INTRODUCTION

The purpose of the Michigan Signal Optimization Guidelines is to provide guidelines and recommendations for conducting signal optimization projects in the state of Michigan in a complete and consistent manner. This document is intended to guide the process, and not to be a restrictive document. As the signal timing process varies significantly by location, each project will have unique requirements that should be discussed and agreed upon by the entire project team, including MDOT, the local jurisdiction(s), consultant(s) and other affected parties. Engineering judgment must ultimately supersede the guidelines herein should the conditions of the specific project warrant it.

This manual is intended to facilitate the signal timing process more efficiently, and therefore should be responsive to issues or questions encountered during the process. Your input as a practitioner is valuable to make this document as comprehensive as possible. Updated copies will be made available periodically on MDOT’s website at www.michigan.gov/mdot. To provide comments, please contact the MDOT Traffic and Safety Division at 517-241-4793.

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What’s New in the 5th Edition?

The *Michigan Signal Optimization Guidelines 5th Edition* contains the following changes from the previous edition:

- Revised collection of 24-hour Volume counts for boulevard intersections (Section 1.1.2)
- Updated guidance on coding pedestrian calls (Section 1.1.4)
- Updated guidance on travel time run requirements (Section 1.2)
- Provided naming convention for the Intersection Inventory forms (Section 1.3)
- Added a new section providing instruction on completing an Intersection Inventory form (Section 1.3.1)
- Provided naming convention and document layout for intersection photograph submittals (Section 1.3.2)
- Added a new section providing instruction on Signal Warrant Analysis (Section 1.8 and 1.9)
- Revised Synchro file naming structure when multiple control sections are present (Section 3.1)
- Updated guidance for volume balancing (Section 2.2.4)
- Updated guidance for determining the peak hour factor for crossovers (Section 2.2.5)
- Updated figures to reflect Synchro upgrades (Section 2.0, Section 3.0, and Section 5.0)
- Updated guidance on determining cycle lengths during optimization (Section 4.5)
- Revised which validation reports need to be completed (Section 5.2)
- Updated guidance on completing the project benefits analysis (Section 6.3)
- Revised final report Table of Contents order and contents (Section 6.4.2)
- Revised Appendix B to reflect updates.
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1.0 DATA COLLECTION

Data collection procedures for each project should be documented in a data collection plan, including types of information to be collected, acceptable collection timeframes, and other procedures as required by the specific project.

The data collection processes and procedures presented herein are based on procedures outlined in the ITE Manual of Transportation Engineering Studies. The ITE manual should be consulted in the event that additional data collection is required beyond what is outlined in this chapter.

1.1 Traffic Counts and Peaking Characteristics

Peak period, off-peak and daily traffic counts are all necessary in order to fully understand the traffic characteristics of an intersection. The following presents guidelines for the conduct of these counts, including when and where they are required, and interpretation and processing of the data.

1.1.1 General Guidelines

Traffic volume data can vary significantly based on day of the week, and is often highly sensitive to holidays and special events. In order to maintain consistency and to assure counts are reflective of typical conditions, traffic volume data collection should adhere to the following general guidelines:

- Counts should be taken on Tuesdays, Wednesdays and Thursdays only, unless special circumstances require data for another day of the week.
- Counts should not be taken during periods of inclement weather (rain, snow or fog events) that may result in atypical traffic flow conditions.
- Counts should not be taken at any time during a week that includes one of the following holidays:
  - Martin Luther King Jr. Day
  - Presidents Day
  - Good Friday
  - Easter Sunday
  - Memorial Day
  - Independence Day
  - Labor Day
  - Thanksgiving
  - Christmas
  - New Years Eve/Day
- Counts should not be taken on the day of the above holidays or any other national holidays.
- Whenever possible, counts should be taken while schools are in session.
- Consideration should be given to the two-week summer “shut-down” period observed by major automakers and suppliers in the state. Shut-down may lead to lower than normal traffic volumes in high employment areas, or higher than normal volumes in recreational areas. Depending on the project location, data collection during the shut-down period should be avoided whenever possible.

1.1.2 24-Hour Volume Counts

24-hour volume counts provide the basis with which to understand the changes in traffic flow over the course of a typical weekday. They will be used to determine when changes in timing programs should occur throughout the day, and to identify if and when a flash operation is appropriate. The following guidelines should be applied when conducting 24-hour approach counts:

- Counts should be taken at all intersection approaches for a period of two weekdays within a typical Monday through Thursday period.
- Counts should be taken on all approaches at locations that currently operate under flash control at any time or currently operate with a special weekend timing plan for a period of seven (7) days, including all days of the week.
• If an interchange lies within the corridor, machine counts should be taken on the unsignalized ramps and the ramps should be modeled within Synchro.
• Additional counts may be performed at the suggestion of the Engineer as warranted by field conditions.

On roadways that utilize directional crossovers, machine counts may be utilized in lieu of manual counts. Recognizing that the timing at crossovers is often a direct reflection of the timing at the nearest major intersection, machine counts can often collect all of the necessary data. A cost savings may be achieved by utilizing machine counts without manual counts at some crossovers. See Figure 1-1 for placement of tube counters.

- Machine counts are typically higher than manual counts since machines count axles not vehicles. As a result, the machine counts and the manual counts should be compared by time period at the primary intersection to determine the variance between them. The machine counts at the crossover should be adjusted accordingly to balance with the main intersection.
- At locations where there is no driveway or minor road coming into the crossover, machine counts will typically provide sufficient data for the analysis. At locations where the crossover turns into a driveway or minor road, a judgment should be made regarding the likelihood that it will control the signal timings or have timings independent of adjacent signals. If likely to control the timings, full manual counts should be taken.
- It is preferable to measure the crossover traffic in the left turn lane as opposed to the crossover itself. Tubes typically count axles and convert the results into the number of vehicles. This is best accomplished by placing the tube at a right angle to the direction of traffic. If placed in the crossover, vehicles may cross at an angle and individual wheels may be counted substantially increasing the measured volume.

![Figure 1-1: Tube Counters on Boulevards](image-url)

1.1.3 Turning-Movement Counts

Turning-movement counts should be collected during the following periods, unless special circumstances exist that warrant additional counting periods:
For the AM and PM peak periods where multiple hours of data are collected, each intersection will have a unique peak hour within the multi-hour count period. To determine which volumes should be used, evaluate the Peak Hour for each intersection and use the volumes that correspond to this hour.

Peak hour factors should be calculated by intersection approach. For example, if the total approach volume \((L + T + R)\) over the study hour is 1000, and the peak 15-minute approach volume \((L + T + R)\) is 300, the peak hour factor applied to all movements for that approach is \(1000/(4\times300) = 0.83\).

1.1.4 Pedestrian Counts

Pedestrian counts should be included as part of intersection turning movement counts. Pedestrian counts are of particular importance at locations where pedestrian volumes play a significant role in intersection operation.

Pedestrian counts and pedestrian push-buttons data should be entered in two different areas. Under the Volume Settings window, the number of pedestrians counted should be entered under the Conflicting Pedestrians per hour. When inputting pedestrian data into the Phasing Settings window, the data is entered in as Pedestrian Calls per hour. It is important to differentiate between the number of pedestrians and the number of actuations/calls when collecting pedestrian data. Multiple pedestrians may cross under 1 (one) actuation.

1.2 Travel Time Data

Travel time data will typically be required to support the evaluation of before- and after-conditions. The extent of study and data to be collected will be determined at the beginning of a project in conjunction with the MDOT project manager. Travel time runs should be performed when six or more signals are being coordinated and are no more than 80 seconds travel time apart. Additional corridors may require travel time runs as requested by the MDOT project manager. PC-Travel, a travel time data collection software, should be used for collecting before- and after-travel time runs. Travel time data collection should follow the procedures outlined in the *ITE Manual of Transportation Engineering Studies*, unless otherwise directed by the MDOT project manager. Typically 5 runs in each direction will be utilized for each of the three time periods.

1.3 Intersection Geometry and Equipment

A field inventory of intersection geometry and equipment should be conducted at each study intersection. Whenever possible, MDOT or the maintaining agency will provide available as-built drawings for use in verifying field data.

Intersection inventory forms should adhere to a standard naming convention unless otherwise discussed in advance with the MDOT project manager. The following is the standard file naming convention:

*Control Section # - Spot # -" Inventory" - Month-Day-Year.pdf*

*Example:* The Woodward Avenue (M-1) corridor within the city of Detroit (Control Section 82400) is being inventoried. The spot number in this case is 025. The date should also be included to decipher between old and the most up-to-date version.

File Name = 82400-025-Inventory - 01-01-2001.pdf
1.3.1 Intersection Inventory and Condition Form

A sample inventory form is included in Appendix B. In general, the inventory should include the following information.

**Section A – Intersection Location and Number**

Section A provides the general information about the intersections location including:

- Main and Cross Street Name
- City/Township, County
- GPS Coordinates: the coordinates should be as close to the center of where the roads cross as possible. For Boulevards it should be the center of the combined intersection. The standard format should be as shown (Latitude/Longitude) and the last two digits should be decimals. Utilization of Google Earth is acceptable for obtaining the coordinates. If an existing inventory form is available and includes the GPS coordinates they should not be changed unless a review shows them to be incorrect.

**Example:** DD-MM-SS.SS

- Intersection Number and Mile Post Number. These are the Control Section, Spot number and Mile Post number provided by MDOT.
- Prime Number
- MDOT Project Number
- The observer who performed the inventory and the date in which it was completed on should also be entered.

**Section B – Street Naming**

Section B provides the names for each approach as indicated by the direction above. If there is no approach in a particular direction, leave this street name blank.

**Section C – Geometry**

Section C provides information regarding approach lanes, intersection measurements, parking lanes, and grades.

- **Thru Lanes:** The number of thru lanes present in each direction.
- **Left and Right Turn Lanes:** Indicates the number of right and left turn lanes and their corresponding lengths. If a turn lane is shared with a thru lane movement, count it as a thru lane. If a two-way left-turn lane (TWLTL) is present, indicate this on the inventory form using the abbreviation TWLTL next to the left turn lane. In Synchro this length should be coded as a TWLTL with a 500 foot storage length unless a field review shows that as unreasonable (i.e.: queuing observed to be longer than 500 feet or it would extend back beyond a major intersection limiting drivers ability to utilize a full 500 feet).
  - If adjacent parking is present and ends before the intersection, thus leaving room for a vehicle to make a right turn, indicate this as an available right turn lane, with storage distance. Observations should be made to determine if traffic is utilizing this space as a right turn lane. Include a note in the comments section indicating this is the case. If the parking ends at the intersection, as can be seen in Figure 1-2 on the southbound approach, then there is no exclusive right turn lane.
  - Turn lane lengths should be measured based on the length of full width pavement, not where the pavement markings stop. If congestion is significant, part of the taper length may be coded as storage. If this is done a remark should be included in the comments section that the operation was being used based on field observation.

- Some approaches will be marked as a single lane but may be wide enough to accommodate multiple lanes of traffic. In this case the operation should be observed and the lanes shown as they function along with a note in the comments section explaining this.
• **Intersection Width:** See section 3.1 for details on measuring intersection widths. If it is a boulevard the near/far stop bar distance should be entered in parentheses after the intersection width.

• **Pedestrian Crossing Length / Button Distance:** See section 3.2 for details on measuring the pedestrian crossing length. The second distance to measure is the distance from the curb to the actual pushbutton. This is most helpful when reducing the walk time from 7.0 sec to 4.0 sec, if this distance is more than the recommended 10 feet and the pedestrian waits near the push button and not the curb, the walk time should be increased. The pedestrian crossing distance and the button distance should be entered in the same entry box. See example:
  
  - **Example:** If the Pedestrian Crossing Distance equals 200 ft and the button distance is 7 feet the data should be entered in as 200' / 7'

• **Adjacent Parking Lane Approach and Departure:** Indicates with a yes, “Y”, or a no, “N” whether a parking lane is present. If a parking lane is present on the near side of the intersection this would be labeled as an Approach Parking Lane, whereas if the parking lane is located on the far side of the intersection it should be labeled as a Departure Parking Lane.
  
