IR-71 CORRIDOR STUDY
BOSTON RD. PARTIAL INTERCHANGE
November 2017
(This page is intentionally left blank)
The Northeast Ohio Areawide Coordinating Agency (NOACA) is a public organization serving the counties of and municipalities and townships within Cuyahoga, Geauga, Lake, Lorain and Medina (covering an area with 2.1 million people). NOACA is the agency designated or recognized to perform the following functions:

- Serve as the Metropolitan Planning Organization (MPO), with responsibility for comprehensive, cooperative and continuous planning for highways, public transit, and bikeways, as defined in the current transportation law.
- Perform continuous water quality, transportation-related air quality and other environmental planning functions.
- Administer the area clearinghouse function, which includes providing local government with the opportunity to review a wide variety of local or state applications for federal funds.
- Conduct transportation and environmental planning and related demographic, economic and land use research.
- Serve as an information center for transportation and environmental and related planning.
- As directed by the Board, provide transportation and environmental planning assistance to the 172 units of local, general purpose government.

NOACA’s Board of Directors is composed of 45 local public officials. The Board convenes quarterly to provide a forum for members to present, discuss and develop solutions to local and areawide issues and make recommendations regarding implementation strategies. As the area clearinghouse for the region, the Board makes comments and recommendations on applications for state and federal grants, with the purpose of enhancing the region’s social, physical, environmental and land use/transportation fabric. NOACA invites you to take part in its planning process. Feel free to participate, to ask questions and to learn more about areawide planning.

For more information, call (216) 241-2414 or log on at www.noaca.org
## 2018 NOACA BOARD OF DIRECTORS

### BOARD OFFICERS

**President:** Armond Budish, County Executive, Cuyahoga County  
**First Vice President:** Valarie J. McCall, Chief of Government & International Affairs, City of Cleveland  
**Second Vice President:** Timothy C. Lennon, Commissioner, Geauga County  
**Secretary:** Ted Kalo, Commissioner, Lorain County  
**Assistant Secretary:** Holly C. Brinda, Mayor, City of Elyria  

**Assistant Secretary:** Michael P. Summers, Mayor, City of Lakewood  
**Treasurer:** Daniel P. Troy, Commissioner, Lake County  
**Assistant Treasurer:** James R. Gills, P.E., P.S.  
Lake County Engineer  
**Assistant Treasurer:** Kirsten Holzheimer Gail, Mayor, City of Euclid  
**Immediate Past President:** Adam Friedrick, Commissioner, Medina County

### BOARD MEMBERS

#### CUYAHOGA COUNTY
- Samuel J. Alai, Mayor, City of Broadview Heights  
- Annette M. Blackwell, Mayor, City of Maple Heights  
- Pamela Bobst, Mayor, City of Rocky River  
- Michael Dylan Brennan, Mayor, City of University Heights  
- Tanisha R. Briley, City Manager, Cleveland Heights  
- Armond Budish, County Executive  
- Glenn Coyne, Executive Director, Planning Commission  
- Timothy J. DeGeeter, Mayor, City of Parma  
- Michael W. Dever, MPA  
- Public Works Director  
- Kirsten Holzheimer Gail, Mayor, City of Euclid  
- Michael D. Gammella, Mayor, City of Brook Park  
- Dale Miller, County Councilman  
- David H. Roche, Mayor, City of Richmond Heights  
- Robert A. Stefanik, Mayor, City of North Royalton  
- Michael P. Summers, Mayor, City of Lakewood

#### CITY OF CLEVELAND
- Anthony Brancatelli, City Councilman

#### GEauga COUNTY
- Freddy L. Collier, Jr., Director, City Planning Commission  
- Blaine A. Griffin, City Councilman  
- Frank G. Jackson, Mayor  
- Martin J. Keane, City Councilman  
- Valarie J. McCall, Chief of Government & International Affairs  
- Matthew L. Sproun, P.E., PMP, Capital Projects Director

#### LAKE COUNTY
- Ben Capelle, General Manager, Laketran  
- Jerry C. Cirino, County Commissioner  
- James R. Gills, P.E., P.S., County Engineer  
- John Hamercheck, County Commissioner  
- Daniel P. Troy, County Commissioner

#### LORAIN COUNTY
- Holly C. Brinda, Mayor, City of Elyria  
- Kenneth P. Carney, Sr., P.E., P.S., County Engineer

#### MEDINA COUNTY
- Jeff Brandon, Trustee, Montville Township  
- Andrew H. Conrad, P.E., P.S. County Engineer  
- Adam Friedrick, County Commissioner  
- Patrick Patton, City Engineer, City of Medina

