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1. Introduction

Parsons Brinckerhoff was retained by Operation New Birmingham to develop and evaluate an engineering concept design, construction and cost feasibility for lowering a section of I-20/I-59 that runs through the north part of downtown Birmingham. The 2004 Birmingham City Center Master Plan explored and recommended the lowering of the portion of the interstate currently on elevated structure, citing a variety of community benefits including safety and capacity improvements, air, noise and vibration impact reductions, and aesthetic and connectivity benefits between the expanding Civic Center District and the downtown.

The goals of this Concept Feasibility Review are to:

1. Identify current and future safety, capacity, operational and connectivity deficiencies in the I-20/I-59 corridor study area, and
2. Develop a lowering concept plan that can feasibly be engineered and constructed, likely mitigate safety, capacity and community impacts and is potentially affordable.

The results of this study will be taken into a stakeholders and community involvement process to help gain community input and consensus in solving current and future needs in the corridor and ultimately determine the level of local community and State support and investment in programming a capital improvement project.

1.1. Study Area

The project study area extends from the 31st Street interchange (Exit 126B) to the east and the Akadelphia interchange (Exit 123) to the west, as well as the Red Top Mountain Expressway (US 280) from its beginning at Richard Arrington Boulevard through the 6th street ramps. For the purposes of this study, the focus of the lowered freeway section is between the I-65 and US 280 interchanges. The I-65 interchange will remain largely intact due to the perceived cost to improve this unusual interchange configuration (where the mainline freeway directions cross over and create a series of left-handed ramp entrances and exits); however, significant improvements are anticipated for the I-20/I-59/US 280 interchange to reduce the complexity and footprint of this interchange and potentially reclaim land for community development.

Figure 1: Project Study Area
Within the study area, the interstate and surface street system is largely urban. The existing I-20/I-59 highway viaduct is one of the defining characteristics of the Civic Center District, separating the Birmingham-Jefferson Civic Center (BJCC) from the downtown area. The highway inhibits development on both sides of the corridor due to its visual and noise impacts. The current viaduct structure is not only unattractive, loud and vibrational, but the on and off-ramp system is unfriendly to pedestrians and confusing to motorists.

Both the BJCC and the Museum of Art are planning expansions. The BJCC expansion includes a 50,000-plus seat multi-purpose arena that will bring large-scale events to the area and further add to capacity and wayfinding deficiencies in the corridor.

Much of the area directly beneath the interstate structures is used for parking. Most north-south streets connecting the Civic Center District and the Downtown pass underneath the structure and there is a modest pedestrian passageway between the Museum of Arts and the BJCC.

Ninth Avenue parallels the interstate between 22nd and 16th Street, serving as an underutilized collector street between segmented freeway ramp access. As a whole, this east-west corridor through the north part of Birmingham is auto and parking dominated and offers few pedestrian amenities.

1.2. Summary of 2004 Birmingham City Center Master Plan Goals and Objectives

Use of “collector-distributor” service roads is often used in urban environments. The following diagrams from the 2004 City Center Master Plan illustrate the concept.

The Birmingham City Center Master Plan Update, released in October 2004, presented several urban design and development principles that relate to the transportation systems and improvements in the study area, including:

- Enhancement of connections and gateways in the Civic Center District,
- Development of “green” streets throughout the downtown, and
- Reorganization of the highway and street network, including access to the interstate system.
The master plan specified the goal to improve I-20/I-59 to better serve the city center. The plan suggests depressing through travel lanes on I-20/I-59 through the city center and flanking the depressed roadway with grade-level boulevards, including spacious sidewalks, tree plantings and creative bridge designs at each street crossing, to create a grand urban space. Figure 2 is a sketch from the Master Plan to illustrate such a concept.

Figure 2: Lowered Freeway and Grand Boulevard Concept Plan

One of the two most frequent issues mentioned in the community in the Master Plan focus groups was the community barrier created by the I-20/I-59 viaduct. Many expressed the opinion that reconfiguration of the freeway lanes, ramps and interchanges would eliminate the unneeded maze of ramps connecting to local streets, and could free up several blocks of downtown land for high-value center city uses. Figure 3 illustrates a collector-distributor system of roads proposed to improve both access and wayfinding in the vicinity of the corridor, making travel from or to the interstate simple using the parallel surface streets that collect and distribute traffic from the ends of the corridor. The Master Plan cited the collector-distributor system built for the recent Fort Washington Way interstate lowering project in Cincinnati.

A project to lower I-20/I-59 and build a parallel surface collector-distributor system through the northern downtown area would open up prime cultural, governmental and/or commercial sites in the Civic Center District. The Museum of Art and BJCC would have greater visibility and accessibility. The crossing surface streets of 16th, 17th, 20th and 23rd Avenues could become “green streets” that connect the Civic Center and Central Business Districts.

Figure 3: Collector-Distributor System
2. Preliminary Evaluation

An evaluation of current traffic and safety conditions was undertaken for the project study area. The first part of this evaluation was an analysis of historic crash data, known contributing factors and a crash trends analysis to describe current crash deficiencies of the current system. A crash rate analysis was prepared to identify high crash locations by segment within the study area. Section 2.1 summarizes the crash data study key findings, with the full study results included in Appendix A: Crash Data Analysis Report.

2.1. Summary of Crash Rate Analysis

To identify locations with a history of crashes in the project study area identified in Figure 4, crash rates for the section of I-20/I-59 between mile-post 124.78 and mile-post 126.24 (a length of 1.46 miles) were segregated based on the number of crashes on a specified section, the average daily traffic on the roadway, the time frame of analysis, and the length of the section, expressed in crashes per one million vehicle-miles\(^1\). A section’s crash rate was then compared to a statewide critical crash rate based in part on the Alabama statewide average crash rate. The comparison is expressed as a ratio of the section crash rate to the critical crash rate. Sections with a critical crash rate factor greater than one are considered high crash locations.

**Figure 4: Crash Rate Analysis Study Area**

Table 1 shows the crash rate analysis results for the study area section of I-20/I-59. As shown in Table 1, the entire study area section has a critical crash rate factor greater than one (2.74). As such, this section is considered to be a high crash location. Also shown in Table 1 is a comparison of crash rates by direction. The number of crashes per direction is relatively evenly split, with both directions also evaluated as having a critical crash rate factor greater

\(^1\) Crash Data provided from ALDOT database for 3-year period between 1/1/2005 and 12/31/2007; ADT data provided from ALDOT Transportation Planning Section website; Statewide average crash rate provided from ALDOT Data for the Roadway Classification of Interstate
than one, similar to the entire section. A study of statewide crashes on individual segments between the years 2005 through 2007 showed that the I-20/I-59 study area corridor had two of the top five locations with the greatest total of accidents statewide, including the number one segment (185 crashes between US 280 and 31st Street) and the number four segment (165 crashes between I-65 and 16th Street) over the 3 year period.

Table 1: Summary of Crash Data Analysis

<table>
<thead>
<tr>
<th>Route</th>
<th>Direction</th>
<th>Total Crashes</th>
<th>Average Daily Traffic</th>
<th>Section Crash Rate</th>
<th>Statewide Average Crash Rate</th>
<th>Statewide Critical Crash Rate</th>
<th>Section Critical Crash Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-20/I-59</td>
<td>Both</td>
<td>171</td>
<td>160,140</td>
<td>2.80</td>
<td>0.87</td>
<td>1.02</td>
<td>2.74</td>
</tr>
<tr>
<td></td>
<td>North</td>
<td>338</td>
<td>88,077</td>
<td>2.40</td>
<td>0.87</td>
<td>1.08</td>
<td>2.23</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>367</td>
<td>88,077</td>
<td>2.61</td>
<td>0.87</td>
<td>1.08</td>
<td>2.42</td>
</tr>
</tbody>
</table>

A spot location analysis was performed for the I-65 and US 280 interchange areas. A section of 0.3 miles in the interchange area was analyzed and Table 2 summarizes the spot location crash rates for these two interchanges:

Table 2: I-20 / I-59 Spot Crash Rate Analysis for 2005 – 2007

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Crashes</th>
<th>Average Daily Traffic</th>
<th>Spot Crash Rate (per million veh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-65-I-20 Interchange</td>
<td>321</td>
<td>160,140</td>
<td>1.83</td>
</tr>
<tr>
<td>I-20 / US280 Interchange</td>
<td>329</td>
<td>156,160</td>
<td>1.92</td>
</tr>
</tbody>
</table>

The data in Table 2 shows that there are safety issues at both interchanges. Comparing the total number of crashes that occurred at both interchanges (650) to the total number of crashes (717) shows that the majority of crashes (approximately 91 percent) was in the vicinity of the two major interchanges and not located throughout the I-20/I-59 section.

Other crash analysis study findings include:

- There appears to be a fairly even distribution of crashes during the week, with less occurring during the weekends.
- During the day, the majority if crashes occurred during the morning hours of 7:00 and 8:00 AM, with another, smaller, peak during the evening hours. Generally, these crash trends seem to correspond with typical peak traffic hours during the week.
- The overwhelming majority of crashes occurred during dry roadway conditions (89 percent) and clear weather (69 percent). Therefore, roadway condition and weather does not appear to be a contributing factor to the high number of crashes.
- The highest percentage of crashes along this section of I-20 / I-59 involved property damage only.
- The primary crash cause was identified as misjudging the stop distance (25 percent of crashes). Other primary causes with a significant percentage included other causes related to driver error. Based on these observations, it appears that the majority (over 50 percent) of the crash causes may be related to traffic congestion rather than geometrics.
- A review of crash types by severity showed that there were very few fatal crashes and a low portion of crashes that involved an injury. The greater majority of crashes involved property damage only. A review of contributing factors for the fatalities showed that one crash involved alcohol, and the other two the driver was listed as not in control.
2.2. Capacity Analysis

A review of freeway capacity and operations was performed for current and future conditions based on the traffic projections from the Birmingham Metropolitan Planning Organization’s traffic forecast model. Figure 5 provides a graphic of current (2007) and future projected (2032) average daily traffic (ADT) volumes on many of the freeway and roadway segments in the study area.

From these traffic volumes and the geometric data collected in the field and from aerial photography, a preliminary-level of traffic analysis was conducted to measure current and future level of service (LOS) conditions on the roadways. The freeways and roadways segments in the study area were evaluated using Highway Capacity Manual (HCM) and related software. The HCM provides the commonly understood level of service (LOS) grade results, ranging from LOS A (optimal level of service) to LOS F (poor, extremely congested conditions). During peak period in urban areas, reasonable levels of congestion can be expected, though sections operating above LOS D may warrant capacity improvements.

From the capacity analysis, it was determined that much of the interstate operates at LOS F during the morning and afternoon commute peak hours. This is consistent with visual observations made in the field, where traffic entering the city was observed to back up past 31st Street to the east and just past Akadelphia interchange to the west during peak periods. The westbound I-20/I-59 off-ramp to 22nd Street was observed to back up onto the interstate in the morning peak period. Figure 6 illustrates the current (2007) LOS for each interstate section by direction.

A similar analysis of the 2032 peak period conditions showed conditions only worsening. Traffic is expected to grow by 0.5% per year for the period between 2007 and 2032 (total growth rate of 11-percent), and traffic forecast in some parts of the system are expected to exceed 180,000 vpd, well exceeding the capacity of I-20/I-59 in the downtown section.

2.3. Interstate and Roadway Geometric Deficiency Review

A review of current roadway design and geometrics was conducted to determine geometric conditions that do not meet current roadway standards and practice. As-built design plans were obtained from ALDOT for sections of the interstate, but much of the corridor was not available for this study. Parsons Brinckerhoff engineers conducted field reviews and used aerial photograph and imagery and cad drawings to document a preliminary determination of geometric elements that are deficient by current design standards. These findings include:

- Vehicles entering westbound I-20/I-59 from the 18th Street ramp enter in a drop lane to NB I-65. The 1,300-foot weave (gore to gore) area is deficient for current traffic volumes.
- Vehicles entering eastbound I-20/I-59 from I-65 northbound enter in a drop lane to the 17th Street off-ramp. The 900-foot weave (gore to gore) area is deficient for current traffic volumes.
- The eastbound I-20/I-59 off-ramp to 17th Street has a 100-foot radius at the bottom of the ramp, which is deficient as a free-flow movement.
- The on-ramp from Richard Arlington Jr. Blvd to westbound I-20/I-59 is a left hand entrance and, enters as a drop lane to SB I-65. The 1,100-foot weave (gore to gore) area is deficient for current traffic volumes. Vehicles from this ramp that desire to exit NB I-65 must cross 3 lanes in 2,400 feet to exit.
- The on-ramp from SB I-65 to eastbound I-20/I-59 is a left hand entrance; Vehicles from this ramp that desire to exit to 17th Street must cross 3 lanes in 2,200 feet to exit.
• The exit from eastbound I-20/I-59 to 22nd Street is a trap lane and has a substandard exit taper (approximately a 1:10 ratio).

• Exit from I-20 WB to 22nd Street is a trap lane and a left hand-exit.