  - See Figure 1-2 for visual of discussion. There is parking available on Main Street only. For the northbound lane Approach Parking should be indicated, whereas for the southbound lane both Approach and Departure Parking should be indicated.

• **Approach Grade:** Grades are indicated as either positive or negative. If the approach is uphill this would be positive, if the approach is downhill it would be negative. A visual estimate of the grade should be entered on the inventory form. For any grade perceived as 2% or less, leave as 0% on the clearance interval calculation spreadsheet (section 4.1). For any grade perceived as 3% or higher, enter these values on the clearance interval calculation spreadsheet. Also note the grades in the REMARKS section of the timing permit. (i.e. EB M-55 approach grade 5%). Leave all grades out of the Synchro files.

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**Figure 1-2:** Approach and Departure Parking Lanes

**Figure 1-3:** Approach and Departure Speed Limits
Section D – Operations

Section D provides information regarding intersection speed limit and operations.

- **Approach and Departure Speed Limit:** Indicates the speed limit in mph for the approach and departure lanes. Make sure that if the speed limit changes at the intersection it is accurately recorded.
  - The official location where a speed limit changes is typically at an intersection. Often the sign is placed a few hundred feet past the intersection to avoid the congested area near the intersection. If the sign is placed a short distance past the intersection, the models should reflect a change at the intersection.
  - See Figure 1-3 for visual of discussion. The speed limit on Main Street is consistently 25 mph, therefore the approach and departure speed limit is the same. On Country Drive the speed limit changes as a vehicle approaches town entering westerly, dropping from 50 mph to 30 mph. Similarly the speed increases as the vehicle leaves town (easterly), increasing from 35 mph to 50 mph. Therefore the EB approach speed limit should be recorded as 30 mph while the departure speed would be recorded as 50 mph.

- **Right Turn on Red:** Indicates any prohibitions/restrictions
  - If Left Turn on Red is allowed at a crossover or one way street, this should be noted in the comments section.

- **Turn Restrictions:** A turning restriction should be indicated when right or left turns are not allowed. This is common on boulevards where the left turn is achieved through crossovers.

Section E – Equipment

- **Pedestrian Signal:** Indicate with a yes, “Y”, or a no, “N” whether a pedestrian signal is present.
  - Pedestrian indications should reflect the crossing that would be in operation with the adjacent vehicle signal. Example: The Northbound approach should include pedestrian information for the east leg of the intersection.
  - If countdown signals are present enter: “Y – Countdown”
- **Pedestrian Push Button:** Indicate with a yes, “Y”, or a no, “N” whether a push button is present.
- **Left Turn Head Type:** The left turn signal head type should be indicated as:
  - 3 - Level Arrow
  - 4 - Level Green Arrow
  - 4 - Level Yellow Arrow Flash
  - Dog-House
- **Right Turn Green Arrow:** Indicates with a yes, “Y”, or a no, “N” whether a right turn green arrow is present.
- **Ambient Light:** MDOT is moving away from internally lighted case signs if there is ambient lighting within the area. Ambient lighting can be provided from an overhead streetlight or from an adjacent parking lot. Any reasonable amount of lighting should be coded as yes. This is a judgment determination. A separate night review is not required.

Section F – Signal Phasing

Section F provides a drawing of each phase for which the signal operates. A solid line indicates that the movement is Protected, a dashed line indicates that the movement is Permitted. Provided in each of the phases are four arrows:

- Permitted Left Arrow
- Protected Left Arrow
- Protected Thru Arrow
- Protected Right Arrow: The protected right turn should only be checked if there is a right turn arrow and it is on during that phase.
For each phase, indicate which movements are allowed, leaving blank those movements that are not stopped. In the case where a signal has more than six phases attach a third page and provide an explanation in the general comments section (I).

Section G – Intersection Layout Diagram

In the space provided a drawing, clean hand sketch or a computerized version, of the intersection should be provided. Data to be included are as follows:

- Thru Lanes
- Turn Lanes
- Width/Measurements
- Crosswalk Length
- Parking Lanes
- Bus Stops
- Signal Poles
- Pedestrian Signal/Push Button
- Controller
- Detection
- Signal Head Direction
- Directional North Arrow: to be indicated via radio button.

To add a computerized version of the intersection layout start by left-clicking anywhere within the gridded-box area. This will bring up a “Select Image File” box. From here route the browser to the correct image file. Click on intersection layout and choose “Select,” this will add the layout to the Inventory form.

Section I – General Comments

Section I provides extra space for anything that is not contained within the Inventory form. A possible item to include is if the layout should be modeled differently in Synchro than from what is shown. This case is most common when an approach lane is marked as a single lane but is wide enough that it is being used as two approach lanes.

Section H – Intersection Location and Number

The information contained within Section H carries over from Page 1 when inserted.

1.3.2 Intersection Photographs

Photographs of each intersection should be taken to ensure the accuracy of recordings on the Inventory Form and as a source of additional information. The approach photo should be taken from a position where all approach and departure lanes and signal equipment is visible. If this cannot be done with one photo or there are unusual features, additional photos should be taken to capture pertinent data.

Intersection photographs should be taken in all approach directions (If there is a one way road or departing ramp include it also) and label accordingly in the Approach Direction (Northbound, Southbound, Eastbound, Westbound, etc). When submitting intersection photographs, all photographs for a single intersection should be contained within one Microsoft Word File. Within the document, photographs are to be labeled with their corresponding directional approach and inserted into the document as follows:

- Major Approach Photographs
- Minor Approach Photographs
- Miscellaneous Approach Photographs

If the intersection is a boulevard take separate photos for both the “near” and “far” approaches. Place the “near” intersection photographs first and the “far” intersection photographs second in the Word document.

Intersection photographs should adhere to a standard naming convention unless otherwise discussed in advance with the MDOT project manager. The following is the standard file naming convention:

**Control Section # - Spot # - “Photo” - Month-Day-Year.doc**
**Example:** The Woodward Avenue (M-1) corridor within the city of Detroit (Control Section 82400) is being inventoried. The spot number in this case is 025. The date that the photo was taken will also be included in the file name.

File Name = 82400 – 025 – Photo – 01-01-2008. doc

### 1.4 Heavy Vehicle Volume

Under typical conditions, the percentage of heavy vehicles in the vehicle mix on a state roadway can be estimated based on MDOT's Average Daily Traffic (ADT) Map and Commercial Vehicle ADT Map, both available on the MDOT website at www.michigan.gov/mdot under “Maps and Publications.” If truck data is obtained during the turning-movement counts, it should be used instead of MDOT’s ADT Map. A default value of two-percent heavy vehicles should be assumed for all other intersection movements where data is not available.

The heavy vehicle percentage (HV%) is typically calculated by approach and not for an individual movement. An exception to this can be made if a particular movement has a higher percentage of truck traffic than the others in the approach. (I.e. Near the Ambassador Bridge there are certain turning movements that feed into the freeway system and thus have very high truck volumes associated with them).

### 1.5 Bus Blockages

Bus blockages can have a measurable impact on intersection performance along corridors with high transit use. A number of bus blockages per hour should be determined or estimated at intersections with bus stops in the near upstream or downstream vicinity. Local transit providers should be contacted when possible to determine bus routing and headways during analysis hours.

### 1.6 Parking Maneuvers

Parking maneuvers adjacent to the travel lanes should be estimated based on number of spaces, nearby land use composition, and parking time and duration restrictions (where applicable). A default of 10 maneuvers/hour should be assumed under typical conditions with an adjacent parking lane. On-Street parking should be coded as shown in Figure 1-4.

### 1.7 Crash Data

Crash data, if available, should be collected for study intersections in order to identify any crash patterns that may be correctable through signal timing or equipment modifications. While most data will be available through MDOT, the assistance of local agencies may be required in some cases. Crash data should be obtained for the last three consecutive years of complete crash data.

It will be at the discretion of the MDOT project manager to determine whether a crash analysis is warranted and should be conducted.
Figure 1-4: Parking Maneuvers Coding Examples

Adjacent parking lane next to an exclusive turn-pocket - Code the number of parking maneuvers in both the exclusive turn pocket (Right or Left) as well as the through, because the parking maneuvers will have an effect on the through vehicles beyond the storage area of the turn pocket.

Adjacent parking lane next to an exclusive turn-lane - Code the number of parking maneuvers for the left or right-turn lane only. Since the parking maneuvers only affect the turn-lane traffic, no maneuvers should be coded for the through lane.

Adjacent parking lane next to a shared through/turn lane - Code the number of parking maneuvers into the through lane only. As there is no exclusive left or right-turn lane, all of the parking maneuvers will influence the through lanes and the shared turning vehicles using these lanes.
1.8 Signal Warrant Guidelines

The Michigan Manual on Uniform Traffic Control Devices (MMUTCD 2005) outlines eight studies and factors used in warranting the use of a traffic control signal. These eight warrants are outlined briefly below and are used in conjunction with the “2005 MMUTCD Signal Warrant Spreadsheet.” For a more detailed description of each signal warrant see Chapter 4C: Traffic Control Signal Needs Studies in the MMUTCD 2005 Manual.

An engineering based study focusing on traffic conditions, pedestrian characteristics, and physical characteristics of the location should be performed before determining the justification of a particular signal. Complying with the traffic signal warrant(s) does not in itself require the removal or addition of a traffic control signal. MDOT primarily focuses on Warrant 1 Condition A, but all warrants should be reviewed to ensure the recommendation doesn’t ignore issues that would benefit from signalization.

Review Traffic & Safety Note 210A for additional details.

It is important to review all criteria in each warrant. Several have delay or crash data requirements. Optimization projects will typically provide all the required data as part of the project. For existing signals, it may be necessary to change the intersection control to two way stop control in Synchro and run SimTraffic to estimate what the delays would be without a signal. A known bug with Synchro causes it to overestimate delays at two way stop controlled intersections.

Once the signal warrants have been completed a list of all the locations should be provided to the PM stating whether the signal is warranted and which warrant it met. If a signal is not warranted all information regarding this signal should be submitted as well.

1.8.1 Signal Warrant File Naming Convention

A signal warrant analysis should be conducted at each study intersection where applicable. Each signal warrant analysis spreadsheet should adhere to a standard naming convention unless otherwise discussed in advance with the MDOT project manager. The following is the standard file naming convention:

Control Section # - Spot # -“Signal Warrant” – Month-Day-Year.xls

Example: The Woodward Avenue (M-1) corridor within the city of Detroit (Control Section 82400) is being inventoried. The spot number in this case is 025. The date should also be included.

File Name = 82400-025-Signal Warrant - Month-Day-Year.xls

1.9 Signal Warrant Analysis

The following will describe how to utilize the “2005 MMUTCD Signal Warrant Spreadsheet” in the determination of signal warrants. All white cells indicate an area of use input, whereas all gray cells indicate an area that is automatically calculated.

Data Input

The 24-hour volume counts performed by machine should be placed into the table for the major and minor approaches. Also the user should indicate:

- The direction for each approach
- The machine number that recorded the counts
While this was originally included to match up with counts completed by MDOT forces, it allows for easy checks in the event of a malfunctioning unit. Consulting firms should track the machines for each count and include them here.

- Manual counts taken within the peak travel hours. The user must answer whether the manual and machine counts were taken on the same day.

Where manual counts were taken on the same day as the machine counts, the spreadsheet will look at the difference between manual and machine counts and adjust the hours without manual counts. This spreadsheet places a higher level of credibility on the manual counts. This ratio is then double checked. In the yellow boxes three results will appear:

- OK: If the counts result in an acceptable ratio
- Check Machine Counts: If the machine counts result in error
- Check Manual Counts: If the manual counts result in error.