#### REGIONAL AND STATE
- Greater Cleveland Regional Transit Authority (GCRTA)  
- Joseph A. Calabrese, CEO and General Manager  
- Northeast Ohio Regional Sewer District (NEORSD)  
- Kyle Dreyfuss-Wells, Chief Executive Officer  
- Cleveland-Cuyahoga County Port Authority  
- William D. Friedman, President/CEO  
- Ohio Department of Transportation (ODOT)  
- Myron S. Pakush, Deputy Director, District 12

- **Ex Officio Member:**  
  - Kurt Princic, Chief, Northeast District Office, Ohio Environmental Protection Agency (OEPA)

### NOACA DIRECTORS

**Grace Gallucci,** Executive Director  
**Billie Geyer,** Comptroller  
**Marvin Hayes,** Director of Communications & Public Affairs  
**Randy Lane,** Director of Programming  
**Susanna Merlone,** EMBA, Director of Administrative Services  
**Kathy Sarli,** Director of Planning  
**Jonathan Giblin,** Associate Director of Compliance
# IR-71 Corridor Study

## Author(s)
Ali Makarachi, Derek Taylor

## Report Date
November 2017

## Performing Organization Name & Address
Northeast Ohio Areawide Coordinating Agency  
1299 Superior Avenue, Cleveland, OH 44114-3204  
Phone: (216) 241-2414 FAX: (216) 621-3024  
Website: [www.noaca.org](http://www.noaca.org)

## Project Task No.
6050 - 01

## NOACA Contract/Grant No.
ODOT/FHWA

## Sponsoring Agency Name & Address
Ohio Department of Transportation  
1980 W. Broad St., Box 899  
Columbus, OH 43216-0899

## Type of Report & Period Covered
FY2018

## Supplementary Notes
Federal funding for this project was provided by the Federal Highway Administration and administered by the Ohio Department of Transportation.

## Abstracts
Interstate 71 (IR-71) is a regionally significant highway that connects Cleveland to Columbus, Cincinnati and Louisville, Kentucky. This study investigated improvements on the operations of the IR-71 corridor from IR-80 to SR-303 and the focus of the study was on scenarios with the highest return on construction investment. This study was conducted in three phases. The first phase compared seven construction alternatives in the northern subarea and three construction alternatives in the southern subarea. Due to the congestion in the northern subarea, the selected alternative of a partial interchange at Boston Road and IR-71 was further analyzed in the second phase. Similar to the phase one, the backbone of the second phase was a comparative analysis for a set of twelve construction design alternatives based on the future morning and afternoon peak period scenarios of the NOACA travel forecasting model. Finally, the phase three of the study identified the origins and destinations of vehicular trips travelling through the proposed Boston interchange ramps during the peak periods.

## Key Words & Document Analysis
A. Descriptors: Corridor Study, IR-71, Comparative Analysis, Congestion Cost, Construction Cost, Level of Service, Partial Interchange, Boston Road, Origin and Destination

B. Identifiers/Open Ended Terms

## Availability Statement
NOACA

## No. Pages

## Price
IR-71 Corridor Study

November 2017

NORTHEAST OHIO AREAWIDE COORDINATING AGENCY
1299 Superior Avenue E.
Cleveland, Ohio 44114

noaca.org

Armond Budish
BOARD PRESIDENT

Grace Gallucci
EXECUTIVE DIRECTOR

Preparation of this publication was financed by appropriations from the counties of and municipalities within Cuyahoga, Geauga, Lake, Lorain and Medina; the U.S. Environmental Protection Agency; and the U.S. Department of Transportation, Federal Transit Administration and Federal Highway Administration, in conjunction with the Ohio Department of Transportation.
Table of Contents
1. Executive Summary .................................................................................................................. 2
2. Background ............................................................................................................................. 5
3. Boston Road Interchange Alternative Evaluations ................................................................... 7
4. Comparative Analyses ............................................................................................................ 11
    Congestion Cost .............................................................................................................. 11
    Construction Cost Items .................................................................................................. 12
    Safety Cost ..................................................................................................................... 14
    Emission Cost ................................................................................................................. 15
    Total Cost Comparison ................................................................................................... 16
5. Conclusion .............................................................................................................................. 21

Maps
1: Phase 1 Project Alternatives

Figures
1: Locations of Major Origins and Destinations
2: Benefit Calculations
3: Design Alternative Benefits Comparison Chart
4: Volume over Capacity Ratio Comparison – SR 82 Segments
5: Volume over Capacity Ratio Comparison – Howe Road Segments

Tables
1: Unit Costs
2: Typical Crash Costs
3: Main Mobile Emission Costs
4: Cost Items of the Design Alternatives with the Boston Road Median
5: Cost Items of the Design Alternatives without Boston Road Median
6: Cost and Traffic Analyses Results for Alternative 1
7: Cost and Traffic Analyses Results for Alternative 2
8: Cost and Traffic Analyses Results for Alternative 3
9: Cost and Traffic Analyses Results for Alternative 4
10: Cost and Traffic Analyses Results for Alternative 5

Appendix 1: Volume over Capacity Ratio Comparisons
Executive Summary

Interstate 71 (IR-71) is a regionally significant highway that connects Cleveland to Columbus, Cincinnati and Louisville, Kentucky. Traffic flow and congestion along this highway corridor varies, but it generally operates near or at capacity level during the peak periods as it passes through urbanized areas such as Strongsville and Medina. The first phase of this study investigated traffic congestion along IR-71 from the State Route (SR) 82 (Royalton Rd) interchange to United States Route (US)-224. The analysis identified adding a partial interchange at Boston Road and IR-71 as the alternative with the highest return.

