Indiana Department of Transportation

MAJOR MOVES

THE NEW US 31

HAMILTON COUNTY

Major Moves Alternative Capacity Analysis Report, 2035

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Contents

Introduction

A Capacity Analysis Study was completed and a Summary Report was prepared by JACOBS *Edwards and Kelcey* for the original PAMP (Preferred Alternative and Mitigation Package) for the US 31 Improvement Project in Hamilton County between I-465 and SR 38/Sheridan Avenue. Each proposed interchange, intersection, freeway segment, weaving section and merge/diverge point was analyzed per the PAMP design with existing and future (year 2015 and year 2035) traffic volumes for the AM and PM peak hours as described in the previous report. As a result of that work, design alternatives were produced by the design teams in charge of the various interchanges and freeway segments to address projected deficiencies. Once these alternative designs were identified, more capacity analysis work was required to determine the most appropriate design alternative to address the projected traffic volumes. Only the AM and PM peak hour traffic volumes of the design year (2035) were used to test the various design alternatives. Similar to the original analysis, various capacity analysis programs were utilized; the methodology of these programs is described in the text below. Every effort was made to hold the original traffic demand model (CUBE) intact so that the originally projected traffic volumes were consistent throughout this work and the previous work however, some of the alternative designs forced modifications to the CUBE model for analysis purposes as access to and from the US 31 corridor was drastically altered through some of the alternative designs. Alternative designs from the PAMP design were generated and studied for the following interchanges and associated intersections:

1. US 31 (Meridian Street) and 96th Street;
2. US 31 (Meridian Street) and I-465 Interchange;
3. US 31 (Meridian Street) and 106th Street Interchange;
4. US 31 (Meridian Street) and 116th Street Interchange;
5. US 31 (Meridian Street) and 131st Street Interchange;
6. US 31 (Meridian Street) and 136th Street Interchange;
7. US 31 (Meridian Street) and 146th / 151st Street Interchange;
8. US 31 (Meridian Street) and 161st Street Interchange;
9. US 31 (Meridian Street) and SR 32; and
10. US 31 (Meridian Street) northbound slip ramp to Old Meridian Street.

The interchange of SR 38 (191st Street) was not reviewed as no alternative designs were put forth due to acceptable LOS ratings in the original PAMP design.

Provided in the Appendix is a summary table of the various design alternatives and the resulting LOS ratings. The preferred alternative is identified in the table as well.

As stated above, the design teams identified the various alternatives however most required additional "tweaking" to provide acceptable LOS ratings. This was accomplished by working together with the design teams to identify deficiencies and potential solutions that were then put into the designs and retested. A detailed description of each location that was studied for the various design alternatives is provided in subsequent sections of this summary report.

Software Utilized

Various computer software programs were use to analyze each design alternative. A description of each software package utilized in this analysis is provided below.

HCS

Highway Capacity Software (HCS) was used to produce Level of Service (LOS) ratings for many locations at the alternative design locations. HCS is based on methodology outlined in the Highway Capacity Manual 2000. As produced by HCS, these LOS ratings serve as quality measures that describe operational conditions within traffic streams in terms of speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience. There are six defined LOS ratings (A-F), with LOS A representing the best operating conditions and LOS F the worst. LOS D is generally considered acceptable in urban areas during peak hour conditions. The six LOS ratings are further defined below.

As directed by INDOT (per email on 2/20/08), LOS ratings of D or better corresponding to freeway segments, weaving segments, intersections, and interchanges, and LOS ratings of E or better corresponding to individual movements within given intersections or interchanges were considered acceptable for this project.

Roadway Level of Service

Level of Service (LOS) is a measure of roadway congestion ranging from A--least congested--to F--most congested. The six LOS letter grades are as follows:

LOS A represents free flow. The general level of comfort and convenience provided to the motorist, passenger, or pedestrian is excellent.

LOS B is in the range of stable flow, but the presence of other users in the traffic stream begins to be noticeable. The level of comfort and convenience provided is somewhat less than at LOS A.

