DEVELOPMENT OF NEW ACTUATED SIGNALIZED INTERSECTION PERFORMANCE MEASUREMENT METHODOLOGIES USING TRAFFIC CONTROLLER INPUT AND OUTPUT DATA

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**Abstract**

The main objective of this research is to determine various automated measures of performance for signalized intersections. Measures of performance were developed and then tested. This project emphasizes measuring the performances for a local traffic controller only using standard detector configurations. This research focuses on the following problems: 1) Develop performance measurement methods that utilize standard detection configurations; and 2) Determine the functionality of performance measurement with standard detection technologies.

**Key Words**

- Performance tests, signalized intersections, simulation, ITS

**Distribution Statement**

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Development of New Actuated Signalized Intersection Performance
1. INTRODUCTION

The main objective of this research is to determine various automated measures of performance for signalized intersections. Measures of performance were developed and then tested. This project emphasizes measuring the performances for a local traffic controller only using standard detector configurations. In the Chapter 2 literature review, problems were identified relevant to this research and these are as follows:

- Performance measures are limited for local control.
- Performance measurement should function with standard detection.
- Logic for performance measurement feedback to controller needs to be developed.
- Higher resolution detection by space and by time is possible for standard detection and should be used for performance measurement.
- Limited possibilities exist for modifying controller feedback logic.
- Proper guidance is not available on how to use performance for local control.

While each of these problems is significant, this research focuses on the following problems:

- Develop performance measurement methods that utilize standard detection configurations.
- Determine the functionality of performance measurement with standard detection technologies.

1.1 Scope of Work

This research project identified several promising performance measures for automatically evaluating and improving local signalized intersection performance. Existing methods for arriving at these performance measures were tested and assessed to determine their strengths and weaknesses. Finally, in the case of the delay performance measure, an additional method was developed and tested.

The scope of work for this research is described in three sections. One is a statement identifying the performance measures selected for further research and an explanation. The second way is defining the extent to which these performance measures were tested for this research project. Finally, the type of data used to support the research endeavors is also explained.
1.2 Which Performance Measures Were Addressed?

The three main performance measures considered for this project are as follows:

- Green time utilization
- Cycle failure detection and
- Delay

Green time utilization is important because it measures the degree to which intersection capacity is utilized overall and by individual phases. For example, a phase may have 30 seconds of green but typically only serves 2 vehicles in the last 10 seconds. In this example, the last 10 seconds of time would be better spent serving another conflicting phase. Cycle failure is the second focus area of this project. Cycle failure can be defined as when one or more queued vehicles for a particular movement must wait through more than one red light to complete the intended movement. Cycle failure detection is essential to identify traffic signal control problems. Delay is the third measure of performance which was examined in this research; According to the Highway Capacity Manual, delay is the additional travel time experienced by a driver, passenger, or pedestrian. It is also one very important performance measure for a signalized intersection and it indicates that an intersection is overcapacity or if the signal timing is insufficient. For example, if a vehicle is in queue at intersection and it is not served in the estimated green phase, it will experience delay and eventually it may experience cycle failure.

1.3 To What Extent Were They Addressed?

The three performance measures were researched individually and their respective research scopes are described here.

a. **Green time utilization**: Determine and develop the means by which it can be simulated/ tested and assess the quality of its measurement using existing techniques.

b. **Cycle failure detection**: Determine and develop the means by which it can be simulated/ tested and assess the quality of its measurement using existing techniques.

c. **Delay**: Determine the means by which it will be automatically measured and assess the quality of its measurement.
1.4 With What Data Were They Tested?

This section describes the data used to test the various performance measures. The primary means for acquiring test data was microscopic traffic simulation. There were four reasons to use microscopic traffic simulation and these are as follows:

- Raw detector data were not available to use as input to test green time utilization and cycle failure.
- Testing performance methodologies in varying traffic conditions with different standard detector configurations resulting from differing approach speeds in the field is the ideal; but achieving this ideal would come at a very high data collection cost if field data were used.
- Testing required for this research is at the concept level, where different items of data, such as signal status, detector status, and ground truth benchmark performance measures were not available from the field.
- Microscopic traffic simulation offers a cost-effective means to acquire simulated raw detector data, controller state, and benchmark performance measurement data.

To measure delay, field data were collected using a video based data collection method. Data were collected from two intersections: one was a four-leg signalized intersection with actuated coordinated controller and the other was a three leg signalized intersection with actuated controller.

2. LITERATURE REVIEW

The purpose of this literature review was to determine the state of automated performance measurement in traffic signal systems and the focus areas for future research. To accomplish, this review assumes that the reader understands the performance measurement concept and the importance of performance measurement in traffic signal systems. This review focuses on identifying and briefly discussing the key issues in which research is needed for full implementation of performance measurement in traffic signal systems.

Five problems were identified as follows and there is a section for each one of these items in the discussion that follows:

- Performance measures for local control
• Performance measurement with standard detection
• Mechanisms for performance measurement-control feedback
• Logic to deal with performance measurement feedback
• Higher resolution detection by space and by time

2.1 Performance Measures for Local Control

There are a variety of performance measures available for local intersection control. Table 2-1 and Table 2-2 summarize these performance measures and the controller and/or software in which they are offered. Based on the options in the two tables, it is clear that a variety of options do exist. However, performance measurement for local control is more limited, with traffic controllers offering fewer performance measurement options. It should be noted that detector configuration and design is more demanding if a detector will be used for measures that require more resolution than what is required for phase calls and extensions (e.g., volume, speed, delay, and stops) in order for these options to work well. Additionally, these measures are reported in an aggregate form, where aggregation intervals are specified in lengths of one minute or more and may be averaged over the cycles occurring within the aggregation interval.

Table 2-1 Existing Performance Measures in Traffic Controllers

<table>
<thead>
<tr>
<th>MOE</th>
<th>ATC 2070 (Controller Models)</th>
<th>NEMA TS2 (Controller Models)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BI Tran</td>
<td>Econolite</td>
</tr>
<tr>
<td>Volume</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Occupancy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Speed</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Delay</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Split Usage Monitoring</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Green Splits</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Average Green Utility</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Gap's/F.O.s/Max's</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Stops</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 2-2 Existing Performance Measures in Traffic Control Software

<table>
<thead>
<tr>
<th>Measures of Effectiveness Reported</th>
<th>Closed-loop Software</th>
<th>Centralized Software</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aries</td>
<td>Actra</td>
</tr>
<tr>
<td>Volume</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Occupancy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Speed</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Delay</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Green Splits</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Average Green Utility</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Gap's/F.O.s/Max's</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Split Monitor Report</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
While offering these performance measures is a step in the right direction, performance measures need to be offered in forms that are not aggregated. The reason for this is that it would be more difficult to diagnose the cause of a phase experiencing cycle failure if detector occupancies are averaged over the cycle or larger time period. For example, in a situation where flow is seriously restricted due to a downstream bottleneck, it would be useful to possess information such as phase status, detector status, and flow that show their conditions over the course of the phase, not an average. The phase’s detector status would change at different points within the green intervals. Knowing the detector status at different points in a phase, together with the controller state for the corresponding phase could help the engineer reach the correct conclusion. In this case, if the light is green, the detector is occupied, and there is no flow then there is some downstream restriction forcing queued vehicle to delay their discharge from the stop bar. The green time could be put to better use by reassigning it to another phase.

