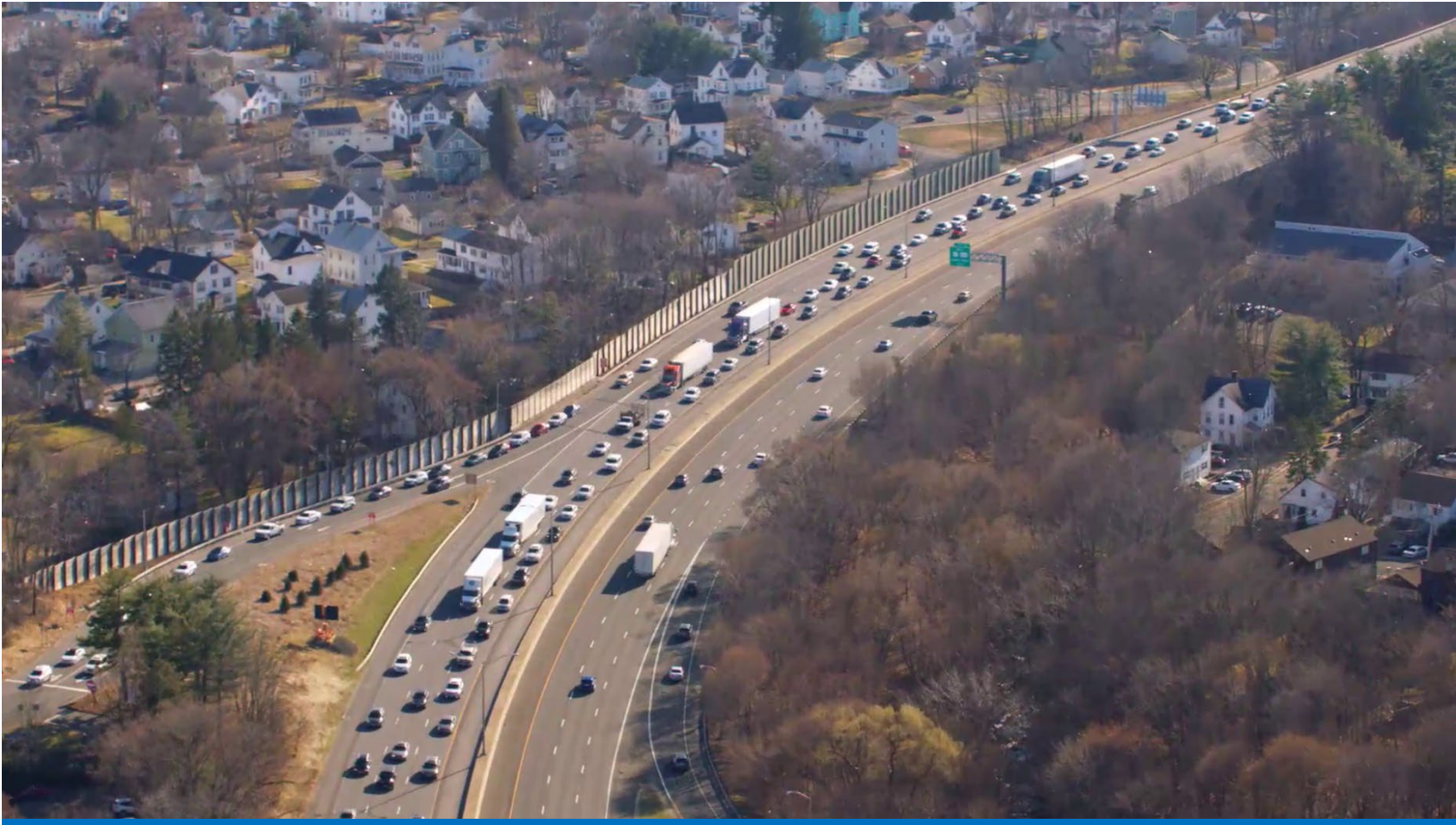

Appendix L TSMO Strategies Engineering White Paper

I-84 Danbury PEL Study

Prepared for: The Connecticut Department of Transportation

August 2025

I-84 Danbury

I-84 Danbury Project

CONCEPT STUDY 23:

TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS STRATEGIES

ENGINEERING WHITE PAPER

November 2022

Prepared For:
Connecticut Department of Transportation

Prepared By:
CDM Smith

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1. Introduction

Transportation Systems Management Operations (TSMO) is an initiative by the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) to integrate operations into planning and programming of projects. TSMO includes a multiple set of strategies to be applied together with the purpose of improving operations and performance of the system through the implementation of multimodal and intermodal, cross-jurisdictional systems, and projects designed to improve transportation system.

The draft purpose for the I-84 Danbury project is to "*reduce congestion and improve mobility of people and goods in the I-84 corridor in greater Danbury*". Therefore, the following strategies which could reduce congestion and improve mobility on I-84 and surrounding local roadways were considered for further evaluation along with the Program Areas:

Program Areas	Strategies
Active Transportation Demand and Management	• Dynamic Lane Use • Temporary or Hard Shoulder Running
Freeway Management	• Freeway Ramp Metering
Traffic Incident Management	• Variable Message Signs and Cameras
Arterial Management	• Traffic signal retiming and optimization
Travel Demand Management	• Telecommuting, Rideshare, Bus and Rail Transit
Public Transportation Management	• Bus and Rail Transit Operations
Corridor Management	• Safety Applications, Access management, and others
Real-time traveler information	• Connected and automated vehicle deployment

2. Dynamic Lane Use (DLU) - Median

2.1. Description of Strategy

The DLU strategy involves dynamically closing or opening individual traffic lanes as warranted and providing advance warning of the closure(s) (using lane use control signals), to safely merge traffic into adjoining lanes. The closing or opening of lanes is typically performed during peak hours.

The DLU strategy is unfamiliar to drivers and has not yet been implemented in Connecticut.

2.2. Design Options

The DLU strategy was considered along the median section between Interchanges 3 and 7. There are two design options:

- **Option 1** removes the existing fixed median on I-84. Moveable barriers are provided at the start and end of the dynamic lane in the median. Based on time of day, motorists are directed into the dynamic lane using moveable barriers and then fixed barriers are provided on either side of the dynamic lane for the entire length to keep traffic moving in that lane. Under this option, removal of the existing fixed median requires removal of lighting and changes to existing drainage. This option will require a 6-foot widening beyond the existing edge of pavement on each side. **Figure 1** shows a typical layout of this option.

- **Option 2** keeps the existing fixed median on I-84. Moveable barriers are constructed on either side of the fixed median and shift inward or outward depending on the time of day to open or close the dynamic lane. This option does not require the removal of lighting and only minimal changes to drainage. This option will require a 6-foot widening beyond the existing edge of pavement on each side. **Figure 2** shows a typical layout of this option.

- **Option 3** keeps the existing fixed median on I-84 and has a dynamic lane which can be opened or closed using variable message signs in advance of and above the highway lanes depending on their use during various times of day. **Figure 3** shows a typical layout of this option.

2.3. Traffic Operations

2.3.1 Mainline Traffic

The traffic analysis was based on an existing year of 2016 and a future year of 2030.

During the weekday A.M. peak period (7 A.M. – 9 A.M.), it should take approximately 5 minutes to travel on I-84 from Interchange 7 to Interchange 3 in the westbound direction (approximately 5 miles). However, due to traffic conditions, it takes approximately 10 minutes to travel between these two points in 2016. With the projected increase in traffic volumes and without any improvements made to I-84, it is anticipated to take approximately 20 minutes to travel between Interchange 7 and Interchange 3 in 2030. With the proposed improvements under the DLU strategy,

Figure 1: Dynamic Lane Use Median Concept – Option 1 (A.M. Peak Hour)

