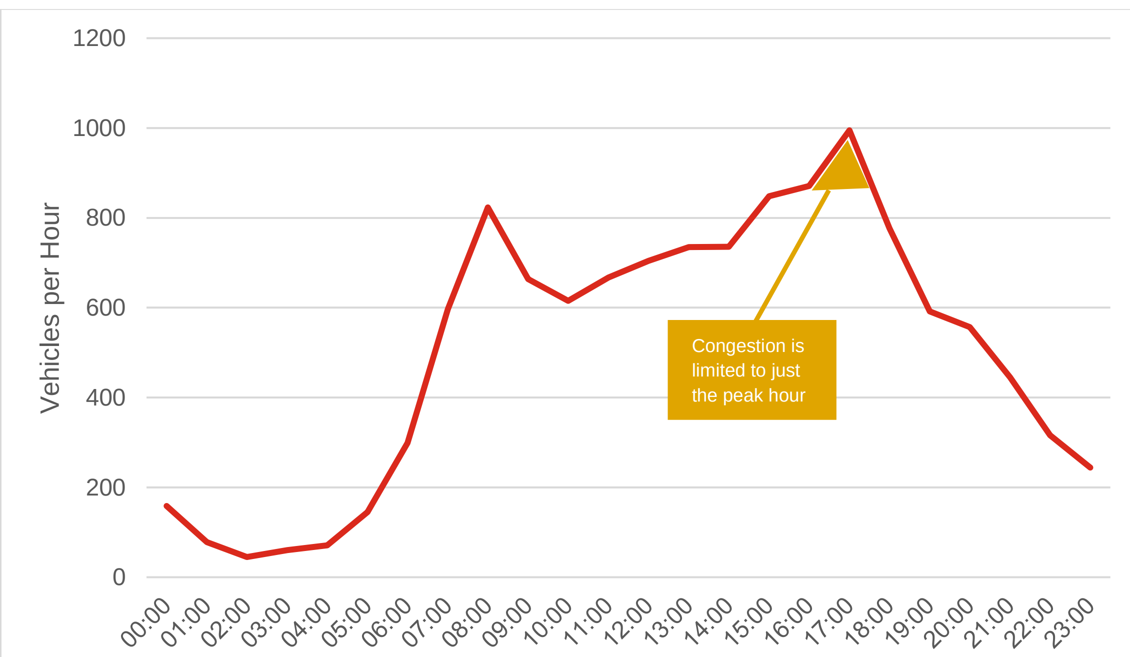
This project will apply current best practices for multimodal street design. The following guidance documents have been used in the development of these recommendations and provide more detailed design guidance that can be referred to as this project moves forward.

- NACTO Urban Street Design Guide (NACTO, 2013)
- Separated Bicycle Lane Guide, (FHWA, 2015)
- MassDOT Separated Bicycle Lane Planning and Design Guide
- Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts (FHWA-HEP-16-055)
- Connecticut Pedestrian Safety Guide (CTDOT, July 2019)
- CT DOT Highway Design Manual

Vehicular Circulation

The overall goal is to make State Street more efficient and equitable for all people, regardless of mode, which can be accomplished by targeting an appropriate vehicular level of service and volume-to-capacity ratio during the peak hours. Traffic congestion should be tolerated for a relatively short period of each weekday, in order to provide access and mobility for other modes over the full day. The chart below shows the hourly traffic volumes on State Street between Chapel and Crown, which has a sharp peak in traffic volume between 5 and 6 PM, indicating that any congestion during peak hour conditions is likely to diminish quickly.

Figure 12: Hourly Volumes on State Street between Chapel and Crown (June 25, 2019)

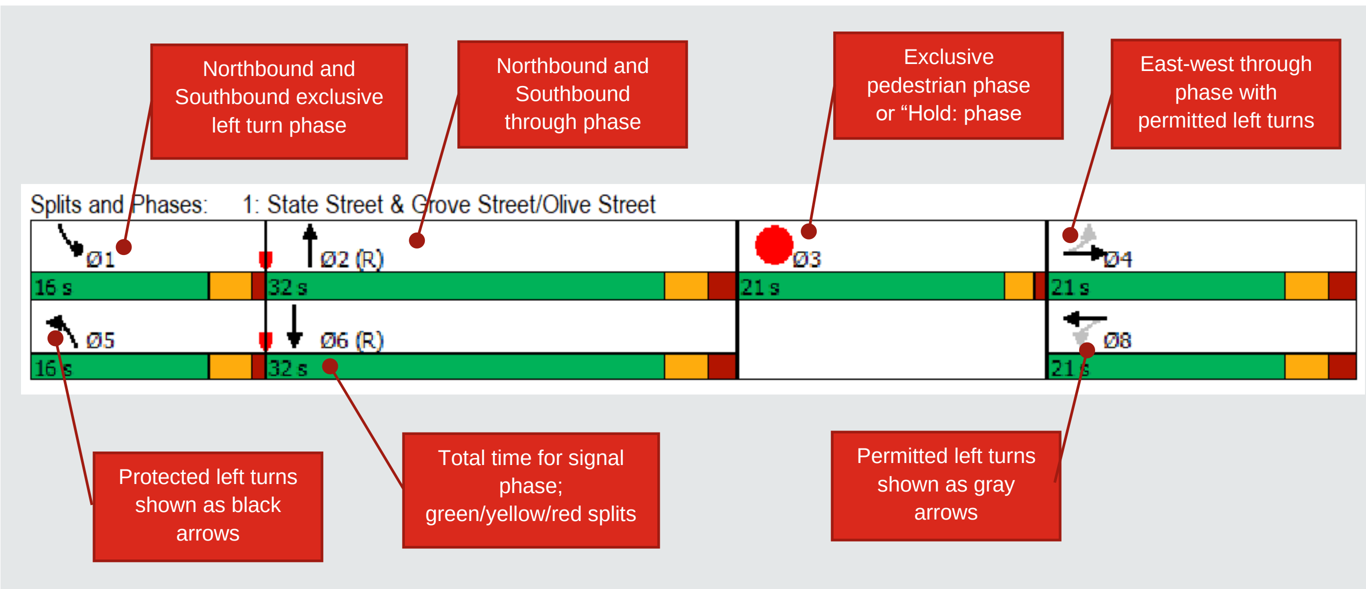


In the following traffic analysis of proposed conditions, the following design objectives apply to traffic operations:

- Target the overall LOS at D, with all approaches to be LOS E or higher.
- Maintain a continuous cycle length of 90 seconds along the entire corridor for improved coordination.
- Wherever possible, use concurrent pedestrian phases with Leading Pedestrian Intervals (LPI), which is expected to increase compliance with the pedestrian signal, reduce delay to pedestrians, and improve safety.

The following pages describes the proposed intersection geometry and signal phasing at each signalized intersection and compares to existing conditions. The Synchro signal phasing diagrams are provided to explain the proposed signal operations. The figure below provides a legend to the signal phasing diagrams.

Figure 13: Signal Phasing Diagram Legend



Pedestrian Safety, Comfort and Convenience

To create a safer and more conducive environment for walking, and to encourage growth in pedestrian and transit mode shares, the following are incorporated into the proposed changes.

- Reduce delay for pedestrians by implementing concurrent pedestrian phasing where possible. Observations and data collected by CDOT indicates that pedestrians often cross without waiting for the signal. Providing concurrent crossing will reduce delay for pedestrians and increase compliance and service with the pedestrian signals.
- Provide a Leading Pedestrian Interval (LPI), which is a short exclusive pedestrian phase in advance of a concurrent phase. This allows waiting pedestrians to get a head start and be more visible to turning traffic and reduces conflicts.
- Provide exclusive left turn phases where feasible to reduce the potential for conflict between pedestrians or bicyclists crossing and left turning vehicles.
- Reduce crossing distances at intersections by minimizing the number of travel lanes and providing curb extensions or bumpouts.
- Reduce traffic speeds by eliminating the opportunities for vehicle passing wherever possible.

Bicycle Infrastructure

Both alternatives include a two-way separated bike facility on the east side of State Street, which will provide a low-stress, high-comfort facility and attract riders of all ages and abilities. It will connect riders to the State Street Station for rail service, to downtown, and serve as a through route for cross-town trips. It will be a key connection between the Farmington Canal Heritage Trail and the Wooster Square neighborhood. Two-way separated bicycle lanes have some advantages over one-way separated bicycle lanes, including a smaller overall footrpint, and higher comfort riding, and more ability for faster riders to pass slower riders using the oncoming bicycle lane

However, a disadvantage of two-way separated bicycle lanes is that they require special consideration at intersections, as bicycles are traveling in a direction that may not be expected by motorists. Therefore, the following considerations are reflected in the proposed conditions.