• For most of the elevated corridor, the outside (right) shoulders are approximately 6 foot wide (standard minimum is 10 foot).

• For most of the elevated corridor, the inside (left) shoulders are approximately 2 foot wide (standard minimum is 4 foot).

• Most on- and off-ramp shoulders are too narrow (approximately 3 feet or less on both sides), providing insufficient room to pass a stalled/disabled vehicle.

• The spacing of interchange ramp entrances and exits exceeds the AASHTO recommended minimum interchange spacing of one interchange per mile in urban areas.

• In many locations, the exit and entrance to interstate does not meet driver expectations, which requires significant and often confusing trailblazing throughout the corridor.

• The presence of columns supporting the elevated freeway obstructs sight distance at many of the intersections along 9th Avenue and at ramp terminals.

• The distances between successive ramp diverges does not permit sufficient advance signage on the following ramps: the westbound I-20/I-59 off-ramp splits to 11th Avenue / 6th Avenue and to US 280 / 6th Avenue (two places), and the eastbound I-20/I-59 exit to 17th Street.

2.4. Interstate Rehabilitation Project

The current elevated I-20/I-59 structure between US280 and I-65 is in need of rehabilitation due to the conditions of the current structures. The current State Transportation Improvement Program (STIP) allocates nearly $21 million dollars to the design and rehabilitation of the existing I-20/I-59 structures between US280 and I-65, with expenditures for the design to begin in 2011 and the rehabilitation expenditures to begin in 2012. This schedule may be delayed by funding limitations, but structural deficiencies reports indicate that the work needs to be done by 2015. The major rehabilitation work needed would require temporary routing of traffic from one structure so that each structure can be rehabilitated without traffic. This will limit the number of through traffic lanes to two in each direction resulting in an extended period of extreme traffic congestion during reconstruction.

As an alternative to the needed rehabilitation project, the programmed funds could be diverted to pay a portion of the cost of lowering the highway system. The construction period to lower the interstate system would be longer, but the final product would provide key benefits by way of safety improvements, air and noise impact reductions, and support of the community’s goals established by the City Center Master Plan. These long term benefits would not be realized with replacement of the current elevated structures in kind.
3. Preliminary Concept, Feasibility and Cost Estimate

3.1. Concept Plan Development

To determine the feasibility of lowering the interstate, a preliminary concept was developed to test the feasibility of engineering, constructing and financing such a concept. The concept for this was developed to adhere to the following parameters:

- The limits of the lowered I-20/I-59 freeway section would be between 31st Street and the I-65 interchange. Due to the costs and extent of geometric improvements required to alter the I-20 / I-59 / I-65 interchange, most of the current interchange movements would remain intact. However, it will require major modifications to the I-20 / I-59 / US 280 interchange.

- The new freeway section must remain within existing roadway right-of-way. While small amounts of right-of-way may be used for easements or taken permanently, impacts to right-of-way, property and structures should be avoided as much as possible.

- The narrowest portion of the corridor is approximately 230 feet wide. This distance was used to develop a maximum cross section of freeway and surface street lanes. Figure 7 illustrates this typical cross section that shows a four lane lowered freeway and a two-lane, one-way surface frontage road in each direction.

- Surface streets will cross over (at-grade) the lowered freeway lanes and include sidewalks.

![Figure 7: I-20/I-59 Lowering Typical Section](image)

From these parameters, a working concept for lowering I-20 / I-59 was developed and is illustrated as Figure 8. The 2030 traffic volumes were also adapted to meet the new concept of roadways and interchanges, illustrated in Figure 9. Note that the concept developed is not meant to be indicative of a final corridor concept, only one that would be feasible based on the preliminary right-of-way and traffic needs data available. Modifications or alternative concepts may be proposed as further engineering and designs study is advanced.

3.2. Concept Engineering

Some preliminary engineering work was completed to evaluate the grades entering and exiting the lowered section at either ends of the corridor. Figure 10 illustrates the corridor profile developed based on the existing ground profile and the grade requirements of the lowered section. The lowered pavement surface elevation was assumed to be 25 feet below the grade of the surface streets and bridge crossings to meet truck clearance and bridge deck height requirements on the lowered freeway.
Figure 8: I-20/I-59 Lowering Concept Plan
• At the eastern end of the corridor, the interstate would begin its decent west of the 31st Street overpass and descend at a 2.8 percent grade to pass underneath the Norfolk Southern Railroad, a grade well within permissible interstate design standards.

• At the western end of the corridor, the interstate would pass beneath the 16th Street bridge and elevate back to the current I-20 / I-59 mainline grades prior to the existing ramps to/from I-65. The critical direction is eastbound, since it starts at a higher elevation. This is due to the eastbound lanes crossing over the westbound lanes in the I-65 interchange. The grade on the eastbound lanes would descend at a 4.5 percent grade, also within the permissible grade for an interstate with a design speed of 60 mph.

Other concept features were engineered to improve traffic safety and capacity in the corridor:

• In the western section of the corridor, the concept includes the addition of several ramp braids to eliminate critical weaving movements. The ramp from southbound I-65 to the 9th Avenue eastbound frontage road is braided so that this traffic does not have merge and weave with traffic from eastbound I-59/I-20 to enter the downtown area. A ramp braid also provides separated movements for traffic from westbound 9th Avenue frontage road entering either westbound I-20/I-59 or northbound I-65. A separate ramp from the 16th Street bridge structure also allows traffic bound for I-65 southbound to enter from the left side and not be forced to weave with I-20/I-59 traffic.

• In the central section of the corridor, a consistent four lanes in each direction are maintained on the interstate and the current bridge crossings between 16th and 23rd Streets are maintained. The concept includes one-way, two-lane frontage roads on both sides of the interstate as opposed to a multi-lane, two-way boulevard on one side of the interstate because the one-way frontage roads provide superior traffic operations, do not require center or left turn lanes on 9th Avenue or the crossing bridges and provides greater flexibility and room during construction. Between 16th and 23rd Streets serves as a collector-distributor system for I-20/I-59 access, providing single points of interstate access that provides improves distribution to/from the local roadway system, improved wayfinding and visibility along the frontage road system and greater control of access to the interstate system.

• In the eastern section of the corridor, the US280 interchange will be significantly modified. All existing free-flow movements will be maintained in the ultimate configuration except the movement from northbound US280 to westbound I-20/I-59. The movement from US280 will be brought to grade and travel through a short two-block, one-way segment before being able to enter eastbound I-20/I-59. Traffic volume forecasts and intersection capacity indicate that sufficient capacity can be provided for this movement. Caraway Boulevard will be re-connected at-grade across the interstate, but 24th and 28th streets will be segmented to accommodate interstate and ramp transitional areas. Overall, the concept improves the grid pattern of local roadways and opens up approximately 21 additional acres of land for redevelopment, including several blocks immediately east of the proposed domed multi-purpose facility.

3.3. Corridor Photosimulation

In addition to the corridor concept layout, a photosimulation of one section of the corridor was developed to better illustrate the impacts and benefits of the concept, illustrated in Figure 11. From an original photo taken atop the Sheridan hotel looking down at the corridor to the west, the photosimulation illustrates the removal of the elevated structures and replacement with the lowered section. As illustrated in the photosimulation, significant space is opened up along the frontage roadways for additional sidewalk and open spaces, particularly in the areas in front of
the Museum of Arts and the BJCC. These areas can be linked with a wide, plaza-like crossing of the interstate to provide improved pedestrian connectivity to the downtown business core areas. The photosimulation illustrates the ability to create “green streets” with improved pedestrian enhancements along 9th Avenue and the crossings streets, a goal identified for the Civic Center District in the Master Plan.

3.4. Concept Constructability
A preliminary evaluation of concept constructability showed that there are no fatal flaws in the proposed concept plan. Challenges to the concept plan include 1) coordination and construction of the Norfolk Southern Railroad bridge east of Caraway Boulevard, 2) providing adequate storm and sewer drainage within corridor bisected by the lowered section and 3) maintenance of traffic during construction (particularly in maintaining, creating and removing connections in the US280 interchange area and shifting traffic from the elevated to lowered roadway sections).

1. Norfolk Southern Railroad crossing: The railroad tracks, currently at-grade, would be reconstructed to be on an overpass structure. This represents one of the engineering challenges for the corridor but is not a fatal flaw. There is one main and two siding tracks crossing at this location and it is thought that trains could use alternative tracks while a bridge could be constructed in phases underneath each track.

2. Drainage for the lowered corridor: A preliminary concept was developed to provide adequate drainage for the corridor that did not include pump-stations. As seen in Figure 9, the freeway corridor profile has a slight natural grade slope from east to west (0.25%) between 23rd and 16th Streets. The low point of the corridor is just south and west of the intersection of 9th Avenue and 15th Street, where current ground elevation (780 ft) is approximately equal to the lowered freeway elevation. Storm and sewer that the corridor severs can be routed to a crossing point of the corridor just beyond where freeway begins its transition out of the lowered section to meet the I-65 interchange ramps. A full drainage plan would need to be developed with final concept and design plans, later in the design process, but there is confidence that this is not a fatal flaw to the concept feasibility.

3. Maintenance of Traffic: Figures 12a-d illustrate the maintenance of traffic during construction phases. During phase I, all traffic would be shifted onto the eastbound (southern) structure, which will provide two travel lanes in each direction, a center barrier and minimal shoulders. Particularly during this phase, through traffic on I-20/I-59 and some of the traffic movements on I-65 would be encouraged to use I-459 as an alternative route through and around Birmingham. During phase 1, the westbound structure would be demolished and the new lowered westbound lanes and westbound frontage road lanes would be constructed. Once completed, all traffic would be shifted from the remaining elevated structure down into the lowered section, which could provide three freeway lanes in the eastbound direction and two freeway lanes in the westbound direction in addition to the two westbound frontage road lanes. There will certainly be challenges to maintain all movements at all times during construction, and a more detailed construction sequencing plan would need to be developed as final concept and design plans are prepared, but there was no identified fatal flaws in the concept.
Figure 11: Corridor Photosimulation

I-20/I-59 from atop Sheraton hotel looking west – Existing Elevated Interstate

I-20/I-59 from atop Sheraton hotel looking west – Lowered Interstate Concept
PHASE 1 CONSTRUCTION SEQUENCING

1. Close ramp E1 (NB I-45 to EB I-20/59)
2. Construct temporary ramp T1 at WB I-20/59 to I-45 NB and close ramp E3
3. Close 15th Street (permanently) and 16th Street (temporarily) between 16th and 17th Avenues
4. Construct temporary ramp T3 and T4 to connect 11th Ave and WB lanes on EB structure to existing WB I-20/59
5. Construct Ramps B5 (modification of I-20/59 off ramp to 23rd St)
6. Close Ramp E11 (NB US 287 to WB I-20/59)
7. Close 20th Street between 15th and 16th Avenues (permanently)
8. Build temporary ramp T5 to reach connection from WB I-20/59 to SB US 287/15th Ave/23 Street and close Ramp E15
9. Construct temporary ramp T6 to reach WB I-20/59 onto EB structure
10. New WB I-20/59 lanes to EB structure (2 lanes each direction)
11. Demolish WB structure and complete work to depress WB freeway lanes and construct one-way WB 16th Avenue fromage road, existing temporary Ramp F7 and Ramp F4; Construct 17th, 18th, 19th, 20th, 21st, and 22nd Street bridges in phases using temporary closures and detours (work zones depicted by shaded area)
PHASE 2 CONSTRUCTION SEQUENCING

1. Construct temporary Ramps T' (29th Street) to depressed EB (20th/59)
2. EB 29th and WB 59th EB structure to new depressed section (3 EB lanes, 2 EB lanes) Demolish EB structure and complete work to depress EB freeways lanes and construct one-way EB 19th Avenue frontage road (shaded area)
3.5. Statement of Concept Feasibility

A project to depress I-20/I-59 through the downtown Birmingham area (as originally proposed in the 2004 Center City Master Plan) is technically feasible from an engineering and design perspective. This preliminary assessment of the project indicates that there are no insurmountable challenges in feasibility or construction. No additional right-of-way is to be acquired. No displacements of residents or businesses are expected, and maintenance of traffic and access can be managed with standard practices. Underground water collection and dispersion is a manageable condition. Environmental impacts appear to be overwhelmingly positive and cultural institutions and north Birmingham neighborhoods will be positively impacted.

Parsons Brinckerhoff has conceptualized, designed and managed construction for several similar highway lowering projects, including the Fort Washington Way project in Cincinnati. This project has since become a national model for redeveloping interstate highways in urban areas, and provides further credibility to the feasibility assessment made in this report.

3.6. Concept Cost Estimate

(Information for this section forthcoming)
4. Preliminary Project Purpose and Need

4.1. Development of a Project Purpose and Need

The development of a project purpose and need is an important part of meeting the National Environmental Policy Act (NEPA) requirements for all Federal Highway Administration (FHWA) projects. FHWA controls all aspects of the interstate system and any modification thereof requires clear documentation of the purpose and need to do so.