LOS C is in the range of stable flow, but marks the beginning of the range of flow in which the operation of individual users becomes significantly affected by interactions with others in the traffic stream. The general level of comfort and convenience declines noticeably at this level.

LOS D represents high-density, but stable, flow. Speed and freedom to maneuver are severely restricted, and the driver or pedestrian experiences a generally poor level of comfort and convenience.

LOS E represents operating conditions at or near the capacity level. All speeds are reduced to a low, but relatively uniform value. Comfort and convenience levels are extremely poor, and driver or pedestrian frustration is generally high.

LOS F is used to define forced or breakdown flow. Operations are characterized by stopping and starting. Over and over, vehicles may progress at reasonable speeds for several hundred feet or more, and then be required to stop. Comfort and convenience levels are extremely poor, and driver or pedestrian frustration is generally high.

For each facility type, one or more performance measures serves as the primary determinant of LOS. Many factors/inputs affect the specified performance measures on which HCS LOS ratings are based (lane widths, shoulder widths, speeds, terrain, heavy vehicles, etc.). For intersections, LOS ratings are based on average control delay per vehicle; for basic freeway segments, weaving segments, and merge and diverge areas, LOS ratings are based on density. The tables below summarize the criteria on which LOS ratings are determined for these facility types in HCS.

LOS Criteria for Intersections

LOS	Signalized Intersection	Two-Way Stop-Controlled Intersection	All-Way Stop-Controlled Intersection
	Control Delay (s/veh)	*Control Delay (s/veh)*	*Control Delay (s/veh)*
A	≤ 10	0-10	0-10
B	> 10-20	> 10-15	> 10-15
C	> 20-35	> 15-25	> 15-25
D	> 35-55	> 25-35	> 25-35
E	> 55-80	> 35-50	> 35-50
F	> 80	> 50	> 50

LOS Criteria for Basic Freeway Segments, Weaving Segments, and Merge & Diverge Areas

LOS	Basic Freeway Segments	Freeway Weaving Segment	Multilane & C/D Weaving Segments	Merge and Diverge Areas
	Density (pc/mi/ln)	*Density (pc/mi/ln)*	*Density (pc/mi/ln)*	*Density (pc/mi/ln)*
A	0-11	≤ 10	≤ 12	≤ 10
B	> 11-18	> 10-20	> 12-24	> 10-20
C	> 18-26	> 20-28	> 24-32	> 20-28
D	> 26-35	> 28-35	> 32-36	> 28-35
E	> 35-45	> 35-43	> 36-40	> 35
F	> 45	> 43	> 40	Demand exceeds capacity

It should be noted that HCS focuses primarily on individual intersections, freeway segments, weaving segments or merge/diverge areas and that it provides output specific to single locations. Limited input values for upstream or downstream conditions can be entered into the software; however, the HCS output can sometimes be overly optimistic, in that network effects are not always accurately analyzed. This is why system-based analysis programs like Synchro and Paramics were also used for this project; differences between these programs are further discussed in a subsequent section of this report.

RODEL

RODEL, a fully interactive program for aiding roundabout design, was used to produce LOS ratings for the existing and proposed roundabouts for the alternative designs. RODEL is an empirical, macroscopic analysis model based on data observations in the United Kingdom. RODEL uses these observations to relate approach capacity to the geometric characteristics of a roundabout approach, such as diameter (D), entry width (E), flare length (L'), and radius (R). Capacity results from RODEL are derived from the Kimbers Equations in LR924 "The Traffic Capacity of Roundabouts" and are based on average delay. The table below summarizes the criteria on which LOS ratings are determined for roundabouts in RODEL.

LOS Criteria for Roundabouts (RODEL)

LOS	Average Delay Range (sec)
A	0-10
B	> 10-15
C	> 15-25
D	> 25-35
E	> 35-50
F	> 50

Synchro

Synchro was also used to produce LOS ratings for the alternative design locations, primarily for cross-street corridors. Synchro is a software package used for modeling and optimizing traffic signal timings. One of the primary benefits of this software package is its ability to model coordinated systems. While HCS only estimates the effects of system coordination on individual locations, Synchro calculates the effects of coordination and analyzes the system as a whole.