- Reduce conflicts from left- or right-turning vehicles with protected phasing or exclusive bicycle phases where required. The *MassDOT Separated Bicycle Lanes Planning and Design Guide* thresholds will be considered in the absence of existing Connecticut or national guidance.
- Protected intersections, which provide safe places for bicycles to wait to cross and enhance visibility of bicyclists to motorists, should be included where feasible.

Two-way separated bicycle lanes can conflict with curbside uses and turning traffic at intersections. An evaluation of potential conflicts along State Street that considers locations along each side of the street with high turning traffic conflicts (more than 100 vehicles per hour for right turns or 50 vehicles per hour for left turns), moderate conflicts (fewer than 100 vehicles per hour for right turns or 50 vehicles per hour for left turns) or curbside uses (parking or bus stops).High turning conflicts will require signalization to separate the turning traffic from the bicycle movements. Figure 14 shows the results, which indicates that there are more conflicts on the west side of State Street than on the east side, including turning traffic (in particular Pitkin Tunnel and parking garage entrance), on-street parking, and bus stops.

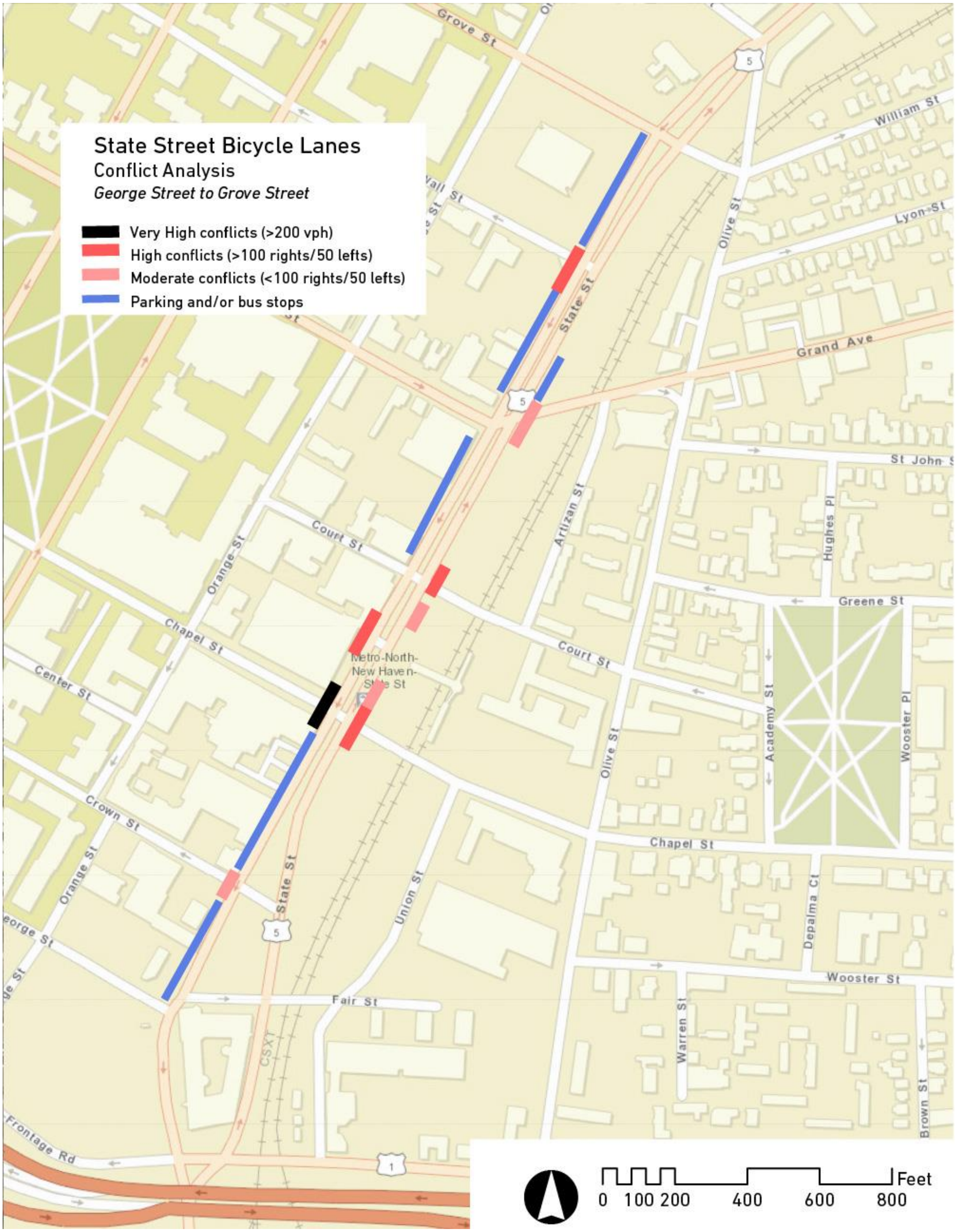
Two-way separated bicycle lanes at signalized intersections can use the vehicle's green phase if there are only moderate conflicts with turning traffic. With separated bicycle lanes on the east side of State Street, there will be three signalized intersections that need to be evaluated for turning conflicts. The table below shows the turning conflicts at each intersection during the AM and PM peak hours.

Table 9: Turning Conflicts at Signalized Intersections (hourly peak hour vehicle turning conflicts)

INTERSECTION	AM Northbound Right turns	AM Southbound Left turns	PM Northbound Right turns	PM Southbound Left turns	Phase separation needed?
ELM & GRAND	64	20	68	33	No
COURT	17	29	12	66	Yes (SB Left)
CHAPEL	13	38	31	76	Yes (SB Left)

The above table demonstrates that the southbound left turning vehicles at Court Street and Chapel Street will need to be separated phase from the bicycle movements. This can be accomplished with providing protected left turn phase at these two intersections, allowing the bicycle movements to travel on the through green phase.

Figure 14: Bicycle Lane Conflict Analysis



Transit Priority

The modernization of New Haven's transit system is important to achieving the City's mode shift and equity goals. This project provides an opportunity to improve bus travel and operations along State Street that will benefit a significant number of people using the regional transit system. Two alternatives are considered for bus transit enhancements:

1) Convert Elm Street to 2-way traffic to improve bus circulation to downtown and reduce rider delay, particularly for several high ridership routes.
2) Queue jump lanes on the Chapel Street and Grand Avenue approaches to State Street will reduce bus travel times along the State Street corridor between Elm/Grand and Chapel for several high ridership routes. Elm Street remains a one-way street in this scenario

ALTERNATIVE 1 – TWO-WAY ELM STREET

This alternative includes the following proposed changes to State Street:

- Reconfiguration of State Street to have one through travel lane in each direction wherever possible and turn lanes where needed at intersections.
- Elm Street is converted to two-way operation, alleviating bus route delays and reducing vehicle-miles traveled in downtown New Haven.
- Traffic signals will have a Leading Pedestrian Interval (LPI) and concurrent pedestrian phasing wherever possible to reduce pedestrian delay and increase intersection efficiency.
- Two-way separated bicycle lanes on the east side of State Street will be provided and will use the existing traffic signals to guide their movements.
- State Street North is closed to vehicles, with the right-of-way used for bicycle infrastructure between Water and Fair Streets, and for redevelopment projects north of Fair Street, per the Utile plan.