Depending on the level of project impacts, some degree of alternative network analysis and mode evaluation will have to be done in the formal NEPA process. If the right-of-way and/or community impacts are great, then a Draft and Final Environmental Impact Statement (EIS) will have to be prepared, which documents project impacts (right-of-way, environmental, historical, ecological, community, etc) and includes comparative analysis to other highway and transit alternatives. However, if the project can be accomplished within existing rights-of-way and can document minimal or positive impact to the community, then the NEPA process requires an “Environmental Assessment (EA)” or “Categorical Exclusion” (CE) which requires a lesser evaluation of impacts and alternatives.

Given that the corridor would likely fall within existing rights-of-way and have mostly positive community, safety and capacity impacts, the later NEPA requirements are expected; however, further study would be required to determine the process required. In either case, a project Purpose or Need statement needs to be developed, and while not required to be formalized at this time, it will be helpful to gather data and public input pertaining to the following draft Purpose and Need list as part of the process:

- The project demonstrates significant safety and operational benefits in the corridor. As noted in section 2.1, the corridor crash rate greatly exceeds the statewide rate, and the proposed design will eliminate many of the current design deficiencies (section 2.3) and operational bottlenecks in the corridor, including providing a shoulder break-down lane.

- The project will also provide significant congestion reduction and travel time benefits compared to future year no-build corridor operations. As the proposed concept provides additional freeway lanes, braiding of critical ramps to eliminate weaving issues, adds additional east-west frontage road capacity through the corridor and improved wayfinding, significant improvements in safety, capacity and operations are expected. The magnitude of improvement will be documented in later phases of the NEPA study process.

- The project will add economic development and meet community goals of the project as recommended in the Master Plan. The proposed expansions of the BJCC and Museum of Arts that will be better served by improved interstate and surface street infrastructure and the project will also reduce noise and vibration impacts currently felt by the adjacent businesses and neighborhoods. Proposed interchange improvements could allow 20-plus acres of land to be reclaimed in an area with expanding development opportunities.

- The project is listed as a community goal in the Birmingham Center City Master Plan, and additional stakeholder and public meeting efforts are planned to strengthen the local and business community support for the project. The project fulfills a Master Plan objective of providing improved connectivity between the Civic Center and Downtown Districts and for the development of “green streets” and improved pedestrian amenities.

Our guidance to Operation New Birmingham is to focus further studies and efforts towards gathering community and business input and consensus, along with conducting additional targeted planning and engineering studies. These efforts should be geared toward defining and reinforcing a stated corridor Purpose and Need required later in the NEPA process.
5. Next Steps

5.1. Identifying Key Players/Stakeholders and Building Community Consensus

More than anything else, building support in the business community, identifying strong, influential “champions” and nurturing broad, overwhelming support in the community are essential to capitalize on an opportunity to eliminate this barrier between the BJCC complex area and the downtown, improve the environment surrounding the Museum of Art and Arts School, and return several blocks currently under the US280 interchange to productive use.

Key local stakeholders should include, but not be limited to:

- City of Birmingham
- Mayor Langford
- Regional Planning Commission
- Alabama Department of Transportation
- Greater Birmingham Community Foundation
- BJCC Community Foundation
- Museum of and School of Fine Art
- Birmingham Planning Commission
- Department of Traffic Engineering
- Operation New Birmingham
- North Birmingham residential associations

To date, Mayor Langford has expressed strong support for the project following a presentation at the January 7th Implementation Board meeting. Also, staffs of the Birmingham Museum of Art, the Greater Birmingham Community Foundation, the Birmingham-Jefferson Convention Center, as well as a number of other business and civic leaders have responded very favorably to the proposal. ONB and Parsons Brinkerhoff will meet with both the ALDOT and district office and present the concept at a business leaders meeting in January, 2009.

A stakeholders meeting is scheduled in February 2009 to disseminate the feasibility report information and received comments and questions on the project feasibility and the process leading towards implementation. Participants will be able to dialogue with Fred Craig of Parsons Brinckerhoff, the Project Manager for the Fort Washington Way project in Cincinnati.

Support from the business community is essential not only for generating political support, but also for maintaining continuity over the period of ten or more years required to complete such projects. Political leadership tends to change during the development of these long-term projects, and it is important to engage new leaders into the process.

5.2. Identifying Potential Funding Sources

Federal, State, and local funding will be a challenge. However, it has often been shown that important projects with significant community benefits generally attract funding one way or another, sooner or later. There will be a need for some State and local funding. Major interstate improvement project such as this are ultimately the result of negotiations with the Federal Highway Administration (FHWA). FHWA owns and maintains the interstate system and all rights-of-way in the system.

Senator Shelby’s ability to support special funding requests could be extremely helpful. Congressmen Arthur Davis and Spencer Bachus, who are also increasingly influential in
Congress, could also be helpful. Support from the Governor and our legislators will be critical in obtaining the cooperation of ALDOT. Obviously, City and County support will also be necessary. It will be the task of the Metropolitan Planning organization to get this project included in the Transportation Improvement Project (TIP) list and request PE funds from ALDOT. This action will lead to the next project development phase of initiating a formal NEPA study, a process that takes several years and several million dollars to develop.

A few additional funding avenues that need further exploration are 1) the ability to transfer funds allocated for the planned maintenance on the existing elevated structures and 2) the ability to obtain the property within current rights-of-way and sell the vacated land as a form of economic development.

5.3. Further Technical Studies

A next step in the project would be to have the City and possibly other stakeholders call upon the Metropolitan Planning Organization (MPO) Regional Planning Commission to recommend funding of additional technical studies that will further define the benefits and obstacles of project implementation. The goal of these studies is to develop a justification for inclusion of a project in the state TIP that will in turn begin the formal NEPA process.

- Outreach program for business & community support
- Assessment of potential alternatives (TSM, transit)
- Development of a formal project Purpose and Need to begin the NEPA process
- Traffic modeling / microsimulation study
- Pedestrian circulation study
- Preliminary air & noise analysis
- Refine project concept and cost estimate

Public outreach activities should be conducted up front to build community consensus and identify the potential benefits and impact resolutions before engaging in the NEPA environmental process. Information gathered should improve understanding of the community needs and goals of the corridor and an assessment of the need for additional studies or activities to meet skeptics of the project. It will also be important to identify any suggestions to alternative solutions to the project, such as transportation system management (TSM) or transit alternatives. Many of these may fail to meet project Purpose and Need but will need documentation as to why not selected in the NEPA process.

Planning, microsimulation and pedestrian studies will further define future traffic conditions for both no-build and build conditions, as well as safety, capacity, and operational benefits of the proposed concept. It will be a key to allowing others to “see” the operational and capacity benefits introduced by the project. Additional visualizations and/or photosimulations may be included to better define the contextual, pedestrian and connectivity features of this project. The study should also include the impacts of the multi-use facility and how that traffic might be better served in the future.

A preliminary assessment of noise and air impact may also provide key information towards the project purpose and needs. Judging by the noise heard standing at street level in the corridor, it is suspected that the corridor well exceeds normal conditions and documenting noise readings and a comparative to other noise generators may further illustrate the problems in this corridor.
APPENDIX A

CRASH STUDY
I-20 / I-59
SAFETY ANALYSIS

DRAFT
TECHNICAL REPORT

JEFFERSON COUNTY, ALABAMA

Prepared for:
City of Birmingham, Alabama

Prepared by:
Parsons Brinckerhoff

November 2008
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1.0 INTRODUCTION

The City of Birmingham in Jefferson County, Alabama is investigating ways to improve the interstate system that runs through town. The primary focus of this study is I-20 / I-59 from I-65 in the west to US 31 (SR 3 / Elton B. Stephens Expressway) in the east. The approximate location for the study area and beginning and ending mile posts is shown in Figure 1 below.

Figure 1: Study Area

The purpose of this technical report is to provide an analysis of safety issues in the study area. This includes determining if there is a history of crashes, any contributing factors, crash trends, and any safety deficiency locations, if possible.
2.0 SAFETY ANALYSIS

A review of crash data was performed for the existing sections of I-20 / I-59 within the project limits to determine if there are any sections or locations along the highway with a history of crashes or safety issues. Crash data was provided by the Alabama Department of Transportation (ALDOT) for a three-year period from January 1, 2005 through December 31, 2007. During this time period, there were a total of 717 crashes within the project limits (MP 124.780 – MP 126.240). Approximately 14% of the total crashes involved at least one injury (98 out of 717 crashes). Of the total number of crashes, three crashes during this time period involved a fatality.

2.1 Crash Rate Analysis

A crash rate analysis was prepared to identify any high crash locations by segment. This is the first step toward identifying any locations with a history of crashes. The section crash rates are based on the number of crashes on a specified section, the average daily traffic on the roadway, the time frame of analysis, and the length of the section. They are expressed in terms of crashes per one million vehicle-miles. A section's crash rate was then compared to a statewide critical crash rate based in part on the Alabama statewide average crash rate. The comparison is expressed as a ratio of the section crash rate to the critical crash rate and is referred to as the critical crash rate factor. It is the threshold above which an analyst can be statistically certain (at a 99.5% confidence level) that the section crash rate exceeds the average crash rate and is not mistakenly shown as higher than the average due to randomly occurring crashes. In practical terms, sections with a critical crash rate factor greater than one are considered high crash locations. Further comparison of the section crash rate to the statewide average crash rate indicates the severity of history of crashes at this location.

The section crash rate is also compared directly to the statewide average crash rate provided by ALDOT. Section rates that exceed the statewide average crash rate but not the critical crash rate may be problem areas, but they are not statistically proven to be higher crash areas. Therefore, this second comparison is used to identify a second tier of highway sections that may have a crash history and could be considered for safety improvements if warranted based on further analysis.

Table 1 shows the crash rate analysis for I-20 / I-59. As the study area is slightly less than a mile and a half long, the corridor evaluation was completed for the entire study area instead of breaking it down into specific sections. A spot crash analysis was conducted following this analysis that takes into account the merge / diverge areas at the interchanges.

As shown in Table 1, the entire section has a critical crash rate factor greater than one (2.74). As such, this section is considered to be a high crash location. Also shown in Table 1 is a comparison of crash rates by direction. The number of crashes per direction is relatively evenly split, with both directions also evaluated as having a critical crash rate factor greater than one, similar to the entire section.
### Table 1: I-20 / I-59 Section Crash Rate Analysis for 2005 – 2007

<table>
<thead>
<tr>
<th>Route</th>
<th>Direction</th>
<th>Begin Milepoint</th>
<th>End Milepoint</th>
<th>Total Crashes</th>
<th>Average Daily Traffic</th>
<th>Section Length (miles)</th>
<th>Exposure “M” (1 MVM)</th>
<th>Statewide Average Crash Rate</th>
<th>Statewide Critical Crash Rate</th>
<th>Critical Crash Rate Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-20 / I-59</td>
<td>Both</td>
<td>124.780 (I-65)</td>
<td>126.240 (US 31)</td>
<td>717</td>
<td>103,140</td>
<td>1.46</td>
<td>205,016</td>
<td>0.670</td>
<td>2.80</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>North</td>
<td>124.780 (I-65)</td>
<td>126.240 (US 31)</td>
<td>328</td>
<td>88,077</td>
<td>1.46</td>
<td>140,809</td>
<td>0.670</td>
<td>2.40</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>124.780 (I-65)</td>
<td>126.240 (US 31)</td>
<td>367</td>
<td>88,077</td>
<td>1.46</td>
<td>140,809</td>
<td>0.670</td>
<td>2.61</td>
<td>1.08</td>
</tr>
</tbody>
</table>

**Critical Crash Rate Factor >1, Section Crash Rate Exceeds Statewide Critical Rate (High Crash Rate Section)**

**Critical Crash Rate Factor <1, Section Crash Rate Exceeds Statewide Average Rate**

**Critical Crash Rate Factor <1, Section Crash Rate Lower Than Statewide Average Rate**

**Notes:**
- Analysis Period: 3 Years 1/1/2005 to 12/31/2007
- Crash rates are expressed in crashes per 1 MVM (1 million vehicle miles traveled)
- Exposure “M” = (ADT x (365 x (Time Frame of Analysis (Years)) x (Section Length) / 1,000,000
- Section Crash Rate = Total Crashes / Exposure
- Critical Crash Rate Factor = Section Crash Rate / Statewide Critical Crash Rate
- ADT = Average Daily Traffic; MVM = Million Vehicle Miles

For the North / South Directional ADT, a Directional Factor of 55% was used based on data from the ALDOT Transportation Planning website. Without additional data, the higher traffic number was assumed for both directions for a "worst-case" scenario. The total number of crashes for the North / South directional split does not add up to 717 as 12 of the crashes could not be identified by location.

**Sources:**
- Crash data for 1/1/2005 to 12/31/2007 from ALDOT Data
- ADT from the ALDOT Transportation Planning website
- Statewide Average Crash Rate Provided from ALDOT Data for the Roadway Classification of Interstate
- Statewide Critical Crash Rate = Statewide Average Crash Rate + K(sqrt(Statewide Average Crash Rate/M)) + 1/(2M); Where K = 2.576 which is equal to a probability of 0.995.
A spot location is typically considered to be an intersection, bridge, major driveway, or a mid-block road section. In this case, the spot location is considered to be an interchange. The length of analysis for the spot was assumed to be 0.30 miles (the approximate distance through the interchange including the ramps). The methodology used to calculate the spot crash rates is similar to that used for calculating the section rates. Only the spot crash rates were calculated though since data for critical crash rates for similar facilities was not available for comparison. The evaluation by spot for the two major interchanges (I-65 and US 31) is shown on Table 2.