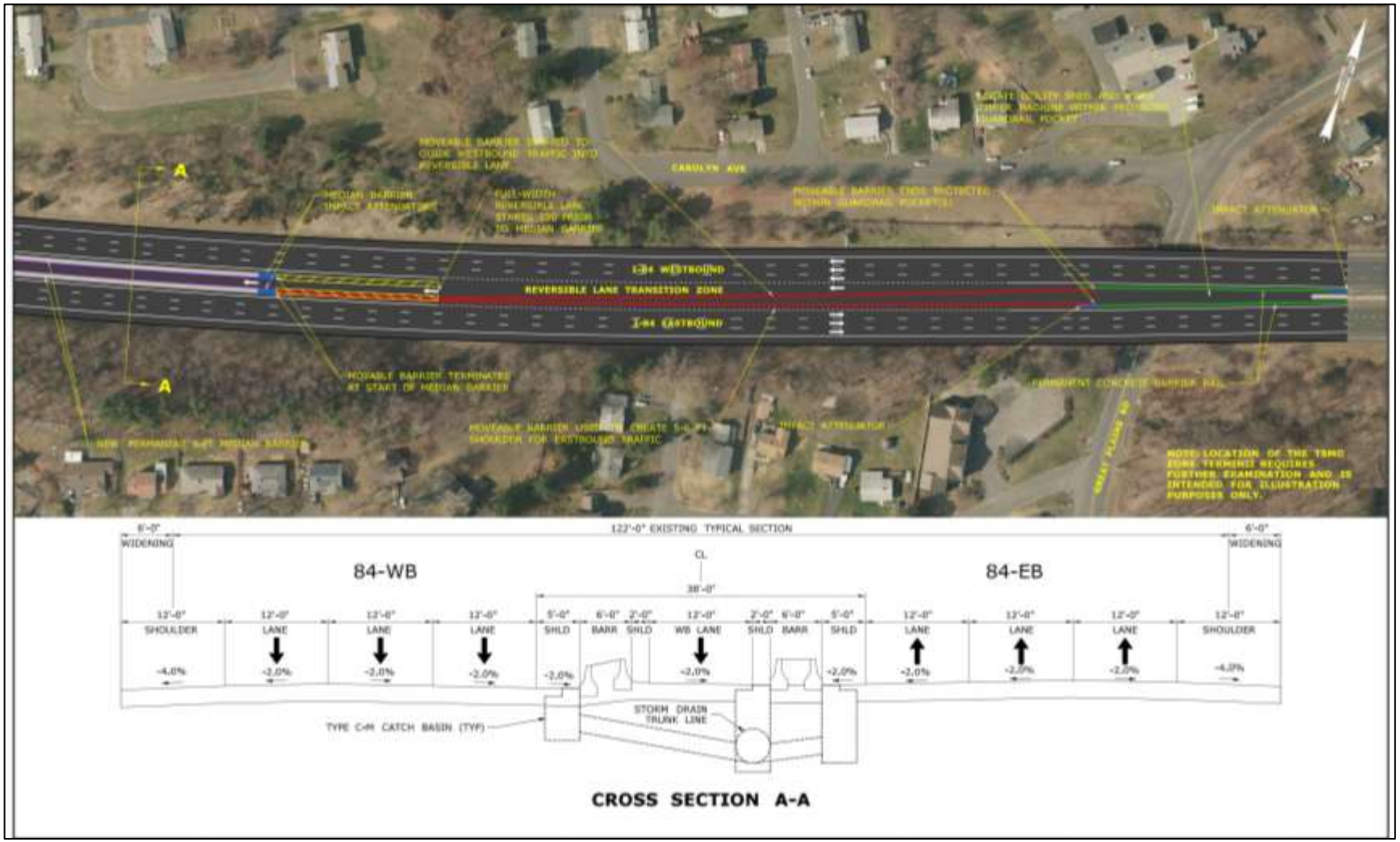


Figure 2: Dynamic Lane Use Median Concept – Option 2 (A.M. Peak Hour)

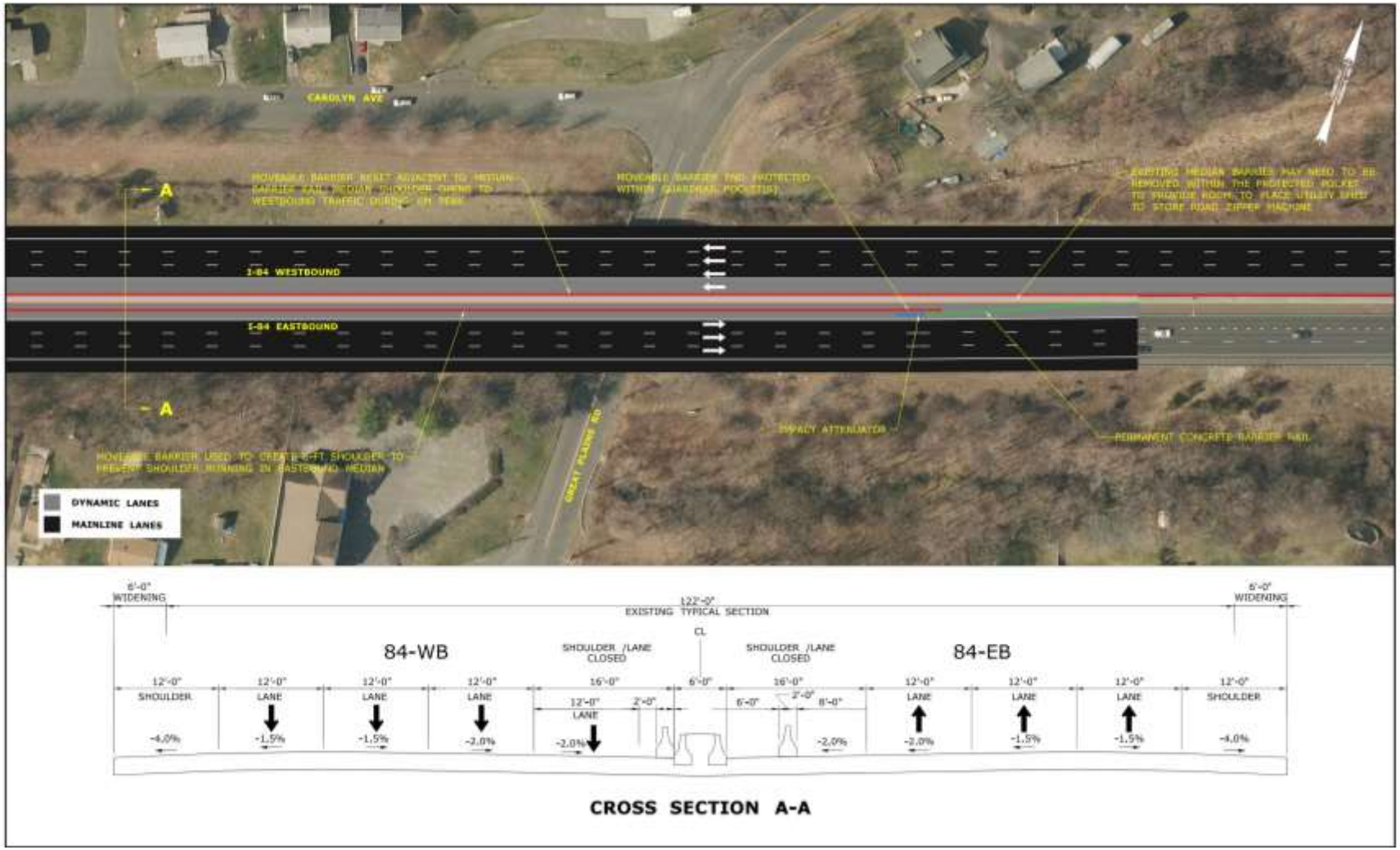
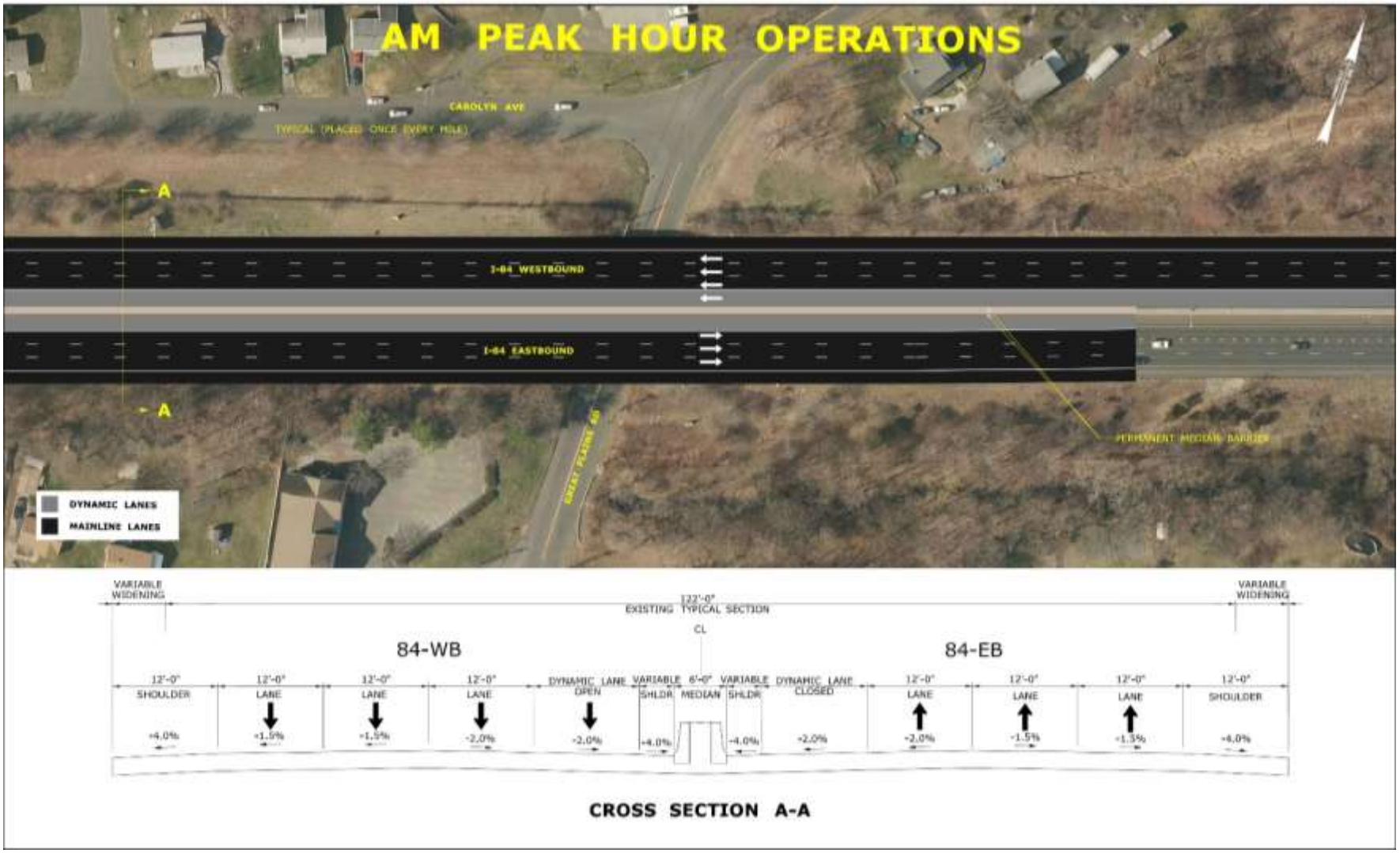