Follow the help cues in the yellow cells below. All volume data that is input into the first tab will be used throughout the remainder of the warrant spreadsheet.

**If the manual counts were taken on a different day than that of the machine counts the higher volume will prevail.**

### Title Sheet

Within the title sheet tab of the spreadsheet the following information should be entered:

- Spot Number: Enter the MDOT control and spot number.
- Intersection: List the Major street name followed by the Minor street name.
- City: Which city is the signal in?
- Date Performed and Performed By: The date in which is signal warrant analysis was performed and by whom.
- Date Volumes Collected

The 24-hour volume counts will automatically be referenced into the table for the major and minor approaches and tabulated accordingly. These counts have been adjusted according to the manual counts performed. Underneath the table, indicate the following by typing in “Yes” or “No.”

- Does the posted speed limit exceed 40mph?
- Does the intersection lie within a community of less than 10,000?
  - The population can be found on the State Transportation Map.
- Verify if you wish to use the 70% Factor to determine if the signal is warranted. The “Can” or “Cannot” portion is automatically pre-determined from the information put in. The 70% Factor can be used when the posted speed limit exceeds 40mph or when the population is less than 10,000 people.

### Warrant 1 – Eight Hour Vehicular Volume

The user must fill in the number of lanes for moving traffic on each approach. For more guidance on particular cases see Traffic & Safety Note 210A. The vast majority of locations will be coded as having 2 or more approach lanes. Turn lanes are typically considered as additional lanes. With existing signals a single lane approach may be coded, but the approach should be reviewed if the lane is wide to determine if it is functioning as two lanes.

The user should also enter which percentage of the original volumes they wish to use. MMUTCD provides four percentage options:
The remaining information within this spreadsheet automatically calculates or draws information in from elsewhere. Table 4C-1 from the MMUTCD Manual is used to determine if Condition A and/or Condition B is met.

- **Condition A** is intended to be used at intersections where the principle reason for a traffic signal is the large volume of intersecting traffic.
- **Condition B** is intended to be used at intersections in which Condition A is not satisfied and there is excessive delay on the minor street.
  - Delay data should be provided to support the use of Condition B

**Note:** If Condition A is satisfied than Warrant 1 is met, this is the case if Condition B is satisfied as well. If neither is met a combination of the two is reviewed.

**Warrant 1A and 1B Graphs**

These tabs will display a line graph showing the volumes versus time of day for both the major and minor streets. All information within these tabs is linked to other tabs and will calculate automatically. Two minimum threshold lines are also noticeable, these are the minimum vehicular volumes used for Warrant 1A and 1B. These minimums are determined by questions within the Warrant 1 tab. This is a good chance to review the volumes that were input.

**Warrant 2 – Four Hour Vehicular Volumes**

Based on the volumes, this tab superimposes the data collected onto MMUTCD Figure 4C-1. Using the number of lanes for each approach, find the corresponding threshold line within the figure. If four or more data points lie above the threshold line then Warrant 2 is satisfied. If the user indicated on the Title Sheet that the 70% Factor should be used this will be reflected on the Warrant 2 tab and thus Warrant 2 should be skipped and answered with “N/A.”

**Warrant 2 (70% Factor):** The second tab for Warrant 2 uses a threshold value that is 70% of the original. Similarly find the corresponding threshold line within the figure. If four or more data points lie above the threshold line then Warrant 2 at the 70% Factor is satisfied. If the user indicated on the Title Sheet that the 70% Factor should be used this will be reflected on the 70% Factor tab and thus Warrant 2 should be used.

**Warrant 3 – Peak Hour**

Warrant 3 is to be used at a location where at a minimum of 1 (one) hour per day the minor traffic suffers undue delay when attempting to enter the major street. This is common at office complexes, schools, or industrial complexes. Answer the following questions in Warrant 3A that are colored white. Warrant 3 should only be utilized if Warrants 1 and 2 are not met.

- Is the minor street controlled by a STOP sign?
- What is the delay of the minor street in vehicle hours? Field measured delay is preferred, but this number can be found by running the delay report in Synchro 7.0.
Does the total entering volume for that hour equal or exceed 800 vehicles per hour (vph) for a four legged intersection or 650vph for a three legged intersection?

The spreadsheet will automatically answer whether the Peak Hour Delay warrant is met for Warrant 3A. Tab Warrant 3B provides a visual representation of the peak hour conditions. In the same fashion as Warrant 2, find the threshold line and if one point falls above the curve, Warrant 3 is satisfied.

**Warrant 3 (70% Factor):** The third tab for Warrant 3 uses a threshold value that is 70% of the original. It should only be utilized if the population or speed limit criteria are met. Find the corresponding threshold line within the figure. If one or more data point(s) lie above the threshold line then Warrant 3 at the 70% Factor is satisfied.

**Warrant 4 – Minimum Pedestrian Volume**

In the spreadsheet for Warrant 4 the user should enter the manual pedestrian counts performed manually into the corresponding cells and answer the following questions by indicating “yes” or “no.”

- Is the pedestrian volume crossing during an average day greater than 100 pedestrians for each of any 4 hours or greater than 190 pedestrians during 1 hour?
- Is there a signal within 300 feet of this intersection?

Once these questions have been answered the spreadsheet will result in a “yes” or “no” response. The project manager should be contacted for approval in one of two cases. First, if the crossing speed is less than 4ft/sec see MMUTCD 4C.05 and the criteria is being reduced. Secondly the project manager will need to approve whether the pedestrian gap should be checked or not. This would check if there were 60 gaps per hour of adequate length for pedestrians to cross during the same time period when the pedestrian volume criterion is satisfied. This measure would have to be determined through a field evaluation and review.

**Warrants 5 – School Crossing**

For the School Crossing warrant the user should input the width of the street and the number of children crossing per group. This information will provide the user with the amount of time necessary to produce a safe gap for children to cross. The safe gap within the spreadsheet is automatically calculated using the following method presented in the MMUTCD 1994 edition:

\[
\text{SafeGap} = 3 + \left( \frac{\text{Width of Street}}{4} \right) + F \quad \text{where:}
\]

\[
F = \left( \frac{\text{Number of Children Per Group} - 1}{5} \right) \times 2
\]

For more information regarding this warrant see Section 4C.06 in the MMUTCD Manual. An engineering study qualifying the reasoning for Warrant 5 should be attached if the warrant is deemed satisfied.

**Warrant 6 - Coordinated Signal System**

When determining if a signal should be placed into a coordinated signal system either condition 1 or condition 2 should be met. Warrant 6 is rarely considered and is in most cases considered unmet. An engineering study qualifying the reasoning for Warrant 6 should be attached if the warrant is deemed satisfied.

**Warrant 7 – Crash Experience**
Warrant 7 is satisfied if all of the conditions are met. User should answer the questions by inputting “Yes” or “No” into the white cells. This information can be found within the provided crash analysis. Angle crashes are the type generally considered to be correctable by signalization. If the crash experience warrant is satisfied, attach an engineering study with this spreadsheet. For existing traffic signals, this warrant should only be reviewed if no other warrant has been met. Assuming the signal addressed an existing crash pattern, a pattern may not show up. If it is the only warrant met and the crash pattern is not present a short write up should be provided to the MDOT project manager for further review.

**Warrant 8 – Roadway Network Warrant**

Warrant 8 is used when installing a traffic control signal is justified as a means to encourage a more organized flow of traffic on the roadway. Warrant 8 is satisfied when one or both of the criteria provided is met. Warrant 8 is not typically utilized by MDOT. If it is determined that it should be used, an engineering study should also be performed. See Section 4C.09 of the MMUTCD for more information.
2.0 NETWORK SET-UP

Synchro networks should be developed to replicate existing conditions during the periods to be analyzed, including the current geometric configuration, existing signal timing parameters (including existing clearance intervals, minimum times, etc.), and traffic volumes. The existing conditions analysis serves both as a point of comparison for the optimized timings, and as a means to calibrate and validate the SimTraffic model (see Section 6.0). The following sections detail the standards and conventions to be used in developing the Synchro models.

2.1 File Structure and Naming Convention

Synchro network files should adhere to a standard naming convention unless otherwise discussed in advance with the MDOT project manager. The following is the standard file naming convention:

Route # - Control Section # - Zone # - Condition – Time Period.sy6

The following abbreviations should be used in file naming:

- Zone Number:
  - Numeric designation (1, 2, 3…)
  - “A” for all (the entire control section if no zone breakdown is used, or if multiple zones are included in the same file)

- Condition:
  - “EX” for existing condition
  - “OPT” for optimized condition
  - “MIT” for optimized condition with geometric or operational mitigation.

- Time Period:
  - “AM” for AM peak period
  - “PM” for PM peak period
  - “OP” for mid-day/off-peak period
  - “NT” for nighttime period (if required due to special circumstances)
  - “WE” for weekend period (if required due to special circumstances)
  - “SP-IN” for an inbound special event timing plan
  - “SP-OUT” for an outbound special event timing plan

Example: The Woodward Avenue (M-1) corridor within the city of Detroit (Control Section 82400) is being divided into two zones, or segments, for optimization – Zone 1 and Zone 2. The file being named represents the optimized condition for Zone 1 during the AM peak period.

File Name = M1-82400-1-OPT-AM.sy6

Once a model contains more than one corridor the naming convention may become too large. For isolated intersections use one Synchro file and place the intersections adjacent to each other but unconnected. Spacing the intersections out geographically causes problems during review as these intersections are easily missed. If more than one corridor is present use different control section numbers in the file name to differentiate between models.

File Name = 82300–82400–83500-OPT-AM.sy6

2.2 Basic Coding Parameters

The following procedures and values should be used when coding the basic Synchro network:
2.2.1 Link Naming

Link names along a single corridor should be as consistent as possible so that the corridor will be recognized as a single arterial and be displayed properly in the time-space diagram.

Road names should match the names on the permit. For Trunklines, it should start with the route number followed by the local name if there is one.

Dummy nodes should be named alphabetically without duplicates. They should also be consistent between time periods.

2.2.2 Link Speed

The link speed coded in Synchro provides the basis for evaluating progressive movement between signalized intersections. As such, the speed should always be set to the posted speed limit, which represents the desired progressive speed. While actual traveled speeds may vary significantly from the posted speed limit, only in approved circumstances should the coded link speed differ from the posted speed limit. A speed limit of 25 MPH should be used for all ramps unless there is a through movement, in which case the speed limit should be set to the speed limit (or estimated prevailing speed) of the receiving lanes.

2.2.3 Ideal Saturated Flow Rate

The default ideal saturated flow rate for a movement at an intersection should be 2,000 vehicles/hour for projects in the Metro Region. 1,900 vehicles/hour should be used for all other regions of the State, or as directed by the MDOT project manager.

2.2.4 Volume Input

To determine which volumes should be entered into the Synchro models select the Peak Hour for each intersection and input the corresponding volumes. Once these volumes have been entered volume balancing between the intersections should be completed. Volume balancing can occur through one of two methods.

- If intersections are spaced far enough apart to allow for the insertion of dummy intersections this method should be adopted. Use the dummy intersections to balance the volumes between the study intersections, regardless of calibration. Thru volumes should always be carried thru first before adding or subtracting volumes from the minor dummy road.
  - The surrounding area should be reviewed to determine if the volumes added or subtracted at the dummy node are reasonable.
- For locations with no access between intersections volumes should be balanced in a manner similar to that of calibration. Anything greater than 10% of the existing volume or 20 vehicles difference between the existing volumes should not be accepted. The intersections should always balance up to the higher volume intersection with the additional volume dropped at the next available dummy node.