Table 2: I-20 / I-59 Spot Crash Rate Analysis for 2005 – 2007

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Crashes</th>
<th>Average Daily Traffic</th>
<th>Spot Crash Rate (per million veh.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-65 / I-20</td>
<td>321</td>
<td>160,140</td>
<td>1.83</td>
</tr>
<tr>
<td>Interchange</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 31 / I-20</td>
<td>329</td>
<td>156,160</td>
<td>1.92</td>
</tr>
<tr>
<td>Interchange</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
- Spot Crash Rates are per 1,000,000 vehicles
- Analysis Period: 3 Years 1/1/2005 to 12/31/2007
- Spot Crash Rate = \( \frac{(1,000,000) \times \text{Total Crashes})}{(365) \times \text{Analysis Period in Years} \times \text{Average Daily Traffic}} \)
- ADT = Average Daily Traffic

Sources:
- Crash data for 1/1/2005 to 12/31/2007 from ALDOT Data
- ADT from the ALDOT Transportation Planning website

The data presented above shows that there is a safety issue at both interchanges. Comparing the total number of crashes that occurred at both interchanges (650) to the total number of crashes (717) shows that the majority of crashes (approximately 91 percent) was in the vicinity of the two major interchanges and not located throughout the section.

2.2 Analysis of Crash Characteristics and Severity

Recognizing that there is a history of crashes along the section of I-20 / I-59 (particularly at the interchanges) under evaluation, the data was further evaluated to determine if there were any identifiable trends that would provide some insight into the cause(s) of the high crash numbers.

The evaluation considered some general characteristics (including crashes by day of week, time of day, road condition, and weather), the manner of collision, and crash severity. All are discussed in more detail below.
2.2.1 General Crash Characteristics

The following graphs (Figures 2 and 3) depict the number of crashes that occurred by the following:

- Day of Week
- Time of Day

Figure 2: Crashes by Day of Week

![Figure 2: Crashes by Day of Week]

Figure 3: Crashes by Time of Day

![Figure 3: Crashes by Time of Day]
Based on the previous graphs, there appears to be a fairly even distribution of crashes during the week, with less occurring during the weekends. During the day, the majority seemed to occur during the morning hours of 7:00 and 8:00 AM, with another, smaller, peak during the evening hours. Generally, these crash trends seem to correspond with typical peak traffic hours during the week.

An evaluation of the roadway condition and weather listed for the crashes that occurred along the I-20 / I-59 corridor in this section showed that the overwhelming majority occurred during dry roadway conditions (89 percent) and clear weather (69 percent). Therefore, the roadway condition and weather does not appear to be a contributing factor to the high number of crashes.

### 2.2.2 Manner of Collision

The primary cause for the manner of collision was examined for all of the crashes that occurred along the study area to determine if there was a specific kind of crash that occurred more frequently than others. **Table 3** shows a breakdown of the crash types. The most frequently occurring crash type was “Misjudge Stop Distance” accounting for approximately 25 percent of the total number of crashes. Other crash causes that had a significant number of crashes included “Following Too Close”, “Unknown”, and “Improper Lane Change or Use”. All of these except for the ones that were listed as “Unknown” are related to driver error which indicates that of the identifiable causes of crash types, the majority (over 50 percent) involve a driver error cause. Therefore, while there are a high number of crashes along this section of I-20 / I-59, the evaluation of crash cause indicates that the majority of these crashes may be primarily attributable to driver error rather than geometric deficiency.
Table 3: Crash Types

<table>
<thead>
<tr>
<th>Primary Cause</th>
<th>Total Number</th>
<th>Percentage of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misjudge Stop Distance</td>
<td>180</td>
<td>25.1%</td>
</tr>
<tr>
<td>Following Too Close</td>
<td>109</td>
<td>15.2%</td>
</tr>
<tr>
<td>Unknown</td>
<td>92</td>
<td>12.8%</td>
</tr>
<tr>
<td>Improper Lane Change or Use</td>
<td>84</td>
<td>11.7%</td>
</tr>
<tr>
<td>Unseen Object or Person or Vehicle</td>
<td>61</td>
<td>8.5%</td>
</tr>
<tr>
<td>Avoid Object or Person or Vehicle</td>
<td>53</td>
<td>7.4%</td>
</tr>
<tr>
<td>Other</td>
<td>48</td>
<td>6.7%</td>
</tr>
<tr>
<td>Driver Not in Control</td>
<td>33</td>
<td>4.6%</td>
</tr>
<tr>
<td>Fail to Yield ROW</td>
<td>15</td>
<td>2.1%</td>
</tr>
<tr>
<td>Driver Condition</td>
<td>6</td>
<td>0.8%</td>
</tr>
<tr>
<td>DUI</td>
<td>6</td>
<td>0.8%</td>
</tr>
<tr>
<td>Defective Equipment</td>
<td>4</td>
<td>0.6%</td>
</tr>
<tr>
<td>Improper Driving for Environment</td>
<td>4</td>
<td>0.6%</td>
</tr>
<tr>
<td>Improper Passing</td>
<td>4</td>
<td>0.6%</td>
</tr>
<tr>
<td>Parts or Cargo From Vehicle</td>
<td>4</td>
<td>0.6%</td>
</tr>
<tr>
<td>Over Speed Limit</td>
<td>3</td>
<td>0.4%</td>
</tr>
<tr>
<td>Improper Backing</td>
<td>2</td>
<td>0.3%</td>
</tr>
<tr>
<td>Vehicle Left Road</td>
<td>2</td>
<td>0.3%</td>
</tr>
<tr>
<td>Illegal or Improper Parking</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Improper Attachment</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Improper Load Size</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Improper Turn - U-Turn</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Pedestrian Violation</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Vehicle Pushed or Towed by Vehicle</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Wrong Side of Road</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Total</td>
<td>717</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

2.2.3 Crash Severity

An evaluation of the crash types by severity was performed to determine if there were a high percentage of crashes that involved a fatality, or injury, or sometimes both. The following table (Table 4) summarizes the number of crashes and percentages of crashes by severity.

Table 4: Crash Severity

<table>
<thead>
<tr>
<th>Crash Severity</th>
<th>Total Number</th>
<th>Percentage of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>3</td>
<td>0.4%</td>
</tr>
<tr>
<td>Injury</td>
<td>98</td>
<td>13.7%</td>
</tr>
<tr>
<td>Property Damage Only</td>
<td>616</td>
<td>85.9%</td>
</tr>
<tr>
<td>Total</td>
<td>717</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
As shown above, the highest percentage of crashes along this section of I-20 / I-59 involved property damage only. The injury percentage is relatively low, along with the percentage of fatalities.

A review of contributing factors for the fatalities showed that one crash involved alcohol, and the other two the driver was listed as not in control. Based on all three of these contributing factors, the crashes were likely due to human error and not deficient roadway geometrics.

2.3 Safety Analysis Summary

Analysis of the crash data shows that there is a history of crashes within the study area. Below is a summary of the key points from this analysis.

- During the three-year period (2005 – 2007), 717 crashes occurred throughout the study area.
- Of these crashes, approximately 14 percent involved an injury (98 out of 717).
- Three crashes during this time period involved a fatality. Further review of the contributing factors indicated that the primary cause was driver error (alcohol was involved or the driver was not in control of the vehicle).
- The entire section has a critical crash rate factor greater than one (2.74). As such, this section is considered to be a high crash location.
- Further analysis by direction showed little differentiation in the number of crashes, and both directions had similar critical crash rates to the entire section.
- The spot crash analysis performed for the two major interchanges (at I-65 and US 31) showed that a high number of crashes have occurred at these locations. In fact after comparing the total number of crashes that occurred at the interchanges to the total number of crashes, the analysis showed that the majority (91 percent) of the crashes occurred in the vicinity of the interchanges.
- Additional review of the general crash characteristics showed that most crashes occurred during the week and during the morning / evening typical peak hours.
- Poor weather and roadway condition did not seem to be a contributing factor to the majority of crashes.
- The primary crash cause was identified as misjudging the stop distance (25 percent of crashes). Other primary causes with a significant percentage included other causes related to driver error. Based on these observations, it appears that the majority (over 50 percent) of the crash causes may be related to driver error rather than geometric issues.
- A review of crash types by severity showed that there were very few fatal crashes and a low portion of crashes that involved an injury. The greater majority of crashes involved property damage only.
APPENDIX B

CAPACITY ANALYSES
### General Information
- **Analyst:**
- **Agency/Company:**
- **Date Performed:** 12/23/2008
- **Analysis Time Period:**
- **Freeway/Dir of Travel:**
- **Weaving Seg Location:**
- **Jurisdiction:**
- **Analysis Year:**

### Site Information
- **Freeway free-flow speed, \( S_{FF} \) (mi/h):** 60
- **Weaving type:** A
- **Volume ratio, VR:** 0.12
- **Weaving ratio, R:** 0.49

### Inputs
- **Inputs:**
  - Freeway free-flow speed, \( S_{FF} \) (mi/h): 60
  - Weaving number of lanes, \( N \): 5
  - Weaving seg length, \( L \) (ft): 850
  - Terrain: Rolling

### Conversions to pc/h Under Base Conditions

<table>
<thead>
<tr>
<th>( V_{o1} )</th>
<th>PHF</th>
<th>Truck %</th>
<th>RV %</th>
<th>( E_T )</th>
<th>( E_R )</th>
<th>( f_{nv} )</th>
<th>( f_p )</th>
<th>( v )</th>
</tr>
</thead>
<tbody>
<tr>
<td>8087</td>
<td>0.95</td>
<td>4</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>0.943</td>
<td>1.00</td>
<td>9023</td>
</tr>
<tr>
<td>( V_{o2} )</td>
<td>200</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>( V_{w1} )</td>
<td>608</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>( V_{w2} )</td>
<td>592</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>( V_{w} )</td>
<td>1263</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9233</td>
</tr>
</tbody>
</table>

### Weaving and Non-Weaving Speeds

<table>
<thead>
<tr>
<th></th>
<th>Unconstrained</th>
<th>Constrained</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weaving (( i = w ))</td>
<td>Non-Weaving (( i = nw ))</td>
</tr>
<tr>
<td>( a ) (Exhibit 24-6)</td>
<td>0.15</td>
<td>0.0035</td>
</tr>
<tr>
<td>( b ) (Exhibit 24-6)</td>
<td>2.20</td>
<td>4.00</td>
</tr>
<tr>
<td>( c ) (Exhibit 24-6)</td>
<td>0.97</td>
<td>1.30</td>
</tr>
<tr>
<td>( d ) (Exhibit 24-6)</td>
<td>0.80</td>
<td>0.75</td>
</tr>
<tr>
<td>Weaving intensity factor, ( W_i )</td>
<td>1.46</td>
<td>0.73</td>
</tr>
<tr>
<td>Weaving and non-weaving speeds, ( S_i ) (mi/h)</td>
<td>35.35</td>
<td>43.91</td>
</tr>
</tbody>
</table>

### Notes
- Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, “Ramps and Ramp Junctions”.
- Capacity constrained by basic freeway capacity.
- Capacity occurs under constrained operating conditions.
- Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
- Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
- Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
- Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
- Four-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
- Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
- Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.
# RAMPS AND RAMP JUNCTIONS WORKSHEET

## General Information

- **Analyst:** Freeway/Dir of Travel: EB2009_section12
- **Jurisdiction:** Junction
- **Date Performed:** 12/22/2008
- **Project Description:**

## Site Information

- **Project Description:**

## Inputs

- **Upstream Adj Ramp:**
  - Yes
  - On
  - No
  - Off
  - **L**: 450 ft
  - **V**: 1768 veh/h

- **Terrain:** Rolling

## Conversion to pc/h Under Base Conditions

<table>
<thead>
<tr>
<th>freeway</th>
<th>PHF</th>
<th>Terrain</th>
<th>% Truck</th>
<th>% RV</th>
<th>fHV</th>
<th>fP</th>
<th>v = V/PHF x fHV x fP</th>
</tr>
</thead>
<tbody>
<tr>
<td>8105</td>
<td>0.95</td>
<td>Rolling</td>
<td>4</td>
<td>0</td>
<td>0.943</td>
<td>1.00</td>
<td>9043</td>
</tr>
<tr>
<td>1020</td>
<td>0.95</td>
<td>Rolling</td>
<td>0</td>
<td>0</td>
<td>1.000</td>
<td>1.00</td>
<td>1074</td>
</tr>
</tbody>
</table>