Although Synchro implements many of the same methods as HCS in analyzing capacity, it also implements the Intersection Capacity Utilization (ICU) 2003 method. The ICU is the sum of time required to serve all movements at saturation given a reference cycle length, divided by the reference cycle length. In addition to delay based LOS ratings (like those produced by HCS), Synchro can also produce ICU LOS ratings, which report on the amount of reserve capacity. However, within this report, Synchro LOS output only refers to delay based LOS.

Paramics

Paramics was the software program that was used first to test the various design alternatives. Paramics is an advanced traffic microsimulation software package capable of taking output from regional travel demand models and simulating traffic operations at the individual-vehicle level, taking into account individual driver behavior. The software has the capability to analyze a wide range of transportation projects from individual intersections to corridors and large areas.

Based on the various design alternatives the arrival / departure traffic patterns changed from the original PAMP designs. Manual adjustments were made to account for these altered arrival / departure traffic patterns by identifying individual turning movements and redirecting them through the immediate system to test queue lengths and view obvious "choke points" created by the various design alternatives. Once the Paramics model indicated an interchange and its associated intersections would operate at acceptable LOS ratings, more detailed analyses were completed on the interchange / intersections with HCS, Synchro, or RODEL.

The determination of LOS in Paramics used the same criteria as listed in the *HCS* and *RODEL* sections above. The specific statistics collected from Paramics for each LOS type were as follows:

Analysis Type	Statistic
Signalized Intersection	Link Delay (s/veh)
Two-Way Stop-Controlled Intersection	Link Stop Time (s/veh)
All-Way Stop-controlled Intersection	Link Stop Time (s/veh)
Basic Freeway Segments	Link Density (pc/mi/ln)
Freeway Weaving Segment	Link Density (pc/mi/ln)
Multilane & C/D Weaving Segments	Link Density (pc/mi/ln)
Merge and Diverge Areas	Link Density (pc/mi/ln)
Roundabout Approaches	Link Delay (s/veh)

Signalization

Similar to the original capacity study work and as directed by RW Armstrong, study intersections were compared to the following criteria in the MUTCD 2000 and the Indiana Supplement to the MUTCD 2000 in order to determine where to locate traffic signals for capacity analysis: Figure 4C-3. "Warrant 3, Peak Hour" or Figure 4C-4. "Warrant 3, Peak Hour (70% Factor)" and Table 4C-1a. "Eight-Hour Vehicular Volume (ADT Equivalent)" when necessary. For the purposes of capacity analysis, signals were located per the process below, as directed by RW Armstrong.

- Compare all intersections to Peak Hour Criteria from the MUTCD 2000 (Figure 4C-3. or Figure 4C-4.) using forecasted DHV volumes for 2015 (construction year) and 2035 (design year).
- If an intersection meets Peak Hour Criteria for a given year (either peak hour), signalize it for purposes of capacity analysis for the given year.
- If an intersection does not meet Peak Hour Criteria for a given year, compare it to Equivalent ADT Criteria from the Indiana Supplement to the MUTCD 2000 (Table 4C-1a.) using the forecasted AADT volumes for the given year.
- If the intersection meets Equivalent ADT Criteria for a given year, signalize it for purposes of capacity analysis for the given year.
- If an intersection does not meet either Peak Hour Criteria or Equivalent ADT Criteria for a given year, consider it unsignalized for the purposes of capacity analysis.

Table 1 in the Appendix summarizes the comparison of the study intersections to the above mentioned criteria.

Similar to the original work, double-right-turn-on-red was prohibited in all capacity analysis, per RW Armstrong and INDOT.