An additional limitation to current controller capabilities and current practice is the use of the performance measurement information to change controller settings. A possible reason for this limited use of performance measurements is their limited usefulness due to their lack of time and space resolution. Given the current set of performance measures available in practice and in research, three gaps are apparent. One is the lack of information detecting a cycle failure. Another is the ability to interpret green time utilization. What proportion of a phase’s green time should have an occupied detector status? This leads to the final gap in practice and research of a performance measurement describing the capacity available for each phase. Possessing this last measure would prove very valuable when attempting to reallocate green times (3).

2.2 Performance Measurement with Standard Detection

Automated performance measures rely heavily on detectors and information on controller states for their input data. Each prospective performance measure may require, or function more favorably, with detectors placed in specific locations. Such is the case for performance measures used by centralized control systems such as SCATS, SCOOT, and OPAC. SCAT requires loop detection at the stop bar. SCOOT and OPAC require loops located just downstream of the upstream intersection at a point where approaching traffic is traveling at free flow speeds (1). Special detection requirements act as a deterrent to agencies implementing adaptive traffic...
control systems, because of the additional cost. If standard detection were sufficient then detectors could be used, sizably reducing implementation costs. It stands to reason that a performance measurement system would be much more accessible to agencies if the detection requirements could be relaxed to include standard detection configurations.

2.3 Mechanisms for Performance Measurement-Control Feedback

There are two perspectives for this portion of the review. One is that of practice and the other is that of experimentation. In practice, the most prevalent mechanism provided for performance measurement-control feedback is that of direct traffic operations observation and manual improved controller settings implementation. For example, an engineer may observe that the queue for a particular phase frequently does not clear. After investigating, the engineer finds that the phase prematurely terminates because of a passage time setting that is set inappropriately low. In response, the engineer increases the setting to more accurately reflect detector gap conditions at the end of the queue. More automated mechanisms are in use, but are restricted to more sophisticated adaptive control systems that are frequently unavailable to institutions maintaining the traffic signal control system.

The experimentation perspective is one taken by researchers desiring to test the use of performance measures as information supporting modifications (automated or otherwise) in controller settings and/or strategies. Ideally, tests would subject research ideas to actual field conditions by incorporating them into the logic of a controller that is operating in the field. For good reason, this option is not available. However, there are other testing approaches available to researchers. Three approaches are available to researchers and all of them involve simulation together with some sort of controller emulation. These approaches are described in the following list. All of the approaches presented in the list below involve using VISSIM as a micro-simulator. Other micro-simulator could be used, given that they provide the features allowing HITL and SIL. Other forms of VAP are not available in other micro-simulators are:

1) Vehicle actuated programming (VAP) with VISSIM
2) Hardware-in-the-loop (HITL) simulation with VISSIM (2)
3) Software-in-the-loop (SIL) simulation with VISSIM
With the first option, the researcher programs all of the controller logic. This presents a problem in that some may question the validity of the controller logic used, because it does not work within the limitations or constraints known and used in the traffic control industry. With the last two options, the researcher has no access to the controller logic. In order to implement performance measurement-controller feedback, researchers need to affect changes externally to approximate desirable controller logic attributes that respond to feedback. These external changes can either be in the form of manually changing controller settings during the simulation to approximate controller decisions or modifying the input information the controller sees from the detectors. The following discussion describes both options for external changes.

*Manually change controller settings*

To simulate the incorporation of volume to capacity ratios in control logic, a researcher could establish a real-time display of v/c measures for each intersection turning movement that are updated continuously. The researcher could then take the following steps during a test simulation:

1) Observe changes in the real-time display of v/c measures and note which movements are operating at capacity and which are operating below capacity.
2) Make changes (during the simulation) in the controller settings to affect a more appropriate distribution of green times.

A similar approach to this was taken by researchers with a key difference being that they observed field operations of an intersection in real-time, making changes to the actual controller as needed (3).

*Modify controller input information*

Controller input information for a basic intersection is typically limited to detector status and/or calls. The basic premise here is to influence controller operations by either holding a detector status to the ON or OFF state. For example, if the phase needs to be terminated then the detector status for that phase could be held to OFF, even in the presence of a vehicle on the detector. This external action would cause the phase to gap out (3).
There are two controller operations that can be affected by detector inputs and they are phase termination and phase extension. The methods by which these operations occur are described below.

**PHASE TERMINATION:** For basic intersections, where no preemption or force-offs are involved, phase termination can occur by either gap-out or max-out. The passage timer and max green timer are both simple to replicate external to the controller in a VAP script. To allow this to take effect when warranted by traffic conditions, steps must be taken so that gap-out and max-out do not occur within the controller unless performance measurement feedback logic dictates that a phase should be terminated. Corresponding settings input in the controller need to be 0.1 second, because performance measurement feedback needs to be responsive. For example, if the feedback logic requires that the phase be terminated then it should take no longer than 0.1 seconds for the timer to expire and phase termination to begin. A longer passage time used in the controller would increase this response time.

**PHASE EXTENSION:** Phase extension is also needed to fully implement performance measurement feedback logic. Two mechanisms need to be overcome in the controller. One is the gap-out and the other is max-out. Dealing with the gap-out mechanism is straightforward as it would only require holding the corresponding detector to ON, until the appropriate time to terminate the phase has arrived. Max-out timing starts at the first serviceable conflicting call. Several options exist for modifying the controller’s max-out timing and logic. These options are listed below:

1. Large **MAX green setting**-VAP emulates max-out logic with its own MAX green setting and accompanying adjustments. Phase termination is executed by the controller via its expired passage timer (gap-out). The passage timer would expire because VAP would set the corresponding detectors to OFF (2).

2. Small **MAX green setting**-Similar to option-1, VAP emulates max-out logic with its own MAX green setting. Phase termination is executed by the controller via its expired MAX green timer. The MAX green timer would expire, because the states of the detectors corresponding to the serviceable conflicting calls would be set to ON.

The former option would be more attractive, because only detectors associated with subject phase would need to be monitored. In contrast, the second option would require that detectors associated with all serviceable conflicting phases be monitored.
2.4 Logic to Deal with Performance Measurement Feedback

Given the performance measurement mechanisms described in the previous section, control logic must be present to determine the action needed and when it should be taken. A variety of information must be considered individually and all together. The types of information that should be considered are as follows:

- Phase plan
- Controller settings
- Controller state
- Intersection geometry
- Detector placement
- Detector status
- Lane configuration
- Turn pocket lengths
- Traffic stream flow variables (volume, speed, headways)
- Performance measurements

A paper presented by Smaglik illustrates how some of the information items can be brought to bear on a performance problem (4). Figure 2-1 illustrates the different information items used together. It is important to note that if any of the items were used alone it would seriously diminish their effectiveness in detecting a performance problem.
There are two traces shown in Figure 2-1 for phase 3, each representing an information item. Trace 1 communicates the phase status and Trace 2 the detector status or presence of vehicles. The small circles or dots represent a third information item, count detector status. In Figure 2-1 (a), the phase 3 status changes to green and then eventually cars are counted, indicating that traffic is flowing. However, in Figure 2-1 (b), traffic flow stops but vehicle presence continues. This latter case is a problem, because phase 3 is green during the no-flow time, suggesting that vehicles cannot continue to discharge even though the light is green. Logic that would effectively use these information items together is given below (4):

IF Phase 3 is green,
AND IF Phase 3 detector has been occupied 10 s or more,
AND IF There is no flow over the detector during those 10 sec,
THEN Drop the call.