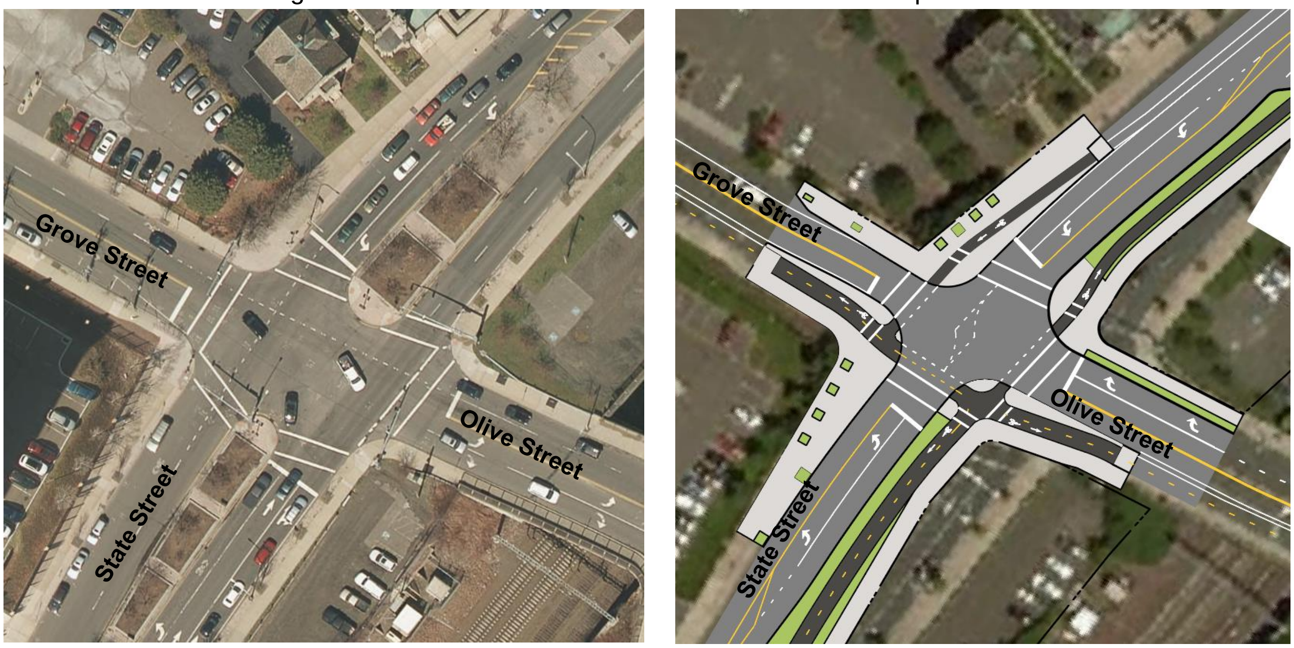
The following pages describe each intersection in detail, and the exhibit attached as Appendix 4 illustrates the design concept.

State Street & Grove Street

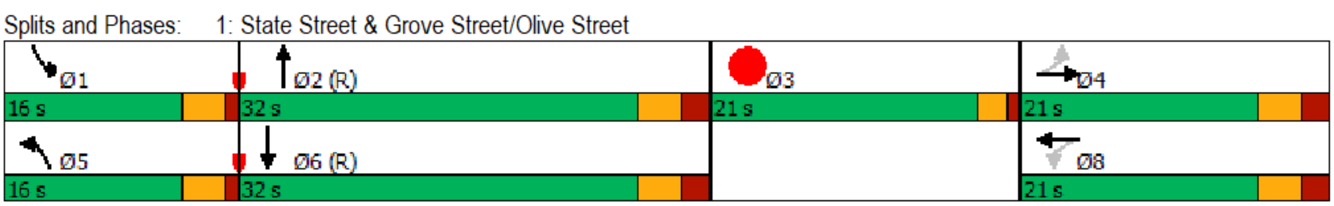
Lane assignments were adjusted to provide through lane in each direction on State Street, with exclusive left turn lanes in each direction. Olive and Grove Streets can each be narrowed to have one through lane in each direction, plus an exclusive right turn lane on Olive Street,

Figure 15: Existing and Proposed Lane Conditions for State Street & Grove Street & Olive Street

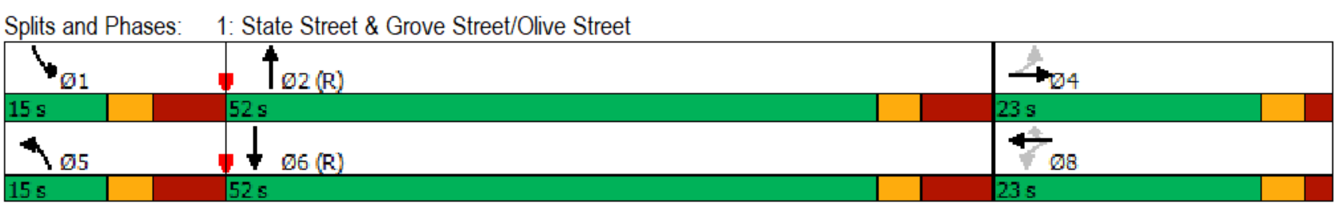
Existing Conditions | Proposed Conditions



Existing Phasing



Proposed phasing



The intersection width and footprint will be substantially smaller, reducing the exposure for pedestrians, and encouraging lower vehicle speeds. State Street will have one travel lane in each direction and exclusive left turn lanes. Grove Street and Olive Street will also be narrower, with one through lane in each direction, plus a right turn lane on Olive Street. The pedestrian phasing will change from exclusive to concurrent with a 3 second LPI in each direction.

State Street & Elm Street & Grand Ave

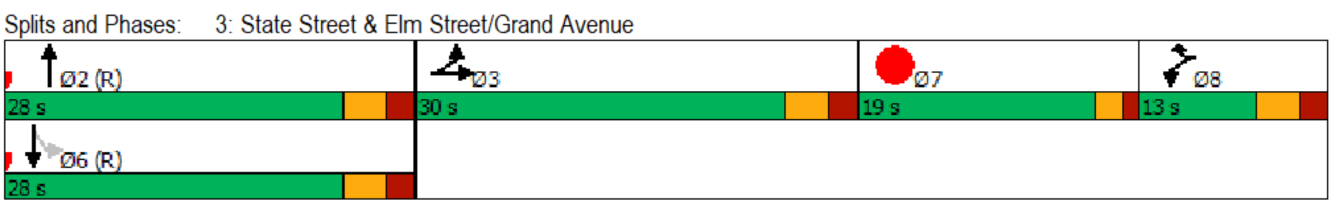
State Street will have one through lane with exclusive left turn lanes in each direction. Southbound left turns onto Grand Avenue will be permitted. Elm Street will be two-way. Both Grand Avenue and Elm Street will have three lane approaches with exclusive right-turn, through and left-turn lanes. The approach geometry will shift Grand Avenue to shift to the south, enabling opposing left turns from Elm and Grand to move simultaneously.

Figure 16: Existing and Proposed Lane Conditions for State Street & Elm Street & Grand Ave

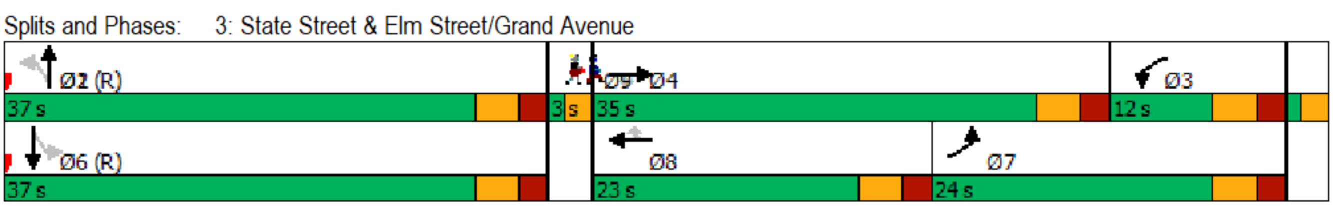
Existing Conditions

Proposed Conditions

Existing Phasing (exclusive pedestrian phase shown as hold phase)



Proposed phasing (3 second LPI and concurrent phase for east-west and north-south crossings)