## Estimation of $v_{12}$

$$L_{EQ} = \text{Equation 25-2 or 25-3}$$

$$P_{FM} = 0.084 \text{ using Equation (Exhibit 25-5)}$$

$$V_{12} = 756 \text{ pc/h}$$

$$v_{12} = 4143 \text{ pc/h (Equation 25-4 or 25-5)}$$

Is $v_{12} > 2,700 \text{ pc/h}$? **Yes**

Is $v_{12} > 1.5 * V_{12}$? **Yes**

If YES, $V_{12a} = 3617 \text{ pc/h (Equation 25-8)}$

## Estimation of $v_{12}$

$$V_{12} = V_{R} + (V_{F} - V_{R})P_{FD}$$

$$L_{EQ} = \text{Equation 25-8 or 25-9}$$

Is $v_{3} or v_{av34} > 2,700 \text{ pc/h}$? **Yes**

Is $v_{3} or v_{av34} > 1.5 * V_{12}$? **Yes**

If YES, $V_{12a} = \text{pc/h (Equation 25-18)}$

## Capacity Checks

### Merge Areas

<table>
<thead>
<tr>
<th>Actual</th>
<th>Capacity</th>
<th>LOS F?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{FO}$</td>
<td>10117</td>
<td>Exhibit 25-7</td>
</tr>
</tbody>
</table>

### Diverge Areas

<table>
<thead>
<tr>
<th>Actual</th>
<th>Capacity</th>
<th>LOS F?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{FO}$</td>
<td>$V_{F} - V_{R}$</td>
<td>Exhibit 25-14</td>
</tr>
<tr>
<td>$V_{R}$</td>
<td>Exhibit 25-3</td>
<td></td>
</tr>
</tbody>
</table>

## Flow Entering Merge Influence Area

<table>
<thead>
<tr>
<th>Actual</th>
<th>Max Desirable</th>
<th>Violation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{R12}$</td>
<td>4691</td>
<td>Exhibit 25-7</td>
</tr>
</tbody>
</table>

## Level of Service Determination (if not F)

$$D_{R} = 5.475 + 0.00734 v_{R} + 0.0078 v_{12} - 0.00627 L_{A}$$

$$D_{R} = 39.1 \text{ (pc/mi/ln)}$$

$$LOS = \text{F (Exhibit 25-4)}$$

## Level of Service Determination (if not F)

$$D_{R} = 4.252 + 0.0086 V_{12} - 0.009 L_{D}$$

$$LOS = \text{Exhibit 25-4}$$

## Speed Determination

<table>
<thead>
<tr>
<th>Actual</th>
<th>Capacity</th>
<th>LOS F?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{FO}$</td>
<td>$V_{F} - V_{R}$</td>
<td>Exhibit 25-14</td>
</tr>
<tr>
<td>$V_{R}$</td>
<td>Exhibit 25-3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Actual</th>
<th>Max Desirable</th>
<th>Violation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{R12}$</td>
<td>4691</td>
<td>Exhibit 25-7</td>
</tr>
</tbody>
</table>

$$D_{R} = 5.475 + 0.00734 v_{R} + 0.0078 v_{12} - 0.00627 L_{A}$$

$$D_{R} = 39.1 \text{ (pc/mi/ln)}$$

$$LOS = \text{F (Exhibit 25-4)}$$

<table>
<thead>
<tr>
<th>Actual</th>
<th>Capacity</th>
<th>LOS F?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{FO}$</td>
<td>$V_{F} - V_{R}$</td>
<td>Exhibit 25-14</td>
</tr>
<tr>
<td>$V_{R}$</td>
<td>Exhibit 25-3</td>
<td></td>
</tr>
</tbody>
</table>

## Flow Entering Diverge Influence Area

<table>
<thead>
<tr>
<th>Actual</th>
<th>Max Desirable</th>
<th>Violation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{R12}$</td>
<td>4691</td>
<td>Exhibit 25-7</td>
</tr>
</tbody>
</table>

## Speed Determination

<table>
<thead>
<tr>
<th>Actual</th>
<th>Capacity</th>
<th>LOS F?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{FO}$</td>
<td>$V_{F} - V_{R}$</td>
<td>Exhibit 25-14</td>
</tr>
<tr>
<td>$V_{R}$</td>
<td>Exhibit 25-3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Actual</th>
<th>Max Desirable</th>
<th>Violation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{R12}$</td>
<td>4691</td>
<td>Exhibit 25-7</td>
</tr>
</tbody>
</table>

**Notes:**

- $V_{FO} = V_{F} - V_{R}$
- $V_{R} = \text{Exhibit 25-3}$
- $D_{R} = 4.252 + 0.0086 V_{12} - 0.009 L_{D}$
- $LOS = \text{Exhibit 25-4}$

**Speed Determination:**

<table>
<thead>
<tr>
<th>Actual</th>
<th>Capacity</th>
<th>LOS F?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_{S}$</td>
<td>0.718</td>
<td>(Exhibit 25-19)</td>
</tr>
<tr>
<td>$S_{R}$</td>
<td>47.1 mph (Exhibit 25-19)</td>
<td></td>
</tr>
<tr>
<td>$S_{0}$</td>
<td>51.0 mph (Exhibit 25-19)</td>
<td></td>
</tr>
<tr>
<td>$S$</td>
<td>49.1 mph (Exhibit 25-14)</td>
<td></td>
</tr>
</tbody>
</table>
### General Information
- **Analyst**
- **Agency or Company**
- **Date Performed**: 12/31/2008
- **Jurisdiction**
- **Analysis Time Period**
- **Project Description**

### Site Information
- **Highway/Direction of Travel**
- **From/To**
- **Analysis Year**

### Flow Inputs
- **Volume, V**: 7085 veh/h
- **AADT**: veh/day
- **Peak-Hr Prop. of AADT, K**: %
- **Peak-Hr Direction Prop, D**: %
- **DDHV = AADT x K x D**: veh/h
- **Driver type adjustment**: 1.00

### Speed Inputs
- **Lane Width**: 12.0 ft
- **Rt-Shoulder Lat. Clearance**: 6.0 ft
- **Interchange Density**: 0.50 l/mi
- **Number of Lanes, N**: 4
- **FFS (measured)**: mi/h
- **Base free-flow Speed, BFFS**: 60.0 mi/h

### Flow Adjustments
- **Calc Speed Adj and FFS**
- **LOS and Performance Measures**

### Glossary
- **Factor Location**

---

<table>
<thead>
<tr>
<th>Application</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational (LOS)</td>
<td>FFS, N, (v_p)</td>
<td>LOS, S, D</td>
</tr>
<tr>
<td>Design (N)</td>
<td>FFS, LOS, (v_p)</td>
<td>N, S, D</td>
</tr>
<tr>
<td>Design (v_p)</td>
<td>FFS, LOS, N</td>
<td>(v_p), S, D</td>
</tr>
<tr>
<td>Planning (LOS)</td>
<td>FFS, N, AADT</td>
<td>LOS, S, D</td>
</tr>
<tr>
<td>Planning (N)</td>
<td>FFS, LOS, AADT</td>
<td>N, S, D</td>
</tr>
<tr>
<td>Planning (v_p)</td>
<td>FFS, LOS, N</td>
<td>(v_p), S, D</td>
</tr>
</tbody>
</table>

---

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### General Information
- **Analyst**
- **Agency or Company**
- **Date Performed**: 12/22/2008
- **Analysis Time Period**
- **Project Description**

### Site Information
- **Highway/Direction of Travel**
- **Jurisdiction**
- **Analysis Year**

### Flow Inputs
- **Volume, V**: 5317 veh/h
- **AADT**: 23.17 veh/day
- **Peak-Hr Prop. of AADT, K**: 4
- **Peak-Hr Direction Prop, D**: Rolling
- **Driver type adjustment**
  - **1.00** for Up/Down %

### Speed Inputs
- **Lane Width**: 12.0 ft
- **Rt-Shoulder Lat. Clearance**: 6.0 ft
- **Interchange Density**: 0.50 l/mi
- **Number of Lanes, N**: 3
- **Base free-flow Speed, BFFS**: 60.0 mi/h

### LOS and Performance Measures
- **Operational (LOS)**  
  \[ v_p = \frac{(V \text{ or } DDHV)}{(PHF \times N \times f_{HV} \times f_p)} \]  
  \[ S = \frac{v_p}{D} \]  
  \[ LOS = \frac{S}{E} \]

- **Design (N)**  
  \[ v_p = \frac{(V \text{ or } DDHV)}{(PHF \times N \times f_{HV} \times f_p)} \]  
  \[ S = \frac{v_p}{D} \]  
  \[ LOS = \frac{S}{E} \]

### Glossary
- **N**: Number of lanes
- **S**: Speed
- **V**: Hourly volume
- **D**: Density
- **v_p**: Flow rate
- **LOS**: Level of service
- **DDHV**: Directional design hour volume

### Calculate Flow Adjustments
- **f_p**: 1.00
- **E_T**: 2.5
  
  \[ f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} \]
  
  \[ f_{HV} = 0.943 \]

### Design Speed Adj and FFS
- **f_LW**: 0.0 mi/h
- **f_LC**: 0.0 mi/h
- **f_ID**: 0.0 mi/h
- **f_N**: 3.0 mi/h
- **FFS**: 57.0 mi/h

### Factor Location
- **E_R**: Exhibits 23-8, 23-10
- **f_LW**: Exhibit 23-4
- **E_T**: Exhibits 23-8, 23-10, 23-11
- **f_LC**: Exhibit 23-5
- **f_p**: Page 23-12
- **f_N**: Exhibit 23-6
- **LOS, S, FFS, v_p**: Exhibits 23-2, 23-3
- **f_ID**: Exhibit 23-7
Ramps and Ramp Junctions Worksheet

General Information

Analyst: Freeway/Dir of Travel
Agency or Company:
Date Performed: 12/22/2008
Junction:
Site Information

Jurisdiction:
Analysis Time Period:
Analysis Year:
Project Description:

Inputs

Upstream Adj Ramp
- Yes
- No

Terrain: Rolling

L_up = ft
V_u = veh/h

Downstream Adj Ramp
- Yes
- No

Terrain:

L_down = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

\[
\text{V} = \frac{\text{PHF}}{\text{LOS F?}}
\]

Freeway
7451
0.95
Rolling
4
0
0.943
1.00
8314

Ramp
2134
0.95
Rolling
0
0
1.000
1.00
2246

Estimation of \( V_{12} \)

\[
V_{12} = \text{V}_F \left( P_{FM} \right)
\]

\[
L_{EQ} = \text{(Equation 25-2 or 25-3)}
\]

\[
P_{FM} = \text{using Equation (Exhibit 25-5)}
\]

\[
V_{12} = \text{pc/h}
\]

\[
V_3 \text{ or } V_{av34} > 2,700 \text{ pc/h?} \]
- Yes
- No

\[
V_12 = \text{pc/h (Equation 25-4 or 25-5)}
\]

\[
V_3 \text{ or } V_{av34} > 1.5 \times V_{12}/2 \]
- Yes
- No

\[
\text{If Yes, } V_{12a} = \text{pc/h (Equation 25-8)}
\]

\[
D_{R} = 5.475 + 0.00734 \, v_{R} + 0.00788 \, V_{12} - 0.00627 \, L_{A}
\]

\[
D_{R} = (\text{pc/mi/ln})
\]

LOS = (Exhibit 25-4)

Flow Entering Merge Influence Area

Actual
Max Desirable
Violation?

V_{12} = 4970
Exhibit 25-14
4400: All
Yes

Flow Entering Diverge Influence Area

Actual
Max Desirable
Violation?