The logic used to in this scenario is simple, but effective as was found in simulation tests (2).

Similar logic comprised of simple IF-THEN and AND-OR statements could be used to address other circumstances that have not been addressed or investigated in research or practice. In each case, the quality with which the circumstance can be addressed depends on the information available or the position, design, and type of detectors. The circumstances are as follows:

---

*Figure 2-1 Phase 3 Flow Profiles of Discharge: (a) normal discharge and (b) blocked discharge (Smaglik, Bullock et al. 2006).*
• Left-turn queue spillback
• Left-turn starvation due to through queue
• Insufficient MAX green time
• Approaching loaded heavy vehicle
• Approaching platoon
• Insufficient detector delay setting
• Loop detector malfunction
• Insufficient passage time

Much more complex issues arise if controller setting changes are intended to be optimal. For example, if a passage time is inadequate (too long or too short) then what should the modified passage time setting be? A heuristic approach could be taken where the passage time is either incrementally increased or decreased until the operational problem no longer exists. Otherwise, complex statistical models combined with systems optimization would be required. Heuristic approaches would be readily implemented in VAP script. Unfortunately, the same is not true for other optimization approach because VAP only supports very basic mathematical functions (5).

Two approaches could be taken to developing performance measurement feedback logic as part of this research project. One is to adapt logic used for existing centralized control software. Adaptations would be needed, because this software requires information that may not be available from standard detector configurations for a local intersection. Another reason that adaptations would be needed is that this software is proprietary and as such the exact logic used for a system of intersections is not publicly available. Limited publicly available documentation creates a situation where the logic can only be understood and transferred to local intersection control at the conceptual level.

The second approach to develop performance measurement feedback logic is to develop local control that is more responsive to performance measurement feedback independent of existing traffic signal control systems. This second approach would be akin to recent work testing phase truncation logic (2). Because the emphasis of this research is on local intersection control, the most prudent option would be the second option. This will lead to simple, direct solutions to
local intersection control feedback, without the overhead of more complex traffic signal systems software.

2.5 Higher Resolution Detection by Space and by Time

While standard detector configurations are a necessary feature for performance measurement, more detailed detection information is also necessary. Higher detection resolution across space would improve the ability to relate traffic stream characteristics to controller settings. For example, many intersections have detectors for an approach that cover more than one lane. In this case, it is difficult to relate vehicle gaps or headways to the passage time setting in a controller. The same is true for situations where multiple detectors are wired to the same controller detector input, which is also a frequent occurrence.

In addition to improved relation between traffic stream characteristics and controller settings, higher detector resolution across space would drastically improve the ability to measure traffic stream parameters as basic as flow rates and speeds. To illustrate this advantage, consider a single vehicle approaching an intersection that stays in one lane. For the sake of this illustration, assume that each lane on the approach has three separate detectors, but each is wired to the same detector input. In this case, the approaching car would cross all three detectors and be counted each time. This situation could be avoided if one of the detectors is set to count and the count actuations are delivered over a dedicated count-channel. If these detectors were each wired to separate controller inputs then counts could naturally be taken (provided the detectors are sufficiently small). Moreover, if the detector configuration allowed, delay information could be collected based on arrival counts (advanced detector) and departure counts (stop bar detector).

Higher detector resolution by time is also necessary, where vehicle actuations are aggregated at only a minimal level (e.g. cycle by cycle or by 10 second interval). High time resolution is especially necessary, where measurements are intended to capture relationships between traffic controller and traffic behavior. For example, vehicle arrival profiles require time aggregation intervals that are smaller than a typical phase length and can capture the variation in vehicle arrival flow rates. Similarly, delay measurements must be supported with arrival and departure counts that reflect the variations in service and arrival flow rates.
3. GREEN TIME UTILIZATION

This chapter discusses the green time utilization measure for this research. This chapter is categorized into six sections for the detailed explanation of the research. The first section introduces green time utilization. After that, problems addressed by this research are addressed in section 3.2. Section 3.3 explains the scope of the research. Section 3.4 describes five steps that were used for the research. In this section, the following issues are also presented:

- Measures of calculating simple green time;
- Relationship between green time utilization and degree of saturation;
- Resource availability and uses;
- Field consideration such as traffic conditions, intersection geometry, detector settings, passage time setting for the testing condition;
- Experimental design model development and
- Experimental design for testing.

Section 3.5 discusses the test results of green time utilization and section 3.6 presents the corresponding analysis of the test results.

3.1 Introduction

Green time utilization is one of the most important measures of performance for signalized intersections. By definition, the percentage of the phase green time that serves traffic is the green time utilization. In this research a simple green time performance was used. For the purposes of this research, simple green time utilization refers to the proportion of a phase’s active time that its corresponding stop bar detector is on.

3.2 Problem Statement

Problems related to green time utilization are listed below:

1. *Very little guidance is given on how this performance measure should be calculated in real-time. It appears that its current forms available in controllers are not very informative.
2. Forms available in centralized control software rely on specialized detector configurations that are not practical for local actuated intersection control.
3. *Very little guidance is given on how this performance measure should be used. Existing
documented uses of green time utilization, in some form, are only contained in elaborate
centralized traffic control systems such as SCATs and SCOOT.

4. A systematic means for relating this measure to controller settings has not been
established.

5. Relationship between green time utilization and degree of saturation (v/c) is assumed in
the SCATs methodology, but is not well documented. In addition, it has not been verified
that it can be used as a surrogate for delay or to estimate delay.

6. *Appropriate green time utilization target values have not yet been determined. As a result
it is difficult to say whether or not a specific value is too high or too low.

7. *Methods for using green time utilization as an index to ascertain the unused capacity
available for improving intersection operations have not been investigated or developed.

Not all problems relating to green time utilization are addressed here. However, problems that
are addressed in this report are indicated by an asterisk.

### 3.3 Scope of Research

The purpose for employing green time utilization measures is to make better judgments
regarding green time that is effectively and ineffectively used at signalized intersections. The
scope of this research is to establish how this performance measure should be calculated using
standard detector configurations. Methods for using the green time utilization performance
measure for evaluating intersection traffic operations were developed. The foci of these methods
are listed below:

1. Relationship with v/c, and
2. Relationship with delay.

Finally, these methods were tested by applying them in a simulation environment in an attempt
to replicate field circumstances that might exist when endeavoring to evaluate and improve
intersection traffic operations. The primary focus of this research addresses the problems stated
in the Problem Statement section.

### 3.4 Methodology

The methodology for this research is organized into five sub sections as listed below and each of
them is explained in detail is the subsection:
1. **Green time utilization measures**: this is a definition of the measure that was investigated, assuming standard detector configurations.

2. **Experiment/testing resources**: this describes the relevant aspects of equipment and software used to test methods for calculating the measure and methods for using the measure.

3. **Field circumstances**: this describes the assumed characteristics of test bed intersections, including traffic conditions, detector configuration, intersection geometry, and controller settings.

4. **Experiment design for development**: this describes the approximate experiment design details such as the variables considered, their associated ranges, and the assumptions needed. In addition, initial models relating dependent variables with independent variables are also discussed. Resources used for obtaining data for developing the models are also described.

5. **Experiment design for testing**: this describes the approximate experiment design details such as the variables considered, their respective ranges, and the error measurements used. A description of how resources were used to execute the testing is also provided.