Individual Design Alternatives

The consistent method utilized for the analysis of the design alternatives was as follows;

1. Determine if the design alternatives required a new travel demand model projections. Alternative designs that provided new connections to the US 31 corridor that were not included in the PAMP design necessitated the need to re-run the CUBE model to provide revised travel demand projections for the design year of 2035.
2. PARAMICS was used for all design alternatives as a starting point to identify obvious deficiencies and long queue locations.
3. SYNCHRO was utilized next. Through the use of SYNCHRO, additional lanes were added, lane control usage was altered, traffic signal timings were modified and individual queue lengths were scrutinized.
4. HCS was used to determine individual intersection measures of effectiveness.
5. RODEL was used to analyze roundabout intersections to determine measures of effectiveness.

The following paragraphs provide a detailed description of each design alternative that was included in this Major Moves Alternative Capacity Study and Summary Report:

US 31 and 96th Street

The intersection of US 31 and 96th Street provided a challenge as there are large volumes projected to pass through the intersection. In particular, the southbound left turn volumes from US 31 to eastbound 96th Street are projected to be very high. These turning volumes are projected to arrive at the intersection directly from the eastbound I-465 off ramp as well as from the north along US 31. To address these volumes and provide adequate LOS ratings for the other traffic movements, two separate designs were analyzed:

1. Disallow left turning movements from southbound US 31 and provide a "Michigan left turn option on 96th Street; and
2. Provide an additional interchange slip ramp from eastbound I-465 directly into the office park in the southeast quadrant of the US 31 and I-465 interchange.

Additional Mitigation Measures Required to Obtain Acceptable LOS ratings

In conjunction with the two design alternatives it became necessary to add additional capacity / lanes to adequately address the southbound US 31 traffic. In addition, it became necessary to include a bypass lane from westbound 96th Street directly to eastbound I-465.

Neither of these design alternatives resulted in a need to alter the traffic demand model. Manual adjustments were made and the Paramics model was used to identify initial deficiencies.

US 31 and I-465 Interchange

A completely new interchange configuration was put forth that reduced the complexity of the proposed interchange by reducing braiding and weaving. The new design also eliminated the CD connecting the I-465 interchange with the 106th Street interchange. In addition, a new slip ramp from westbound I-465 to northbound Pennsylvania Street was introduced to reduce the southbound US 31 to eastbound 96th Street traffic volumes. As stated above, an eastbound I-465 slip ramp was proposed to deliver traffic directly into the office park in the southeast quadrant of the US 31 / I-465 interchange, thereby reducing the southbound US 31 to eastbound 96th Street left turn traffic volumes.

Additional Mitigation Measures Required to Obtain Acceptable LOS ratings

The interchange analysis was completed under two separate options; 4 lanes in both directions on I-465 and 5 lanes in both directions on I-465. This was necessary due to the unacceptable LOS ratings obtained with only 4 lanes on I-465.

The westbound I-465 slip ramp to northbound Pennsylvania Street required a run of the traffic demand model as this is a new traffic connection that was not included in the PAMP.

US 31 and 106th Street

The only design alternative that was tested was a revised tight diamond alternative. The alternative included the removal of the CD connecting I-465 and 106th Street as described above.

Additional Mitigation Measures Required to Obtain Acceptable LOS ratings

Due to the unacceptable LOS ratings found at the 106th Street at Pennsylvania Street as a multi-lane roundabout in 2035, this intersection needed to be analyzed as a conventional, signalized intersection. Additionally, capacity was added to the design alternative as needed at any intersection on the 106th St. corridor where unacceptable LOS was found in individual movements during either the Synchro or HCS analysis process.

US 31 and 116th Street

There were initially three design alternatives explored at the 116th St. interchange. The alternatives analyzed were the roundabout interchange, the SPUI (Single Point Urban Interchange), and the revised tight diamond interchange. All three of the design alternatives were analyzed assuming the 116th and Pennsylvania intersection with a roundabout design. All three initial designs failed, and the failure was due to the inability of 116th and Pennsylvania to function as a roundabout. The SPUI was chosen as the preferred design alternative, and it was agreed that the 116th and Pennsylvania St. intersection would be analyzed as a signalized intersection.