This Report summarizes the second phase of the study conducted by The Northeast Ohio Areawide Coordinating Agency (NOACA), which analyzes alternatives for a partial interchange design at Boston Road and IR-71. Similar to the first phase of the IR-71 corridor study, the backbone of the second phase is a comparative analysis for a set of selected construction design alternatives based on the future morning and afternoon peak period scenarios of the NOACA travel forecasting model.

The study considered five alternatives for the partial interchange at Boston Road and IR-71. Each alternative includes a pair of scenarios for the Boston Road lane configuration. A median lane along Boston Road distinguishes each pair of scenarios. Combining the partial interchange alternatives and Boston Road median alternatives generated ten individual alternatives. Additionally, the “No Build” and “Full Interchange” alternatives played the benchmark roles for the conducted comparative analysis.

A benefit value was calculated for each alternative by comparing its total cost to that of the “No Build” alternative. The total cost is comprised of congestion, preliminary engineering, right of way acquisition, construction, construction engineering, maintenance, safety, and emissions costs. These costs were then decreased by estimated reduction in congestion costs, and the savings magnitude is the overall comparison indicator. Aggregating all these costs for each alternative and comparing them with the specified benchmark quantified the positive or negative return of each alternative. The highest positive return justifies the construction design alternative in terms of cost, however, traffic congestion is also important in selecting the best candidate.

Boston Road Interchange Alternative Evaluations

Considering the residential neighborhoods in the west of the intersection of Boston Road and IR-71 as the major trip generators, and the employment centers in the north and south, five possible partial interchange alternatives were designed. This alternative was assumed as alternate 1, or the base alternate and alternatives 2, 3, 4 and 5 add supplemental ramps.

1. Exit-ramp from SB IR-71 to Boston Road in City of Strongsville.

Alternative 1 (Base)
2. On-ramp from Boston Road to NB IR-71 in City of Brunswick.

Alternative 2

3. On-ramp from Boston Road to NB IR-71 in City of Strongsville.

Alternative 3

4. On-ramp from Boston Road to SB IR-71 in City of Brunswick.

Alternative 4

5. Exit-ramp from NB IR-71 to Boston Road in City of Strongsville.

Alternative 5

The “No Build” and a full interchange were considered as the benchmark alternatives.
Findings

- Alternative 4 without a Boston Road median provides the highest potential benefit.

- Congestion impacts are between 0% to +/- 20% for most alternatives.

- Alternative 2 and 3 offer the highest traffic improvements on Howe Road and SR-82.

- Traffic congestion will slightly increase on certain segments of IR-71 regardless of the alternatives.

- All alternatives make Boston Road and Carpenter Road more congested.

- All alternatives do not have any noticeable impacts on SR 303 congestion.
Background

The Northeast Ohio Areawide Coordinating Agency (NOACA) and the Ohio Department of Transportation (ODOT) have partnered on a study to investigate improvements on the operations of the Interstate 71 (IR-71) corridor by reducing congestion and improving safety. Specifically examining the high-level need for one or more interchanges in the corridor to provide the most relief in terms of congestion.

IR-71 is a regionally significant highway that connects Cleveland to Columbus, Cincinnati and Louisville, Kentucky. Traffic flow and congestion along this highway corridor varies, but it generally operates near or at capacity level during the peak periods as it passes through urbanized areas such as Strongsville and Medina.

First phase of this study investigated traffic congestion along IR-71 from the State Route (SR) 82 (Royalton Rd) interchange to United States Route (US)-224 and evaluating a potential interchange at Boston Road. The analysis identified adding a partial interchange at Boston Road and IR-71 as the alternative with the highest potential return.

The second phase of the study was to analyze alternatives for a partial interchange design at Boston Road and IR-71. Similar to the first phase of the IR-71 corridor study, the backbone of the second phase was a comparative analysis for a set of selected construction alternatives based on the future morning (AM) and afternoon (PM) peak period scenarios of the NOACA travel forecasting model.