**Experiment design for testing**: this describes the approximate experiment design details such as the variables considered, their respective ranges, and the error measurements used. A description of how resources were used to execute the testing is also provided.

### 3.4.1 Green Time Utilization Measures and V/C Ratio Calculation

**Simple green time utilization**

Equation 3-1 describes how this representation of green time utilization should be calculated using detector data for $\phi$. The numerator of this equation is the sum of times that the active phase detector is occupied, which is assumed to be the time that the phase is serving vehicles. The variable $d_i^\phi$ is ‘1’ if the active phase detector is occupied and zero otherwise. In this way, only the occupied detector times are included in the summation. The denominator is the sum of detector intervals, whether the detector is occupied (on) or unoccupied (off) and should be equivalent to the phase green time.
GU$_{\phi} = \frac{\sum_{i \in T} (d^i_{\phi} \cdot t^i_{\phi})}{\sum_{i \in T} t^i_{\phi}}$

Where

\( \phi \)  
Active phase,

\( GU_{\phi} \)  
Green time utilization for \( \phi \),

\( i \)  
interval of time during which the detector status does not change for \( \phi \).

\( T \)  
contiguous set of detector status time intervals for the G interval of \( \phi \),

\( d^i_{\phi} \)  
Detector status for the \( \phi \) during detector interval \( i \) (\( d^i_{\phi} = 1 \) if detector is on, zero otherwise), and

\( t^i_{\phi} \)  
Time length of detector interval \( i \) during \( \phi \) (seconds)

### 3.4.2 Experiment/Testing Resources

Resources that were brought to bear on this research were VISSIM simulation software and Excel/VBA. These resources and the way that they were used are described in this subsection. In section 3.4.2.1, the use of VISSIM software to generate the experiment has been narrated and in section 3.4.2.2, the data processing application by COM is described.

#### 3.4.2.1 VISSIM Simulation Software

VISSIM was used to generate experiment and test data based on data output from microscopic simulation. VAP was used to create the basic actuated intersection control logic, where the following standard controller features were included: passage timer, min green timer, max green timer, yellow and all-red timers, gap-out, max-out, rest in green, eight phase operation, simultaneous gap-out, dual entry, max recall, memory lock, and delay.

Application of green time utilization calculation methods were enacted on-line using VAP. This enabled these methods to generate feedback to the VAP controller for application testing.
VAP was developed so that the variables $t^i_{\phi}$ and $d^i_{\phi}$ were determined and thus available to calculate green time utilization on-line. In addition, the *.ldp file settings were configured to output Green Utilization (GU) as well as the variables. GU is an on-line calculation of green time utilization, calculated by VAP. The variables $t^i_{\phi}$ and $d^i_{\phi}$ were on hand to calculate the green time utilization measures off-line for purposes of verification.

3.4.2.2 Excel/VBA/COM

The bulk of data processing was executed within the Excel/VBA environment. The activities completed in this manner are listed as follows:

1. off-line calculation of v/c, using a macro written by Uriah Jones
2. off-line calculation of green time utilization performance measures
3. execute multiple runs by varying the random number seeds and volumes

3.4.3 Field Circumstances

Field circumstances that were used for this research are commonly encountered. These circumstances can be discussed in categories of traffic conditions, detector configuration, intersection geometry, and controller settings. The following discussion describes these conditions, with the intention of putting forth the default conditions. Based on the experiment designs, these conditions were changed.

Traffic conditions

The range of through traffic volumes for the phase in question was determined based on a desired range for degree of saturation. This range was such that traffic conditions varied from nearing congestion (v/c = 0.80) to capacity (v/c = 1.0). The respective volumes for these conditions were determined by assuming fixed time control with green times set to the max green values. Only passenger cars were present. Left turn volumes were set to 100 vph and right turn volumes were set to 0 vph. Approach speeds ranged were set to 25, 35, and 45 mph. No pedestrians were included in the simulation.
**Detector configuration**

The ITD standard for detector configurations was adopted and the VISSIM detector configuration was updated to satisfy these conditions for each of the speeds stated in the description of traffic conditions. Each detector had a dedicated channel to the controller, with the exception of the detectors used for zone detection at the stop bar. Detectors did not cover more than one lane.

**Intersection geometry**

Each approach has a one lane left turn pocket, a one lane right turn pocket and two through-only lanes.

**Controller settings**

Controller was set for phasing included 8 phases. The remaining settings were set as listed below:

- Min greens: 5 seconds,
- Max recall: off
- Simultaneous gap-out: on
- Dual entry: on
- Memory lock: off
- Delay: ff
- Max green: 30 seconds (through phase); 20 second (left turn phase)
- Yellow: (25 mph), (35 mph), and (45 mph)
- Red: (25 mph), (35 mph), and (45 mph)

**Passage Time settings**

Three separate passage time settings were employed. The determination of the passage time settings was based upon data collected for the end of queue gap time. For each intersection, simulations were run and the stop-bar detector gap experienced between departure of the queue and subsequent vehicle arrival or end of green was measured. The end of queue gap times was
then arranged into a cumulative distribution. From the cumulative distribution, the 50%, 85%, and 95% values were selected as the passage times to be used in the intersection from which the end of queue gap times were collected.

The purpose of selecting three separate passage times was to provide passage time settings that would create scenarios ranging across different phase termination conditions.

1. Green terminated too quickly to fully service the queue,
2. Green terminated just in time to service the queue, and
3. Green extends past the end of the queue.

3.4.4 Experiment Design for Model Development

In this research three items were developed. Two are relationships between green time utilization and degree of saturation (v/c) and delay. The third is a method for using green time utilization as an index of unused capacity. Experiment design for each of these is discussed below.

3.4.4.1 GU (Green Utilization) vs. V/C and Delay

The volumes needed to change in order to vary the delays for the turning movements (5 sec to >60 sec). In addition, the v/c ratio needed to range from 0.80 to 1.0. There was no need to exceed v/c = 1 because at that point and beyond GU would essentially be 1.0.

To create these conditions in a simulation environment, the volumes were varied from 775 to 1100vph and the output data were processed using an Excel/VBA macro to determine the v/c ratio and verify that the desired v/c ranges were satisfied. The VISSIM node output file was used to verify that the desired delay ranges were satisfied. The resulting v/c and delay values were included in the dataset used for analysis.

Each of the measures needed to be compared on the same time scale, which was the end of green for a given phase. Green time utilization, v/c, and delay were all calculated and/or aggregated for these times and a database was created with the following fields:

- Run ID (sequence number)
- Phase number (1 through 8)
3.4.4.2 GU as an Index of Unused Capacity

**PHASE GU:** The Phase GU describes the level of GU for each phase of a given intersection. Phase GU represents the proportion of used green time for the phase.

**INTERSECTION GU:** The Intersection GU describes the level of GU for an entire intersection, and is the total used time/unused time for all of the phases within the intersection.

It is believed that GU is closely related to v/c ratio, and it may be used as an index of the unused capacity of the intersection. In order to determine if GU may be used as an index of the unused capacity in this research, the GU and v/c ratio was collected for each of the scenario’s described in Section 3.4.3. Using the collected data, a linear relationship was created between GU and v/c ratio. If the relationship between GU and v/c ratio is determined to be statistically significant, then it may be concluded that GU may be used as a measure of unused capacity.