V_{12} = 4970
Exhibit 25-14
4400: All
Yes

Speed Determination

\[
M_s = \text{(Exhibit 25-19)}
\]

\[
S_r = \text{mph (Exhibit 25-19)}
\]

\[
S_0 = \text{mph (Exhibit 25-19)}
\]

\[
S = \text{mph (Exhibit 25-14)}
\]

\[
D_{R} = 0.630 \text{ (Exhibit 25-19)}
\]

\[
S_r = 48.7 \text{ mph (Exhibit 25-19)}
\]

\[
S_0 = 59.2 \text{ mph (Exhibit 25-19)}
\]

\[
S = 51.6 \text{ mph (Exhibit 25-15)}
\]
### General Information

<table>
<thead>
<tr>
<th>Analyst</th>
<th>Highway/Direction of Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Description</td>
<td>Jurisdiction</td>
</tr>
<tr>
<td>Date Performed</td>
<td>Analysis Time Period</td>
</tr>
</tbody>
</table>

### Site Information

<table>
<thead>
<tr>
<th>Agency or Company</th>
<th>From/To</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Performed</td>
<td>12/31/2008</td>
</tr>
<tr>
<td>Jurisdiction</td>
<td>Analysis Year</td>
</tr>
</tbody>
</table>

### Flow Inputs

| Volume, V | 7432 veh/h |
| AADT | veh/day |
| Peak-Hr Prop. of AADT, K | %Trucks and Buses, P T |
| Peak-Hr Direction Prop, D | %RVs, P R |
| DDHV = AADT x K x D | Grade | Length |

### Calculate Flow Adjustments

\[ f_p = 1.00 \]
\[ E_T = 2.5 \]
\[ f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} \]

### Speed Inputs

| Lane Width | 12.0 ft |
| Rt-Shoulder Lat. Clearance | 6.0 ft |
| Interchange Density | 0.50 l/mi |
| Number of Lanes, N | 3 |
| FFS (measured) | FFS |
| Base free-flow Speed, BFFS | 60.0 mi/h |

### LOS and Performance Measures

### Glossary

| N - Number of lanes | S - Speed |
| V - Hourly volume | D - Density |
| v_p - Flow rate | FFS - Free-flow speed |
| LOS - Level of service | BFFS - Base free-flow speed |
| DDHV - Directional design hour volume | |

### Design (N)

| Design (N) | Design LOS |
| v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p) | v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p) |
| S | pc/h/ln |
| D = v_p / S | pc/mi/ln |
| LOS | |

### Factor Location

| E_R - Exhibits 23-8, 23-10 | f_{LV} - Exhibit 23-4 |
| E_T - Exhibits 23-8, 23-10, 23-11 | f_{LC} - Exhibit 23-5 |
| f_p - Page 23-12 | f_N - Exhibit 23-6 |
| LOS, S, FFS, v_p - Exhibits 23-2, 23-3 | f_{ID} - Exhibit 23-7 |

### Plan for Flow and Speed Adjustments

| f_p | 1.00 |
| E_T | 2.5 |
| f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} | 0.943 |

### Design (N)

| Design (N) | Design LOS |
| v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p) | v_p = (V or DDHV) / (PHF x N x f_{HV} x f_p) |
| S | pc/h |
| D = v_p / S | pc/mi/ln |
| LOS | |

### Required Number of Lanes, N

| E_R - Exhibits 23-8, 23-10 | f_{LV} - Exhibit 23-4 |
| E_T - Exhibits 23-8, 23-10, 23-11 | f_{LC} - Exhibit 23-5 |
| f_p - Page 23-12 | f_N - Exhibit 23-6 |
| LOS, S, FFS, v_p - Exhibits 23-2, 23-3 | f_{ID} - Exhibit 23-7 |

### Glossary

| N - Number of lanes | S - Speed |
| V - Hourly volume | D - Density |
| v_p - Flow rate | FFS - Free-flow speed |
| LOS - Level of service | BFFS - Base free-flow speed |
| DDHV - Directional design hour volume | |

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**General Information**
- Analyst: Highway/Direction of Travel
- Agency or Company: From/To
- Date Performed: 12/19/2008
- Analysis Time Period: Jurisdiction
- Project Description: Analysis Year

**Flow Inputs**
- Volume, \( V \): 8603 veh/h
- AADT: 8603 veh/day
- Peak-Hr Prop. of AADT, \( K \): 4
- Peak-Hr Direction Prop, \( D \): 0
- DDHV = AADT x \( K \) x \( D \): 1.00 veh/h

**Calculate Flow Adjustments**
- \( f_p \): 1.00
- \( E_T \): 2.5
- \( f_{HV} = \frac{1}{[1+P_T(E_T - 1) + P_R(E_R - 1)]} \): 0.943

**Speed Inputs**
- Lane Width: 12.0 ft
- R-Lat. Clearance: 6.0 ft
- Interchange Density: 0.50 i/mi
- Number of Lanes, \( N \): 4
- FFS (measured): 60.0 mi/h

**Calc Speed Adj and FFS**
- \( f_{LW} \): 0.0 mi/h
- \( f_{LC} \): 0.0 mi/h
- \( f_{ID} \): 0.0 mi/h
- \( f_{N} \): 1.5 mi/h
- \( FFS \): 58.5 mi/h

**LOS and Performance Measures**
- Operational (LOS) \( \nu_p \): 2400 pc/h/ln
- Design (N) \( \nu_p \): 2400 pc/h/ln

**Glossary**
- \( S \): Speed
- \( D \): Density
- \( \nu_p \): Flow rate
- LOS: Level of service
- DDHV: Directional design hour volume

**Factor Location**
- \( E_R \): Exhibits 23-8, 23-10
- \( f_{LW} \): Exhibit 23-4
- \( E_T \): Exhibits 23-8, 23-10, 23-11
- \( f_{LC} \): Exhibit 23-5
- \( f_{P} \): Page 23-12
- \( f_{N} \): Exhibit 23-6
- \( f_{ID} \): Exhibit 23-7

---

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### General Information

<table>
<thead>
<tr>
<th>Analyst</th>
<th></th>
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<tbody>
<tr>
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<td></td>
</tr>
<tr>
<td>Date Performed</td>
<td>12/19/2008</td>
</tr>
<tr>
<td>Analysis Time Period</td>
<td></td>
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</tbody>
</table>

### Site Information

<table>
<thead>
<tr>
<th>Freeway/Dir of Travel</th>
<th>section6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaving Seg Location</td>
<td></td>
</tr>
<tr>
<td>Jurisdiction</td>
<td></td>
</tr>
<tr>
<td>Analysis Year</td>
<td></td>
</tr>
</tbody>
</table>

### Inputs

| Freeway free-flow speed, $S_{FF}$ (mi/h) | 60 |
| Weaving number of lanes, $N$             | 5  |
| Weaving seg length, $L$ (ft)             | 1000 |
| Terrain                                | Rolling |
| Weaving type                           | A |
| Volume ratio, $VR$                      | 0.31 |
| Weaving ratio, $R$                      | 0.50 |

### Conversions to pc/h Under Base Conditions

<table>
<thead>
<tr>
<th>$(pc/h)$</th>
<th>$V_{o1}$</th>
<th>PHF</th>
<th>Truck %</th>
<th>RV %</th>
<th>$E_T$</th>
<th>$E_R$</th>
<th>$f_{nv}$</th>
<th>$f_p$</th>
<th>$V_w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{o2}$</td>
<td>200</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>0.943</td>
<td>1.00</td>
<td>7763</td>
</tr>
<tr>
<td>$V_{w1}$</td>
<td>1684</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>1.000</td>
<td>1.00</td>
<td>1772</td>
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<tr>
<td>$V_{w2}$</td>
<td>1665</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
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<td>2.0</td>
<td>1.000</td>
<td>1.00</td>
<td>1752</td>
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<tr>
<td>$V_w$</td>
<td>4324</td>
<td></td>
<td></td>
<td></td>
<td>2.5</td>
<td>2.0</td>
<td>1.000</td>
<td>1.00</td>
<td>7973</td>
</tr>
</tbody>
</table>

### Weaving and Non-Weaving Speeds

#### Unconstrained

| $a$ (Exhibit 24-6) | 0.35 |
| $b$ (Exhibit 24-6) | 2.20 |
| $c$ (Exhibit 24-6) | 0.97 |
| $d$ (Exhibit 24-6) | 0.80 |

#### Constrained

Weaving intensity factor, $W_i$ 4.57
Weaving and non-weaving speeds, $S_i$ (mi/h) 23.97

| $a$ (Exhibit 24-6) | 0.35 | 0.0020 |
| $b$ (Exhibit 24-6) | 2.20 | 4.00   |
| $c$ (Exhibit 24-6) | 0.97 | 1.30   |
| $d$ (Exhibit 24-6) | 0.80 | 0.75   |

#### Number of lanes required for unconstrained operation, $N_w$ 2.08
#### Maximum number of lanes, $N_w$ (max) 1.40

| If $N_w < N_w$ (max) unconstrained operation |  |
| If $N_w > N_w$ (max) constrained operation |  |

### Weaving Segment Speed, Density, Level of Service, and Capacity

| Weaving segment speed, $S$ (mi/h) | 34.71 |
| Weaving segment density, $D$ (pc/mi/ln) | 66.25 |
| Level of service, LOS | F |
| Capacity of base condition, $c_b$ (pc/h) | 29270 |
| Capacity as a 15-minute flow rate, $c$ (veh/h) | 8745 |
| Capacity as a full-hour volume, $c_h$ (veh/h) | 8308 |

### Notes

- Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
- Capacity constrained by basic freeway capacity.
- Capacity occurs under constrained operating conditions.
- Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
- Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
- Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
- Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
- Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
- Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.
BASIC FREEWAY SEGMENTS WORKSHEET

General Information
Analyst: Highway/Direction of Travel
Agency or Company: From/To
Date Performed: 1/16/2009
Analysis Time Period: Jurisdiction
Analysis Year: Analysis Year
Project Description:

Flow Inputs
Volume, V: 8621 veh/h
AADT: 0.95
Peak-Hr Prop. of AADT, K: 4
Peak-Hr Direction Prop, D: 0
DDHV = AADT x K x D: 1.00 veh/h
Driver type adjustment:

Calculate Flow Adjustments
f_p: 1.00
E_T: 2.5
f_HV = 1/[1+P_T(E_T - 1) + P_R(E_R - 1)]: 0.943

Speed Inputs
Lane Width: 12.0 ft
Rt-Shoulder Lat. Clearance: 6.0 ft
Interchange Density: 0.50 l/mi
Number of Lanes, N: 5
FFS (measured): 60.0 mi/h
Base free-flow Speed, BFFS: 60.0 mi/h

LOS and Performance Measures
Operational (LOS): v_p = (V or DDHV) / (PHF x N x f_HV x f_p) 1924 pc/h/ln
S: 58.8 mi/h
D = v_p / S: 32.7 pc/mi/ln
LOS: D

Design (N)

Factor Location
E_R - Exhibits 23-8, 23-10
E_T - Exhibits 23-8, 23-10, 23-11
f_p - Page 23-12
f_LW - Exhibit 23-4
f_LC - Exhibit 23-5
f_N - Exhibit 23-6
f_ID - Exhibit 23-7

Glossary
N - Number of lanes
V - Hourly volume
v_p - Flow rate
LOS - Level of service
DDHV - Directional design hour volume

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**General Information**

**Analyst**

**Agency or Company**

**Date Performed** 12/19/2008

**Jurisdiction**

**Analysis Year** 2009

**Project Description**

Flow Inputs

- **Volume, V** 6255 veh/h
- **AADT**
- **Peak-Hr Prop. of AADT, K**
- **Peak-Hr Direction Prop, D**
- **DDHV = AADT x K x D**
- **Driver type adjustment**

Calculate Flow Adjustments

- **fp** 1.00
- **ET** 2.5
- **EHV = 1/[1+PT(ET-1) + PR(ER-1)]** 0.943

Speed Inputs

- **Lane Width** 12.0 ft
- **Rt-Shoulder Lat. Clearance** 6.0 ft
- **Interchange Density** 0.50 l/mi
- **Number of Lanes, N** 3
- **FFS (measured)**
- **Base free-flow Speed, BFFS** 60.0 mi/h

LOS and Performance Measures

Operational (LOS)

- **v_p = (V or DDHV) / (PHF x N x f_HV x f_p)** 2326 pc/h/ln
- **S**
- **D = v_p / S** pc/mi
- **LOS**

Design (N)

- **v_p = (V or DDHV) / (PHF x N x f_HV x f_p)** pc/h
- **S** mi/h
- **D = v_p / S** pc/mi

Glossary

- **N** - Number of lanes
- **S** - Speed
- **V** - Hourly volume
- **D** - Density
- **v_p** - Flow rate
- **LOS** - Level of service
- **DDHV** - Directional design hour volume

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### General Information

- **Analyst**: Highway/Direction of Travel
- **Date Performed**: 12/23/2008
- **Analysis Time Period**: Analysis Year
- **Project Description**: Project Description

### Site Information

- **Jurisdiction**: Jurisdiction
- **Flow Rate (pc/h/ln)**: Flow Rate

### Flow Inputs

- **Volume, V**: 8121 veh/h
- **AADT**: ve/day
- **Peak-Hr Prop. of AADT, K**: %Trucks and Buses, P_T
- **Peak-Hr Direction Prop, D**: %RVs, P_R
- **DDHV = AADT x K x D**: veh/h
- **Driver type adjustment**: Up/Down %

### Speed Inputs

- **Lane Width**: 12.0 ft
- **Rt-Shoulder Lat. Clearance**: 6.0 ft
- **Interchange Density**: 0.50 I/mi
- **Number of Lanes, N**: 4
- **FFS (measured)**: mi/h
- **Base free-flow Speed, BFFS**: 60.0 mi/h

### LOS and Performance Measures

- **Operational (LOS)**: 
  - \( v_p = (V \text{ or } DDHV) / (PHF \times N \times f_{HV} \times f_p) \)
  - \( S = v_p / D \)
  - \( D = v_p / S \)
  - \( LOS = E \)

### Design (N)

- **Design (N)**: 
  - Design LOS

### Glossary

- **N**: Number of lanes
- **S**: Speed
- **V**: Hourly volume
- **D**: Density
- **v_p**: Flow rate
- **LOS**: Level of service
- **DDHV**: Directional design hour volume

### Factor Location

- **E_R**: Exhibits 23-8, 23-10
- **f_{LW}**: Exhibit 23-4
- **E_T**: Exhibits 23-8, 23-10, 23-11
- **f_{LC}**: Exhibit 23-5
- **f_{ID}**: Exhibit 23-6
- **LOS, S, FFS, v_p**: Exhibits 23-2, 23-3
- **f_{N}**: Exhibit 23-7