2.2.5 Peak Hour Factor

Peak hour factors should be applied by intersection approach, and the peak hour factor for the approach as a whole should be entered for all movements on that approach. For example, if the total approach volume (L + T + R) over the study hour is 1000, and the peak 15-minute approach volume (L + T + R) is 300, the peak hour factor applied to all movements for that approach is 1000/(4*300) = 0.83.

Peak hour factors lower than 0.60 or greater than 0.95 should not be used. Should the calculated peak hour factors fall out of this range, the minimum or maximum range value should be applied. Exceptions may be made for locations where the turning movement peak hour factors should be calculated separately from the overall approach peak hour factor. This may occur at schools or factories where an
approach may have steady overall volumes thru the peak hour, but the turning movement going to or from the traffic generator may have strong peaking characteristics. An exception should also be made for peak hour factor associated with crossovers contained with a boulevard intersection.

Example: For a northbound to southbound crossover the northbound left turn lane feeding into the crossover should have a peak hour factor that reflects the crossover volumes. See Figure 2-1 for example.

![Figure 2-1: Crossover Peak Hour Factor](image)

**2.2.6 Right and Left-Turn Lane Storage Distances**

Right and left-turn lane storage lengths should be coded in Synchro as the distance from the stop bar to the beginning of the taper, or the end of the full-lane width. Figure 2-2 provides an example of the turn lane storage length to code in Synchro.

For intersections with continuous two-way left-turn lanes, the left-turn lane storage length should typically be coded as 500 feet as a default value. However, care should be taken to consider the impact of opposing driveways and nearby intersections on the practical storage length available. The following issues should be considered in determining storage length in the case of continuous two-way center left-turn lanes:

- Observed queues exceeding 500 feet contained within the left-turn lane
- Observed queues of less than 500 feet which overflows from the left-turn lane
- Closely-spaced driveways or intersections, the location of which reduces the practical available left-turn storage at the signalized intersection.

Typically, taper lengths should not be measured. However, if an intersection has a long taper length and vehicles are using the taper length as additional storage the portion of the taper being used as storage should be measured and coded as part of the storage distance. This should be noted on the inventory sheet.
2.2.7 Michigan Boulevard

Michigan boulevards should be coded as parallel, one-way links, connected by crossing streets and crossover lanes within the median space, in order to appropriately replicate field operations. An example boulevard layout is depicted in Figure 2-3.

Crossover lanes should be coded as short links connecting both directions of the divided roadway. Crossover lanes typically function as a short two-lane segment, as the width of the lane at the point of u-turn accommodates wide truck movements, and often serves simultaneous turns for smaller vehicles.

The origin-destination feature should be used wherever possible to properly proportion movements at the crossover locations.

2.2.8 Travel Time

Synchro provides a calculation of link travel time, shown in the link settings window. This travel time is based solely on the link distance and speed provided by the user, and should not be adjusted from the default setting.

NOTE: A known Synchro v.5 bug will occasionally cause an unintended override of the travel time value (overridden values are shown in red). If this occurs, click in the affected field and press F12 to reset the value.

2.3 Intersection Numbering

Because Synchro limits intersection numbers to four numeric digits (no symbols or letters), MDOT numbering standards using the control section and spot number cannot be followed. In addition, boulevard intersections, represented by more than one node in Synchro, only have one unique spot number in the MDOT system.

The following node numbering guidelines have been developed to match MDOT’s numbering system as much as possible, while accommodating multi-node intersections and projects that span multiple control sections. Node numbering should follow these guidelines except as otherwise directed by the MDOT Project Manager.
Signalized nodes for projects with one Control Section:

Node Number = 1 + Spot Number

Example: Spot #034 = Node #1034

Signalized nodes for projects with multiple Control Sections:

1. Each Control Section included in the project should each be given a unique number 1-8, in order along a corridor (if applicable)

2. Node number = Control Section # + Spot Number

Example: Control Section 80000 = #2 (the second control section included in the project)

Control Section 80000, Spot Number 034 = Node #2034

Signalized nodes for boulevard intersections (more than one Synchro node representing a single spot number):

1. The Northwest-most node should be numbered based on the standard numbering system above

2. Additional nodes should be numbered by varying the hundreds digit of the node number, counting back from “9” going counterclockwise.

Example: Control Section 80000 (#2), Spot Number 034 is a boulevard/boulevard intersection (represented by four Synchro nodes):

Northwest-most Node = Node #2034
Southwest-most Node = Node #2934
Southeast-most Node = Node #2834
Northeast-most Node = Node #2734

Unsignalized Nodes:

Unsignalized nodes (including sign-controlled intersections, bend nodes, etc.) should be numbered in the 9000’s for ease of segregating during the reporting process. If the node is directly associated with an adjacent signal, such as the unsignalized node at a crossover, it should be numbered in association with the signalized node similar to the way boulevard intersections are numbered.

2.4 Standard Intersection Phasing Set-Up

The signal phasing used in Synchro modeling should follow the phasing as documented on the timing permit wherever possible. In cases where the timing permit phasing is unclear, NEMA standard phasing sequence should be used.

When coding intersection phasing, it is imperative that the offset is referenced properly to the initial phase (or start-up phase) in the controller. While maintaining agencies differ in their assignment of the initial controller phase (based on major street, cardinal direction, etc.), the following standard should be applied to assure Synchro network consistency.

Offsets should always be set to match the existing permit if possible, if this is not possible reference the beginning of the green indication for phases 2+6.
2.5 Boulevard Phasing Set-Up

Boulevard signals are represented by two or more individual signalized intersections in Synchro – one for each direction of travel of each divided roadway. The intersections must therefore be grouped, or clustered, as they functionally operate using the same controller.

Boulevard signal phasing must be coded to replicate the trail green (TG) for traffic crossing the divided roadway. Because Synchro does not replicate the controller logic of the trail green sequence, the length of the trail green for the far-side signal must instead be represented by an extension of the all-red time for the near-side signal. In order for this trail green sequence to be coded appropriately, the near- and far-side signals must be coded as independent phases.

Example: The through movements of an east-west minor roadway at an intersection with a major roadway would typically be served by phases 4+8, phase 4 representing one direction of traffic, and phase 8 representing the other. If the minor roadway is intersecting a divided roadway, phase 4 would represent both directions of travel at the near-side signal, and phase 8 would represent both directions of travel at the far-side signal. Phase 4 would have an extended all-red time equal to the calculated all-red time plus the trail green time to allow the median space to clear at the end of the phase. Figures 2-5 and 2-6 illustrate this example.
3.0 SIGNAL TIMING PARAMETERS

3.1 Clearance Interval Calculations

The following standards shall be applied for calculating yellow and all-red intervals. Refer to MDOT’s Signal Change Interval Guidelines for more information.

If the existing clearance intervals at a study intersection have been previously updated to the most recent MDOT clearance intervals standards, the clearance intervals should not be changed unless one of the conditions is met:

- The All-Red Clearance Interval has changed by more than 0.2 seconds between the existing clearance interval and the calculated clearance interval
- The Flashing Don’t walk interval has changed by more than 1 second between the existing FDW and the calculated FDW.

If the existing clearance intervals have not been updated to the most recent guidelines, update them regardless of how much they change.

When calculating clearance intervals, opposing directions (northbound and southbound for example) of traffic should be calculated separately, and the larger of the calculated yellow and all red values should be applied to both paired approaches. In addition, the yellow and all red times calculated for the through movements of an approach should be applied to protected left-turn phases, if any, for that approach. However, if opposing directions of traffic are operating as split phased, they should be calculated independent of each other. A standardized spreadsheet has been created and should be used to calculate all clearance intervals. See Figure 3-1 for an example spreadsheet.

Figure 3-1: Clearance Interval Calculation Spreadsheet

| A | B | C | D | E | F | H | I | J | K | L | N | O | P | T | W | Y | Z | AC |
| 1 | Street Name | 55555-55-001 | FIRST STREET | NB | Y | 25 | 60 | 57 | 0 | 7.0 | 4.0 | Y | 2 | Y | 7.0 | 3.5 | 2.5 | 17.0 | 13.0 | 14.0 |
| 2 | | | MAIN STREET | EB | Y | 25 | 60 | 57 | 0 | 7.0 | 4.0 | N | 2 | 10.0 | 3.5 | 2.5 | 13.0 | 9.0 | 2.0 |
| 3 | | | | | | | | | | | | | | | | | | | |
| 4 | 55555-55-002 | SECOND STREET | SB | N | 25 | 60 | 57 | 0 | 7.0 | 4.0 | Y | 2 | Y | 7.0 | 3.5 | 2.5 | 17.0 | 13.0 | 14.0 |
| 5 | | | MAIN STREET | EB | Y | 25 | 60 | 57 | 0 | 7.0 | 4.0 | N | 2 | 10.0 | 3.5 | 2.5 | 13.0 | 9.0 | 2.0 |
| 6 | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | |
| 8 | 55555-55-003 | THIRD STREET | NB | Y | 25 | 60 | 57 | 0 | 7.0 | 4.0 | Y | 2 | Y | 7.0 | 3.5 | 2.5 | 17.0 | 13.0 | 14.0 |
| 9 | | | MAIN STREET | EB | Y | 25 | 60 | 57 | 0 | 7.0 | 4.0 | N | 2 | 10.0 | 3.5 | 2.5 | 13.0 | 9.0 | 2.0 |
| 10 | | | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | | | |
| 12 | 55555-55-004 | FOURTH STREET | NB | Y | 25 | 60 | 57 | 0 | 7.0 | 4.0 | Y | 2 | Y | 7.0 | 3.5 | 2.5 | 17.0 | 13.0 | 14.0 |
| 13 | | | MAIN STREET | EB | Y | 25 | 60 | 57 | 0 | 7.0 | 4.0 | N | 2 | 10.0 | 3.5 | 2.5 | 13.0 | 9.0 | 2.0 |
| 14 | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | | | |
| 18 | 55555-55-005 | FIFTH STREET | SB | N | 25 | 60 | 57 | 0 | 7.0 | 4.0 | Y | 2 | Y | 7.0 | 3.5 | 2.5 | 17.0 | 13.0 | 14.0 |
| 19 | | | MAIN STREET | EB | Y | 25 | 60 | 57 | 0 | 7.0 | 4.0 | N | 2 | 10.0 | 3.5 | 2.5 | 13.0 | 9.0 | 2.0 |
| 20 | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | |
3.1.1 Yellow Clearance Intervals

Calculation of yellow clearance intervals (after both through and left-turn phases) shall adhere to the following methodology:

- The range of the yellow interval shall be 3.5 to 5.0 seconds. Calculated intervals less than 3.5 seconds shall be increased to 3.5 seconds.
- Yellow intervals shall be rounded to the nearest 1/10th of a second.
- The following formula shall be used to calculate the yellow interval:

\[ Y = t + \frac{V}{2a \pm 64.4g} \]

where:
- \( Y \) = yellow change interval (seconds)
- \( t \) = Perception-reaction time (second)
- \( V \) = Approach speed (feet/second)
- \( a \) = Deceleration rate (feet/sec\(^2\))
- \( g \) = grade of approach, in percent divided by 100 (downhill is negative)

- Use the following predetermined values in the above formula when calculating the yellow interval:
  - \( t = 1.0 \) second;
  - \( a = 10 \) feet/sec\(^2\)
  - \( V = \) speed limit; for driveways/malls, freeway ramps and crossovers use 25 mph

- The grade of the roadway should be visually estimated. 0% should generally be used unless the grade is estimated to be greater than 2%. If a grade other than 0% is used, it should be noted in the remarks section of the timing permit.