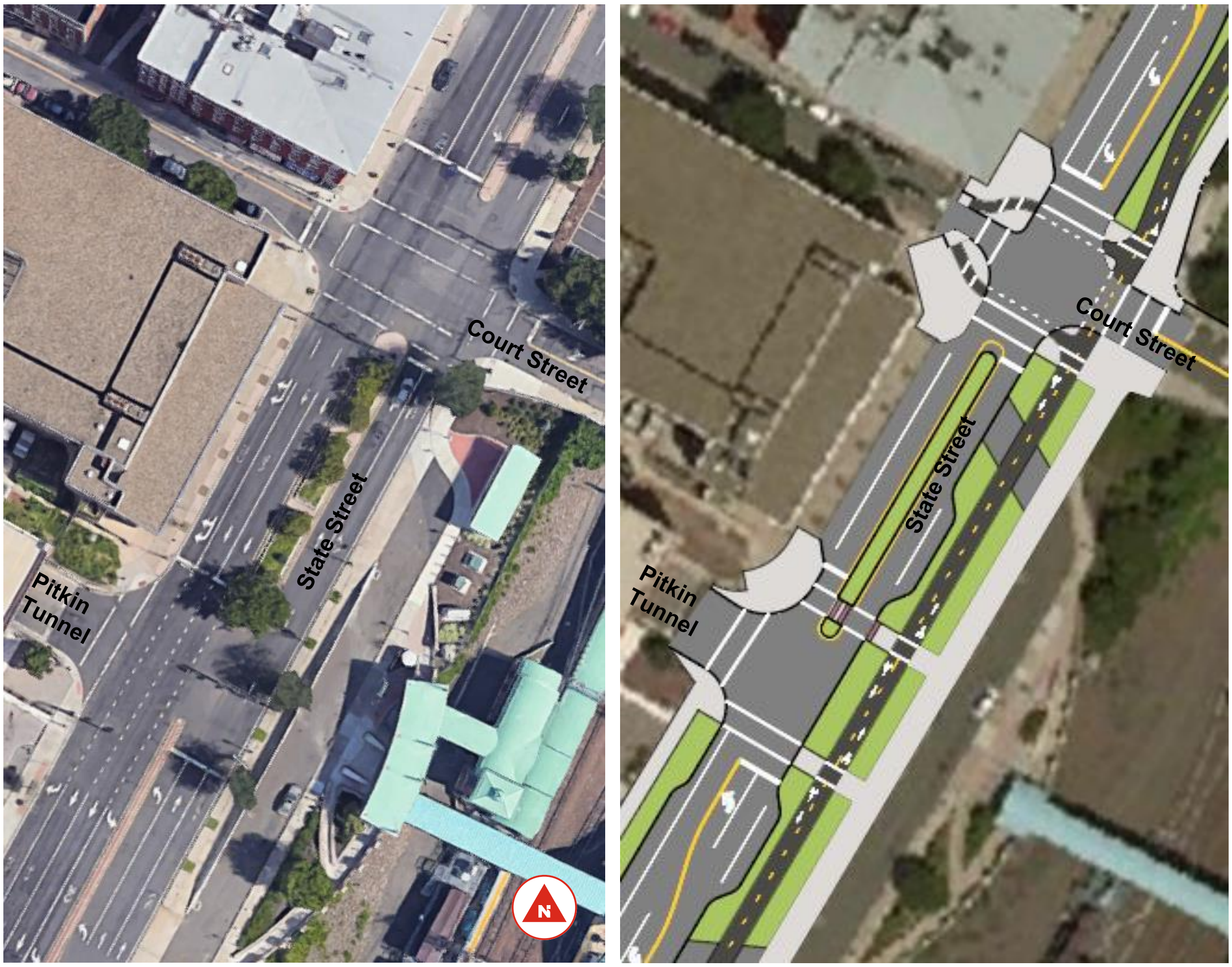


The final design and signal operation of this intersection should consider the tradeoffs of adding leading pedestrian intervals, which may reduce the overall level of service to E but provide greater safety for pedestrians. It is recommended that updated traffic counts be conducted before final design, as many cities are seeing sustained reduced peak hour traffic due to more people working from home.

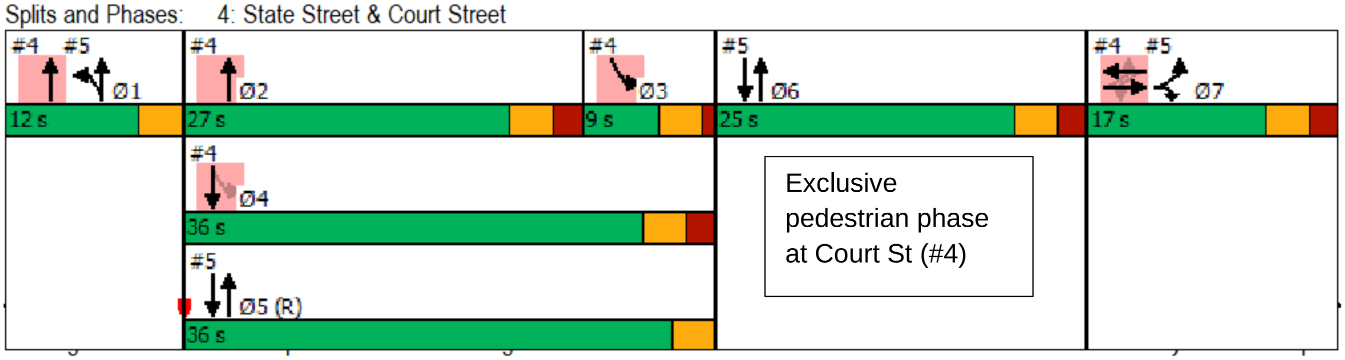
State Street & Court Street and Pitkin Tunnel Entrance

These two signalized intersections operate with one controller. The existing and proposed geometry are illustrated in the following figures. The proposed conditions have one through travel lane in each direction on State Street. Pedestrian crosswalks are provided at the Pitkin Tunnel signal.

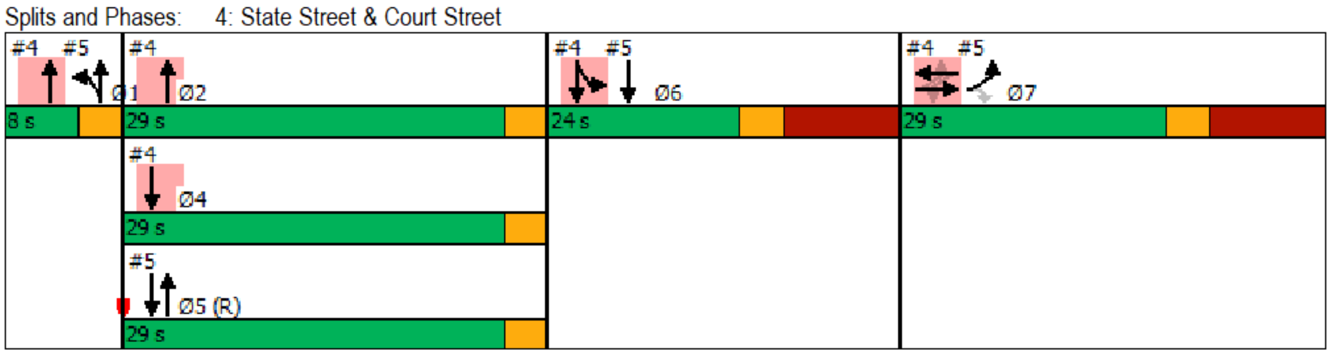
Figure 17: Existing and Proposed Conditions – State Street & Court Street and Pitkin Tunnel



Existing Phasing



Proposed Phasing (includes 3 second LPI for each crossing)