Map 1 displays the locations of alternatives which were considered in phase 1 of this study including road additions, widening and new interchanges.
Map 1: Phase 1 Project Alternatives

Alternatives
- I-71 South Auxiliary Lane
- Howe Rd Widening
- Boston Rd - Full Interchange
- Boston Rd - Half Interchange
Boston Road Interchange Alternative Evaluation

The second phase considered five alternatives for the partial interchange at Boston Road and IR-71. Each alternative includes a pair of scenarios for the Boston Road lane configuration. A median lane along Boston Road distinguishes each pair of scenarios. Combining the partial interchange evaluation and Boston Road median alternatives generated ten individual alternatives. Considering the residential neighborhoods in the west of the intersection of Boston Road and IR-71 as the major trip generators and the employment centers in the north and south, five possible partial interchange alternatives were evaluated. Figure 1 schematically depicts the locations of these origins and destinations.
1. Exit-ramp from SB IR-71 to Boston Road in City of Strongsville. This alternative was assumed as alternate 1, or the base alternate and targeted users will be those making southbound return work trips during the afternoon peak period. Alternatives 2, 3, 4 and 5 add supplemental ramps.

2. On-ramp from Boston Road to NB IR-71 in City of Brunswick. This supplemental ramp will be potentially used by drivers making northbound work trips during the morning peak period. The residents in the west of IR-71 will make right turn on this ramp.
3. On-ramp from Boston Road to NB IR-71 in City of Strongsville. This supplemental ramp will be potentially used by drivers making northbound work trips during the morning peak period. The residents in the west of IR-71 will make left turn on this ramp.

4. On-ramp from Boston Road to SB IR-71 in City of Brunswick, which includes a realignment of Carpenter Road. This ramp will serve drivers traveling southbound for their morning work trips.
5. Exit-ramp from NB IR-71 to Boston Road in City of Strongsville. Drivers traveling northbound on IR-71 from work locations in the south will exit using this ramp to reach their residences during the afternoon peak period.

The “No Build” and a full interchange were considered as the benchmark alternatives.
Comparative Analyses

A future year modeling scenario was developed for each specified alternative, and the NOACA travel forecasting model runs were executed. A comparative analysis was conducted based on the following cost items:

- Congestion Cost
- Preliminary Engineering Cost
- Right-of-Way acquisition Cost
- Construction Cost
- Construction Engineering Cost
- Maintenance Cost
- Safety Cost
- Emissions Cost

The next sections document a short description for each cost estimation procedure.

Congestion Cost

As demand approaches the capacity of a road (or of the intersection along the road), extreme traffic congestion sets in. Traffic congestion causes longer trip times, slower speed and increased delay. Traffic engineering and financial indicators of travel delay and wasted fuel due to congestion were combined as a performance measure of congestion cost. This combined measure was calculated based on the following assumptions and procedure.

Assumptions

Average Fuel Cost = $2.5 per Gallon

Average miles a vehicle can travel on one gallon of fuel = 25.73 miles per gallon. According to several sources, in 2015, the average Ohio gasoline consumption per day per capita was about 1.059 gallons, and therefore the calculated daily fuel consumption for the NOACA region is 2,145,911 gallons. The 2015 total Vehicle Mile Traveled (VMT) was about 55,224,583 vehicle miles and therefore the average miles per gallon is the quotient of VMT divided by total daily gasoline consumption.

Median Value of time per hour = $12.27

The 2015 median annual income in the NOACA region was about $51,049 which results in $24.54 per hour. The US Department of Transportation and other sources indicate a range of 30 to 60 percent of average earnings for value of travel time.

Auto occupancy varies during the peak and off-peak periods of a day.

The NOACA travel forecasting model estimates a range of 1.21 to 1.485 for average auto occupancy during the five periods of AM peak, midday, PM peak, night time, and early morning modeling scenarios.

Procedure

The congestion cost procedure utilizes the NOACA travel forecasting model, and a set of assumptions to calculate the additional times that are required to travel a road segment due to
traffic congestion conditions. The following steps were implemented to calculate the total congestion costs:

- The **average road segment delay** is the difference between the estimated travel time under actual (often congested) conditions and under uncongested conditions.

\[
\text{Average Road Segment Delay (hr)} = \frac{\text{Length of the road Segment (miles)}}{\text{Modeled Road Segment speed (mph)}} - \frac{\text{Length of the road Segment (miles)}}{\text{Free Flow Speed (mph)}}
\]

- The **total delay on a road segment** is product of the average delay and total vehicles traveling this segment.

\[
\text{Road Segment Delay (hr)} = \text{Average Road Segment Delay} \times \text{Total Traffic Volume}
\]

- The **road segment delay cost** is calculated by multiplying the estimated road segment delay by average passenger car occupancy and the occupants’ average value of time.

\[
\text{Road Segment Delay Cost ($)} = \text{Road Segment Delay} \times \text{Average auto occupancy} \times \text{Average Value of time}
\]

- Vehicles waste additional fuel when they are under congested conditions. The **additional consumed fuel cost** can be estimated using the below calculated delay and auto operating cost.