The higher the measured value of GU the less unused capacity exists. Therefore, a target value range of GU could be determined based on the desired range of v/c ratio for the intersection. And the controller could be modified to allow input based on the value of GU. If the GU is below the desired target range, the controller settings could be modified to increase the GU until it falls within the desired range. Conversely, if the measured GU was too high, then controller settings could again be modified to lower the GU.

3.4.5 Experiment Design for Testing

A number of scenarios were created to conduct the experiment. This section outlines the inputs for the scenarios and the method for determination of relationships from the experiment data.
3.4.5.1 Simulation Input

For each scenario given in the Section 3.4.3, five separate simulations were run. Each simulation consisted of 5 minutes of run time before recording occurred, 15 minutes of recorded simulation, and ended with 5 minutes of run time in which no data were collected.

VISSIM was configured to create three output files: Detector and phase status data, data collection point data, raw vehicle data. The first step taken in the VBA macro was to import the output data from VISSIM into the excel worksheets. The signal data are imported from the *.ldp file, the data collection points are imported from the *.mer file, and the vehicle records are imported from the *.fzp file. Signal control data and values for Delay and Simple GU were recorded for each simulation in the *.ldp output files from VISSIM. Following the simulations, data were collected out of the *.ldp files by Excel macros. Values for GU were calculated on-line for each cycle.

Values of GU were recorded at the end of each cycle; a typical simulation would have approximately 10 cycles for the 15 minutes of recorded simulation time. To determine the GU value for a simulation run, all recorded GU values for the simulation were averaged. This was calculated separately for each measure of GU.

3.4.5.2 Simple GU

The values collected in the *.ldp files were used to establish a relationship between GU, as determined by the simple measure, and v/c ratio as well as delay. The collection and evaluation of the data was accomplished as outlined in section 3.4.1.1. Based on the collected data, a linear relationship was established for each GU measure against both v/c ratio and delay. The quality of the relationships was assessed using the Data Analysis package in Excel to determine the level of significance for each relationship.

3.4.5.3 GU as a Surrogate for V/C Ratio and/or Delay

Based upon the quality of the relationship between GU and v/c ratio and GU and delay, GU was used as a surrogate for v/c ratio and/or delay. If the data collected shows that there were a highly significant relationship between GU and either v/c ratio or delay, than it may be allowable to use...
GU to determine an approximate measure of either v/c ratio or delay. The GU measure was evaluated in order to determine its appropriateness for use as a surrogate of v/c ratio or delay.

3.5 Simulation Results

The resulting data from the simulations was analyzed with the Excel Data Analysis package, and linear relationships between Delay and GU, and v/c ratio and GU were established. Table 3-1 and Table 3-2 show the results of the data analysis. Relationships follow the form of the following equations;

\[ \frac{v}{c} = \beta_0 + \beta_1 \times GU \]  
\[ Delay = \beta_0 + \beta_1 \times GU \]

Table 3-1 and Table 3-2 also include the adjusted R-square values, significance, and t-test for both the intercept and independent variable (X variable); which are included to show the quality of the relationship.

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>( \beta_0 )</th>
<th>( \beta_1 )</th>
<th>Adj. ( R^2 )</th>
<th>Significance</th>
<th>Intercept</th>
<th>X Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple GTU</td>
<td>59.282</td>
<td>26.647</td>
<td>0.144</td>
<td>3.46*10^{-6}</td>
<td>12.399</td>
<td>4.845</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>( \beta_0 )</th>
<th>( \beta_1 )</th>
<th>Adj. ( R^2 )</th>
<th>Significance</th>
<th>Intercept</th>
<th>X Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple GTU</td>
<td>73.289</td>
<td>0.403</td>
<td>0.0583</td>
<td>0.00278</td>
<td>24.37</td>
<td>3.048</td>
</tr>
</tbody>
</table>

To be significant a model must have a significance value of <0.05. The GU relationship with both v/c ratio and delay was determined to be significant.

3.6 Analysis of Data

Throughout this section, figures are used to represent the results of the simulation runs comparing degree of saturation and delay to GU. Each data point on the graphs represents the averaged GU values for all cycles during a simulation, there were approximately 10 cycles per simulation run. Data from all scenarios were used in the creation of the plots and the subsequent
data analysis. Thus relationships were established independent of speed of approach or passage time.

3.6.1 Simple GU

The Simple GU is the basic measurement of Green Time Utilization that was employed in the experiment. A linear relationship between v/c ratio and GU was found. Although a high level of variability was measured as the v/c ratio decrease below 0.8. All data points were determined from one approach whose volume was varied to obtain a range of v/c ratios while the remaining approaches were subjected to a constant high volume. At a low volume, the measured approach may have had the green extended due to the higher traffic flow on the opposite approach. Thus creating artificially low values for GU. Alternatively, if low passage times were used then the green may be artificially shortened, thus yielding the high GU values seen in the low v/c ratio range.

It would appear that the Simple GU measure approaches a maximum value as it nears 95%. Since GU is measured over a period of approximately 10 cycles, and the more cycles that are included increase the likelihood that a cycle will occur without fully utilizing the green time, a max attainable value of less than 100% was expected.

![Figure 3-1 Simple GU vs. Degree of Saturation](image-url)
The horizontal lines seen in Figure 3-1 represent the GU range corresponding to a v/c ratio of 0.9 to 0.95. A range of 83% to 85% GU corresponds to a v/c ratio of 0.9 to 0.95. This range is representative of traffic conditions nearing capacity.

As seen in Figure 3-1 and Figure 3-2 GU increases both with an increase in v/c ratio and also an increase in Delay. An increase in GU as v/c increases was expected, for with higher demand volumes there was tend to be longer queues, and resultantly higher number of vehicles using the intersection. Similarly, an increase in Delay represents an increase in demand on the intersection.

The variability of the GU measurement was significantly higher in the Delay model. Overall, the higher variability of the Delay model is attributed to the inherent variability in delay calculations. Despite the increase in variability, the Delay model still proves to be statistically significant. Unlike the v/c ratio model, the Delay model exhibits no increase in variability as the Delay decreases.

4. CYCLE FAILURE

This chapter provides the discussion of cycle failure performance measure for signalized intersection. Section 4.1 is the introduction of this chapter. Section 4.2 states the problem related to the cycle failure research. Section 4.3 addresses the scope of the research. Section 4.4
describes the methodology used to measure cycle failure by Texas method. Here the background of the Texas method and the definition of Texas method and ground truth are addressed. Section 4.5 addresses the data collection for this research. This section includes the approach parameter and intersection that were used for the experiment and also the tests that were done for the experiment. Section 4.6 and section 4.7 explains the test result of the experiment and the analysis of the result respectively.

4.1 Introduction

Cycle failure is a performance measure for signalized intersection. The method used to measure the cycle failure for this research is called Texas Method as the method was first used in Texas. The concept of Texas method is based upon the percentage of overloaded cycle and overloaded factor was introduced by The Canadian Capacity Guide for Signalized Intersections. Overload factor determines the proportions of cycles in which the accumulated demand exceeds the capacity of a given lane or approach. Overload factor is determined by computing the ratio of the number of overloaded cycles to the number of consecutively surveyed cycles. The equation used to compute the overload factor is as follows:

\[
OF = \left( \frac{No}{N} \right) \times 100\% \quad 4-1
\]

Where,
- OF = the overload factor
- No = the number of overloaded cycles
- N = the total number of consecutively surveyed cycles, with N > 20.