---

**Flow Rate (pc/h/ln)**

<table>
<thead>
<tr>
<th>Flow Rate (pc/h/ln)</th>
<th>Application</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>7200</td>
<td>Operational (LOS)</td>
<td>FFS, N, v_p</td>
<td>LOS, S, D</td>
</tr>
<tr>
<td>4700</td>
<td>Design (N)</td>
<td>FFS, LOS, v_p</td>
<td>N, S, D</td>
</tr>
<tr>
<td>4900</td>
<td>Design (v_p)</td>
<td>FFS, LOS, N</td>
<td>v_p, S, D</td>
</tr>
<tr>
<td>4700</td>
<td>Planning (LOS)</td>
<td>FFS, N, AADT</td>
<td>LOS, S, D</td>
</tr>
<tr>
<td>4700</td>
<td>Planning (N)</td>
<td>FFS, LOS, AADT</td>
<td>N, S, D</td>
</tr>
<tr>
<td>4700</td>
<td>Planning (v_p)</td>
<td>FFS, LOS, N</td>
<td>v_p, S, D</td>
</tr>
</tbody>
</table>
### General Information
- **Project Description**: Oper.(LOS)
- **Analysis Year**: 2009

### Site Information
- **Highway/Direction of Travel**: WB2009_section10

### Flow Inputs
- **Volume, V**: 7995 veh/h
- **AADT**: veh/day
- **Peak-Hr Prop. of AADT, K**: %
- **General Terrain**: Rolling
- **Driver type adjustment**: 1.00

### Calculate Flow Adjustments
- **f_p**: 1.00
- **E_T**: 2.5

### Speed Inputs
- **Lane Width**: 12.0 ft
- **Rt-Shoulder Lat. Clearance**: 6.0 ft
- **Interchange Density**: 0.50 I/mi
- **Number of Lanes, N**: 4
- **Base free-flow Speed, BFFS**: 60.0 mi/h

### LOS and Performance Measures
- **Operational (LOS)**
  - \( v_p = \frac{(V \text{ or DDHV})}{(PHF \times N \times f_{HV} \times f_p)} \)
  - \( D = \frac{v_p}{S} \)
  - \( S = \frac{v_p}{D} \)
- **Design (N)**
  - \( v_p = \frac{(V \text{ or DDHV})}{(PHF \times N \times f_{HV} \times f_p)} \)

### Glossary
- **N**: Number of lanes
- **S**: Speed
- **V**: Hourly volume
- **D**: Density
- **v_p**: Flow rate
- **LOS**: Level of service
- **DDHV**: Directional design hour volume

### Factor Location
- **E_R**: Exhibit 23-10
- **f_LW**: Exhibit 23-4
- **f_LC**: Exhibit 23-5
- **f_N**: Exhibit 23-6
- **f_ID**: Exhibit 23-7

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**FREEWAY WEAVING WORKSHEET**

### General Information
- **Analyst**: 
- **Agency/Company**: 
- **Date Performed**: 12/23/2008
- **Analysis Time Period**: WB2009_section9

### Site Information
- **Freeway/Dir of Travel**: 
- **Weaving Seg Location**: 
- **Jurisdiction**: 
- **Analysis Year**: 

### Inputs
- **Freeway free-flow speed, $S_{FF}$ (mi/h)**: 60
- **Weaving number of lanes, $N$**: 5
- **Weaving seg length, $L$ (ft)**: 1500
- **Terrain**: Rolling
- **Weaving type**: A
- **Volume ratio, $VR$**: 0.32
- **Weaving ratio, $R$**: 0.46

### Conversions to pc/h Under Base Conditions
<table>
<thead>
<tr>
<th></th>
<th>$V$</th>
<th>PHF</th>
<th>Truck %</th>
<th>RV %</th>
<th>$E_T$</th>
<th>$E_R$</th>
<th>$f_{nv}$</th>
<th>$f_p$</th>
<th>$v$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{o1}$</td>
<td>6291</td>
<td>0.95</td>
<td>4</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>0.943</td>
<td>1.00</td>
<td>7019</td>
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<tr>
<td>$V_{o2}$</td>
<td>200</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>1.000</td>
<td>1.00</td>
<td>210</td>
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<td>$V_{w1}$</td>
<td>1705</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
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<td>2.0</td>
<td>1.000</td>
<td>1.00</td>
<td>1794</td>
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<tr>
<td>$V_{w2}$</td>
<td>1461</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>1.000</td>
<td>1.00</td>
<td>1537</td>
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<tr>
<td>$V_w$</td>
<td>3331</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>$V_{nw}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V$</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>7229</td>
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### Weaving and Non-Weaving Speeds

<table>
<thead>
<tr>
<th></th>
<th>Unconstrained</th>
<th>Constrained</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weaving ($i = w$)</td>
<td>Non-Weaving ($i = nw$)</td>
</tr>
<tr>
<td>$a$ (Exhibit 24-6)</td>
<td>0.35</td>
<td>0.0020</td>
</tr>
<tr>
<td>$b$ (Exhibit 24-6)</td>
<td>2.20</td>
<td>4.00</td>
</tr>
<tr>
<td>$c$ (Exhibit 24-6)</td>
<td>0.97</td>
<td>1.30</td>
</tr>
<tr>
<td>$d$ (Exhibit 24-6)</td>
<td>0.80</td>
<td>0.75</td>
</tr>
<tr>
<td>Weaving intensity factor, $W_i$</td>
<td>3.09</td>
<td>0.52</td>
</tr>
<tr>
<td>Weaving and non-weaving speeds, $S_i$ (mi/h)</td>
<td>27.22</td>
<td>47.86</td>
</tr>
</tbody>
</table>

| Number of lanes required for unconstrained operation, $N_w$ | 2.19 |
| Maximum number of lanes, $N_w$ (max) | 1.40 |

- If $N_w < N_w$ (max) unconstrained operation
- If $N_w > N_w$ (max) constrained operation

### Weaving Segment Speed, Density, Level of Service, and Capacity
- **Weaving segment speed, $S$ (mi/h)**: 38.62
- **Weaving segment density, $D$ (pc/mi/ln)**: 54.68
- **Level of service, $LOS$**: F
- **Capacity of base condition, $c_b$ (pc/h)**: 9830
- **Capacity as a 15-minute flow rate, $c$ (veh/h)**: 9274
- **Capacity as a full-hour volume, $c_h$ (veh/h)**: 8810

### Notes
- a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, “Ramps and Ramp Junctions”.
- b. Capacity constrained by basic freeway capacity.
- c. Capacity occurs under constrained operating conditions.
- d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
- e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
- f. Weaving segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
- g. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
- h. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.
- i. Type D weaving segments do not operate well at volume ratios greater than 0.10. Poor operations and some local queuing are expected in such cases.
BASIC FREEWAY SEGMENTS WORKSHEET

General Information
Analyst: Highway/Direction of Travel: WB2009_section8
Agency or Company: Jurisdiction: Analysis Year
Date Performed: 12/22/2008
Analysis Time Period
Project Description

Site Information

Flow Inputs
Volume, V: 6207 veh/h
AADT: veh/day
Peak-Hour Prop. of AADT, K
Peak-Hr Direction Prop, D
DDHV = AADT x K x D veh/h
Driver type adjustment

Calculate Flow Adjustments

f_p: 1.00
E_T: 2.5

Calc Speed Adj and FFS
Lane Width: 12.0 ft
Rt-Shoulder Lat. Clearance: 6.0 ft
Interchange Density: 0.50 l/mi
Number of Lanes, N: 3
FFS (measured): mi/h
Base free-flow Speed, BFFS: 60.0 mi/h

 LOS and Performance Measures
Operational (LOS)

\[ v_p = \frac{(V \text{ or DDHV})}{(\text{PHF} \times N \times f_{HV} \times f_p)} \]

\[ S = \frac{v_p}{D} \]

\[ D = \frac{v_p}{S} \]

LOS: \[ F = \frac{D}{S} \]

Design (N)

Design LOS

\[ v_p = \frac{(V \text{ or DDHV})}{(\text{PHF} \times N \times f_{HV} \times f_p)} \]

\[ S = \frac{v_p}{D} \]

\[ D = \frac{v_p}{S} \]

Required Number of Lanes, N

Glossary

Factor Location

E_R - Exhibits 23-8, 23-10
f_LW - Exhibit 23-4
E_T - Exhibits 23-8, 23-10, 23-11
f_LC - Exhibit 23-5
f_p - Page 23-12
f_N - Exhibit 23-6
f_ID - Exhibit 23-7
RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information

Analyst Freeway/Dir of Travel WB2009_section7
Agency or Company Junction
Date Performed 12/22/2008 Jurisdiction
Analysis Time Period Analysis Year
Project Description

Input

Upstream Adj Ramp
☐ Yes     ☐ On
☐ No      ☐ Off
L_up = 1000 ft
V_u = 1300 veh/h

Downstream Adj Ramp
☐ Yes     ☐ On
☐ No      ☐ Off
L_down = ft
V_D = veh/h

Terrain: Rolling
S_FF = 60.0 mph    S_FR = 35.0 mph

Conversion to pc/h Under Base Conditions

<table>
<thead>
<tr>
<th>(pc/h)</th>
<th>V (Veh/hr)</th>
<th>PHF</th>
<th>Terrain</th>
<th>%Truck</th>
<th>%RV</th>
<th>fHV</th>
<th>f_p</th>
<th>V = V/PHF x fHV x f_p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeway</td>
<td>5276</td>
<td>0.95</td>
<td>Rolling</td>
<td>4</td>
<td>0</td>
<td>0.943</td>
<td>1.00</td>
<td>5887</td>
</tr>
<tr>
<td>Ramp</td>
<td>931</td>
<td>0.95</td>
<td>Rolling</td>
<td>4</td>
<td>0</td>
<td>0.943</td>
<td>1.00</td>
<td>1039</td>
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<tr>
<td>UpStream</td>
<td>1300</td>
<td>0.90</td>
<td>Rolling</td>
<td>0</td>
<td>0</td>
<td>1.000</td>
<td>1.00</td>
<td>1444</td>
</tr>
<tr>
<td>DownStream</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Estimation of v12

V12 = V_F (P FM)
L_EQ = 1354.36 (Equation 25-2 or 25-3)
P FM = 0.583 using Equation (Exhibit 25-5)
V12 = 3432 pc/h
V3 or V_av34 = 2455 pc/h (Equation 25-4 or 25-5)

If V3 or V_av34 > 2,700 pc/h? ☐ Yes ☐ No
If Yes, V12 = pc/h (Equation 25-8)

Flow Entering Merge Influence Area

Actual Max Desirable Violation?

V_R12 = 4471 Exhibit 25-7 4600:All No

Flow Entering Diverge Influence Area

Actual Max Desirable Violation?

V12 = Exhibit 25-14

Level of Service Determination (if not F)

D_R = 5.475 + 0.00734 v_R + 0.0078 V12 - 0.00627 L_A
D_R = 33.6 (pc/mi/ln) LOS = F (Exhibit 25-4)

Level of Service Determination (if not F)

D_R = 4.252 + 0.0086 V12 - 0.009 L_D
D_R = (pc/mi/ln) LOS = (Exhibit 25-4)

Speed Determination

M_s = 0.592 (Exhibit 25-19)
S_R = 49.3 mph (Exhibit 25-19)
S_0 = 52.5 mph (Exhibit 25-19)
S = 50.4 mph (Exhibit 25-14)

References:

- Exhibit 25-7
- Exhibit 25-14
- Exhibit 25-19
- Exhibit 25-4
- Exhibit 25-3
- Exhibit 25-12
- Exhibit 25-15
- Exhibit 25-16
BASIC FREEWAY SEGMENTS WORKSHEET

General Information

Site Information

Analyst Highway/Direction of Travel
Agency or Company
From/To
Date Performed
Jurisdiction
Analysis Time Period
Analysis Year
Project Description

Oper.(LOS)       Des.(N)    Planning Data

Flow Inputs

Volume, V 5277 veh/h Peak-Hour Factor, PHF 0.95
AAADT veh/day %Trucks and Buses, P_T 4
Peak-Hr Prop. of AADT, K %RVs, P_R 0
General Terrain: Rolling
DDHV = AADT x K x D Grade % Length mi
Driver type adjustment 1.00

Calculate Flow Adjustments

f_p 1.00  E_R 2.0
E_T 2.5

Calc Speed Adj and FFS

Lane Width 12.0 ft f_LW mi/h
Rt-Shoulder Lat. Clearance 6.0 ft f_LC mi/h
Interchange Density 0.50 l/mi f_D mi/h
Number of Lanes, N 3 f_N mi/h
FFS (measured) 60.0 mi/h FFS 60.0 mi/h
Base free-flow speed, BFFS

LOS and Performance Measures

Operational (LOS)

v_p = (V or DDHV) / (PHF x N x f_HV x f_p) 1963 pc/h/ln
S 58.4 mi/h
D = v_p / S 33.6 pc/mi/ln
LOS D