Figure 3: Dynamic Lane Use Median Concept – Option 3 (A.M. Peak Hour)

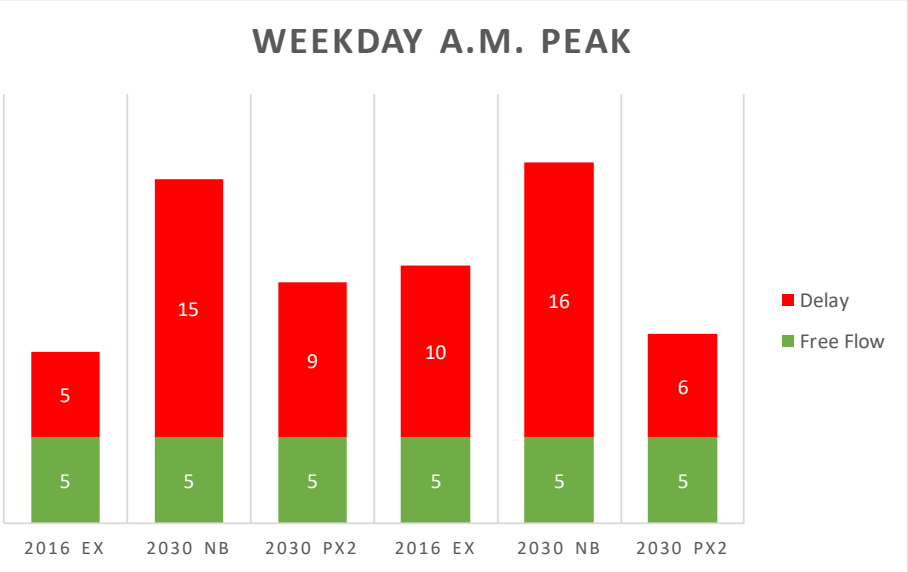


the anticipated travel time in 2030 between Interchange 7 and Interchange 3 on I-84 will be 14 minutes, which results in a **total reduction of 6 minutes of delay** during the A.M. Peak.

During the weekday A.M. peak period, it should take approximately 5 minutes to travel on Route 7 southbound from the merge with I-84 at Interchange 7 to Interchange 3 on I-84 in the westbound direction (approximately 5 miles). However, due to traffic conditions on Route 7 near the merge with 84 at Interchange 7, it takes approximately 15 minutes to travel between these two points in 2016. With the projected increase in traffic volumes and without any improvements made to I-84 or Route 7, it is anticipated to take approximately 21 minutes to travel on Route 7 southbound to Interchange 3 on I-84 in 2030. With the proposed improvements under the DLU strategy, the anticipated travel time in 2030 on Route 7 southbound to Interchange 3 on I-84 will be 11 minutes, which results in **a total reduction of 10 minutes of delay** during the A.M. Peak.

Refer to **Figure 3** for the travel times and delay noticed on I-84 and Route 7 during the weekday A.M. peak period.

Figure 3: Weekday A.M. Peak Travel Times – DLU - Median



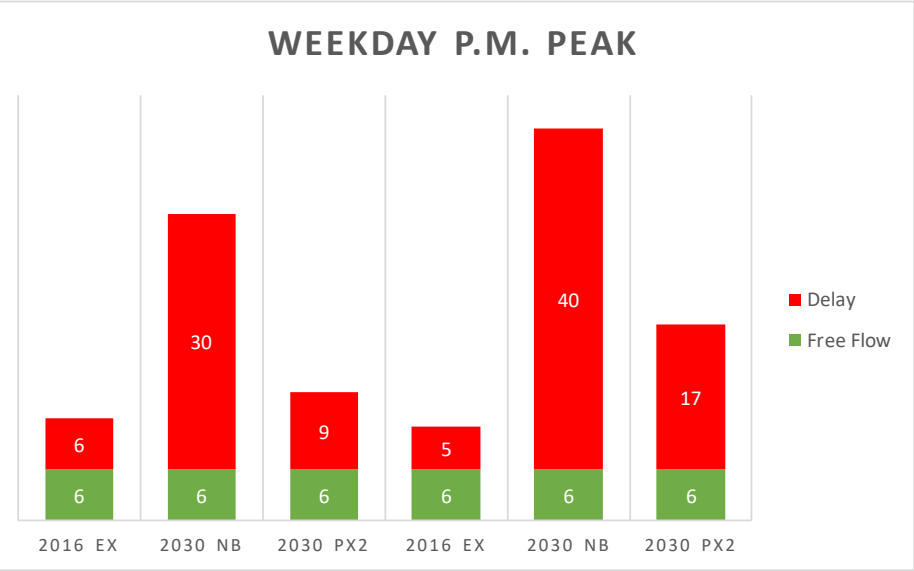
During the weekday P.M. peak period (4 P.M. – 6 P.M.), it should take approximately 6 minutes to travel from Interchange 3 to Interchange 7 on I-84 in the eastbound direction (approximately 6 miles). However, due to traffic conditions on I-84, it takes approximately 12 minutes to travel between these two points in 2016. With the projected increase in traffic volumes and without any improvements made to I-84, it is anticipated to take approximately 36 minutes to travel between Interchange 3 and Interchange 7 in 2030. With the proposed improvements under the DLU strategy, the anticipated travel time in 2030 between Interchange 3 and Interchange 7 on I-84 will be 15 minutes which results in **a total reduction of 21 minutes of delay** during the P.M. Peak.

During the weekday P.M. peak period, it should take approximately 6 minutes to travel on Route 7 northbound from the merge with Interchange 3 to Interchange 7 on I-84 in the eastbound direction (approximately 6 miles). However, due to traffic conditions on Route 7, it takes approximately 11

minutes to travel between these two points in 2016. With the projected increase in traffic volume and without any improvements made to I-84 or Route 7, it is anticipated to take approximately 46 minutes to travel on Route 7 northbound to Interchange 7 on I-84 in 2030. This is because of the merge of Route 7 northbound traffic with I-84 eastbound at Interchange 3. With the proposed improvements under the DLU strategy, the anticipated travel time in 2030 to travel on Route 7 northbound to Interchange 7 on I-84 will be 23 minutes, which results in **a total reduction of 23 minutes of delay** during the P.M. Peak.

Refer to **Figure 4** for the travel times and delay during the weekday P.M. peak period noticed on I-84 and Route 7.

Figure 4: Weekday P.M. Peak Travel Times – DLU - Median



As noted in Figures 3 and 4, the improvements proposed under the DLU strategy will have a positive impact on the reduction in travel time and delays along the I-84 corridor within Danbury.

2.3.2 Local Traffic

Under the DLU strategy, no changes are anticipated on local streets.

2.4. Effects to Mainline I-84

The DLU strategy utilizes the median area to provide an additional operational lane in the peak direction of traffic flow. Under Option 1, the left shoulder between the third travel lane and the fixed median barrier is 5 feet and the shoulders on either side of the dynamic lane are 2 feet wide. These shoulder widths do not meet design standards.

Under Option 2, there is a 2-foot left shoulder in the peak direction of traffic. In the off-peak direction, the left shoulder width is 8 feet. These shoulder widths do not meet design standards.

The right shoulder is 12 feet wide and meets design standards under both options. No horizontal alignment changes are anticipated under either option.

Under Option 3, there is a variable shoulder width (4 to 8 feet) on the left side in the peak direction of traffic based on the amount of widening. In the off-peak direction, the left shoulder width is 20 feet. The left shoulder width in the peak direction does not meet design standards. The right shoulder is 12 feet wide and meets design standards. No horizontal alignment changes are anticipated under this option.

2.5. Effects to Vertical Geometry

No changes in vertical geometry are anticipated.

2.6. Key Constructability Elements

- Construction will be undertaken using typical methods.
- Multiple stages will be required to shift traffic during construction.
- Option 1 requires removal of existing lighting and changes to existing drainage.
- Existing bridges will require rehabilitation or replacement.
- A "zipper" machine is installed to move the barrier based on time of day under Options 1 and 2. This machine is housed in the median area when not in use.

2.7. Effects to Local Streets

No changes are anticipated on local streets.

2.8. Anticipated Right of Way Needs

No additional right of way is required.

2.9. Construction Cost Estimate

Table 1 lists the construction cost estimate based on 2020 dollars (in millions) for Options 1, 2, and 3. The construction cost estimate does not include right-of-way and engineering costs.

Table 1 – Construction Cost Estimate – DLU – Median

Estimated Item	Cost (in millions)		
	Option 1	Option 2	Option 3
Roadway	$139	$94	$85
Structures	$67	$36	$36
Environmental Compliance (5% of above items)	$13	$9	$4
Minor Items (30%) [(1)]	$67	$45	$36
Maintenance & Protection of Traffic (6%) [(1)]	$22	$13	$13

Estimated Item	Cost (in millions)		
	Option 1	Option 2	Option 3
Clearing & Grubbing (3%) (1)	$13	$9	$4
Construction Staking (1%) (1)	$4	$4	$4
Mobilization & Project Closeout (10%) (1)	$36	$22	$22
Other Non-Contract Items (State Police, ITS, Utilities)	$72	$49	$45
Incidentals (15%) (1)	$72	$45	$40
Contingency (30%) (1)	$108	$67	$63
Total (based on 2020 dollars)	**$616**	**$395**	**$355**

Notes: (1) Percentages based on cost estimating guidelines and represent the highest value in the range.