3.1.2 All-Red Clearance Intervals

Calculation of all-red clearance intervals (after both through and left-turn phases) shall adhere to the following methodology:

- The all-red interval cannot be less than 1 second or greater than 2.5 seconds. In certain circumstances, such as at a SPUI intersection, 2.5 seconds of all-red time may not be enough time for a vehicle to clear the intersection and additional all-red time must be provided to ensure safe operations. Exceeding the all-red clearance interval maximum requires the approval of the MDOT project manager.
- The following formula shall be used to calculate the all-red clearance interval:

\[ AR = \frac{w + L}{V} \]

where:
- \( w \) = Width of intersection, measured from the near-side stop bar to the far edge of the conflicting extended travel lane along the actual vehicle path of a through vehicle (feet). The measurement should include any right turn lanes as conflicting lanes of traffic. At “T” intersections, “w” is measured from the near-side stop bar to the opposing curb in the path a through vehicle would travel. Figure 3-2 illustrates how “w” is measured for both a standard 4-leg
intersection and a “T” intersection. The intersection width should be rounded up to the nearest 5-foot increment.

\[ L = \text{Length of vehicle (feet)} \]
\[ V = \text{Approach speed (feet/second)} \]

- Use the following predetermined values in the above formula when calculating the all-red interval:

\[
L = 20 \text{ feet} \\
V = \text{speed limit; for driveways/malls, freeway ramps and crossovers use 25 mph}
\]

**Figure 3-2: Measuring Intersection Width**

### 3.1.3 Boulevard Clearance Intervals

For boulevard crossings, the following method shall be applied to determine clearance and trail green intervals:

**Step 1:** Determine the clearance intervals for each side of the boulevard separately using the methods shown in Section 4.1.1 and 4.1.2. Take the longer of the two intervals and apply it to both sides of the boulevard.

**Step 2:** To determine the trail green (tg), use the following formula:

\[
tg^* = \frac{\text{distance from near side stop bar to median stop bar (ft)}}{\text{speed limit (ft/sec)}}
\]

* The minimum value is 2 seconds. Values shall be rounded up to the next whole number.

### 3.2 Pedestrian Intervals

#### 3.2.1 Walk Intervals

For locations with pedestrian signals, the pedestrian walk interval should generally be **7.0 seconds or greater**. Walk intervals less than 7.0 seconds will be considered if the pedestrian time requirements exceed the vehicular time requirements for that particular movement, and if low pedestrian demand exists. The walk interval shall be no less than 4.0 seconds.

#### 3.2.2 Flash Don’t Walk (FDW) Intervals

The Flash Don’t Walk (FDW) interval should be calculated as follows:

\[
FDW^* = \frac{\text{Distance from curb to curb}}{4 \text{ feet per second}^{**}}
\]
Round FDW up to next whole number.
**3.5 feet per second may be considered if there are high volumes of senior citizens or children. The MDOT project manager should be consulted prior to changing this.

- If a crosswalk exists, distance is measured along the crosswalk line closest to the stop bar from near curb to far curb. However, in the case where the pedestrian timing requirements exceed the time necessary to serve vehicular movements, the distance can be measured from the near curb to the extended edge of furthest travel lane. (see Figure 3-3 scenario A).

- If there are two concurrent crosswalks, then use the longest distance (see Figure 3-3 scenario B).

- If there is no crosswalk and/or no stop bar, measure the distance from near curb to edge of furthest travel lane extended (see Figure 3-3 scenario C).

- If there are no pedestrian features at an intersection (such as marked crosswalks and pedestrian signals) a FDW interval should not be provided.

- Extended Pedestrian Clearance
  - For EPIC Controllers: If possible, do not time the Flashing Don’t Walk through the all red clearance interval. Extension of the FDW interval through the all red clearance interval requires the approval of the MDOT project manager.
  - For EPAC Controllers: There have been issues with the controller staying in step when the Extended Pedestrian Clearance value is changed to 2 (FDW runs thru the yellow, but not the all red)
    - In order to avoid complications related to this, the Extended Pedestrian Clearance should be maintained with the value as 1 (FDW runs through the yellow and the all red), unless the existing is already set to 2 and is operating correctly.

Figure 3-3: Measuring Pedestrian Crossing Distances
3.2.3 Minimum Green Intervals

Minimum green (minimum initial) intervals should be determined for each signal phase for the purposes of calculating a minimum split, as well as for any actuated or semi-actuated signals. Minimum green intervals should be applied as follows:

- **10.0 seconds** should be used for all major street thru movements, including:
  - State trunklines
  - Major arterial roadways

- **7.0 seconds** should be used for the following:
  - Minor cross-street movements (i.e. subdivision entrances, driveways, secondary roadways)
  - All left-turn phasing with the exception of actuated permitted-protected left-turn phasing
  - At locations with low turning volumes, the minimum green for left turn phases may be reduced to 5.0 seconds with approval of the MDOT project manager.

- **5.0 seconds** should be used for actuated permitted-protected left-turn phasing. A minimum vehicle recall will always be set for actuated permitted-protected left-turn phasing where a flashing red is used. Locations with a 5 section (dog house) or the flashing yellow left-turn operation do not require the minimum vehicle recall for permitted-protected left-turn phasing.

3.2.4 Minimum Split Calculations

Minimum splits for each phase must be calculated and entered into Synchro in order to conduct the optimization. The greater of the minimum green split or minimum pedestrian split represents the minimum split. The minimum green split is calculated with the following equation:

$$\text{SPLIT}_{\text{min}} = G_{\text{min}} + Y + AR$$

The pedestrian minimum split is calculated using one of three equations based on the extended pedestrian clearance type. The extended pedestrian clearance defines whether the Flashing Don’t Walk will extend through the Yellow, All-Red, both, or neither. The three cases of extended pedestrian clearance and the corresponding equation for the minimum split are found in Table 3-1.

<table>
<thead>
<tr>
<th>Description</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flashing Don’t Walk extends through the Yellow and All-Red</td>
<td>$\text{SPLIT}<em>{\text{min}} = W</em>{\text{min}}^* + FDW$</td>
</tr>
<tr>
<td>Flashing Don’t Walk extends through the Yellow and ends at the beginning of All-Red</td>
<td>$\text{SPLIT}<em>{\text{min}} = W</em>{\text{min}}^* + FDW + AR$</td>
</tr>
<tr>
<td>Flashing Don’t Walk ends at the start of Yellow (Not Used)</td>
<td>$\text{SPLIT}<em>{\text{min}} = W</em>{\text{min}}^* + FDW + Y + AR$</td>
</tr>
</tbody>
</table>

Where:

- $G_{\text{min}}$ = Minimum Green Time (Minimum Initial)
- $Y$ = Yellow Time
- $AR$ = All Red Time
- $W_{\text{min}}$ = Minimum Walk Time
- $FDW$ = Flash Don’t Walk Time

*For intersection approaches with no pedestrian signals, $W_{\text{min}}$ and $FDW$ are equal to zero.

For the Existing Conditions models with EPIC or EF-140 controllers, the minimum times should be based on the minimum interval times with the exception that clearance intervals (Flash Don’t Walk, Yellow and All Red intervals) should match the value actually running. Normally the minimum interval and the...
dial/split interval times should be identical for clearance intervals, but occasionally they are not. Minimum Green/Walk intervals should always be based on the minimum interval times.

**NOTE 1:** It is important to note a difference in methodology between the way Synchro calculates the minimum split based on pedestrian timing, and the timing method used by MDOT. Synchro assumes that the Flash Don’t Walk phase and the Yellow vehicle phase are sequential and not concurrent. In other words, Synchro assumes that the pedestrian indication will stop flashing and enter a steady Don’t Walk as vehicles receive the Yellow indication.

MDOT, however, allows the FDW indication to occur concurrently with the Yellow and in some cases All-Red phases (see Section 4.2 for more information), meaning the minimum split based on pedestrian timing would be lower than that calculated by Synchro. For this reason, before entering the FDW time in Synchro, FDW intervals should be reduced by the length of the Yellow interval and/or All-Red interval where appropriate based on the extended pedestrian clearance type to avoid “double counting” the concurrent time in the minimum split equation.

**NOTE 2:** At locations with pedestrian push-buttons, the vehicle splits when there are no pedestrian calls are often timed less than the splits when there are pedestrian calls. Synchro does not currently allow the user to input one minimum split for when there is a pedestrian call, and another for when there is not a pedestrian call. The following methodology shall be followed for entering the minimum splits into Synchro for locations with pedestrian push-buttons:

1. The minor cross-street with pedestrian push-buttons should be renamed in Synchro to indicate the pedestrian push-buttons, e.g. “Elm Street (Push-Buttons).”

2. Identify the representative state of the signal during each peak hour that is being modeled. If there are only a few ped-calls during the peak hour, the representative state of the signal would be the splits associated with no ped-call. If there are frequent ped-calls during the peak hour, the representative state of the signal would be the splits associated with the ped-call.

3. If pedestrian volumes are low and the signal typically operates without ped calls, the splits associated with no ped-call should be entered into Synchro. The pedestrian Walk and FDW times should be entered for all movements with a pedestrian crossing. The minimum splits entered for the approaches associated with the pedestrian push-button movement(s) should only be the minimum vehicle splits \( (G_{\text{min}} + Y + AR) \). If the minimum vehicle splits associated with the pedestrian push-button movement(s) are less than what is calculated by Synchro for the minimum split required for a pedestrian crossing \( (W_{\text{min}} + FDW + AR) \) a Minimum Split Error (red text) will appear in the signal timing window in Synchro. This error shall be disregarded in these situations. Figure 3-4 illustrates what the phasing window would look like in Synchro for this situation.

4. If pedestrian calls are frequent, the splits associated with a ped-call should be entered into Synchro. The minimum splits entered for the approaches associated with the pedestrian push-button movement(s) should be the minimum split required for a pedestrian crossing \( (W_{\text{min}} + FDW + AR) \) assuming it is larger than the minimum vehicular split. No Minimum Split Errors should appear in Synchro.

5. Setting the offset when a signal uses push buttons will require some engineering judgment. The following provides some direction on issues to consider:

   - **EPAC Controller**
     1. If the controller loses step when the push button is activated. (This will occur if the side street split is less than the minimum pedestrian split):
        - If there are infrequent pedestrian push button activations - Set the offset based on no push button activation

---

*Michigan Department of Transportation, Traffic and Safety, October 2008*
• If there are frequent pedestrian push button activations – The splits should be adjusted so that it does not lose step.

2. If the controller does not lose step when the push button is activated. (EPAC controllers typically must have vehicle actuation on the minor road to allow the controller to stay in step during a pedestrian actuation. This will result in variable early greens.):
   • The offset should be set based on no push button activation.

   o **EPIC Controller**
      1. If the controller loses step when the push button is activated. (This will occur if the side street split is less than the minimum pedestrian split):
         • EPIC controllers won’t accommodate this type of operation. Adjust the splits to accommodate the pedestrian timings while staying within the cycle length.
      2. If the controller does not lose step when the push button is activated. (The start of mainline green for EPIC controllers with push buttons will vary depending on if the push button is activated. This will result in variable early greens depending on vehicle volumes):
         • If pedestrian actuations are infrequent, the Synchro model should be based on not having pedestrian actuation – The offset on the permit should be based on not having a pedestrian actuation. Typically, the start of the mainline green will be at the beginning of the last interval and the Synchro offset will correspond with the mainline green starting at the beginning of the last interval. However, the offset on the timing permit is based on the start of the first interval. The offset on the timing permit will need to be adjusted from what is shown in Synchro to account for the early mainline green.
         • If pedestrian actuations are frequent, the Synchro model should be based on having pedestrian actuation - The offset on the permit should be based on having a pedestrian actuation. Typically, the start of the mainline green will be the start of the first interval and the Synchro offset will correspond with the mainline green starting at the beginning of the first interval. The offset on the timing permit should match the offset shown in Synchro.
### 3.3 Actuated Signal Settings

The following values should serve as default settings in the case of actuated signals exceptions for the vehicle extension and minimum gap may occur:

- **Vehicle Extension** = 3.0 seconds
- **Minimum Gap** = 3.0 seconds
- **Time Before Reduce** = 0.0 seconds
- **Time to Reduce** = 0.0 seconds

For actuated locations, extra attention should be paid to make sure that phases are on the correct side of the barrier so the signal will operate correctly when simulated in SimTraffic.