Design (N)

Required Number of Lanes, N

Glossary

Factor Location

E_R - Exhibits 23-8, 23-10  f_LW - Exhibit 23-4
E_T - Exhibits 23-8, 23-10, 23-11  f_LC - Exhibit 23-5
f_p - Page 23-12  f_N - Exhibit 23-6
f_HV = 1/[1+P_T(E_T - 1) + P_R(E_R - 1)] 0.943

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### General Information

- Analyst: Freeway/Dir of Travel
- Agency or Company: WB2009_section5
- Date Performed: 12/22/2008
- Project Description: Analysis Time Period
- Jurisdiction: Analysis Year

### Inputs

- **Upstream Adj Ramp**
  - Yes: On
  - No: Off
  - Length: 1300 ft
  - Volume: 2271 veh/h

- **Terrain:** Rolling

- **Downstream Adj Ramp**
  - Yes: On
  - No: Off
  - Length: ft
  - Volume: veh/h

### Conversion to pc/h Under Base Conditions

<table>
<thead>
<tr>
<th>Location</th>
<th>V (Veh/hr)</th>
<th>PHF</th>
<th>Terrain</th>
<th>%Truck</th>
<th>%Rv</th>
<th>fHV</th>
<th>f_P</th>
<th>V = V/PHF x fHV x f_P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeway</td>
<td>6576</td>
<td>0.90</td>
<td>Rolling</td>
<td>4</td>
<td>0</td>
<td>0.943</td>
<td>1.00</td>
<td>7745</td>
</tr>
<tr>
<td>Ramp</td>
<td>1300</td>
<td>0.90</td>
<td>Rolling</td>
<td>0</td>
<td>0</td>
<td>1.000</td>
<td>1.00</td>
<td>1444</td>
</tr>
</tbody>
</table>

### Estimation of \( v_{12} \)

\[
L_{EQ} = \text{pc/h (Equation 25-2 or 25-3)}
\]
\[
P_{FM} = \text{using Equation (Exhibit 25-5)}
\]
\[
v_{12} = \text{pc/h (Equation 25-4 or 25-5)}
\]

- If \( v_3 \) or \( v_{av34} > 2,700 \text{ pc/h} \)
  - Yes
  - No

- If \( v_3 \) or \( v_{av34} > 1.5 \times v_{12} \)
  - Yes
  - No

- If Yes, \( V_{12a} = \text{pc/h (Equation 25-8)} \)

### Level of Service Determination (if not F)

\[
D_R = 5.475 + 0.00734 \times v_R + 0.0078 \times v_{12} - 0.00627 \times L_A
\]

### Speed Determination

\[
S_0 = \text{mph (Exhibit 25-15)}
\]
\[
S = \text{mph (Exhibit 25-14)}
\]
\[
M_S = \text{(Exhibit 25-19)}
\]
\[
S_R = \text{mph (Exhibit 25-19)}
\]
\[
S = \text{mph (Exhibit 25-15)}
\]

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**General Information**

- Analyst: [Name]
- Agency/Company: [Company]
- Date Performed: 12/23/2008
- Analysis Time Period: [WB2009_section4]

**Site Information**

- Freeway/Dir of Travel
- Weaving Seg Location
- Jurisdiction
- Analysis Year

**Inputs**

- Freeway free-flow speed, \( S_{FF} \) (mi/h): 55
- Weaving number of lanes, \( N \): 5
- Weaving seg length, \( L \) (ft): 920
- Terrain: Rolling

**Conversions to pc/h Under Base Conditions**

<table>
<thead>
<tr>
<th>( V )</th>
<th>PHF</th>
<th>Truck %</th>
<th>RV %</th>
<th>( E_T )</th>
<th>( E_R )</th>
<th>( f_w )</th>
<th>( f_p )</th>
<th>( v )</th>
</tr>
</thead>
<tbody>
<tr>
<td>6045</td>
<td>0.94</td>
<td>4</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>0.943</td>
<td>1.00</td>
<td>6816</td>
</tr>
<tr>
<td>200</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>1.000</td>
<td>1.00</td>
<td>2180</td>
</tr>
<tr>
<td>531</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
<td>1.000</td>
<td>1.00</td>
<td>558</td>
</tr>
</tbody>
</table>

**Weaving and Non-Weaving Speeds**

<table>
<thead>
<tr>
<th></th>
<th>Unconstrained</th>
<th></th>
<th>Constrained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaving ( (i = \text{w}) )</td>
<td>Non-Weaving ( (i = \text{nw}) )</td>
<td>Weaving ( (i = \text{w}) )</td>
<td>Non-Weaving ( (i = \text{nw}) )</td>
</tr>
<tr>
<td>a (Exhibit 24-6)</td>
<td>0.35</td>
<td>0.0020</td>
<td></td>
</tr>
<tr>
<td>b (Exhibit 24-6)</td>
<td>2.20</td>
<td>4.00</td>
<td></td>
</tr>
<tr>
<td>c (Exhibit 24-6)</td>
<td>0.97</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>d (Exhibit 24-6)</td>
<td>0.80</td>
<td>0.75</td>
<td></td>
</tr>
</tbody>
</table>

- Weaving intensity factor, \( Wi \): 3.99
- Weaving and non-weaving speeds, \( S_i \) (mi/h): 24.02

**Notes**

- Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, “Ramps and Ramp Junctions”.
- Capacity constrained by basic freeway capacity.
- Capacity occurs under constrained operating conditions.
- Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
- Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
- Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
- Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
- Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
- Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.
### General Information

- **Analyst**: Highway/Direction of Travel
- **Agency or Company**: From/To
- **Date Performed**: 12/22/2008
- **Analysis Time Period**: Jurisdiction
- **Analysis Year**: Analysis Year
- **Project Description**: Project Description

### Flow Inputs

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume, V</td>
<td>veh/h</td>
<td>8117</td>
</tr>
<tr>
<td>AADT</td>
<td>veh/day</td>
<td></td>
</tr>
<tr>
<td>Peak-Hr Prop. of AADT, K</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak-Hr Direction Prop, D</td>
<td>veh/h</td>
<td>1.00</td>
</tr>
<tr>
<td>DDHV = AADT x K x D</td>
<td>veh/h</td>
<td></td>
</tr>
</tbody>
</table>

**Driver type adjustment**:

- PHF: 0.95
- %Trucks and Buses, P<sub>T</sub>: 4
- %RVs, P<sub>R</sub>: 0
- General Terrain: Rolling

### Calculate Flow Adjustments

| f<sub>p</sub> | 1.00 |
| E<sub>T</sub> | 2.5 |
| f<sub>HV</sub> = 1/[1+P<sub>T</sub>(E<sub>T</sub>-1) + P<sub>R</sub>(E<sub>R</sub>-1)] | 0.943 |

### Speed Inputs

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Width</td>
<td>ft</td>
<td>12.0</td>
</tr>
<tr>
<td>Rt-Shoulder Lat. Clearance</td>
<td>ft</td>
<td>6.0</td>
</tr>
<tr>
<td>Interchange Density</td>
<td>l/mi</td>
<td>0.50</td>
</tr>
<tr>
<td>Number of Lanes, N</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>FFS (measured)</td>
<td>mi/h</td>
<td></td>
</tr>
<tr>
<td>Base free-flow Speed, BFFS</td>
<td>mi/h</td>
<td>60.0</td>
</tr>
</tbody>
</table>

### Design (N)

<table>
<thead>
<tr>
<th>Design (N)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design LOS</td>
<td></td>
</tr>
<tr>
<td>Design LOS</td>
<td></td>
</tr>
<tr>
<td>v&lt;sub&gt;p&lt;/sub&gt; = (V or DDHV) / (PHF x N x f&lt;sub&gt;HV&lt;/sub&gt; x f&lt;sub&gt;p&lt;/sub&gt;)</td>
<td>2264 pc/h/ln</td>
</tr>
<tr>
<td>S</td>
<td>51.4 mi/h</td>
</tr>
<tr>
<td>D = v&lt;sub&gt;p&lt;/sub&gt; / S</td>
<td>44.0 pc/mi/ln</td>
</tr>
<tr>
<td>LOS</td>
<td></td>
</tr>
</tbody>
</table>

### Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Number of lanes</td>
</tr>
<tr>
<td>V</td>
<td>Hourly volume</td>
</tr>
<tr>
<td>D</td>
<td>Density</td>
</tr>
<tr>
<td>f&lt;sub&gt;p&lt;/sub&gt;</td>
<td>Flow rate</td>
</tr>
<tr>
<td>LOS</td>
<td>Level of service</td>
</tr>
<tr>
<td>DDHV</td>
<td>Directional design hour volume</td>
</tr>
</tbody>
</table>

### Site Information

- **Oper.(LOS)**
- **Des.(N)**
- **Planning Data**

### Operational (LOS)

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>v&lt;sub&gt;p&lt;/sub&gt; = (V or DDHV) / (PHF x N x f&lt;sub&gt;HV&lt;/sub&gt; x f&lt;sub&gt;p&lt;/sub&gt;)</td>
<td>2264 pc/h/ln</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>51.4 mi/h</td>
<td></td>
</tr>
<tr>
<td>D = v&lt;sub&gt;p&lt;/sub&gt; / S</td>
<td>44.0 pc/mi/ln</td>
<td></td>
</tr>
</tbody>
</table>

### LOS and Performance Measures

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Factor Location

- E<sub>R</sub> - Exhibits 23-8, 23-10
- f<sub>LW</sub> - Exhibit 23-4
- E<sub>T</sub> - Exhibits 23-8, 23-10, 23-11
- f<sub>LC</sub> - Exhibit 23-5
- f<sub>p</sub> - Page 23-12
- f<sub>N</sub> - Exhibit 23-6
- f<sub>ID</sub> - Exhibit 23-7

### Projection Inputs

- **Project Description**: Project Description

---

**Flow Inputs**

- **Volume, V**: 8117 veh/h
- **AADT**: 
- **Peak-Hr Prop. of AADT, K**: 
- **Peak-Hr Direction Prop, D**: 
- **DDHV = AADT x K x D**: 

**Driver type adjustment**:

- **PHF**: 0.95
- **%Trucks and Buses, P<sub>T</sub>**: 4
- **%RVs, P<sub>R</sub>**: 0
- **General Terrain**: Rolling

**Calculate Flow Adjustments**

- **f<sub>p</sub>**: 1.00
- **E<sub>T</sub>**: 2.5
- **f<sub>HV</sub> = 1/[1+P<sub>T</sub>(E<sub>T</sub>-1) + P<sub>R</sub>(E<sub>R</sub>-1)]**: 0.943

**Speed Inputs**

- **Lane Width**: 12.0 ft
- **Rt-Shoulder Lat. Clearance**: 6.0 ft
- **Interchange Density**: 0.50 l/mi
- **Number of Lanes, N**: 4
- **FFS (measured)**: 
- **Base free-flow Speed, BFFS**: 60.0 mi/h

**Design (N)**

- **Design (N)**: 
- **Design LOS**: 
- **v<sub>p</sub> = (V or DDHV) / (PHF x N x f<sub>HV</sub> x f<sub>p</sub>)**: 2264 pc/h/ln
- **S**: 51.4 mi/h
- **D = v<sub>p</sub> / S**: 44.0 pc/mi/ln

**LOS and Performance Measures**

- **LOS**: 

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**HCS+™ Version 5.3**

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### General Information

**Analyst**

- Highway/Direction of Travel: WB2009_section11
- Jurisdiction: Analysis Year

**Date Performed**

- 12/22/2008

**Project Description**

- Oper.(LOS) [□]
- Des.(N) [□]
- Planning Data [□]

### Flow Inputs

**Volume, V**

- 6207 veh/h

**AADT**

- Veh/day

**Peak-Hr Prop. of AADT, K**

- %Trucks and Buses, P_T

**Peak-Hr Direction Prop, D**

- Veh/h

**Driver type adjustment**

- 1.00

**Calculate Flow Adjustments**

- \( f_p \) = 1.00
- \( E_T \) = 2.5

### Speed Inputs

**Lane Width**

- 12.0 ft

**Rt-Shoulder Lat. Clearance**

- 6.0 ft

**Interchange Density**

- 0.50 I/mi

**Number of Lanes, N**

- 3

**FFS (measured)**

- Mi/h

**Base free-flow Speed, BFFS**

- 60.0 Mi/h

### Design (N)

**Design (N)**

- Design LOS

**Required Number of Lanes, N**

- D = \( \frac{v_p}{S} \)

- LOS = \( F \)

### Glossary

- \( N \) - Number of lanes
- \( V \) - Hourly volume
- \( v_p \) - Flow rate
- LOS - Level of service
- DDHV - Directional design hour volume

### Factor Location

- \( E_R \) - Exhibits 23-8, 23-10
- \( f_{LW} \) - Exhibit 23-4
- \( E_T \) - Exhibits 23-8, 23-10, 23-11
- \( f_{LC} \) - Exhibit 23-5
- \( f_p \) - Page 23-12
- \( f_N \) - Exhibit 23-6
- \( f_{ID} \) - Exhibit 23-7