2.10. Pros and Cons

Pros:

- Peak hour delay is reduced.
- Typical construction methods could be used.
- Does not require additional right-of-way.
- Could be implemented in a short timeframe.

Cons:

- Does not address lane continuity on I-84.
- Does not address the left-hand entrance and exit ramps in the I-84 corridor.
- Lacks consistent design speed throughout the I-84 corridor.
- Does not propose changes to the existing interfaces to local streets.
- Interchange 6 remains a partial interchange.
- Does not improve access to the Danbury Hospital.
- Left shoulders do not meet design standards when DLU is operational.
- Unable to use shoulder for emergency use during peak hour.
- Unfamiliar to drivers and may create confusion.

3. Temporary or Hard Shoulder Running (HSR)

3.1. Description of Strategy

The HSR Strategy involves dynamically using the right shoulder as warranted and providing advance warning of the use of the shoulder which allows motorists to enter and exit the shoulder. The use of the shoulder is typically allowed during peak hours. Dynamic or static signs are provided to direct motorists in and out of the shoulder.

The HSR strategy is unfamiliar to drivers and has not yet been implemented in Connecticut.

3.2. Design Options

The HSR strategy was considered between Interchanges 3 and 7 during peak hours. This option will require a 4-foot widening beyond the existing edge of pavement on each side. This provides a 14-foot shoulder on each side. When the shoulder is in use for travel (a 12-foot travel lane), a 2-foot shoulder is available. **Figure 5** shows a typical layout of this option.

3.3. Traffic Operations

3.3.1 Mainline Traffic

The traffic analysis was based on an existing year of 2016 and a future year of 2030.

During the weekday A.M. peak period (7 A.M. – 9 A.M.), it should take approximately 5 minutes to travel on I-84 from Interchange 7 to Interchange 3 in the westbound direction (approximately 5 miles). However, due to traffic conditions, it takes approximately 10 minutes to travel between these two points in 2016. With the projected increase in traffic volumes and without any improvements made to I-84, it is anticipated to take approximately 20 minutes to travel between Interchange 7 and Interchange 3 in 2030. With the proposed improvements under the HSR strategy, the anticipated travel time in 2030 between Interchange 7 and Interchange 3 on I-84 will be 20 minutes, which results in **no change in travel times** during the A.M. Peak.

During the weekday A.M. peak period, it should take approximately 5 minutes to travel on Route 7 southbound from the merge with I-84 at Interchange 7 to Interchange 3 on I-84 in the westbound direction (approximately 5 miles). However, due to traffic conditions on Route 7 near the merge with 84 at Interchange 7, it takes approximately 15 minutes to travel between these two points in 2016. With the projected increase in traffic volumes and without any improvements made to I-84 or Route 7, it is anticipated to take approximately 21 minutes to travel on Route 7 southbound to Interchange 3 on I-84 in 2030. With the proposed improvements under the HSR strategy, the anticipated travel time in 2030 on Route 7 southbound to Interchange 3 on I-84 will be 11 minutes, which results in **a total reduction of 10 minutes of delay** during the A.M. Peak.

Refer to **Figure 6** for the travel times and delay noticed on I-84 and Route 7 during the weekday A.M. peak period.

Figure 5: Hard Shoulder Running Concept – A.M. Peak Hour

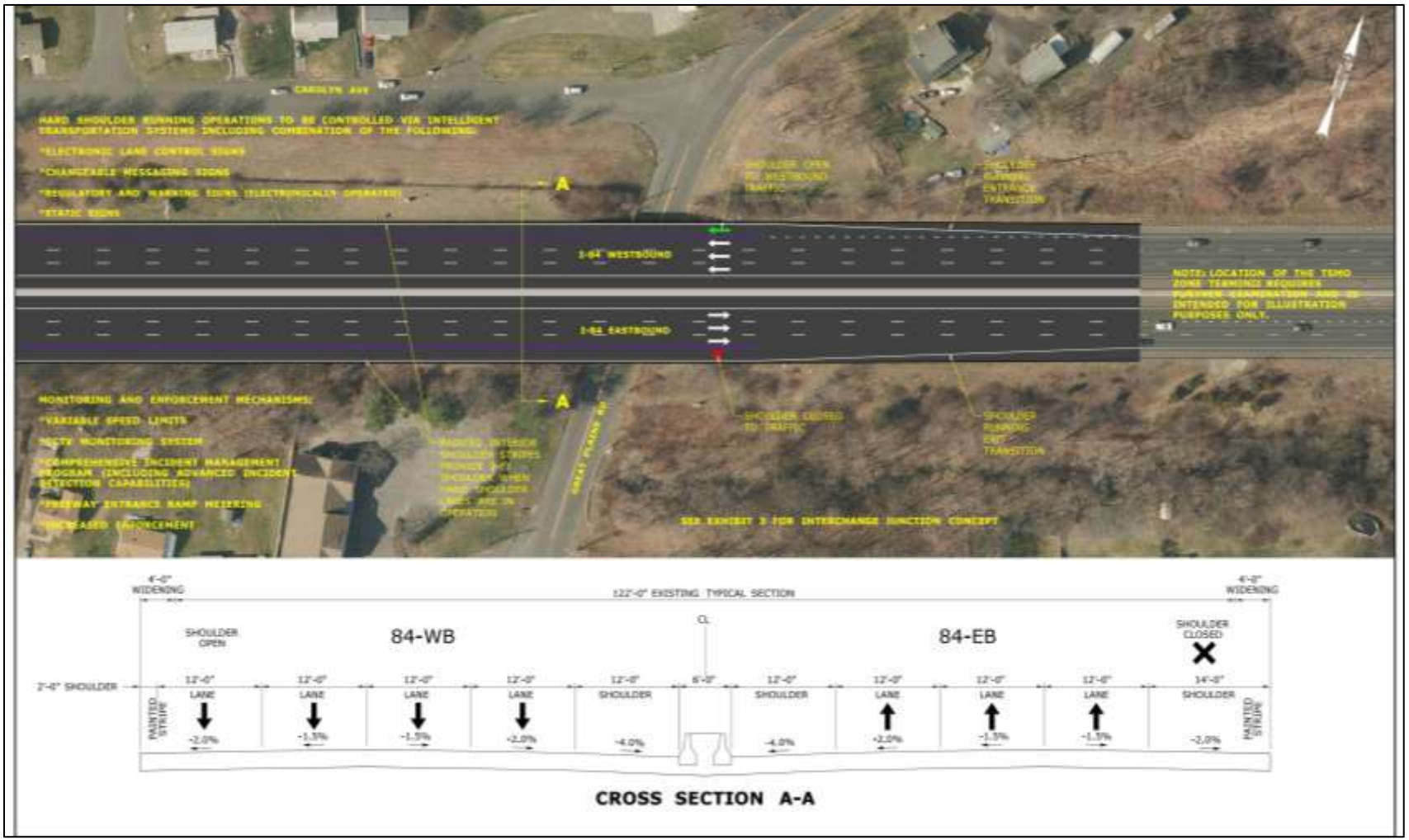
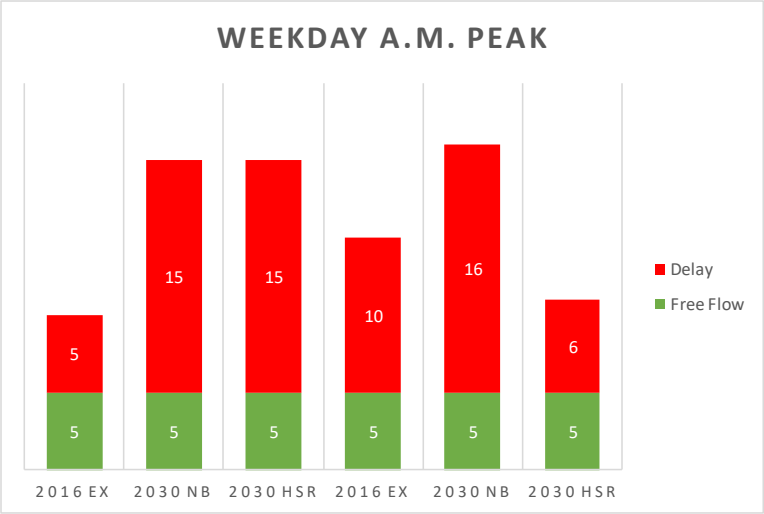