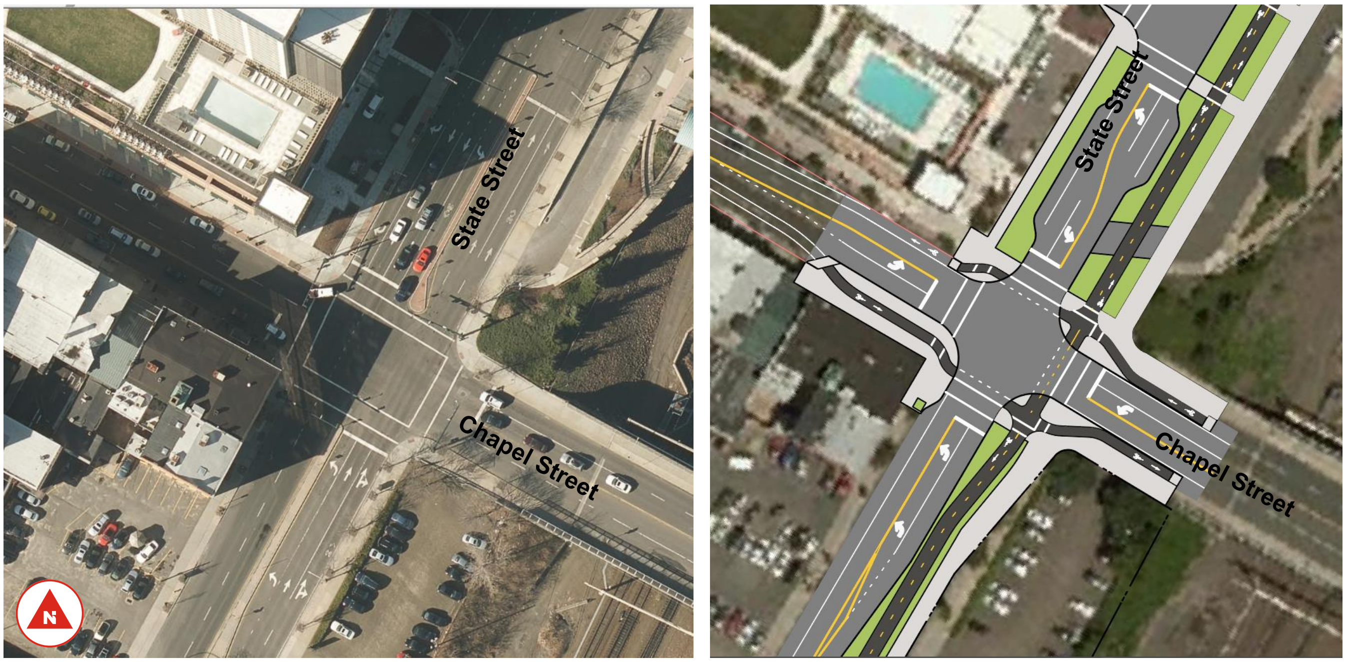


The pedestrian phasing will be changed to concurrent, allowing pedestrians to cross State Street during phase 7. Crosswalks are proposed to be added at the Pitkin Tunnel intersection, enhancing pedestrian access to the State Street Station. The crossing distance will be significantly shorter. If desired, a median can be maintained between Court and Pitkin Tunnel to further enhance pedestrian safety and comfort while crossing State Street.

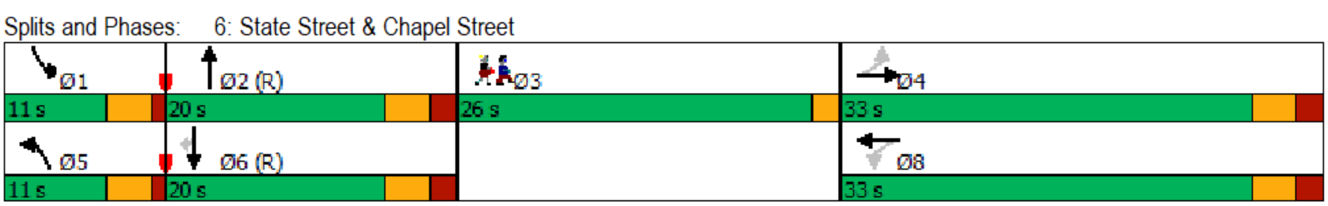
State Street & Chapel Street

State Street will have one travel lane in each direction and exclusive left turn lanes. With Elm Street converted to two-way operation, bus routes are likely to change, and there may be fewer buses turning from Chapel onto State Street. It is also expected that there will be fewer southbound right turns, as some of these vehicles will instead turn right at Elm Street.

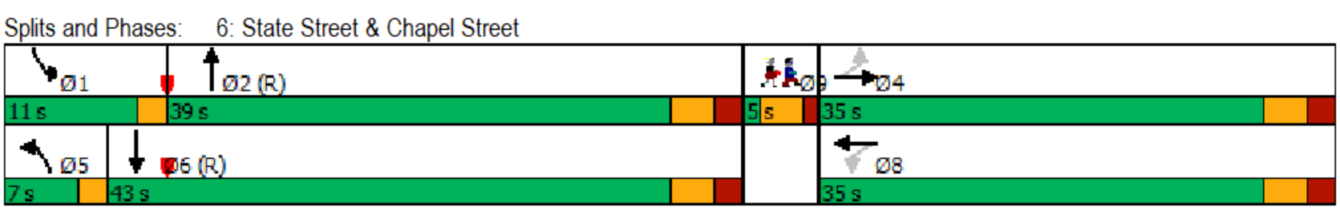
Figure 18: Existing and Proposed Conditions at State Street & Chapel Street



Existing Phasing



Proposed Phasing (includes 3 seconds for LPI for crossing State Street)

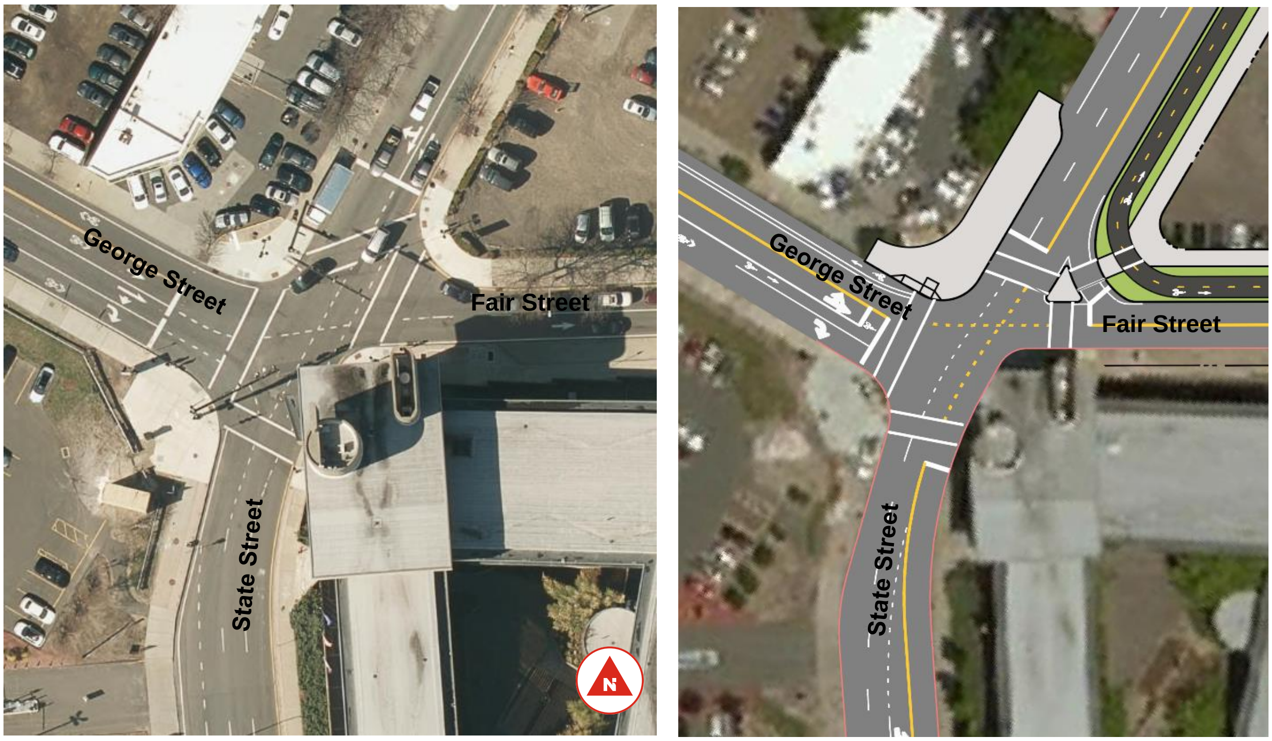


The existing phasing provides a long exclusive pedestrian phase, which is dictated by the need for pedestrians to clear the long distance across State Street. In the proposed conditions, the phasing is changed to concurrent pedestrian phases with a 5 second LPI for the State Street crosswalk. This will result in less delay for pedestrians, improving compliance and service for pedestrian crossings. Bicycles will be able to cross Chapel Street on the vehicle green phase.

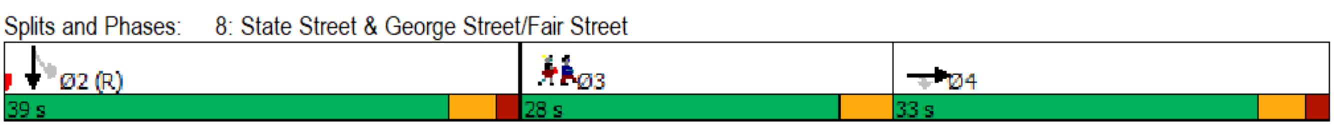
State Street & George Street & Fair Street

This intersection will see a significant change in operations, as Fair Street changes from one-way eastbound to a two-way street. State Street is proposed to have two southbound lanes, but only one northbound lane is needed to maintain LOS D.