The Canadian Capacity Guide defines an overloaded cycle to be one in which 100 per cent of the green time was utilized by traffic and that there was a queue present at the end of the amber period. In determining if the phase is overloaded, the procedures specified in the manual require that the phase be divided into sub-intervals (usually 5 seconds) and that an observer determines the following:

1. If all of the phase sub-intervals are utilized by at least one vehicle, and
2. If there was a queue present at the end of the amber period
4.2 Problem Statement

The only method proposed for detecting cycle failure using standard detection is the Texas Method. Unfortunately, this method was not validated in the field or using simulation. This is the focus of the research discussed in this chapter.

4.3 Scope of the Research

This research focuses on testing the Texas method for cycle failure detection in a simulation environment. Only standard detection was used and the simulation software used was VISSIM. The purpose of the testing was to validate the Texas Method’s capability to identify cycles experiencing cycle failure conditions in a variety of traffic operation conditions.

4.4 Methodology

This section is divided into two sub section; in the first sub section, the background information of the Texas Method is mentioned and in the 2nd sub section the intersection geometry concept is provided.

4.4.1 Background

Kevin Balke(10), at Texas Transportation Institute, and the Texas Department of Transportation (TxDOT) worked together to assess the performance of their traffic signals and how data for performance measures (such as cycle time; queue service time; duration of green, yellow chance, Allred clearance and red interval; number of vehicle entering green, yellow change, all red clearance and red intervals; yellow change and all red clearance violation rates) were collected. Balke decided that a similar approach could be used to determine the percentage of overloaded cycles, with a slight variation. The Canadian Capacity Guide approach would work well for a phase of a fixed duration, but under actuated control, if the controller detected a gap in the traffic stream of a certain size, the controller would terminate the phase. If the controller was functioning properly, then the intersection would never have any portion of the phase that went unutilized – instead the controller would gap the signal out and go to the next phase. The only time that a phase could be considered overloaded is when the following two conditions are met:
when the phase terminates as a result of it either a) reaching its maximum limit or b) being forced off, and
- A constant call for service existing the entire time that the phase was active.

To determine if a phase terminated with demand, the system would need to monitor the status of the phase call detectors during the entire duration of the phase. If, at the start of the red clearance interval, the system detected a call on the phase detector AND the phase call detector never changed its state (from “ON” to “OFF”) for the entire time the phase was active, then one can assume that the queue did not clear. When this occurs, the system needs to flag the phase as experiencing a failure. Balke, interchangeably labeled this failure as a phase or a cycle failure. A cycle failure rate is computed by summing the number of failed cycles and dividing by the total number of cycles in the observation period.

Balke used two intersections (see Figure 4-1 and Figure 4-2) in Texas to examine the type of performance measures that could be collected and develop a system for automatically collecting these performance measures in the field. Figure 4-1 and Figure 4-2 below display the intersection geometry and loop detector placement at the two intersections. Traffic Signal Performance Measurement System (TSPMS) (11) prototype was developed and installed at these two intersections that exhibited different operating characteristics.

Figure 4-1 Intersection of US-79 and SH 36 in Milano, Texas
Figure 4-2 Intersection of FM 247 and FM 2821 in Huntsville, Texas

The Traffic signal Performance measurement system (TSPMS) was designed to automatically collect data so that it could be used to evaluate how meaningful and appropriate several different performance measures were (12). The report concluded that the cycle failure rate is a measure of congestion that exists on an approach. It can be used to assess whether or not there is enough green time provided on an approach to service its demand. It quantifies the number of cycles where a queue fails to clear during the allotted green time. A high cycle failure rate on only one approach might indicate that more green time is needed to allocate to that approach or that there is a problem with the detection system. High cycle failure rates on more than one approach might indicate the need to increase the overall cycle length or capacity at that intersection. Balke did not test how well this cycle failure detection method worked under different identified intersection or approach conditions. From this point forward this method will be referred to as the Texas Method.

**4.4.2 Ground Truth and Texas Method Definition**

The Texas Method was tested using VISSIM, a micro-simulation modeling software package. The geometry of the four approach intersection was used that include two lanes each direction and a left-turn bay in each approach. Each lane included a 30 foot stop detector. Figure 4-3 displays the intersection below:
Using the VISISM output files, an algorithm was created to do the following tasks:

**Task1**: Use the vehicle record file to establish the ground truth of which vehicles and phases experienced cycle failure

**Task2**: Use the Texas, occupancy-based method to estimate cycle failure.

**Ground truth**

The ground truth was established using the individual vehicle tracking capabilities of VISSIM. Each individual vehicle was checked to see if it had experienced cycle failure. A vehicle was considered to have experienced cycle failure if that vehicle was in queue (speed less than 3 mph) behind the stop bar at the beginning of the red phase and is still behind the stop bar at the beginning of the next red phase.

Figure 4-3 The VISSIM intersection geometry with stop bar detection
Texas Method

For this method the only information needed was the percentage of time that the stop bar detector was being occupied. If the stop bar detector was occupied 100% of time up to the end of green then the cycle had failed. If the detector was not occupied 100% of time, the cycle did not fail. This is how Balke defined this method.

4.5 Data Collection

This section describes the data collection for cycle failure. The data were taken using the micro simulation software VISSIM. This section is divided into two sub sections. Section 4.5.1 describes the intersection and the parameters that were used for the research. Section 4.5.2 describes the simulation tests.

4.5.1 Intersection and Approach Parameters

The intersection parameters that were varied in the simulation runs were: speed, phasing, passage time, and maximum green. The combination of these different parameters created 24 different cases and can be seen in Table 4-1 below.
Table 4-1 Parameter combination used for each case

<table>
<thead>
<tr>
<th>Volume</th>
<th>Low Speed</th>
<th>Medium Speed</th>
<th>High Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4-phase</td>
<td>2-phase</td>
<td>4-phase</td>
</tr>
<tr>
<td>Low Passage Time</td>
<td>Low Max Green</td>
<td>Low Max Green</td>
<td>Low Max Green</td>
</tr>
<tr>
<td></td>
<td>High Max Green</td>
<td>High Max Green</td>
<td>High Max Green</td>
</tr>
<tr>
<td>High Passage Time</td>
<td>Low Max Green</td>
<td>Low Max Green</td>
<td>Low Max Green</td>
</tr>
<tr>
<td></td>
<td>High Max Green</td>
<td>High Max Green</td>
<td>High Max Green</td>
</tr>
</tbody>
</table>

Where,

- Low speed = 25 mph
- Medium Speed = 35 mph
- High Speed = 45 mph
- Low Passage Time = 1 sec (for low speed), 2 sec (for medium and high Speed)
- High Passage Time = 3 sec (for low speed), 4 sec (for medium and high Speed)
- High Max Green = 40 sec (for thru movements), 25 sec (for left-turn movements)
- Low Max Green = 25 sec (for thru movements), 15 sec (for left-turn movements).

The parameters that made up the 24 different cases were consistent for each different phase and approach. In order to introduce some variability within the geometry of the intersection some approach parameters were varied. Four different volume scenarios were used. Each volume scenario included two high volume approaches and two low volume approaches. The intersection...
also included two high left-turn movement percentages and two low left-turn movement percentages. Figure 4-4 below displays the above described intersection.