Figure 6: Weekday A.M. Peak Travel Times – HSR

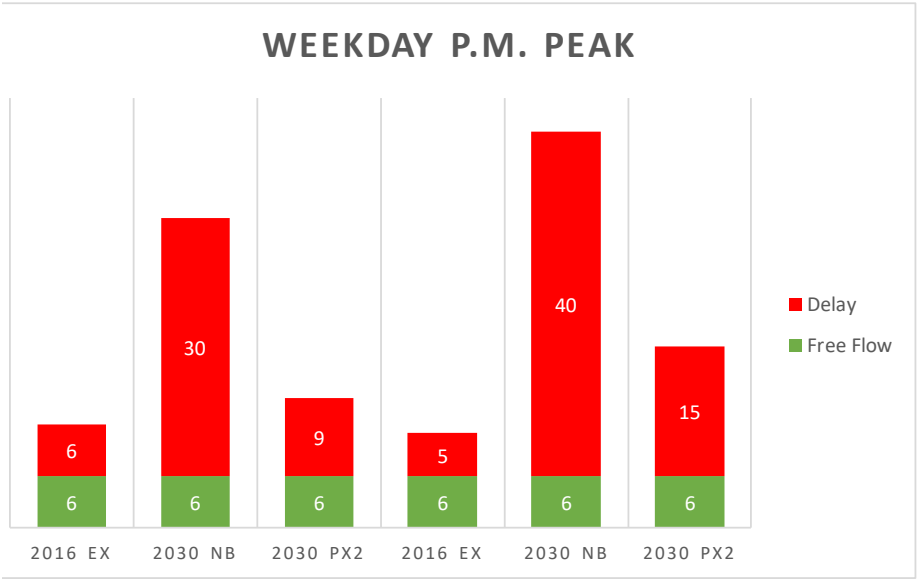


During the weekday P.M. peak period (4 P.M. – 6 P.M.), it should take approximately 6 minutes to travel from Interchange 3 to Interchange 7 on I-84 in the eastbound direction (approximately 6 miles). However, due to traffic conditions on I-84, it takes approximately 12 minutes to travel between these two points in 2016. With the projected increase in traffic volumes and without any improvements made to I-84, it is anticipated to take approximately 36 minutes to travel between Interchange 3 and Interchange 7 in 2030. With the proposed improvements under the HSR strategy, the anticipated travel time in 2030 between Interchange 3 and Interchange 7 on I-84 will be 15 minutes, which results in a **total reduction of 21 minutes of delay** during the P.M. Peak.

During the weekday P.M. peak period, it should take approximately 6 minutes to travel on Route 7 northbound from the merge with Interchange 3 to Interchange 7 on I-84 in the eastbound direction (approximately 6 miles). However, due to traffic conditions on Route 7, it takes approximately 11 minutes to travel between these two points in 2016. With the projected increase in traffic volume and without any improvements made to I-84 or Route 7, it is anticipated to take approximately 46 minutes to travel on Route 7 northbound to Interchange 7 on I-84 in 2030. With the proposed improvements under the HSR strategy, the anticipated travel time in 2030 to travel on Route 7 northbound to Interchange 7 on I-84 will be 21 minutes, which results in **a total reduction of 25 minutes of delay** during the P.M. Peak.

Refer to **Figure 7** for the travel times and delay during the weekday P.M. peak period noticed on I-84 and Route 7.

Figure 7: Weekday P.M. Peak Travel Times – HSR



As noted in Figures 6 and 7, the improvements proposed under the HSR strategy will have a positive impact on the reduction in travel time and delays during the weekday P.M. period along the I-84 corridor within Danbury. During the weekday A.M. peak period, there is no anticipated benefit in travel time and delay on I-84, but Route 7 shows a positive impact.

3.3.2 Local Traffic

No changes are anticipated on local streets.

3.4. Effects to Mainline I-84

The HSR strategy utilizes the right shoulder area to provide an additional operational lane in the peak direction of traffic flow. This option will require a 4-foot widening beyond the existing edge of pavement on each side. This provides a 14-foot shoulder on each side. When the shoulder is in use for travel, a 2-foot shoulder is available. During this time, the shoulder cannot be used as a breakdown area or by emergency vehicles.

3.5. Effects to Vertical Geometry

No changes in vertical geometry are anticipated.

3.6. Key Constructability Elements

- Construction will be undertaken using typical methods.
- Multiple stages will be required to shift traffic during construction.
- Local traffic detours may be required during construction.

- Existing bridges will require rehabilitation or replacement to accommodate the roadway widening and vertical clearances.

3.7. Effects to Local Streets

No changes are anticipated on local streets.

3.8. Anticipated Right of Way Needs

No additional right-of-way is required.

3.9. Construction Cost Estimate

Table 1 lists the construction cost estimate based on 2020 dollars (in millions). The construction cost estimate does not include right-of-way and engineering costs.

Table 2 – Construction Cost Estimate - HSR

Estimated Item	Cost (in millions)
Roadway	$ 11
Structures	$ 8
Environmental Compliance (5% of above items)	$ 1
Minor Items (30%) (1)	$ 6
Maintenance & Protection of Traffic (6%) (1)	$ 2
Clearing & Grubbing (3%) (1)	$ 1
Construction Staking (1%) (1)	$ 1
Mobilization & Project Closeout (10%) (1)	$ 4
Other Non-Contract Items (State Police, ITS, Utilities)	$ 8
Incidentals (15%) (1)	$ 7
Contingency (30%) (1)	$ 10
Total (based on 2020 dollars)	**$ 59**

Notes: (1) Percentages based on cost estimating guidelines and represent the highest value in the range.

3.10. Pros and Cons

Pros:

- Peak hour delay is reduced.
- Typical construction methods could be used.
- Does not require additional right-of-way.
- Could be implemented in a short timeframe.

Cons:

- Does not address lane continuity on I-84.
- Does not address the left-hand entrance and exit ramps in the I-84 corridor.
- Lacks consistent design speed throughout the I-84 corridor.
- Does not propose changes to the existing interfaces to local streets.
- Interchange 6 remains a partial interchange.

- Does not improve access to the Danbury Hospital.
- Unable to use shoulder for emergency use during peak hour.
- Unfamiliar to drivers and may create confusion.

4. Freeway Ramp Metering

4.1. Description of Strategy

The FRM Strategy involves the use of ramp signals to meter the flow of traffic onto the freeway. A traffic signal is installed on the on-ramp that controls the flow of traffic entering the freeway based on available gaps in the rightmost travel lane.

4.2. Design Options

The FRM strategy was considered for the following locations:

- Federal Road on-ramp to Route 7 southbound (Interchange 7)
- Main Street on-ramp to I-84 westbound (Interchange 5)
- Main Street on-ramp to I-84 eastbound (Interchange 5)

Figure 8 shows these locations.

4.3. Traffic Operations

4.3.1 Mainline Traffic

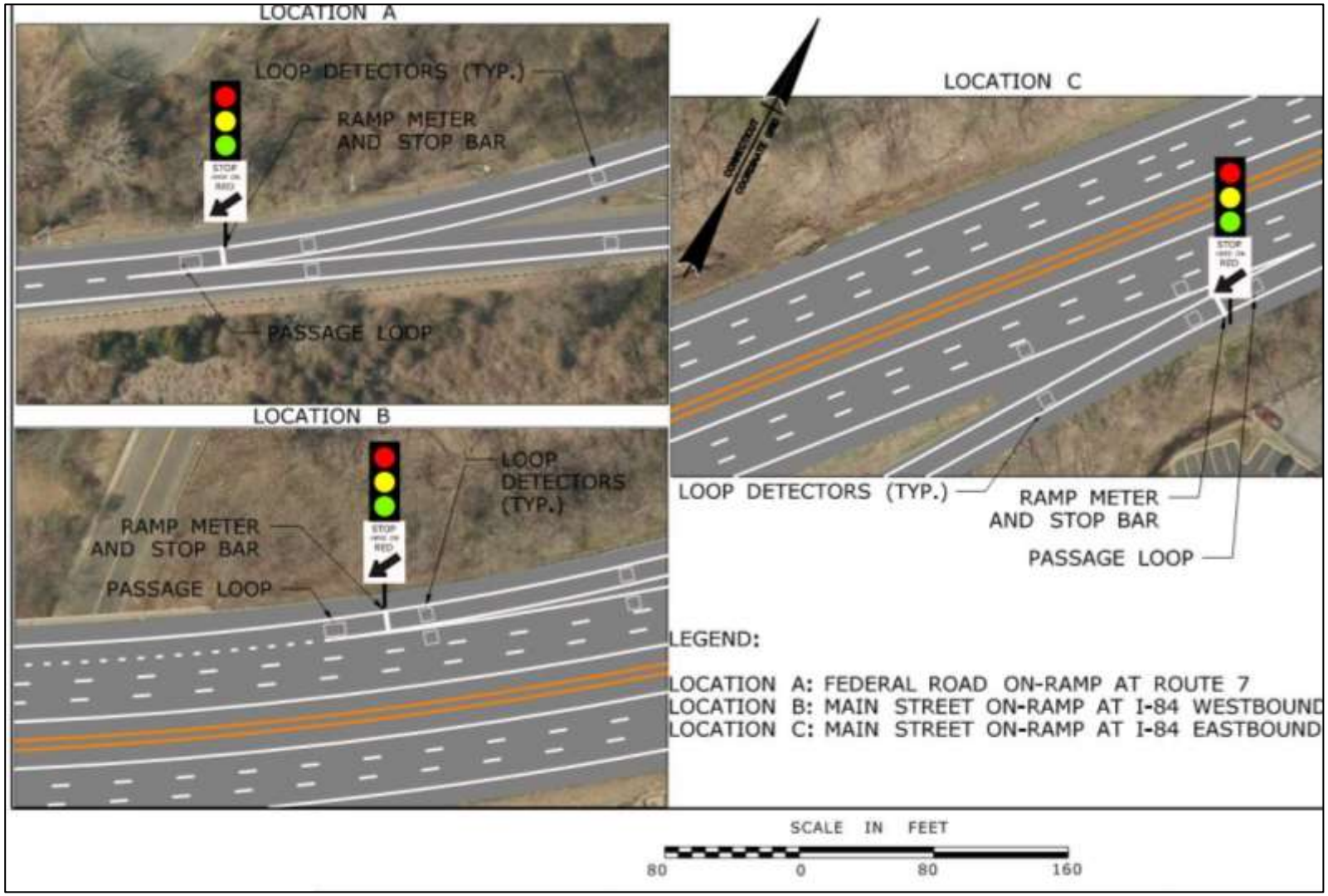
The traffic analysis was based on an existing year of 2016 and a future year of 2030. The three (3) locations identified earlier were evaluated on traffic operations. The result of the traffic operations analysis is described below:

Federal Road on-ramp to Route 7 southbound

During the weekday A.M. peak period, it should take approximately 5 minutes to travel on Route 7 southbound from the merge with I-84 at Interchange 7 to Interchange 3 on I-84 in the westbound direction (approximately 5 miles). However, due to traffic conditions on Route 7 near the merge with I-84 at Interchange 7, it takes approximately 15 minutes to travel between these two points in 2016. With the projected increase in traffic volumes and without any improvements made to I-84 or Route 7, it is anticipated to take approximately 21 minutes to travel on Route 7 southbound to Interchange 3 on I-84 in 2030. With the proposed improvements under the FRM strategy, the anticipated travel time in 2030 on Route 7 southbound to Interchange 3 on I-84 will be 13 minutes, which results in **a total reduction of 8 minutes of delay** during the A.M. Peak. This is due to the ramp meter installed on the Federal Road on-ramp which meters traffic entering Route 7.

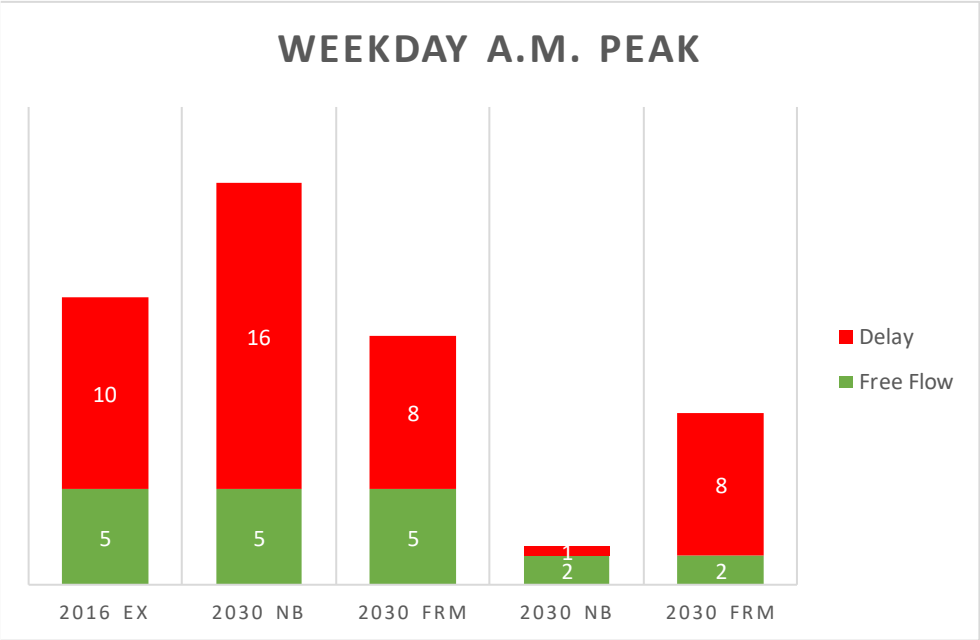
With the proposed improvements under the FRM strategy, during the weekday A.M. peak period, the Federal Road on-ramp is anticipated to experience an increase in **7 minutes of delay** during the A.M. Peak in 2030. This is due to the ramp meter installed on the Federal Road on-ramp which creates a backup onto Federal Road. To alleviate this congestion and queuing, significant traffic improvements (roadway widening and turn lanes) on Federal Road will be required.

Figure 8: Freeway Ramp Metering Locations



Refer to **Figure 9** for the travel times and delay noticed on Route 7 and Federal Road during the weekday A.M. peak period.

Figure 9: Weekday A.M. Peak Travel Times – FRM
Federal Road On-Ramp on Route 7 Southbound



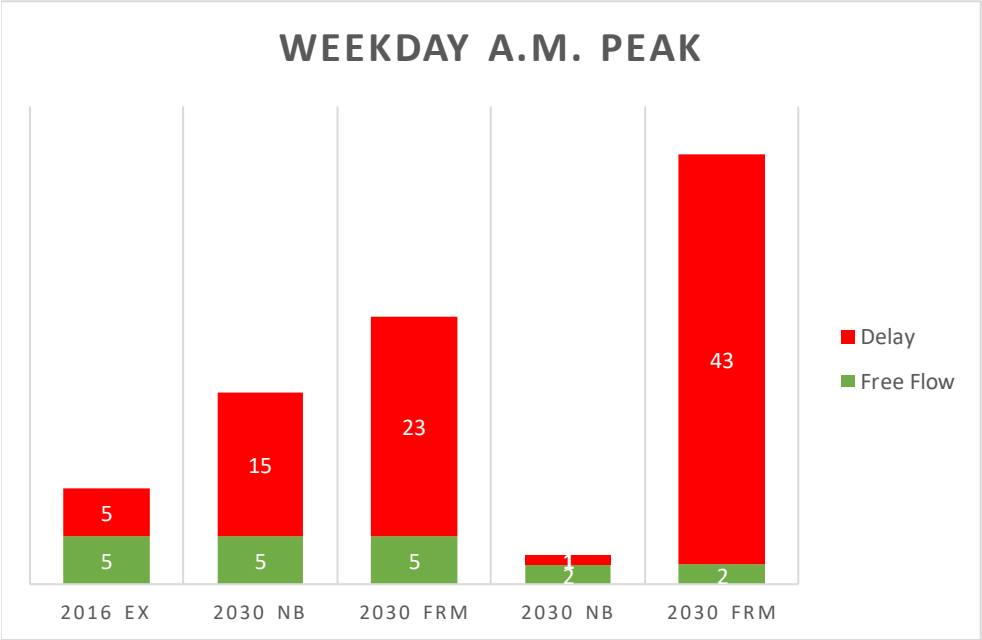
Main Street on-ramp to I-84 westbound

For this location, the weekday A.M. peak period was analyzed. During the weekday period (7 A.M. – 9 A.M.), it should take approximately 5 minutes to travel on I-84 from Interchange 7 to Interchange 3 in the westbound direction (approximately 5 miles). However, due to traffic conditions, it takes approximately 10 minutes to travel between these two points in 2016. With the projected increase in traffic volumes and without any improvements made to I-84, it is anticipated to take approximately 20 minutes to travel between Interchange 7 and Interchange 3 in 2030. With the proposed improvements under the FRM strategy, the anticipated travel time in 2030 between Interchange 7 and Interchange 3 on I-84 will be 28 minutes, which results in an increase in **8 minutes of delay** during the A.M. Peak. This delay is caused by the congestion on Main Street that attributes to the queue on I-84 westbound off ramp and consequently results to a backup on I-84 westbound mainline.

During the weekday A.M. peak period, the Main Street on-ramp is anticipated to experience an increase in **42 minutes of delay** during the A.M. Peak in 2030. This is due to the ramp meter installed on the Main Street on-ramp which creates a backup onto Main Street. To alleviate this congestion and queuing, significant traffic improvements (roadway widening and turn lanes) on Main Street will be required.

Refer to **Figure 10** for the travel times and delay noticed on I-84 and Main Street during the weekday A.M. peak period.

Figure 10: Weekday A.M. Peak Travel Times – FRM
Main Street On-Ramp on I-84 westbound



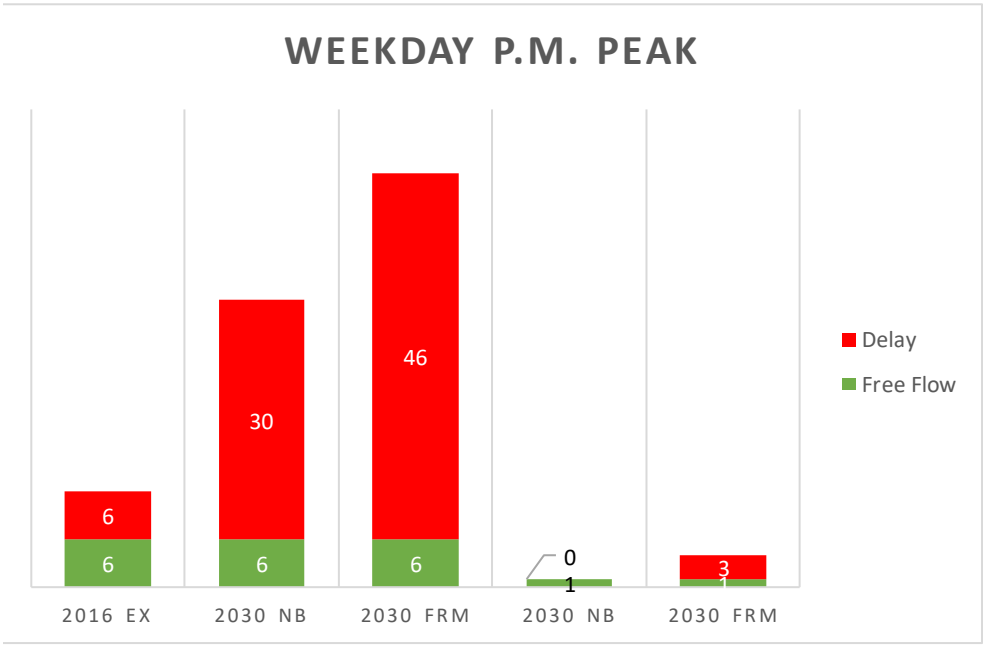
Main Street on-ramp to I-84 eastbound

For this location, the weekday P.M. period was analyzed. During the weekday P.M. peak period (4 P.M. – 6 P.M.), it should take approximately 6 minutes to travel from Interchange 3 to Interchange 7 on I-84 in the eastbound direction (approximately 6 miles). However, due to traffic conditions on I-84, it takes approximately 12 minutes to travel between these two points in 2016. With the projected increase in traffic volumes and without any improvements made to I-84, it is anticipated to take approximately 36 minutes to travel between Interchange 3 and Interchange 7 in 2030. With the proposed improvements under the FRM strategy, the anticipated travel time in 2030 between Interchange 3 and Interchange 7 on I-84 will be 52 minutes, which results in an increase in **16 minutes of delay** during the P.M. Peak. This is because the traffic is backed up at the Downs Street exit and installing a ramp meter at the Main Street on-ramp does not improve traffic operations on I-84.