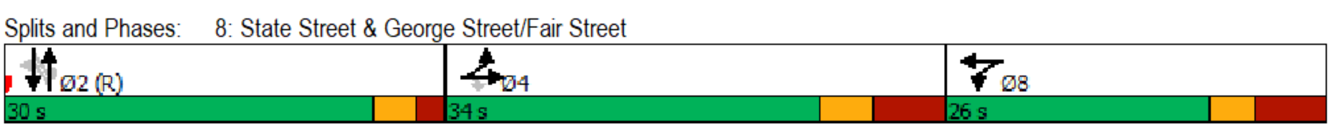
Figure 19: Existing and Proposed Conditions at State Street & George Street & Fair Street



Existing Phasing



Proposed Phasing (LPI is included in 5 second all-red following phases 4 and 8)



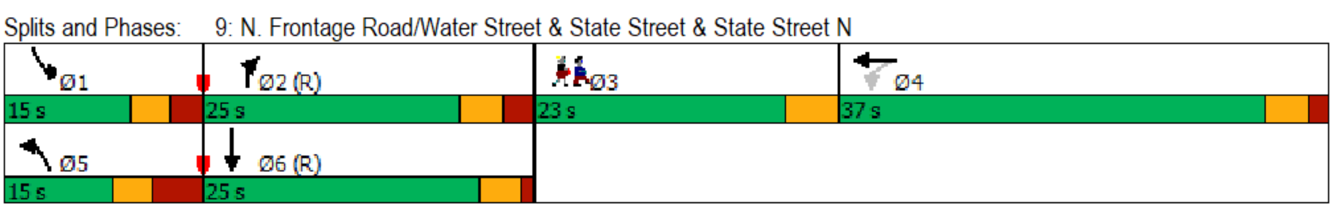
Currently, there is a long exclusive pedestrian phase, operating at a 100 second cycle length. In the proposed conditions, pedestrians cross concurrently during phases 2 and 8, with 3 second LPI (shown with additional all red time).

State Street & Water Street

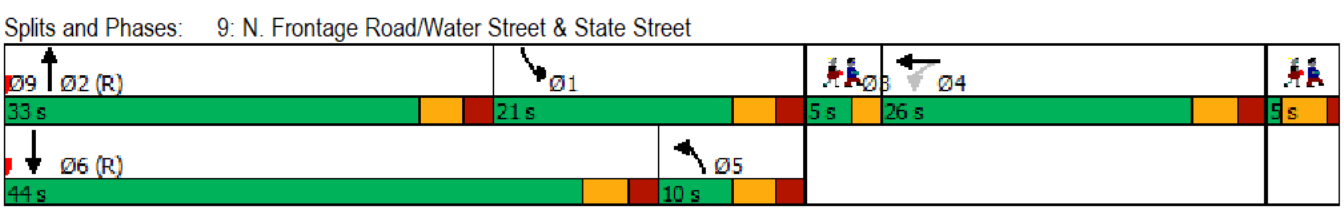
This intersection is reconfigured so that State Street is a two-way street, and State Street North is closed to vehicular traffic, and designed as a bicycle route.

Figure 20: Existing and Proposed Conditions at State Street & Water Street

Existing Phasing



Proposed Phasing

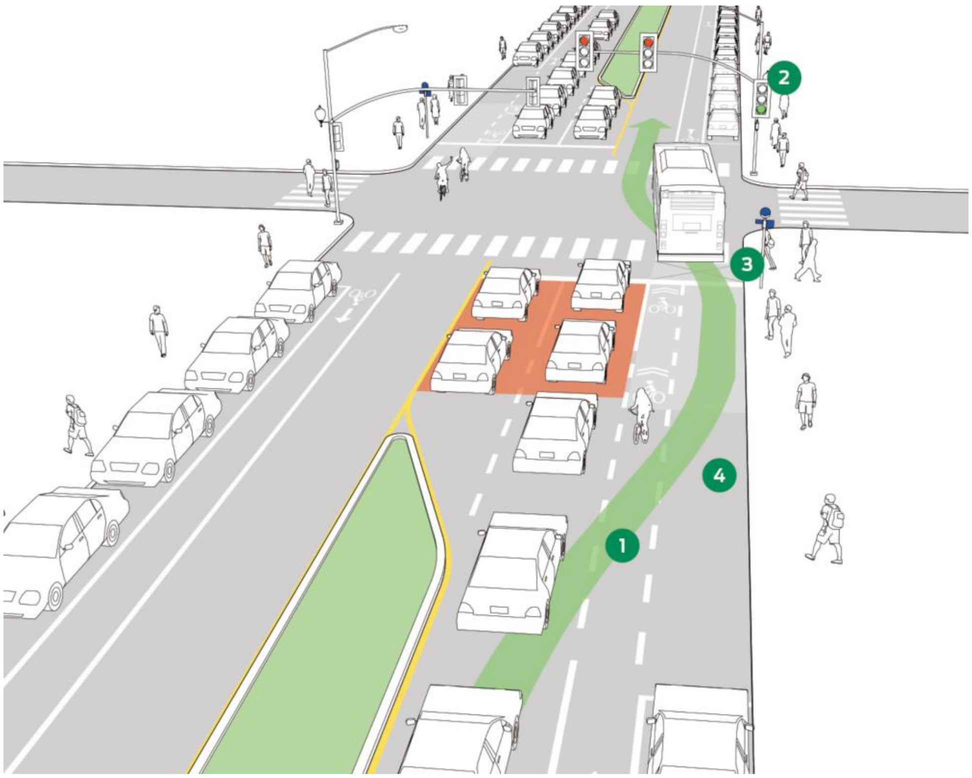


The proposed signal phasing provides 5 second LPI for both crossing directions and lagging protected left turn phases.

ALTERNATIVE 2 – QUEUE JUMP LANES

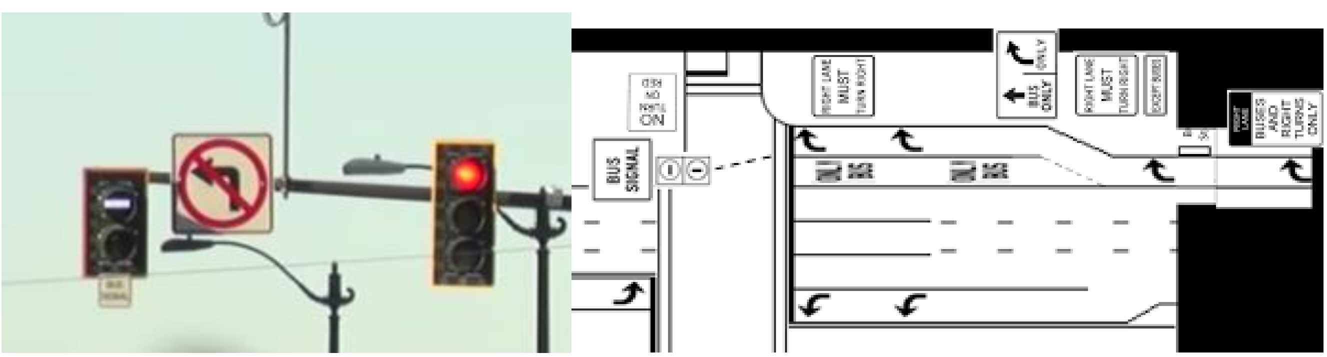
This alternative will be nearly identical to Alternative 1 in terms of lane geometry and separated bicycle lanes. The primary difference is that Elm Street will remain as a one-way street, and bus queue jump lanes will be provided at the two critical approaches for bus circulation: on Chapel Street and Grand Avenue. The queue jump lanes will be combined with Transit Signal Priority (TSP), which will detect a waiting bus and provide a signal to allow the bus through the intersection ahead of other traffic.

Figure 21: Queue Jump Lane Concept (NACTO Urban Street Design Guide)



The queue jump lanes will include bus detection and signal priority, likely utilizing signal faces that were developed for Light Rail Transit (LRT) and approved for use in bus queue jump lanes in 2006 in the MUTCD. The examples below show the signal face display and an example bus queue jump lane design.

Figure 22: Examples of LRT Signal Displays used for Bus Queue Jump Lanes



This alternative will have nearly identical traffic operations as Alternative 1 at all intersections except for Elm & Grand, and Chapel, which are discussed in more detail on the following pages.