![Intersection diagram](image)

**Figure 4-4 Intersection with volume and left-turn movement parameters**

Where,

- Low left-turn movement % = 15%
- High left-turn movement % = 30%

- Volume scenario 1 = high volume approach 1400 vph, low volume approach 1200 vph
- Volume scenario 2 = high volume approach 1300 vph, low volume approach 1200 vph
- Volume scenario 3 = high volume approach 1200 vph, low volume approach 1100 vph
- Volume scenario 4 = high volume approach 900 vph, low volume approach 800 vph.
4.5.2 Simulation Tests

Each case/volume combination was ran 6 different times, using a different random seed each time, for 35 minutes which included the 5 minutes of warm-up time before actual data was collected. There were a total of 576 different simulation runs that allowed 288 hours of simulation data to be analyzed.

For each of the 576 runs a table, like the one displayed in Table 4-2. The top portion contains the ground truth information such as the times a phase was active, actual times a phase failed, and the % of cycles that failed. The middle bottom portion of the table displays how many times the Texas Method detected a cycle failure.

Table 4-2 Summary output table for each VISSIM simulation run

<table>
<thead>
<tr>
<th>Case 1, Volume 1, Random Seed 10</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
<th>Phase 5</th>
<th>Phase 6</th>
<th>Phase 7</th>
<th>Phase 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Times Active</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>18</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td>Times Fail</td>
<td>17</td>
<td>19</td>
<td>8</td>
<td>3</td>
<td>19</td>
<td>19</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>% of Cycle Failures</td>
<td>89.5</td>
<td>100.0</td>
<td>42.1</td>
<td>16.7</td>
<td>100.0</td>
<td>100.0</td>
<td>31.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Texas Method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Times Fail</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Texas Method % Fails</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Omission</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commission</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Omission</td>
<td>17</td>
<td>19</td>
<td>8</td>
<td>2</td>
<td>18</td>
<td>17</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Correct fail detection</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Correct no-fail detection</td>
<td>2</td>
<td>0</td>
<td>11</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>18</td>
</tr>
</tbody>
</table>

The bottom portion of Table 4-2 compares the ground truth to the Texas Method in four possible outcomes. The two outcomes are that the Texas Method either correctly identified the cycle as a cycle that experience cycle failure (correct fail detection) or a cycle that did not experience cycle failure (correct no-fail detection). The third outcome would be the case where the cycle did not actually experience cycle failure but the Texas Method classified it as a cycle that did experience cycle failure (commission). The four outcomes would be the case where the cycle did experience cycle failure and the Texas Method classified it as a cycle that did not experience cycle failure (omission).
To help manage the number of tables, the 6 tables that were generated for each case and volume scenario by choosing 6 different number seeds, were averaged. This reduced the number of tables from 576 to 96. This will explains why some numbers of cycles and times fails are no longer whole numbers.

### 4.6 Simulation Results

From these 96 averaged tables the sums of the totals are shown Table 4-3. It can be seen that there was a wide range in the percentage of cycle failures among the different phases. In phase 4 only 6% of the cycles experienced cycle failure, whereas 68% of the cycles failed in phase 5.

<table>
<thead>
<tr>
<th>Table 4-3 Summary of all VISSIM simulation outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Volume scenarios</td>
</tr>
<tr>
<td>Times Fail</td>
</tr>
<tr>
<td>% of Cycle Failures</td>
</tr>
<tr>
<td>Texas Method Times Fail</td>
</tr>
<tr>
<td>Texas Method % Fails</td>
</tr>
<tr>
<td>Commission</td>
</tr>
<tr>
<td>Omission</td>
</tr>
<tr>
<td>Correct fail detection</td>
</tr>
<tr>
<td>Correct no-fail detection</td>
</tr>
</tbody>
</table>

Of the through movements, phases 2 and 6 experienced highest rate of cycle failures, 50% and 13% respectively. This is the result of these two approaches having the higher volumes. Phase 2 had significant higher cycle failure than phase 6 because its approach includes a higher left-turn movement percentage causing significantly higher queue spill backs that block the through lane.

Of the left-turn movements phase 5 experienced the highest rate of cycle failure at 68%. This is because phase 5 is a high left-turn movement percentage that is also in a high volume approach. This combination produced the highest rate of cycle failure because of the queue spill back blocking access to the lane vehicles desire to reach.

Observing the data by volume scenario it is noted that the volume 4 scenario did not produce very many cycle failures in any phase. This is because the high volume approaches only had 900 vehicles per hour. Since there were two through movement lanes and one left-turn movement
lane, in the high left turn-movement percentage approach the corresponding volumes would be 270 vph in the left turn lane, and 315 vph per lane in the through lanes. These volumes were not high enough to produce significant number of cycle failures. Table 4-4 displays the sums for the total averaged output for the volume scenario 4. The total number of cycles that failed for this volume scenario was less than 1% of the total number of cycles.

Table 4-4 Summary of Volume scenario 4 totals

<table>
<thead>
<tr>
<th>Volume 4 totals</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
<th>Phase 5</th>
<th>Phase 6</th>
<th>Phase 7</th>
<th>Phase 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Times Active</td>
<td>542</td>
<td>554</td>
<td>552</td>
<td>554</td>
<td>554</td>
<td>554</td>
<td>540</td>
<td>554</td>
</tr>
<tr>
<td>Times Fail</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>22</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>% of Cycle Failures</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Texas Method Times Fail</td>
<td>1.3</td>
<td>0</td>
<td>4</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Texas Method % Fails</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Commission</td>
<td>1.2</td>
<td>0</td>
<td>3</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Omission</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>22</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Correct fail detection</td>
<td>0.2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Correct no-fail detection</td>
<td>536</td>
<td>554</td>
<td>546</td>
<td>553</td>
<td>531</td>
<td>554</td>
<td>534</td>
<td>554</td>
</tr>
</tbody>
</table>

If the volume 4 scenario is removed from the data set, the new total sums are summarized in the Table 4-5. In this new total sums table phase 2 still has the highest rate of cycle failure for the through movement but it has increased to almost 70%. For the left-turn movement Phase 5 still has the highest rate of cycle failure has increased to almost 93%.

Table 4-5 Summary of Volume scenarios 1, 2, and 3 totals

<table>
<thead>
<tr>
<th>Sum of Volumes 1, 2 and 3</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
<th>Phase 5</th>
<th>Phase 6</th>
<th>Phase 7</th>
<th>Phase 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Times Active</td>
<td>1393</td>
<td>1397</td>
<td>1407</td>
<td>1402</td>
<td>1398</td>
<td>1399</td>
<td>1402</td>
<td>1401</td>
</tr>
<tr>
<td>Times Fail</td>
<td>409.2</td>
<td>973</td>
<td>476</td>
<td>109.5</td>
<td>1297</td>
<td>254</td>
<td>753</td>
<td>129</td>
</tr>
<tr>
<td>% of Cycle Failures</td>
<td>29.4</td>
<td>69.6</td>
<td>33.8</td>
<td>7.8</td>
<td>92.8</td>
<td>18.2</td>
<td>53.7</td>
<td>9.2</td>
</tr>
<tr>
<td>Texas Method Times Fail</td>
<td>100.2</td>
<td>1</td>
<td>251</td>
<td>12.3</td>
<td>4</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Texas Method % Fails</td>
<td>7</td>
<td>0</td>
<td>18</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Commission</td>
<td>54.3</td>
<td>0</td>
<td>96</td>
<td>10.3</td>
<td>1</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Omission</td>
<td>363</td>
<td>973</td>
<td>321</td>
<td>109</td>
<td>1294</td>
<td>242</td>
<td>753</td>
<td>129</td>
</tr>
<tr>
<td>Correct fail detection</td>
<td>45.8</td>
<td>1</td>
<td>155</td>
<td>2.0</td>
<td>3</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Correct no-fail detection</td>
<td>929</td>
<td>423</td>
<td>835</td>
<td>1281</td>
<td>100</td>
<td>1137</td>
<td>649</td>
<td>1271</td>
</tr>
</tbody>
</table>
4.7 Analysis of the Results

The Texas Method only flagged a small percentage of cycles as having experienced cycle failure. The results show that there are larger numbers of omissions in all the phases. Where all the phases experienced cycle failure, the Texas Method did not flag any cycle failures in two different phases. In four other phases less than 2% of the cycles were flagged as having experienced cycle failure.