During the weekday P.M. peak period, the Main Street on-ramp is anticipated to experience an increase in **3 minutes of delay** during the P.M. Peak in 2030. This is due to the ramp meter installed on the Main Street on-ramp which creates a backup onto Main Street. To alleviate this congestion and queuing, significant traffic improvements (roadway widening and turn lanes) on Main Street will be required.

Refer to **Figure 11** for the travel times and delay during the weekday P.M. peak period noticed on I-84 and Main Street.

Figure 11: Weekday P.M. Peak Travel Times – FRM
Main Street on-ramp on I-84 eastbound



4.3.2 Local Traffic

All three (3) locations where a ramp meter is proposed for installation will create a significant impact on adjacent local streets i.e. Federal Road and Main Street. Significant traffic improvements such as roadway widening, turn lanes, traffic signal upgrades, and others will be required to mitigate those impacts.

4.4. Effects to Mainline I-84

No changes are anticipated on the I-84 mainline for this strategy.

4.5. Effects to Vertical Geometry

No changes in vertical geometry are anticipated.

4.6. Key Constructability Elements

Construction will be undertaken using typical methods.

4.7. Effects to Local Streets

This strategy will require significant traffic improvements such as roadway widening, turn lanes, traffic signal upgrades, and others to mitigate traffic impacts resulting from the ramp meter installed on the on-ramp locations. Traffic diversions are anticipated by motorists to other local streets because of the delay experienced by the ramp meters.

4.8. Anticipated Right of Way Needs

No additional right-of-way is required.

4.9. Construction Cost Estimate

The construction cost estimate is about **$500,000** per location.

4.10. Pros and Cons

Pros:

- Could be implemented in a short time frame.
- Typical construction methods could be used.
- Does not require additional right of way.

Cons:

- Does not reduce peak hour delay on I-84 or local streets.
- Unfamiliar to drivers and may create confusion.
- Requires local street traffic improvements.
- Diverts traffic to adjacent local streets.

5. Other TSMO Strategies

5.1. Traffic Incident Management (TIM)

The TIM Strategy involves the use of Intelligent transportation Systems (ITS) technologies to detect, respond, and clear incidents on a freeway system. These technologies include the use of roadside devices such as variable message signs, cameras, highway advisory radio, and others. The presence of such devices on the freeway provides information to motorists which assists them make travel choices.

The Connecticut Department of Transportation (CTDOT) is planning short-term (0-5 years) traffic incident management systems along the I-84 corridor in Danbury. These include three (3) Variable Message Signs (VMS), eleven (11) camera locations, and supporting communications infrastructure. **Figure 12** shows these locations along I-84. The three (3) VMS locations are:

- I-84 eastbound near Interchange 2
- I-84 eastbound near Interchange 5
- I-84 westbound near Interchange 7

The eleven (11) additional camera locations are:

- Interchange 2 (1 camera)
- Kenosia Avenue overpass (1 camera)
- Interchange 3 (2 cameras)
- Between Interchanges 4 and 5 (1 camera)
- Franklin Street underpass (1 camera)
- Interchange 5 (1 camera)
- Interchange 6 (1 camera)
- Great Plains Road underpass (1 camera)
- Interchange 7 (1 camera)
- Interchange 8 (1 camera)

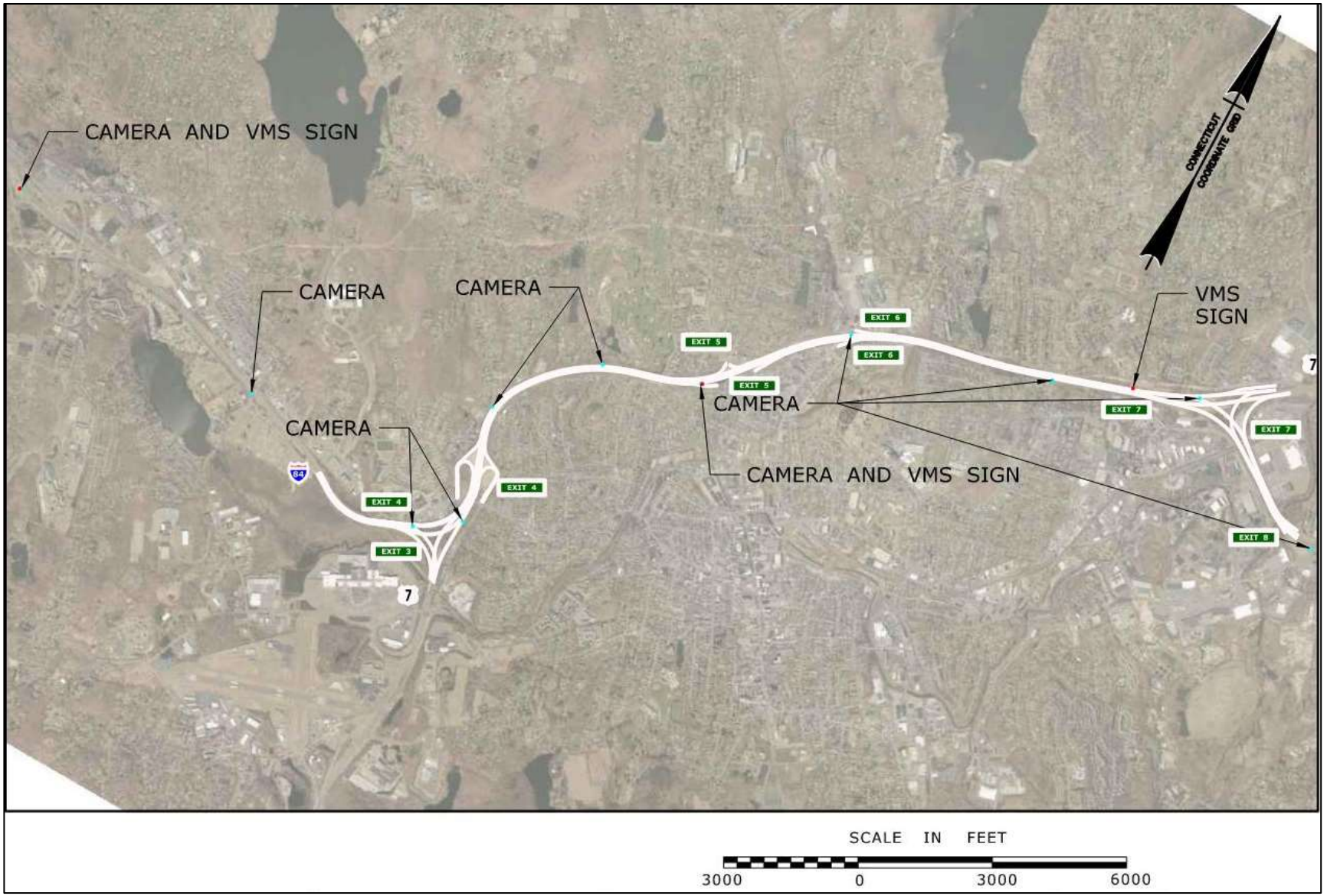
The total construction cost is estimated to be about **$18 million**.

5.2. Arterial Management

The Arterial Management strategy is associated with improving the operations on arterials with the use of traffic signal technologies such as signal retiming and optimization, signal modernization and upgrades, use of adaptive systems, and extracting performance measures using the Automated Traffic Signal Performance Measures (ATSPM).

For the I-84 Danbury project, there are opportunities working with the City of Danbury to evaluate and implement arterial management strategies on key corridors such as Mill Plain Road, Lake Avenue, Main Street, North Street, Federal Road, Newtown Road, and others.

Figure 12: Traffic Incident Management System Locations



5.3. Travel Demand Management

The Travel Demand Management (TDM) Strategy looks at opportunities to reduce the use of single occupant vehicles in the transportation system. The Federal Highway Administration (FHWA) defines TDM as management of both the growth of traffic and the periodic shifts in traffic demand on a given network or system to better manage traffic congestion and improve the performance of the transportation system. Managing travel demand involves use of a variety of tools and strategies that provide travelers, regardless of whether they drive alone, with travel choices - such as work location, route, time, and mode. TDM strategies, or solutions that re-distribute or reduce travel demand, can be implemented by both the public sector and the private sector.