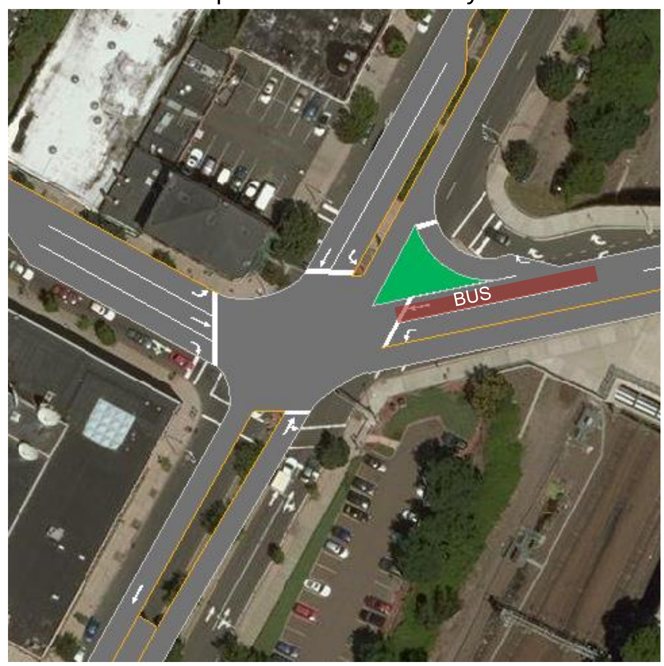
State Street & Elm Street & Grand Ave

State Street will have one through lane in each direction. A southbound exclusive left lane can be accommodated to allow turns onto Grand Avenue, which is currently not permitted. There will be one eastbound through lane from Elm to Grand, which allows the alignment of Grand to shift to the south and enables opposing left turns from Elm and Grand to move simultaneously. A queue jump lane can be accommodated within the intersection's existing footprint, as there will be only one westbound left turn lane.

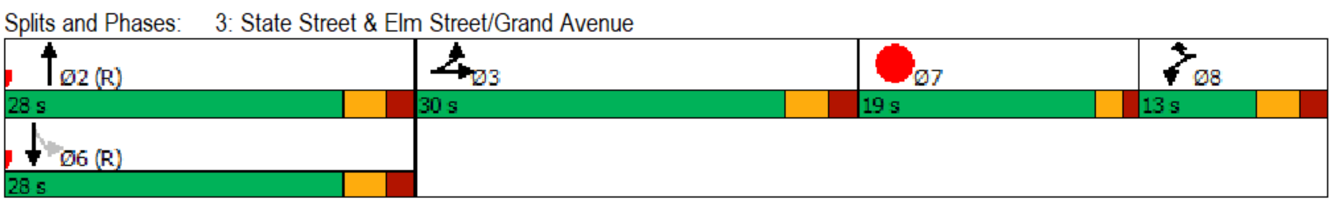
Figure 23: Existing and Proposed Lane Conditions for State Street & Elm Street & Grand Ave

Existing Conditions

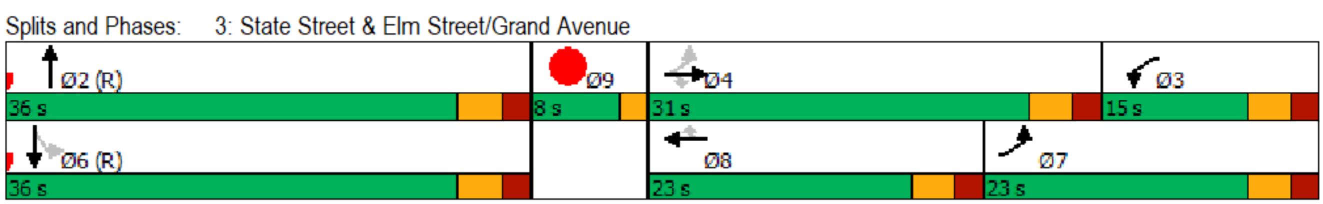
Proposed Lane Geometry



Existing Phasing



Proposed phasing (Hold phase includes 8 seconds for bus priority phase)

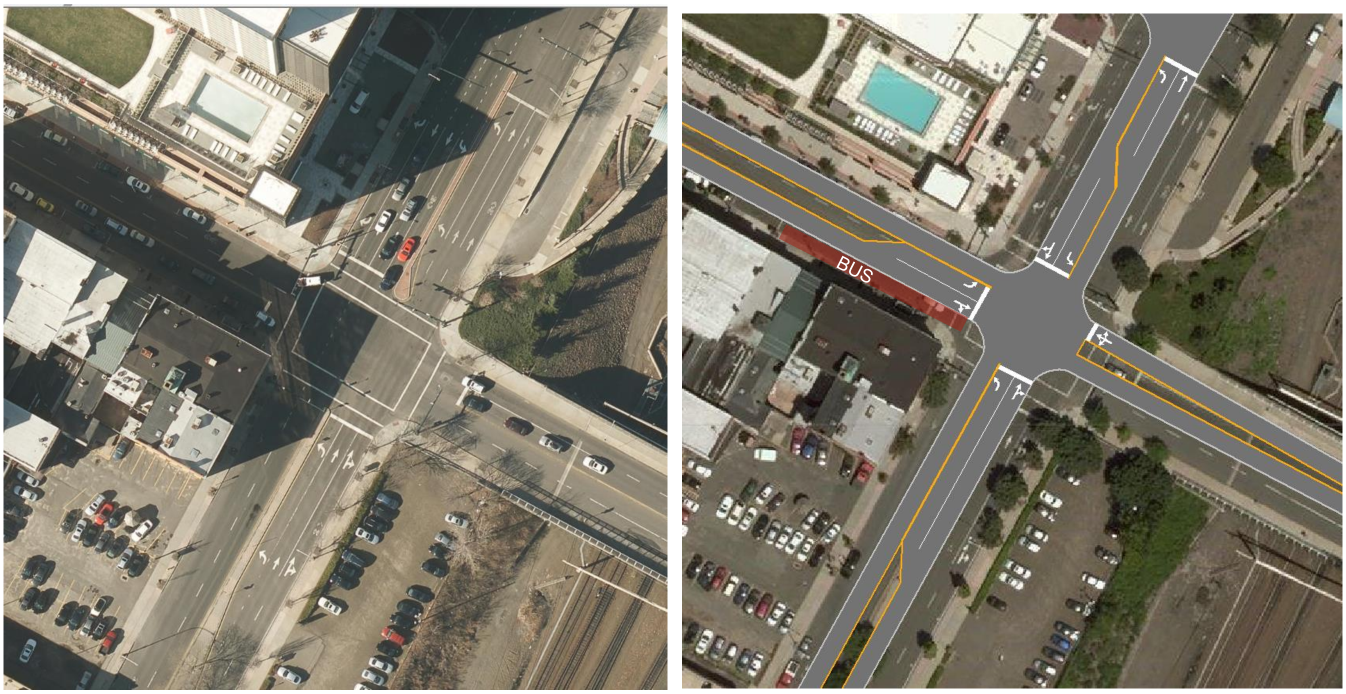


The transit signal priority will provide a hold phase of 5 seconds under the proposed conditions, where all traffic is stopped except for buses in the queue jump lane on Grand Avenue. Pedestrians crossing State Street have a 3 second LPI followed by concurrent phase. Pedestrians crossing Elm and Grand will have a concurrent pedestrian phase, as there are no turning conflicts along Elm, and few pedestrians cross Grand Avenue.

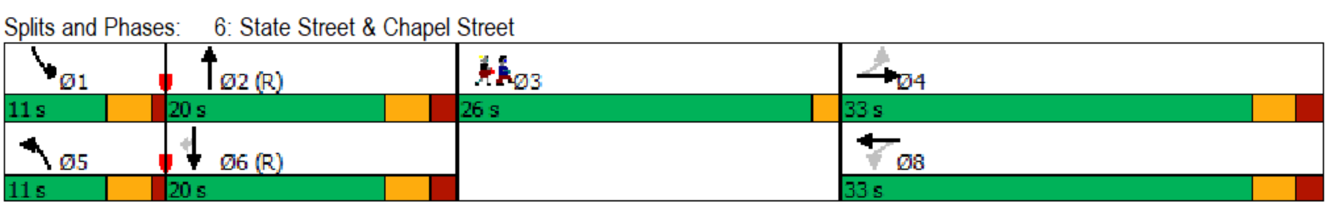
State Street & Chapel Street

This intersection sees significant bus traffic, with numerous buses stopping along the curb on Chapel as it approaches State Street, and then turning left onto State Street to head north. The proposed conditions have one through travel lane in each direction on State and Chapel Streets, which exclusive left turn lanes on the northbound, southbound and eastbound approaches. The bus queue jump lane will be along the curb on Chapel Street.