\[
\text{Road Segment Fuel Cost ($)} = \text{Road Segment Delay} \times \text{Modeled Road Segment Speed} \times \text{auto Operating cost}
\]

- The **average auto operating cost** is estimated by dividing the fuel cost per gallon by the average miles a vehicle can travel on one gallon of fuel.

\[
\text{Average Auto Operating Cost ($)} = \frac{\text{Fuel Cost per gallon}}{\text{Average miles a vehicle can travel on one gallon of fuel}}
\]

- Finally, the **total road segment congestion cost** comprises of two elements; delay cost and fuel cost.

\[
\text{Road Segment Congestion Cost ($)} = \text{Road Segment Delay Cost} + \text{Road Segment Fuel Cost}
\]

**Construction Cost Items**
The preliminary engineering, right of way acquisition, construction, construction engineering, maintenance costs were estimated based on the assumed unit costs, which are illustrated in table 1.
<table>
<thead>
<tr>
<th>Cost Item/ Parameter</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Period</td>
<td>20 Years</td>
</tr>
<tr>
<td>Area of a Lane-Mile (Sq. Ft)</td>
<td>12 x 5,280 = 63,360</td>
</tr>
<tr>
<td>On or Off-Ramp Construction Cost per Sq. Ft</td>
<td>$30</td>
</tr>
<tr>
<td>Construction Cost of a Lane-Mile of Ramp</td>
<td>$1,900,800</td>
</tr>
<tr>
<td>Construction Cost of a Four-Legged Signalized Intersection</td>
<td>$425,000</td>
</tr>
<tr>
<td>Width of a Median Lane (Ft)</td>
<td>11</td>
</tr>
<tr>
<td>Two-Way Left-Turn Lane (TWLTL) Construction Cost per Sq. Ft</td>
<td>$22</td>
</tr>
<tr>
<td>Construction Cost of a Mile of TWLTL</td>
<td>$1,277,760</td>
</tr>
<tr>
<td>TWLTL Cost for Boston Rd, from SR42 to W 130th St (2.04 miles)</td>
<td>$2,606,630</td>
</tr>
<tr>
<td>Right of Way (R/W) Cost per Sq. Ft</td>
<td>$15</td>
</tr>
<tr>
<td>R/W width of a Ramp Lane (Ft)</td>
<td>40</td>
</tr>
<tr>
<td>Average Cost of Demolishing a House ($)</td>
<td>$350,000</td>
</tr>
<tr>
<td>Maintenance Cost Per Sq. Ft</td>
<td>$4</td>
</tr>
<tr>
<td>Number of Maintenance Cycles in the Project Period</td>
<td>3</td>
</tr>
<tr>
<td>Maintenance Cost of a Lane-Mile</td>
<td>$253,440</td>
</tr>
<tr>
<td>Preliminary Engineering Cost for a Ramp only (Scenario 1)</td>
<td>10% of Construction Cost</td>
</tr>
<tr>
<td>Preliminary Engineering Cost for a Half Interchange (Scenarios 2-5)</td>
<td>18% of Construction Cost</td>
</tr>
<tr>
<td>Construction Engineering Cost for a Ramp only (Scenario 1)</td>
<td>5% of Construction Cost</td>
</tr>
<tr>
<td>Construction Engineering Cost for a Half Interchange (Scenarios 2-5)</td>
<td>10% of Construction Cost</td>
</tr>
</tbody>
</table>
Safety Cost
The crash risk in congested areas within the study area was considered and corresponding costs were calculated. The reported crashes referenced to a specific location were used to identify crash patterns and more specifically, severity, and frequency of crashes. A crash severity scale known as the KABCO scale shown in Table 2, provided by the Federal Highway Administration, was considered to calculate the potential costs as a measure of safety analysis. The KABCO injury scale was developed by the National Safety Council (NSC) and frequently used by law enforcement for classifying injuries.

K: Fatal
A: Incapacitating injury
B: Non incapacitating injury
C: possible injury
O: No injury (property damage only)

<table>
<thead>
<tr>
<th>Injury/ Severity Level</th>
<th>Estimated Crash Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatality (K)</td>
<td>$4,008,900</td>
</tr>
<tr>
<td>Disabling Injury (A)</td>
<td>$216,000</td>
</tr>
<tr>
<td>Evident Injury (B)</td>
<td>$79,000</td>
</tr>
<tr>
<td>Possible Injury (C)</td>
<td>$44,900</td>
</tr>
<tr>
<td>Property Damage only (O)</td>
<td>$7,400</td>
</tr>
</tbody>
</table>
Emission Cost
The emission costs were calculated using the most recent version of the US Environmental Protection Agency’s (US EPA) mobile emissions modeling software, named MOVES2014a. Emissions factors for all vehicle class types (e.g. passenger vehicles, buses, heavy-duty trucks) were developed for nitrogen oxides (NOx), volatile organic compounds (VOCs), and fine particulate matter (PM2.5) that are the main mobile emissions of concern in Northeast Ohio. These emissions factors estimate the grams of each pollutant released per mile (g/mi) for each vehicle class, under various parameters. Emissions factors were selected for vehicles traveling 27.5-32.5 miles per hour (mph), which is approximately the average travel speed for vehicles in the US, according to the US Department of Transportation (US DOT) Department of Transportation Statistics. Emission factors were also selected for buses traveling 12.5-17.5 mph, which is the average travel speed for buses in the NOACA region.