#### 3.3.1 Inhibit Max Setting

For actuated coordinated signals, the inhibit max setting in Synchro is used to designate whether unused time from a phase that is skipped or gaps out early is given to other uncoordinated phases so that they exceed their maximum split or if all unused time should be given to coordinated phases.

- An inhibit max setting of “YES” allows unused or extra time to be given to uncoordinated phases and should be used if the mode setting of 7-Dual Coordinated is used on the timing permit.
• An inhibit max setting of “NO” means all unused time will go to the coordinated phases and should be used in most other situations.

The Inhibit Max setting in EPAC controller is unrelated to the Synchro setting. In an EPAC controller, setting the Inhibit Max to “YES” implies that the signal is running coordinated and the dial/split times should override the Max time settings.
4.0 **OPTIMIZATION**

4.1 **Zone Assignment**

In many cases it may be necessary or desirable to divide a project area into smaller signal zones in order to accommodate different cycle lengths. However, zone splitting should be minimized to the greatest extent possible in order to promote progressive movement along state trunklines and other major arterial corridors.

The following are examples of conditions where zone splitting should be considered:

- Where a transition occurs from a median-divided to undivided roadway
- At a highly-congested intersection where congestion prevents progressive movement, even when a common cycle length is used.
- Where unique geometric conditions necessitate signal phasing not consistent with other intersections within the project area.
- Where a natural break in progression occurs, such as at a “T” intersection, the crossing of a freeway, or a long segment of roadway (greater than 1.5 miles) without a signalized intersection.

Zone assignments must be approved by the MDOT project manager before proceeding with the optimization process.

4.2 **Coordination with Adjacent Signals**

Coordination with adjacent signals should be investigated under certain conditions so that the optimization project causes the least possible disruption to the surrounding signal network. The following are examples of when coordination with adjacent signals should be investigated:

- When a signal is closely adjacent (less than ¼ mile) to the project area/corridor.
- When the optimized cycle length for the project area/zone is the same as the surrounding signal network, and cross-progression could be accommodated.
- When single intersections adjacent to the project area are left isolated (not functioning with any system) by the optimization project.

The extent of coordination may vary, from proposed changes in offsets to a complete re-timing. Every effort should be made to determine coordination requirements in advance of proceeding with an optimization project. The extent of coordination should be discussed and determined in conjunction with the MDOT project manager.

4.3 **Phasing**

MDOT applies a standard phasing sequence wherever possible in order to remain consistent with driver expectations. Signal phasing should not be changed unless special conditions exist where other phasing strategies are required, or would result in a substantial improvement over standard phasing.

The following phasing sequences are typically used:

- Left turns must **LAG** the through movement where a flashing red ball or 4th level left-turn arrow permissive-protected phasing is used.
- Left turns should **LAG** the through movement where a flashing yellow arrow or 5 section permissive-protected phasing is used.
  - Where there is significant benefit, the MDOT project manager may approve having the left turn phase **LEAD**.
- Left turns should **LEAD** the through movement where protected-only phasing is used.
4.4 Splits

A signal phase “split” refers to the sum of the green, yellow and all-red time for any given phase. For simplicity, splits determined during the optimization process should be whole numbers (i.e. 32 seconds vs. 31.7 seconds).

4.5 Optimization Techniques

It should be noted that the optimization functions in Synchro do not typically provide timings consistent with MDOT’s preferences. Care should be taken by the engineer to manually adjust the timings based on the following general guidelines:

- Cycle Lengths: Cycle lengths should generally be evaluated first based on the quality of progression for the trunkline corridor, and secondly based on the resulting local intersection delay. Typically, cycle lengths that provide optimum progression for a high-volume trunkline will yield the best overall network performance.
  - The progression and splits must be reviewed during the process of selecting a cycle length as the splits and offsets that Synchro provides are often impractical and/or provide excessive time to minor movements and thus may point to a less than ideal cycle length.
  - It is possible to eliminate certain cycle lengths that are unsuitable for the corridor.
    - If a corridor has a high volume with multiple left turn phases, a 60-70 second cycle length can typically be eliminated.
    - On a low volume corridor, with closely spaced signals, higher cycle lengths will typically result in poor progression and excessive delays for minor movements.

- Splits: Signal phase splits should be manually adjusted in general to favor the trunkline corridor (typically the higher volume roadway), while maintaining acceptable LOS C or better on the intersecting roadway. Special attention should be paid to locations where a major arterial crosses the trunkline. In addition, signalized crossovers should be timed as an extension of the main intersection, with identical splits.

- Offsets: Offsets should generally be adjusted to provide optimal progression for the predominant peak direction, while maintaining the best possible progression in the off-peak direction. If the cycle length remains the same in optimized conditions as in existing conditions, a common reference point should be established for ease of comparing the existing and optimized offset plan. A reference intersection should be selected (typically a major crossroad or a signal at one end of the corridor) and the existing offset at that location held constant for the optimized condition, with all other offsets developed around it.

4.6 Measures of Effectiveness

Measures of Effectiveness (MOEs) should be evaluated to determine the effectiveness of the optimization process. MOEs to be considered vary between the local intersection and network levels:

- Local Intersections:
  - Intersection control delay and level of service (Highway Capacity Manual method) should be evaluated as the primary MOE at the local intersection level. Wherever possible, Level of Service (LOS) C or better should be achieved for all approaches. However, judgment should be used to balance approach levels of service based on relative traffic demand.

- Network/System:
  - Progression bandwidth should be evaluated as the primary MOE at the network/system level. The optimization should aim not only to provide the maximum bandwidth along major corridors, but to position the band to provide progression for the leading vehicles in the platoon (leading edge bandwidth) wherever possible.
While other MOEs should be evaluated as part of the optimization and reporting process (see Section 5.3), the above MOEs should be considered the most important when making optimization decisions and adjustments.

4.7 Time-of-Day Schedules

The time-of-day schedule for the project area/zone should be updated as part of the optimization process to designate when the various timing plans should be in affect. The following guidelines should be followed in determining the time-of-day schedule:

- Signals typically operate under three timing plans: AM peak period, PM peak period, and a mid-day/off-peak/weekend plan.
- 24-hour counts should be used to determine when timing plan changes should occur based on the traffic flow pattern. Figure 4-1 presents an example of a typical 24-hour traffic flow pattern of an average weekday, and illustrates where timing plan changes may be appropriate.
- The time-of-day schedule should be the same for all signals within a zone in order to maintain coordination, except when signals change in and out of flash operation.
- Certain locations may require special mid-day, night, or weekend timing plans to accommodate unique conditions, such as school dismissal or shift changes. In such cases, coordination should be maintained whenever possible with adjacent signals operating on a standard schedule.
- When a signal comes out of flash mode or changes dial/splits, it must go thru a period of correction where the controller adjusts the timings to move the offset to the desired time. During this correction the offsets tend to be random and progression will often be poor. Depending on the cycle length, how much the offset needs to be adjusted and how much correction the controller can make per cycle, this can take multiple cycles and last for as much as 10-15 minutes. In the AM time period, it is often beneficial to start the timing plan while volumes are still relatively low but growing quickly. This allows all the controllers to be coordinated when the peak volumes arrive. There may be situations where this is beneficial for the PM time period, but the midday volumes are typically substantially higher than the early morning volumes and the PM peak is typically more of a gradual increase in volumes as opposed to the sharp spike typically seen in the AM time period.

At locations with current flash schedules, the period(s) of flash operation should be reviewed based on 24-hour volume data. While flash schedule is not explicitly addressed in the current edition of the Michigan Manual of Uniform Traffic Control Devices (MMUTCD), MDOT’s internal guideline on setting flash schedule, consistent with direction set forth in the 1994 MMUTCD, which follows:

“When for a period of four or more consecutive hours any traffic volume drops to 50 percent or less of the stated volume warrants, it is desirable that flashing operation be substituted for conventional operation for the duration of such periods. However, such flashing operation should be restricted to no more than three separate periods during each day.”

An exception to the 1994 MMUTCD guidelines as stated above is as follows. Flashing operation should only be considered during time periods where the minor road traffic volume drops to 50 percent or less of the volume warrants for Warrant 1 (Minimum Vehicular Volume). Also, engineering judgment should be used in cases when unique intersection characteristics may warrant deviation from this guideline, such as locations where major road volumes are exceptionally high or there are sight restrictions. Intersection flash schedules should be evaluated and updated based on these criteria.
Flash schedules should generally be kept consistent along a corridor. To do this, flash schedules at individual intersections may be shortened, but they should not be extended beyond what the volume criteria allows. If the signals can be grouped into major and minor intersections or separate segments that would have significantly different flash schedules, utilizing two flash schedules may be considered. Utilizing more than three flash schedules on a corridor should generally be avoided.

**Figure 4-1: Example Timing Plan Changes by Time-of-Day**

![Diagram of Major Road at Minor Road - Volume vs. Time](image-url)
5.0 MICROSIMULATION

Microsimulation should be conducted using SimTraffic to further evaluate the network performance both before and after optimization. This evaluation should focus on the effectiveness of progression along major corridors and identification of potential storage issues. The following sections document specific procedures to be followed when conducting microsimulation.

5.1 Simulation Timeframe

A full hour of analysis is typically used for all microsimulation analyses, in addition to an adequate period for network seeding. However, duration may be evaluated and determined on a project-by-project basis, as simulation of large networks may become prohibitively long.

Network Seeding Period

The network seeding period must at a minimum be long enough for one vehicle to travel from one entry point of the network to the farthest exit point of the network. This length of time should be approximated based on distance, speed limits and consideration of signal density and congestion within the network. No data should be recorded during the seeding interval.

Analysis Period

The analysis hour should reflect fluctuations in traffic flow over an hour period, as represented by the Peak Hour Factor (PHF). The PHF defines the intensity of traffic flow during the peak 15-minutes of the hour period, relative to the remainder of the hour. The location of the peak 15-minute period within the peak hour may vary, even within a single corridor. However, under normal conditions, the peak 15-minute period may be estimated to occur within the middle two 15-minute intervals of the hour.

In order to reflect this variation in traffic flow over the hour, the analysis hour should be divided into three distinct intervals – a 15-minute pre-peak interval, a peak 15-minute interval, and a 30-minute recovery interval. The PHF should be applied during the peak 15-minute interval only. An anti-PHF (an inverse of the PHF used to reduce volume levels during the off-peak intervals) should be applied during the pre-peak and recovery intervals. Figure 5-1 illustrates this interval set-up.

5.2 Calibration and Validation

The SimTraffic model of the existing conditions must be calibrated and validated to actual field conditions before further analysis is conducted. In addition to performing adjustments to the simulation parameters to better reflect nuances experienced in the field, this process serves as an opportunity to validate the accuracy of the Synchro model inputs.
SimTraffic model outputs should be compared against any available and comparable field data to determine the validity of the model results. On a typical project, this would be traffic volumes served. A comparison of actual turning-movement counts that were input into Synchro and the SimTraffic model results can be done using the SimTraffic VOLUME EXITED report. This report should be conducted to assure that the actual volume levels observed in the field are being replicated by the SimTraffic model. The greater of ±10 percent or ±20 vehicles is considered a reasonable threshold for model validation. Figure 5-2 illustrates an example report to be included in the final report (see Section 7.2). The report shows the volume exited, the volume input, as well as the percent of volume exited. If volume on a certain approach is very low, usually the ±20 vehicle rule will apply.