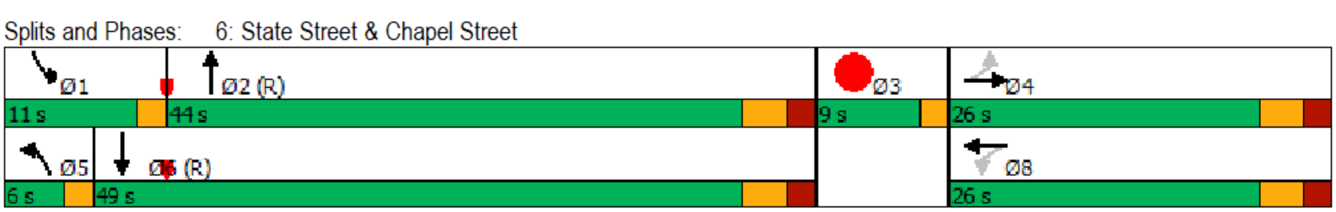
Figure 24: Existing and Proposed Conditions at State Street & Chapel Street



Existing Phasing



Proposed Phasing



The existing phasing provides a long exclusive pedestrian phase. In the proposed conditions, the phasing is changed to have concurrent pedestrian phases with LPI. In the above phasing diagram, the 9 second hold phase accounts for both the exclusive transit phase of 6 seconds and LPI of 3 seconds.

ANALYSIS OF PROPOSED 2040 CONDITIONS

A 2040 traffic volume scenario was developed for the vehicular traffic analysis to be consistent with the LOTCIP requirements.

Pedestrian Conditions

The pedestrian conditions will be significantly safer and more convenient for pedestrians due to shorter crossing distances and shorter wait time due to the concurrent phasing. The table below summarizes the changes.

Table 10: Existing and Proposed Future Pedestrian Signal Operations and Crossing Distances

Intersection		*Pedestrian Phasing Alternative 1*	*Pedestrian Phasing Alternative 2*	*Existing crosswalk length (feet)*	*Proposed crosswalk length (feet)*
State/Grove	Exclusive	Concurrent w/ LPI	Concurrent w/ LPI	93	33
State/Elm/Grand	Exclusive	Concurrent w/ LPI	Concurrent	75	38
State/Court	Exclusive	Concurrent w/ LPI	Concurrent w/ LPI	75	33
State/Pitkin	No Crosswalk	Concurrent w/ LPI	Concurrent w/ LPI	n/a	38
State/Chapel	Exclusive	Concurrent w/ LPI	Concurrent	75	33
State/George/Fair	Exclusive	Concurrent w/ LPI	Concurrent w/ LPI	56	35
State/Water	Exclusive	Concurrent w/ LPI	Concurrent w/ LPI	55	45

Alternative 1 provides a higher degree of safety and comfort for pedestrians, with LPI provided at each intersection. Alternative 2 does not have LPI at Elm/Grand and Chapel due to the queue jump lanes requiring additional signal time. If LPI were included at these locations, the LOS would drop to E, and vehicle queuing and delays would be higher; or the signal cycle length would need to be increased. These trade-offs would need to be considered further if Alternative 2 was selected for implementation

Traffic Level of Service

Traffic operations under the 2040 planning scenarios are summarized on the table below and included in detail in Appendix 3. In all cases, the CT DOT urban arterial standard of peak hour LOS of D or better is met. In addition, no major movement has LOS E or better.

Table 11: 2040 Intersection Levels of Service

Intersection	*AM No Build*	*PM No Build*	*AM Alt 1*	*PM Alt 1*	*AM Alt 2*	*PM Alt 2*
State/Grove	C	C	C	C	C	C
State/Elm/Grand	C	C	C	D	C	D
State/Court	B	C	C	B	C	B
State/Pitkin	A	B	B	C	B	C
State/Chapel	D	D	C	C	C	D
State St/George/Fair	C	D	C	D	C	D
State St/Water	C	C	C	C	C	C

The proposed alternatives would result in changes in LOS of no more than one letter grade, with the majority unchanged. In all cases LOS is D or better. Alternative 1 has better LOS at Chapel than Alternative 2

Average queue lengths are provided below for northbound and southbound queues, which show that queue lengths fit well within the estimated available stacking length. Alternative 2 has slightly higher queues at Chapel and Elm/Grand than Alternative 1

Table 12: Average Northbound Queue Lengths on State Street

Intersection	*Available Length*	*AM Alt 1*	*PM Alt 1*
State/Grove	700	193	585
State/Elm/Grand	430	196	120
State/Court	170	163	117
State/Pitkin	170	72	125
State/Chapel	480	194	168
State/George/Fair	340	44	132
State St/Water	760	138	182

Table 13: Average Southbound Queue Lengths on State Street

Intersection	*Available Length*	*AM Alt 1*	*PM Alt 1*
State/Grove	330	285	211
State/Elm/Grand	700	246	191
State/Court	430	149	153
State/Pitkin	170	27	135
State/Chapel	170	157	138
State/George/Fair	360	66	216
State St/Water	340	85	155

Synchro also provides measures of corridor operations, which will provide an indication about the driver's experience traveling along the entire corridor. The table below shows some key arterial measures, and more data is available in Appendix 3.

Table 14: Corridor Measures of Effectiveness (2040)

Period		*No Build*	*Alt 1*	*Alt 2*
AM Peak	Total Delay (seconds per vehicle)	15	15	17
	Average Speed (mph)	11	11	10
PM Peak	Total Delay (seconds per vehicle)	20	23	32
	Average Speed (mph)	8	8	6

Alternative 1 has similar total delay and average speed as the no build scenario, and Alternative 2 has somewhat higher delays and lower average speeds. Overall, the corridor will operate more efficiently with improved signal coordination and concurrent pedestrian phases.

CONCLUSIONS

The proposed changes for State Street through downtown New Haven include the following key elements:

- State Street will generally have one through travel lane in each direction, with turn lanes where volumes warrant.
- Two-way separated bicycle lanes will be provided on the east side of the street, where there are fewer conflicts with driveways and intersections.
- Elm Street is converted to two-way operations, which will greatly simplify bus circulation through downtown and improve bus operations and reduce vehicle-miles-traveled through downtown.
- Pedestrians will have shorter crossing distances and signal operations will change so that there are shorter waiting times, reducing the likelihood of pedestrians trying to cross outside of the pedestrian phase.

Together, these changes will provide substantial improvements for people walking, bicycling and taking transit, while maintaining acceptable peak hour levels of congestion for motorists.

Alternative 1 is recommended as the benefits for transit, pedestrians and traffic circulation are greater than for Alternative 2.

PEDESTRIAN QUALITY OF SERVICE

The pedestrian environment will be substantially improved under both Alternatives with the following outcomes:

- Safer conditions due to reduced speeding
- Shorter crossing distance at signalized intersections
- Lower pedestrian delay with concurrent pedestrian phasing

Alternative 1 has safer conditions at the Chapel and Elm/Grand intersections because LPI can be provided at both locations.

BICYCLE LEVEL OF TRAFFIC STRESS

Both alternatives provide a high comfort, low stress facility. The signalized intersections can be phased to avoid conflicts with turning vehicles and meet current guidelines.

TRANSIT OPERATIONS

In Alternative 1, converting Elm Street to 2-way operations will have significant benefit to the City of New Haven's transit system, allowing more efficient transit routes and lower delays. The queue jump lanes in Alternative 2 will reduce the delays for two important turning movements on several high ridership routes.

VEHICULAR TRAFFIC OPERATIONS

All signalized intersections will operate at LOS D or better during the peak hours under the 2040 traffic scenario. Alternative 1 has lower delays, reflecting the benefits of Elm Street's 2-way operation and lower vehicle-miles-traveled. The corridor travel times show some improvement in both alternatives due to improved signal coordination and more efficient operations.

APPENDIX 1
TRAFFIC COUNTS

APPENDIX 2
FUTURE TRAFFIC PROJECTION WORKSHEETS

APPENDIX 3
SYNCHRO MODEL REPORTS

- 2020 Existing Conditions
  - AM Peak Hour Intersection Reports
  - AM Peak Hour Corridor Report
  - PM Peak Hour Intersection Reports
  - PM Peak Hour Corridor Report
- 2040 Proposed Conditions
  - AM Peak Hour Intersection Reports
  - AM Peak Hour Corridor Report
  - PM Peak Hour Intersection Reports
  - PM Peak Hour Corridor Report

APPENDIX 4
ILLUSTRATIVE DESIGN CONCEPT