The selected emission factors (in g/mi) were then multiplied by the total Vehicle Miles Traveled (VMT) associated with each scenario alternative. It is worth mentioning that the VMT is an indicator of the travel levels on the roadway system by motor vehicles, and varies by subarea and scenario alternative. These VMT values are calculated using the NOACA travel demand model and are broken down into vehicle classes. This step also provided estimates of total grams of each pollutant per day, for each scenario alternative.

In order to calculate the mobile emission costs, first the estimated grams per day for each scenario were converted into total metric tons per year and then multiplied by the most recent costs per ton for NOx, VOCs, and PM2.5 from the Federal Highway Administration. Table 3 shows the estimated mobile emission costs.

<table>
<thead>
<tr>
<th>Main Mobile Emission</th>
<th>Emission Cost per ton (2017 $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOCs</td>
<td>2,032</td>
</tr>
<tr>
<td>NOx</td>
<td>8,010</td>
</tr>
<tr>
<td>PM2.5</td>
<td>366,414</td>
</tr>
</tbody>
</table>
**Total Cost Comparison**

A comparative analysis was conducted based on the total of all the cost items of each alternative. These total costs were compared with that of the “No Build” scenario as the benchmark. The comparative analyses illustrate that if the estimated total construction costs are justified by the reduction in congestion costs, then the savings magnitude as a benefit is the overall comparison indicator. Figure 2 displays the total cost items and calculating equation.

**Figure 2: Benefit Calculations**

![Benefit Calculations Diagram]

Tables 4 and 5 show the estimated cost items for each alternative with, and without a median lane for Boston Road, and the last column presents the benefit as the alternative selection indicator. Also, Figure 3 illustrates alternative cost chart for comparison.
Table 4: Cost Items for Alternatives with a Boston Road Median

<p>| Alternative          | Cost Item (2017$) | Cost Item | Cost Item | Cost Item | Cost Item | Cost Item | Cost Item | Cost Item | Cost Item | Cost Item | Cost Item |
|----------------------|-------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                      |                   | Congestion| Preliminary| Right-of- | Construction| Construction| Maintenance| Safety | Emission | Benefit |
| No Build             |                   | 463,217,800 | 0 | 0 | 0 | 0 | 0 | 6,079,174 | 40,411,256 | 0 |
| 1 (Base)             |                   | 430,993,250 | 433,977 | 5,865,360 | 4,339,770 | 216,989 | 608,865 | 5,814,857 | 40,688,650 | 20,746,512 |
| 2                    |                   | 442,077,250 | 1,045,838 | 10,255,920 | 5,810,210 | 581,021 | 1,027,459 | 5,859,095 | 40,998,202 | 2,083,235 |
| 3                    |                   | 445,028,050 | 1,028,731 | 9,574,960 | 5,715,170 | 571,517 | 989,405 | 5,847,485 | 40,916,963 | 35,948 |
| 4                    |                   | 416,333,500 | 1,047,505 | 12,696,320 | 5,819,470 | 581,947 | 837,189 | 5,835,412 | 40,832,481 | 25,724,405 |
| 5                    |                   | 432,377,450 | 1,114,267 | 11,079,760 | 6,190,370 | 619,037 | 1,179,676 | 5,799,817 | 40,583,408 | 10,764,446 |
| Full Interchange     |                   | 437,122,600 | 2,295,365 | 39,713,520 | 12,752,030 | 1,275,203 | 3,272,649 | 5,875,474 | 40,747,768 | -33,346,379 |</p>
<table>
<thead>
<tr>
<th>Alternative</th>
<th>Cost Item (2017$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Build</td>
<td></td>
</tr>
<tr>
<td></td>
<td>463,217,800</td>
</tr>
<tr>
<td>1 (Base)</td>
<td>444,743,350</td>
</tr>
<tr>
<td>2</td>
<td>437,444,100</td>
</tr>
<tr>
<td>3</td>
<td>417,870,200</td>
</tr>
<tr>
<td>4</td>
<td>456,135,250</td>
</tr>
<tr>
<td>Full Interchange</td>
<td>438,899,550</td>
</tr>
</tbody>
</table>
Figure 3: Alternative Benefits Comparison Chart
This analysis led to conducting a traffic engineering evaluation based on the congestion measure of “Volume over Capacity Ratio” (V/C) for segments of eight roads and highways in the study area during the morning and afternoon peak periods. These roads and highways are: SR 82, SR 303, IR-71, Boston Road, Howe Road, Carpenter Road, SR 82 -IR-71 ramps, SR303- IR-71 ramps and Boston Road- IR-71 ramps. In total, 1,600 V/C segment ratios were analyzed.