Once calibrated and validated, any adjusted parameters are stored in a SimTraffic configuration file (extension .sim for SimTraffic version 7). If the Synchro file is modeled in SimTraffic without the appropriate configuration file in the same directory, SimTraffic will use default parameters, thereby negating the calibration and validation process. Therefore, appropriate .st7 files, representing the calibration of existing conditions, should be used when modeling optimized conditions, and should accompany all file transmittals.

### 5.3 Measures of Effectiveness

SimTraffic Measures of Effectiveness (MOEs) should be collected and evaluated as a means of further assessing the results of the optimization process. The following MOEs should be reviewed during the analysis process, and should be included in the final report (see Section 7.2):

- Total Network Delay
- Average Network Speed
- Total Network Travel Time
- Total Network Stops


6.0 TIMING PERMITS AND REPORTS

6.1 Timing Permits

Once timing plans are approved in Synchro, a timing permit should be prepared documenting the timing parameters to be entered into the controller. MDOT maintains timing permit forms for EPIC and EPAC controller types. Sample forms are included in Appendix B.

Timing permits should be prepared in accordance with MDOT’s Timing Plan Preparation Guidelines, which documents procedures for completing timing permits. Timing permit files should be named with the control section spot number and the prepared by date.

Timing Permit File Name = 55555-01-555_05-29-08

6.2 Field Adjustments

A field review of implemented timings is required for all projects in order to assure that timings have been implemented properly, and that the signal timings are facilitating traffic as they were designed. The field review of implemented timings should include the following steps:

- A timed check of the accuracy of phase splits should be conducted.
- Verification of offsets should be conducted by performing a driving check of the time-space diagram relationship.
- Any observed and unexpected conditions, such as cycle failures, extensive queuing or spillbacks, should be noted and further reviewed to determine whether reallocation of green time is required or appropriate.
- The time-space diagram relationship should be critically reviewed to determine whether progression is maintained as intended, and whether adjustments should be made to better facilitate coordinated traffic flow.

Any recommended adjustments after implementation should be documented in a brief memo, along with updated signal timing permits reflecting the proposed adjustments.

6.3 Project Benefits Analysis

A project benefits analysis should be performed for each project, quantitatively evaluating conditions both before and after the new timings are in place. This analysis will typically require collection of travel time or other data both before and after implementation. Specific procedures, however, will vary by project, and will be determined in conjunction with the MDOT project manager at the beginning of the project.

The benefit analysis can be preformed using two different methodologies:

- The preferred method for corridors is to utilize PC-Travel data from before- and after-travel time runs. MDOT provides a Signal Optimization Benefit/Cost Analysis Spreadsheet. Data from PC-Travel reports can be quickly entered into this spreadsheet along with traffic volume information to generate a benefit/cost summary for the project.
- A second benefit analysis can be performed using results from SimTraffic. This method should be used when studying isolated intersections, small groupings of signals (typically 5 or fewer), or any other situation where before or after travel time runs are unavailable. The benefit analysis uses the following MOE’s from SimTraffic:
  - Stop Delay (sec/veh)
  - Travel Time (hr)
  - Average Speed (mph)
  - Fuel used (gal)
  - HC Emissions (g)
  - CO Emissions (g)
  - NOx Emissions (g)
  - Vehicles Exited
Several assumptions regarding average values have been made; these values are as follows:

- Average Cost of Fuel: $2.50
- Average Number of Work days per Year: 250
- Average Vehicle Occupancy: 1.1
- Average Value of Time per Individual: $13.75

These values should be verified with the PM prior to completing the analysis. Volume counts for each peak hour should also be input into the analysis.

### 6.4 Project Report

Each optimization project should include a final report documenting the project process and results, as well as all data collected for the signal timing effort. The following sections describe the required documentation.

#### 6.4.1 Measures of Effectiveness Documentation

All Measures of Effectiveness (MOEs) should be summarized in a tabular format within the project report for ease of review. The summary of MOEs prepared for the optimization analysis should include a comparison between existing and optimized conditions results. Following are sample formats for MOE summary tables:

**Table X: Comparison of Optimized and Existing Intersection Operations – Zone 1, PM Peak Hour**

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Existing Condition</th>
<th>Optimized Condition</th>
<th>Change (sec/veh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delay (sec/veh)</td>
<td>LOS</td>
<td>Delay (sec/veh)</td>
</tr>
<tr>
<td>Main Street/Elm Street</td>
<td>47.6 D</td>
<td></td>
<td>41.3 D</td>
</tr>
<tr>
<td>Main Street/Walnut Street</td>
<td>24.9 C</td>
<td></td>
<td>18.2 B</td>
</tr>
</tbody>
</table>

Source: Synchro

**Table Y: Comparison of Optimized and Existing Network Operations – Zone 1, PM Peak Hour**

<table>
<thead>
<tr>
<th>MOE</th>
<th>Existing Condition</th>
<th>Optimized Condition</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Delay (hours)</td>
<td>370</td>
<td>320</td>
<td>-14%</td>
</tr>
<tr>
<td>Total Stops</td>
<td>15000</td>
<td>13000</td>
<td>-13%</td>
</tr>
<tr>
<td>Total Travel Time (hours)</td>
<td>600</td>
<td>500</td>
<td>-17%</td>
</tr>
<tr>
<td>Average Speed (mph)</td>
<td>27</td>
<td>34</td>
<td>+26%</td>
</tr>
</tbody>
</table>

Source: SimTraffic
6.4.2 Report Organization

Optimization project reports should generally be organized into the following sections:

**Project Summary**

The first page of the report should provide a one-page summary table detailing pertinent project scope and results information. The summary should include the following information:

<table>
<thead>
<tr>
<th>SIGNAL OPTIMIZATION PROJECT SUMMARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDOT Job Number</td>
</tr>
<tr>
<td>Route Number and Name</td>
</tr>
<tr>
<td>Control Section(s)</td>
</tr>
<tr>
<td>Location (City/Township, County)</td>
</tr>
<tr>
<td>Project Limits (Cross-Streets)</td>
</tr>
<tr>
<td>Project Limits (Mileposts)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field Study Results</th>
<th>AM Peak</th>
<th>Mid-Day</th>
<th>PM Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time Reduced by (minutes):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northbound</td>
<td>1.2</td>
<td>0.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Southbound</td>
<td>1.0</td>
<td>0.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Stopped Time Reduced by (minutes):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northbound</td>
<td>0.8</td>
<td>0.2</td>
<td>1.6</td>
</tr>
<tr>
<td>Southbound</td>
<td>0.6</td>
<td>0.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Speed Increased by (mph):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northbound</td>
<td>5.0</td>
<td>2.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Southbound</td>
<td>4.0</td>
<td>1.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Daily Vehicle-Hours of Travel Reduced by: 500 Vehicle-Hours
Daily Fuel Consumption Reduced by: 300 Gallons
Daily Pollutant Emissions Reduced by: 1000 Pounds VOC, NOx
Daily Time and Fuel Savings: $1,400 Dollars
Annual Time and Fuel Savings: $350,000 Dollars
Project Cost: $100,000 Dollars
Funding Source: CMAQ
Average Daily Traffic: 20,000 Vehicles per Day
Annual Benefit/Cost Ratio: 3.5

If the project incorporates multiple corridors, a summary for the entire project should be incorporated. The Field Study Results would not be listed. The summary for the individual corridors should be included in an appendix separate for each corridor.

**Table of Contents**

Following the Project Summary, provide a table of contents detailing page numbers of report sections, tables and figures.

1.0 Introduction

The Introduction section should include a brief description of the project area, including a map, and a list of intersections included in the analysis.

2.0 Data Collection

The Data Collection section should include a description of the data collected, including dates. Any unusual circumstances surrounding the data collection effort should be identified, such as construction, weather conditions, etc.
3.0 Existing Operations Analysis

The Existing Operations Analysis section should document the following:
- Synchro analysis results in tabular form
- The SimTraffic model calibration and validation process
- SimTraffic analysis reports in tabular form

4.0 Crash Analysis

The Crash Analysis section should identify critical crash locations and discernable crash patterns at critical locations.

5.0 Optimization Analysis

The Optimization Analysis and Results section should document the following:
- A brief description of the optimization process, including cycle length selection (Maps should be provided in cases where multiple cycle lengths are employed during the same time period).
- Discussion of any proposed phasing modifications
- Synchro analysis results in tabular form
- SimTraffic analysis results in tabular form

7.0 Project Implementation and Benefits

The Project Implementation and Benefits section should document the following:
- A discussion of the implementation process, including field review and necessary timing modifications.
- Project benefits analysis summary that includes a comparison of before and after travel time runs.
- Identification of any items for consideration that were mitigated (or may potentially be mitigated) as a result of this project.

8.0 Items for Further Consideration

Include any recommendations to further improve operations or safety, including equipment upgrades, geometric or striping reconfiguration, addition or deletion of signal phases, removal of signals due to lack of warrant, or other modifications. Also make a note where further study would be required to determine the exact scope or effectiveness of potential improvements.

Potential items to identify for improvement may include:
- Operations and safety, i.e. signal timing/phasing, turn restrictions, lane assignment, adjacent parking.
- Geometry that impacts both traffic operations and safety, i.e. lane geometry, sight distance issues, offset vehicle paths.

NOTE 1: For those current projects were deficiency memos are being created, please change the name to “Items for Further Consideration” and include not only the previously identified deficiencies but the recommended enhancements for the area. It is understood that some improvements/enhancements will not be identified until after the optimization task, which should be reflected in the final report.

NOTE 2: An advanced submittal regarding items for consideration should only be submitted if there the item is critical.
Appendix A: Traffic Volume and Travel Time Data

A sample MDOT formatted traffic volume data submittal and guidelines for the submittal of MDOT formatted traffic volume data is included in Appendix A of this document.

Appendix B: Intersection Inventory and Condition Reports

Appendix C: Timing Permits

Appendix D: Synchro and SimTraffic Reports

A sample Synchro analysis report format is included in Appendix D of this document. A sample SimTraffic analysis report format is included in Appendix D of this document.

Appendix E: Project Benefits Analysis Spreadsheet

The report should be prepared in a concise manner, using maps, figures and tables where appropriate to best convey the information.
APPENDIX A

MDOT Traffic Volume Data Submittal Format
**MDOT Traffic Volume Data Submittal Format**

The following are guidelines for the submittal of traffic volume data (manual and machine counts) to MDOT for signal optimization projects:

- **File Format** - All manual and machine counts should be exported into a Microsoft Excel format (.xls).

- **File Name** – The file name will be the Control Section/Spot # followed by the date of the manual traffic count. The following is an example:

  77091-01-012_Jan27-2005_Counts.xls

- **Worksheet Arrangement** – The Excel file will contain one worksheet for the manual traffic counts, and separate worksheets for each of the machine counts with the worksheet tabs named accordingly (NB Machine Counts, SB Machine Counts, etc.).

- **Manual Traffic Counts General Info** – The manual traffic counts worksheet will contain the following info at the top of the worksheet:
  - Control Section/Spot #
  - Location (the MDOT name for the intersection)
  - City/Township
  - Date (the date the manual traffic count was collected)
  - Weather (weather conditions if applicable)
  - Collected By (a note about who collected the counts)

  **Example**

<table>
<thead>
<tr>
<th>Control Section/Spot #</th>
<th>77091-01-012</th>
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<tr>
<td>Location:</td>
<td>M-25 Pine Grove at Hancock</td>
</tr>
<tr>
<td>City/Twp:</td>
<td>Port Huron</td>
</tr>
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</tr>
<tr>
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<td>Collected By:</td>
<td>MDOT</td>
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- **Machine Counts General Info** – The machine counts worksheet(s) will contain the following info at the top of the worksheet:
  - Type of Count (direction of count taken and any pertinent information)
  - Location (where on the roadway was the count taken)
  - City/Township
  - Start Date (date the machine count was started)
  - Collected By (a note about who collected the counts)

  **Example**

  | Type of Count:         | NB M-25 24-Hour Vehicle Count |
  | Location:              | M-25 (210' South of Hancock St.) |
  | City/Twp:              | Port Huron |
  | Start Date:            | 2/1/2005 (Tuesday) |
  | Collected By:          | MDOT |
Offset Intersections – If the offset intersections are on the same controller, the counts should be summarized in one Excel file. If the offset intersections are on separate controllers, the counts should be summarized in separate Excel files.