Additional Mitigation Measures Required to Obtain Acceptable LOS ratings

The close proximity of Pennsylvania St. with the SPUI interchange required additional mitigation measures in order to obtain acceptable LOS and limit unsafe weaving conditions. A signal was added for the North to East ramp movement to limit unsafe weaving conditions. Additional capacity was added to the preferred design alternative at intersections along the 116th St. corridor where unacceptable LOS was found in individual movements during either the Synchro or HCS analysis process.

US 31 and 131st Street

There were initially two design alternatives explored at the 131st St. interchange. The alternatives analyzed were the roundabout interchange and the revised tight diamond interchange. After initial analysis, additional traffic was added to the interchange based on a potential development in the NE quadrant of the interchange. This development created a 4 approach intersection at 131st and Pennsylvania St. Further analysis was performed for both the roundabout interchange alternative and for the revised diamond alternative under the new conditions.

Additional Mitigation Measures Required to Obtain Acceptable LOS ratings

Additional capacity was added to the preferred design alternative at intersections along the 131st Street corridor where unacceptable LOS was found in individual movements during either the Synchro or HCS analysis process.

US 31 and 136th Street

There were initially two design alternatives explored at the 136th St. interchange. The alternatives analyzed were the roundabout interchange and the revised tight diamond interchange. The revised tight diamond interchange was selected as the preferred alternative design.

Additional Mitigation Measures Required to Obtain Acceptable LOS ratings

Additional capacity was added to the preferred design alternative at intersections along the 136th Street corridor where unacceptable LOS was found in individual movements during either the Synchro or HCS analysis process.

US 31 and 146th / 151st Street Interchange Area

Two design alternatives were submitted for analysis purposes. The first was a modified PAMP design that incorporated additional lanes for capacity reasons and better incorporation of the local Thoroughfare Plans. The second design alternative involved full connections with Greyhound Pass to US 31 and supplemental slip ramp configurations. The second design alternative did require a new run of the CUBE traffic demand model as the connections were altered significantly from the original PAMP design. The second design alternative is the preferred alternative based on LOS ratings for traffic flow.

Additional Mitigation Measures Required to Obtain Acceptable LOS ratings

Additional capacity was added to the preferred design alternative at intersections and roadway segments within the 146th Street / 151st Street area where unacceptable LOS was found in individual movements during either the Synchro or HCS analysis process.

US 31 and 161st Street Interchange

There were initially two design alternatives analyzed at the 161st St. interchange. The alternatives analyzed were the roundabout interchange and the revised tight diamond interchange. The revised tight diamond interchange was selected as the preferred alternative design. These analyses did not require new CUBE model traffic forecasts.

Additional Mitigation Measures Required to Obtain Acceptable LOS ratings

Additional capacity was added to the preferred design alternative at intersections and roadway segments along 161st Street where unacceptable LOS was found in individual movements during either the Synchro or HCS analysis process.

US 31 and SR 32 Interchange

One alternative design was reviewed. This alternative design included a 5 lane section on SR 32 east of US 31 and a revised diamond interchange. No additional CUBE model requirements were necessary.

Additional Mitigation Measures Required to Obtain Acceptable LOS ratings

Additional capacity was added to the preferred design alternative at intersections and roadway segments along SR 32 where unacceptable LOS was found in individual movements during either the Synchro or HCS analysis process.

US 31 at Old Meridian Street

In an effort to mitigate the anticipated heavy eastbound 116th Street left turns to northbound Pennsylvania Street traffic, a slip ramp from northbound US 31 to northbound Old Meridian Street, north of 116th Street, was considered as an addition to the PAMP design. This alternative resulted in a new CUBE model run as this connection was not part of the original PAMP design. The roundabout at Old Meridian Street and Pennsylvania Street was included as part of the analysis due to its close proximity to this new alternative design.

Additional Mitigation Measures Required to Obtain Acceptable LOS ratings

No additional mitigating measures were required for this alternative design.