Appendix 1 depicts several examples of the V/C ratios comparison for the congested segments of SR 82 and Howe Road during the morning and afternoon peak periods.
Conclusion

As discussed, ten partial interchange alternatives were considered and alternative 1 was assumed as the base alternative, and the other alternatives included an additional ramp. The total cost of these alternatives were compared with that of the “No Build” scenario as the benchmark of study.

As illustrated in the last column of Table 4, Table 5, and also in Appendix 1, alternative 4 without the Boston Road median has the highest potential benefit. More than one third of this benefit is due to alternative 1, or base alternative of the construction.

Alternative 4 with the Boston Road median has the second highest potential benefit. Alternative 1 occupies the third position in the ranking of potential benefits. Additional ramps of other alternatives are not cost effective, and, in fact, alternatives 2, 3, and 5 lose the benefits gained from alternative 1.

As analyzed in the phase 1 of the IR-71 corridor study, the full interchange alternative, as shown in tables 4 and 5, has the lowest potential benefit.

A traffic congestion analysis followed the cost comparative analysis using the “Volume over Capacity Ratio” (V/C) as the performance measure. This analysis considered about ten segments of eight roads and highways for the ten alternatives in the study area during the morning and afternoon peak periods. In total, about 1,600 peak period V/C segment ratios were calculated and compared with those of the ‘No Build” scenario.

The traffic congestion analysis indicated that:

- For any alternative, the congestion impacts are in the range 0% to 20%.
- The impact of adding a Boston Road median is negligible on other roads in the study area.
- All alternatives generally make SR 82, Howe Road, SR82- IR-71 ramps and SR303-IR71 ramps less congested depending on the morning or afternoon peak periods.
- All alternatives make Boston Road and Carpenter Road more congested.
- All alternatives do not have any noticeable impacts on SR 303 traffic congestion.
- Alternative 1 moderately improves the congestion on SR 82 and Howe Road.
- Alternatives 2 and 3 take the congestion improvements of the phase 1 of construction to a higher level on SR 82 and Howe Road and decrease the V/C values up to 25%.
- The congestion on IR-71 will slightly increase on certain segments for all the alternatives.

Tables 6 and 7 summarize the cost and traffic analyses results for the phase 1 and phase 2 of the alternatives evaluation.

**Table 6: Cost and Traffic Analyses Results for Alternative 1**

<table>
<thead>
<tr>
<th>Alternative 1 (Base)</th>
<th>Selection Criterion</th>
<th>Benefit</th>
<th>Adding Boston Road median preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost</td>
<td>High</td>
<td>Added Benefit</td>
<td></td>
</tr>
<tr>
<td>Selection Criterion</td>
<td>Congestion</td>
<td>Boston Road median preference</td>
<td></td>
</tr>
<tr>
<td>Howe Road</td>
<td>Moderate improvements</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SR 82</td>
<td>Moderate improvements</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>IR-71</td>
<td>Slight increase on certain segments</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Boston Road</td>
<td>Moderately increase</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SR 303</td>
<td>No improvements</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Selection Criterion</td>
<td>Second Ramp Benefit</td>
<td>Adding Boston Road median preference</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------</td>
<td>--------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Total Cost</td>
<td>All benefit lost</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Howe Road</td>
<td>Significant high improvements</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>SR 82</td>
<td>Significant high improvements</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>IR-71</td>
<td>Slight increase on certain segments</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Boston Road</td>
<td>Moderately increase</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SR 303</td>
<td>No improvements</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Alternative 3</td>
<td>Selection Criterion</td>
<td>Second Ramp Benefit</td>
<td>Adding Boston Road median</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Total Cost</td>
<td>None</td>
<td>All benefit lost</td>
<td></td>
</tr>
<tr>
<td>Selection Criterion</td>
<td>Congestion</td>
<td>Boston Road median preference</td>
<td></td>
</tr>
<tr>
<td>Howe Road</td>
<td>Significant high improvements</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>SR 82</td>
<td>Significant high improvements</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>IR-71</td>
<td>Slight increase on certain segments</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Boston Road</td>
<td>Moderately increase</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SR 303</td>
<td>No improvements</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>
Table 9: Cost and Traffic Analyses Results for Alternative 4