Multi-Approach Intersections – There will occasionally be situations where there are more than four approaches at an intersection. On the Manual Counts worksheet, simply add these additional approaches to the right of usual four approaches and label accordingly. For the machine counts, insert additional worksheets and name accordingly for the additional approaches.

Boulevard Intersections – Boulevard roadway intersections are to be treated as one intersection and summarized in one Excel file. Crossovers adjacent to the boulevard intersection are to be summarized in separate Excel files (a different file for each crossover).

Closely Spaced Intersections – For closely spaced intersections, such as those near highway on/off ramps, locations that are on the same controller should be summarized in the same Excel file. Care must be taken in the naming of the Manual Count approaches and Machine Count locations so that it is easily understood what approach is being described.
### Sample Turning Movement Count Submittal Format

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APPENDIX B

INTERSECTION INVENTORY AND CONDITION FORM
# Intersection Inventory and Condition Form

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<th>Main Street Name:</th>
<th>Control Section # / Spot #</th>
<th>Mile Post #</th>
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<td>Intersection Number:</td>
<td>PR Mile Point</td>
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<td>City/Township:</td>
<td>Prime Number:</td>
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<td>County:</td>
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<td>Latitude (N)</td>
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## Approach (Direction of Travel)

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<th>NORTHBOUND</th>
<th>SOUTHBOUND</th>
<th>EASTBOUND</th>
<th>WESTBOUND</th>
<th>ADD'L APPROACH</th>
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## Geometry

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<th>Thru Lanes (#)</th>
<th>Left Turn Lanes (#/Length in ft)</th>
<th>Right Turn Lanes (#/Length in ft)</th>
<th>Intersection Width*</th>
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<table>
<thead>
<tr>
<th>Ped. Crossing Length/Button Distance (ft)**</th>
<th>Adjacent Pkg Approach Lane (Y/N)</th>
<th>Adjacent Pkg Departure Lane (Y/N)</th>
<th>Approach Grade (±%)</th>
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## Operations

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<th>Approach Speed Limit (MPH)</th>
<th>Departure Speed Limit (MPH)</th>
<th>Right Turn On Red (Y/N)</th>
<th>Turn Restrictions (Y/N)</th>
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| If Yes, describe: | |
|------------------||

## Equipment

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<th>Pedestrian Signal (Y/N)</th>
<th>Pedestrian Push Button (Y/N)</th>
<th>Left Turn Head Type***</th>
<th>Right Turn Green Arrow (Y/N)</th>
<th>Ambient Lighting (Y/N)</th>
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* Width of intersection, measured from the near-side stop bar to the far edge of the conflicting extended travel lane along the actual vehicle path of a thru vehicle (feet).
** Pedestrian crossing distance is measured along the crosswalk line closest to the stop bar from near curb to extended edge of furthest travel lane.
*** Left turn signal head type should be indicated as 3-Level Arrow, 4-Level Green Arrow, 4-Level Yellow Arrow Flash, or Dog House-Type.
* Width of intersection, measured from the near-side stop bar to the far edge of the conflicting extended travel lane along the actual vehicle path of a thru vehicle (feet).

** Pedestrian crossing distance is measured along the crosswalk line closest to the stop bar from near curb to extended edge of furthest travel lane.
APPENDIX C

SAMPLE TIMING PERMIT FORMS
# SOLID STATE TRAFFIC SIGNAL TIMING PERMIT

## Hours of Operation

| HOUR | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| MINIMUM TIME | | | | | | | | | | | | | | | | | | | | | | | | | |

## Internal Timing (Seconds)

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## Load Switch

| LOAD | SWITCH | DESCRIPTION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|------|--------|-------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| TIME | | | | | | | | | | | | | | | | | | | | | | | | | | |

## Signal Plan - Cycle Sequence Chart

| CYCLE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| TIME | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## Remarks

- C = Correction, I = Enter Flash, O = Exit Flash
- Controller Type:
  - [ ] EPIC
  - [ ] EF140
  - [ ] Other
- Flash Hours:
  - [ ] to
  - [ ] Daily
  - [ ] None
  - [ ] Pre-Empt
  - [ ] Countdown Peds
- Date Timing Installed:
- Location:
- Job # (If Applicable):
- City/Twp.:
- County:
- Control Section: Spot #
- Prepared By:
- Date:
- Mile Point:

---

Page 1 of 3

CLEAR PAGE 1

CLEAR ALL
## Advanced Timing Parameters Form

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Prepared by: ____________________________

Data: ____________________________

Location: ____________________________

Control Section-Spot #: ____________________________

Page 2 of 3
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### Preemption System Data
- Locking
- Non-Locking
- MIN ORNL(s)
- Priority: PE1/5, PE1/6, PE5/5, PE5/6
- Status

### Remarks

PREPARED BY: [Name]
DATE: [Date]
LOCATION: [Location]
CONTROL SECTION-SPOT #: [Number]

CLEAR PAGE 3
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PREPARED BY:       DATE:
FLASH HOURS:       DAILY      NONE
NIGHT FLASH:       FY = FR =
CONFLICT FLASH:     FY = FR =
CONTROLLER TYPE:   EPAC
Other:     PRE-EMPTY
COUNTDOWN PEDS

CLEAR PAGE 1  CLEAR ALL
## ADVANCED TIMING PARAMETERS FORM

### SYSTEM INFORMATION

- **Controller Type:**
  - [ ] EPAC
  - [ ] Other:

- **System Type:**
  - [ ] Closed Loop
  - [ ] Stand By
  - [ ] Group 1
  - [ ] Group 2
  - [ ] Address:
    - [ ] TBC
    - [ ] TBCKPS
    - [ ] None
    - [ ] Other:

- **If TBC, Synchrony by:**
  - [ ] TOD
  - [ ] Event:

- **Interconnect Type:**
  - [ ] Hardware
  - [ ] Fiber-Optic
  - [ ] Radio
  - [ ] Phone Drop:
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- **If Phone Drop, Phone #:**

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### COORDINATION DATA

- **Operation Mode:**
- **Coordination Mode:**
- **Maximum Mode:**
- **Correction Mode:**
- **Offset Mode:**
- **Force Mode:**
- **Max Dwell:**
- **Yield Period:**

### REMARKS

### ADDITIONAL OVERLAP DATA

- **Overlap Phase:**
  - [ ] Lead Bays
  - [ ] Phases Overlapped
  - [ ] T.G. (s)
  - [ ] Y (s)
  - [ ] R (s)
  - [ ] <Y
  - [ ] <GRN

- **PREPARED BY:**
- **DATE:**
- **LOCATION:**

- [ ] MDOT
- [ ] County
- [ ] City
- [ ] Consultant

- **CONTROL SECTION #:**

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Page 2 of 3
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**Priority**

- PE1 1/2 3/4 PE1 3/4 PE1 5/6

**Status**

**Remarks**

**Prepared By:**

**Date:**

**Location:**

**Control Section-Spot #:**

**CLEAR PAGE 3**
APPENDIX D

SYNCHRO AND SIMTRAFFIC
SAMPLE ANALYSIS REPORT FORMATS
## Sample SYNCHRO HCS Analysis Report Format

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PM HOUR

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<td>1134</td>
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Turn Type  Perm Perm Perm Perm Perm Perm Perm
Protected Phases  2 2 2 3 6 4 8
Permitted Phases  2 2 2 6 4 8

Actuated Green, G (s) 51.0 51.0 51.0 51.0 51.0 17.2 17.2 17.2 17.2
Effective Green, g (s) 54.0 54.0 54.0 54.0 54.0 20.0 20.0 20.0 20.0
Actuated g/C Ratio 0.68 0.68 0.68 0.68 0.68 0.25 0.25 0.25 0.25
Clearance Time (s) 8.0 8.0 8.0 8.0 8.0 5.8 5.8 5.8 5.8

Lane Grp Cap (vph) 226 1279 1081 98 1399 239 435 425 465

\[\text{v/s Ratio Prot} = 0.60 \quad \text{v/s Ratio Perm} = 0.46\]

\[\text{v/s Ratio Perm} = 0.08 \quad \text{v/s Ratio Perm} = 0.12\]

Uniform Delay, d1 7.2 10.5 4.6 5.0 7.8 23.3 25.5 27.4 25.2
Progression Factor 0.53 0.52 0.05 0.53 0.44 1.00 1.00 1.00 1.00
Incremental Delay, d2 9.9 8.1 0.2 4.8 2.3 1.1 3.7 18.0 3.0
Delay (s) 13.7 13.5 0.4 7.4 5.6 24.4 29.2 45.4 28.2
Level of Service B B A A A C C D D
Approach Delay (s) 12.3 5.7 28.6 36.0
Approach LOS B A C D

Intersection Summary

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<thead>
<tr>
<th>HCM Average Control Delay</th>
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<tr>
<td>14.4</td>
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<tr>
<td>HCM Volume to Capacity ratio</td>
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Cycle Length (s) 80.0

\[\text{Sum of lost time (s) = 6.0}\]

\[\text{Critical Lane Group}\]

\[\text{ICU Level of Service} = F\]

Synchro 5 Report
HCM Signalized Intersection Capacity Analysis
### Sample SIMTRAFFIC Network MOE Output Report

**SimTraffic Performance Report**  
**PM PEAK HOUR**  
**ZONE 1**  
**OPTIMIZED**

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<td>Total Stops</td>
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<td>Travel Time (h)</td>
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<td>Avg Speed (mph)</td>
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8/27/2003  
PARSONLVL7-FF51
APPENDIX E

SAMPLE BENEFIT COST ANALYSIS SPREADSHEET
## PEAK HOUR SUMMARY STATISTICS

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<thead>
<tr>
<th>Time Period</th>
<th>Average</th>
<th>Average</th>
<th>Average</th>
<th>Fuel Consumption</th>
<th>CO</th>
<th>HC</th>
<th>NOx</th>
<th>Total</th>
<th>Travel Time</th>
<th>CO</th>
<th>HC</th>
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## PEAK PERIOD SUMMARY STATISTICS

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<tbody>
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<td>46.7</td>
<td>31.9</td>
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<tr>
<td>Change</td>
<td>3.9</td>
<td>-8.7</td>
<td>2.0</td>
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<tr>
<td>EB Before</td>
<td>416.8</td>
<td>57.0</td>
<td>31.5</td>
</tr>
<tr>
<td>After</td>
<td>422.6</td>
<td>24.7</td>
<td>25.6</td>
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<tr>
<td>Change</td>
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<td>-32.3</td>
<td>6.9</td>
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<tr>
<td>PM Peak Period (3:00 PM - 7:00 PM)</td>
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## DAILY SUMMARY STATISTICS

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<td>(g/day)</td>
<td>(kilojoules/day)</td>
<td>(kilojoules/day)</td>
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<td>-0.6%</td>
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## BENEFIT/COST EVALUATION

### Fuel Savings
- Daily Savings: $75.65
- Yearly Savings: $18457
- 1-Year B/C Analysis: $491759
- Total Project Cost: $60,000
- Benefit/Cost: 8.17
- 3-Year B/C Analysis: Total Savings: $1,455,273
  - Benefit/Cost: 24.50

### Assumptions
- Avg. Cost of Fuel ($/gallon): $2.10
- Avg. # of Workdays/Year: 250
- Avg. Vehicle Occupancy: 11
- Avg. Value of Time/Individual ($/hr): $15.75