In the public sector, a variety of TDM services are available in the Greater Danbury area including park-and-ride lots, carpool/vanpool services through CTrides, and bike/transit integration. CTrides, which is subsidized by the State of Connecticut through CTDOT, offers two services with its NuRides and vRides programs. NuRides is a service that connects local commuters and provides an incentive to form carpools. This program rewards commuters that track their commute trips and provides additional points to commuters who telecommute, use shared rides, or use transit. vRides is a service offered by Enterprise, in partnership with CTrides and private employers, to set up and operate vanpools.

The private sector can contribute to TDM by allowing their employees to work flexible hours and to telecommute. This enables employee flexibility to avoid commuting during peak hours of travel, or to work from home. These options help in alleviating peak hour congestion. Another TDM strategy offered by the private sector is shared vehicles including taxi services and shared mobility services, like Uber and Lyft.

For the I-84 Danbury project, Concept 4 (Non-Highway option) looks at opportunities to enhance bus and rail transit in the Greater Danbury area. These options coupled with the public and private sector opportunities to enhance TDM can potentially reduce vehicle trips on the highway system. Implementing this strategy will require coordination and partnership between the public (city, state, region) and private sector (employers).

5.4. Public Transportation Management

The Public Transportation Management strategy is associated with improving the operations on public transportation. For the I-84 Danbury project, Concept 4 (Non-Highway option) looks at opportunities to enhance bus and rail transit in the Greater Danbury area. These options can be considered and implemented early in the process.

5.5. Corridor Traffic Management

The Corridor Traffic Management strategy involves safety applications, access management, traffic network surveillance, and others.

Safety applications such as highway curve warning signage, pavement markings and striping, and others can be implemented to improve driver expectancy and travel experience. Highway curve warning signs can be installed where there is a change in the horizontal curvature of the highway. The warning signs can be supplemented with a speed advisory plaque. For the I-84 Danbury project, the following is a list of locations (shown in **Figure 13**) where the warning signs could be installed:

Eastbound direction

- Approaching Interchange 3
- Approaching Interchange 5
- Approaching Interchange 7

Westbound direction

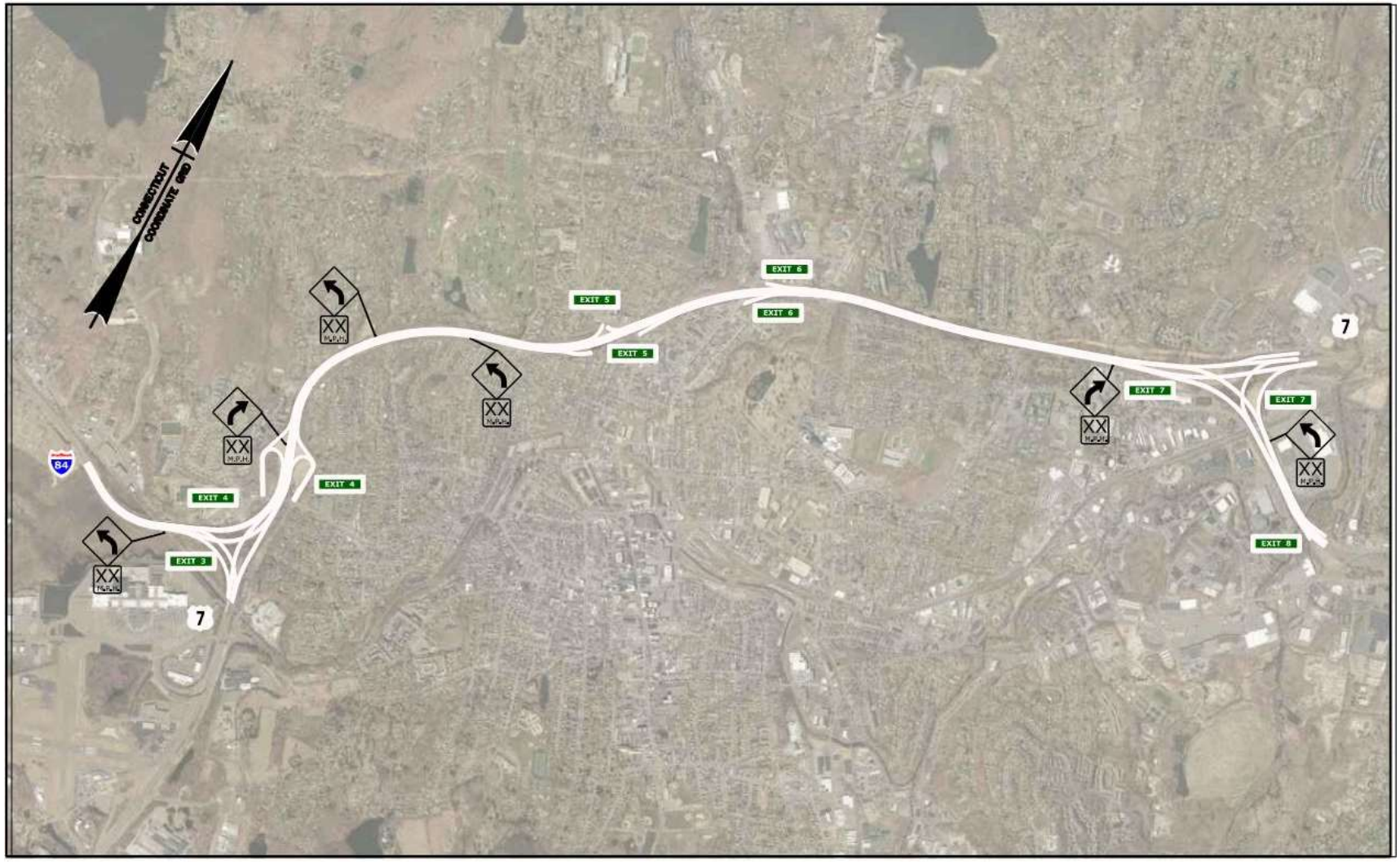
- Approaching Interchange 3
- Approaching Interchange 4
- Approaching Interchange 7

Pavement markings with highway shields (interstate, U.S., state, and others) could be installed to supplement the highway signage. Pavement markings for I-84 and U.S. Route 7 shields could be installed in advance of Interchanges 3 and 7 to improve driver expectancy for left hand exits.

5.6. Connected and Automated Vehicle Deployment

Connected vehicle (CV) deployment involves the use of applications to communicate between vehicle to vehicle, vehicle to infrastructure such as roadside devices, traffic management center, operations center, and others to reduce crashes and improve the efficiency of the transportation system. Use of autonomous vehicle (AV) deployment prevents human errors and choices. This leads to potential reduction in crashes. CV deployments are active in many parts of the country and have been tested over many years. AV deployment are still being tested in several states including Connecticut where the legislation has authorized AV testing with a human operator.

Figure 13: Potential Highway Curve Warning Signage Locations



6. Assessment

The following is an assessment of TSMO strategies applicable to the I-84 Danbury corridor and could be implemented in a relatively short time frame (0-5 years):

- The **Dynamic Lane Use – Median** is a viable strategy and is anticipated to reduce congestion and improve mobility on the highway. However, this strategy does not reduce congestion or improve mobility on the local roads. It does not address other modes of travel adjacent to the highway such as pedestrian, bicycle, or public transit travel modes. There is a potential for driver confusion and misuse of the dynamic lane specifically when it is not intended for use. This could lead to potential enforcement issues. This strategy could be constructed using typical methods.

- The **Temporary Shoulder or Hard Shoulder Running** is a viable strategy and is anticipated to reduce congestion and improve mobility on I-84 during the weekday P.M. peak period and on Route 7. However, this strategy introduces safety concerns at the gore areas and weaving near entrance and exit ramps. This strategy may impact operations on local roads which have access to the highway. It does not address other modes of travel adjacent to the highway such as pedestrian, bicycle, or public transit travel modes. This strategy could be constructed using typical methods.

- The **Freeway Ramp Metering** is anticipated to reduce congestion and improve mobility on the highway. However, this strategy creates additional congestion when motorists divert to adjacent local roads adjacent to the freeway on-ramp. This does not improve mobility on local roads. It does not address other modes of travel adjacent to the highway such as pedestrian, bicycle, or public transit travel modes. This strategy could be constructed using typical methods.

- **Traffic Incident Management System** strategies could be implemented in a short time frame and can help the motorists get notifications of incidents and delays in the area. This enables them make travel choices. Therefore, this strategy could reduce congestion and improve mobility on the highway.

- **Arterial Management** strategies could help improve traffic signal operations and flow on the local road system. These strategies do not reduce congestion and mobility on the highway. However, these strategies could reduce congestion and improve mobility on the local roads.

- **Travel Demand Management** strategies could help reduce the use of single occupant vehicles on the highway. Therefore, travel demand management has a potential to reduce congestion and improve mobility on the highway and on the local roads. It does address other modes of travel adjacent to the highway such as pedestrian, bicycle, or public transit travel modes.

- **Public Transportation Management** strategies address other modes of travel adjacent to the highway such as bus and rail transit modes. Therefore, these strategies could help reduce congestion and improve mobility on the local roads.

- **Corridor Traffic Management** such as highway curve signage and pavement markings provide short term maintenance improvements to help driver expectancy on the highway.

- **Connected and Automated Vehicle systems** could be deployed in the I-84 Danbury corridor once the infrastructure and testing are completed in Connecticut.