<table>
<thead>
<tr>
<th>Selection Criterion</th>
<th>Second Ramp Benefit</th>
<th>Adding Boston Road median preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost</td>
<td>High</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selection Criterion</th>
<th>Congestion</th>
<th>Boston Road median preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Howe Road</td>
<td>High improvements</td>
<td>NO</td>
</tr>
<tr>
<td>SR 82</td>
<td>High improvements</td>
<td>NO</td>
</tr>
<tr>
<td>IR-71</td>
<td>Slight increase on certain segments</td>
<td>NO</td>
</tr>
<tr>
<td>Boston Road</td>
<td>Moderately increase</td>
<td>YES</td>
</tr>
<tr>
<td>SR 303</td>
<td>No improvements</td>
<td>NO</td>
</tr>
</tbody>
</table>
Table 10: Cost and Traffic Analyses Results for Alternative 5

<table>
<thead>
<tr>
<th>Alternative 5</th>
<th>Selection Criterion</th>
<th>Second Ramp Benefit</th>
<th>Adding Boston Road median</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Cost</td>
<td>All benefit lost &amp; additional cost</td>
<td>Restore benefit</td>
</tr>
<tr>
<td></td>
<td>Selection Criterion</td>
<td>Congestion</td>
<td>Boston Road median preference</td>
</tr>
<tr>
<td>Howe Road</td>
<td></td>
<td>High improvements</td>
<td>NO</td>
</tr>
<tr>
<td>SR 82</td>
<td></td>
<td>High improvements</td>
<td>NO</td>
</tr>
<tr>
<td>IR-71</td>
<td></td>
<td>Slight increase on certain segments</td>
<td>NO</td>
</tr>
<tr>
<td>Boston Road</td>
<td></td>
<td>Moderately increase</td>
<td>YES</td>
</tr>
<tr>
<td>SR 303</td>
<td></td>
<td>No improvements</td>
<td>NO</td>
</tr>
</tbody>
</table>
Appendix 1: Volume over Capacity Ratio Comparisons

![Volume over Capacity Ratio Comparison Diagram](image-url)
IR-71 Corridor Study - Boston Partial Interchange

VOLUME OVER CAPACITY RATIO COMPARISON

Alternative 2 /3
AM Peak

SR 82

Falling Water Rd

Southpark

Hove Rd

IR 71

Alternative 4
AM Peak

SR 82

Falling Water Rd

Southpark

Hove Rd

IR 71

Alternative 2

Alternative 3

Alternative 4
IR-71 Corridor Study - Boston Partial Interchange

VOLUME OVER CAPACITY RATIO COMPARISON

Alternative 1 (Base)

SR 82

Falling Water Rd

Southpark

IR 71

0.76

0.84

2.05

0.92

No Build

PM Peak

SR 82

Falling Water Rd

Southpark

IR 71

0.87

0.95

2.32

1.19

Alternative 1 (Base)
IR-71 Corridor Study - Boston Partial Interchange

VOLUME OVER CAPACITY RATIO COMPARISON

Alternative 2/3
PM Peak

Alternative 4
PM Peak

SR 82

Falling Water Rd

Southport

IR 71

IR 71

Howe Rd

0.78

0.73

0.77

0.85

1.78

2.07

0.93

0.93

Alternative 2

Alternative 3

Alternative 4
IR-71 Corridor Study - Boston Partial Interchange

VOLUME OVER CAPACITY RATIO COMPARISON

Alternative 2
- 0.72
- 0.67
- 0.91
- 0.73
- 0.71

Alternative 3
- 0.82
- 0.72
- 0.91
- 0.73
- 0.71

Alternative 4
- 0.87
- 0.72
- 0.91
- 0.73
- 0.71

Alternative 2
- 1.05
- 0.84
- 1.16
- 0.99
- 1.03

Alternative 3
- 1.05
- 0.84
- 1.16
- 0.99
- 1.03

Alternative 4
- 1.05
- 0.84
- 1.16
- 0.99
- 1.03

-32-
IR-71 Corridor Study - Boston Partial Interchange

VOLUME OVER CAPACITY RATIO COMPARISON

No Build

PM Peak

IR 71

SR 82

Southpark

SB

Pomeroy Blvd

1.19

Shurmer Rd

1.08

Cantebury Dr

0.85

Glendale Ave

Lenox Dr

IR 71

SR 82

Alternative 1

PM Peak

No Build

Shurmer Rd

1.08

Cantebury Dr

0.85

Glendale Ave

Lenox Dr

IR 71

SR 82

Alternative 1

0.90

0.80

0.85

Alternative 1(Base)
IR-71 Corridor Study - Boston Partial Interchange

VOLUME OVER CAPACITY RATIO COMPARISON

Alternative 2/3
PM Peak

Alternative 4
PM Peak

SR 82

0.80

0.87

Pomeroy Blvd

Shumner Rd

Canttonbury Dr.

Glendale Ave.

Lanier Ave.

IR 71

0.96

0.96

0.84

0.84

WB

EB