Observing phase 5 more closely it is noted from Table 4-5 that on 1394 out of 1398 cycles (or 99.7%) the Texas Method either omitted the cycle failures that occurred or correctly identified the cycle that did not fail. The stacked histogram in Figure 4-5 displays the first 8 cases (low speed) with in combination with the 3 different volume scenarios. For example on the horizontal axis, C1V1 refers to case 1 and volume scenario 1. The figure for the medium and high speeds would not look significantly different than this one.

In phase 5 there are a high percentage of cycles failing in the cases with the protected left-turns and even a higher percentage in the cases with a permitted left-turn. The reason the Texas Method omitted all these cycle failures was noted in the visual observation of the simulation. In this cases where the approach volumes are high, there is queue from the through movement that spill backs and blocks access to the left turn bay. During this time the stop bar detector becomes
unoccupied, even though there still is a demand for that phase, and the Texas Method flags the cycle as not failing. This situation can be observed in part (a) of the figure below. In part (b) and (c) are examples of how the left-turn movement spill backs caused blockage of the through lanes.

![Figure 4-6 Queue spill backs that cause lane blocking](image)

Table 4-5 displays that out of the 1397 times that phase 2 was active all but only one can be classified as cycles that the Texas Method correctly detected as no-fail or the Texas Method failed to detect the cycle failure that actually occurred. These results can be seen in the figure below (Figure 4-7). It can be observed that there are fewer cycles that failed in the protected left-turn cases. These cases yielded fewer left-turn spillbacks that would block the through lanes. The protected left-turn cases however did still have cycle failures that were omitted by the Texas Method.

There were many times that it was observed that even during free flow traffic there are times when the distance gap between two vehicles was larger than the length of the detector (30 feet). This was even more of an issue at the high speed situation when to ensure a safe stopping distance between vehicles driver have to provide more separation from one another.
In Table 4-5 it was noted that the Texas Method flagged the most cycle failures in phase 3. After further investigating, nearly all the flagged cycles were in the permitted left-turn cases. The figure below displays the low speed, permitted left-turn cases. In these cases the Texas Method omitted on the average a total of less than 1 cycle therefore it was excluded from the figure.

**Figure 4-8 Phase 3, Low speed data**

Phase 3 has the most favorable conditions for the Texas Method to flag cycle failures. The reason is that in these scenarios the low volume approach and high left-turn movement percentage does not allow the through vehicles to block the left-turn bay. This eliminates one
problem that is a big issue in a lot of the phases. Since the movement is permitted in these cases the vehicles were never allowed to reach a free flowing traffic state with gaps larger than the stop bar detector.

5. DELAY

This chapter discusses delay and it is organized into six sections including the introduction Section. Section 5.2 describes the problem related with this research; section 5.3 discusses the scope of the research for this project. Section 5.4 provides a description of the automated delay measurement methodology; in this section the procedure for measuring approach delay (associated with the automated data collection method) is presented. Section 5.5 describes the field data collection environment and data recorded time periods. In section 5.4.2, an automated data collection method is discussed and Principles of video detector placement and data processing steps are addressed. Section 5.4.2.2 describes the vehicle tracking data which narrates the processes that were used to collect/calculate the benchmark data and delays. In section 5.5.2, the description of how to collect the Free Flow Travel Time (FFTT) is presented. Section 5.5.4 presents the validation results of the proposed field data collection method. In this section the test results are also analyzed.

5.1 Introduction

Delay is considered to be one of the important measures of effectiveness (MOE) to evaluate the performance of signalized intersections. It is the sole basis that is used in the Highway Capacity Manual (HCM) (6) to determine the service quality (level of service) of different movements at signalized intersection. Delay is hard to directly measure from the field. In many circumstances, the delay could be directly measured from the field, but it can be costly due to requirement of intensive data collection efforts and extensive human resources. It is also most cost effective to employ an appropriate model and calibrate/validate the performance of the model only rely on limited field data as input. With increasing transportation technologies and increasing public concern regarding congestion costs, the need for frequent high quality traffic system performance measurements has increased. Field delay measurements could prove valuable to traffic systems analysts, attempting to locate and resolve problem areas in traffic systems. In addition, field delay measurements could help inform travelers of more desirable routes.
5.2 Problem Statement

Problems related to this research are as follows:

1. It is very labor intensive and expensive to measure delay directly from the field.
2. Current research does not document the effects of detection error on delay measurement when using video detection.

5.3 Scope of the Research

The focus of this research was to measure approach delay using an automated methodology that extracts the delay from field recorded video data. This research describes an automated approach delay measurement method with the intent to accomplish three major objectives:

1) Automated field data collection,
2) Increasing delay measurement resolution by measuring turning movement delays, and
3) Increasing the accuracy of field delay measurement.

To achieve these objectives, three delay measurement techniques were used for the research 1) automated delay measurement technique 2) vehicle tracking delay measurement technique (providing the benchmark approach delay measurements and deceleration delay) and 3) HCM queue delay measurement technique, which were adjusted to approach delay by adding deceleration delay. The automated delay measurement is based on point detection of vehicle events at different locations on the intersection approach. The automated delay measurement results were finally compared to vehicle tracking delay results, which represent the benchmark delay values, and HCM delay measurement results. Then two statistical analyses Mean percent error (MPE) and Mean absolute percent error (MAPE) were used to compare the correlation between automated and benchmark delay measurements.

5.4 Methodology

5.4.1 Event Based Delay Measurement

To measure delay for this research, the automated delay measurement was applied by using a video detection system to record the vehicle data and then followed the approach delay
measurement methodology that was proposed by Kebab(7). The automated delay measurement followed Kebab’s methodology, which collected individual vehicle timestamps at specific points for each approach. Three data collection points, Event X, Event 1, and Event 3, were placed on each experiment approach to collect vehicle timestamps, from the time vehicles entered the system until vehicles completely left the system (See Figure 5-1). The locations and assumptions of the three proposed events are presented as follows.

**Figure 5-1 Event Locations for Automated Delay Measurement**

1) Event X is located at a point beyond the maximum queue length. The locations of Event X remain the same for each approach regardless of the different time-of-day. They can be varied by different approaches depending on the observed maximum queue length at each approach.

2) Event 1 is located at a point where the turning movements have fully developed. It is assumed that no lane change occurred after vehicles passed Event 1 until completely through the intersection (Event 3). Assuming no lane change between these two points allows the adoption of a *first-in first-out* (FIFO) queue discipline for each given lane. Because of the FIFO discipline, the nth vehicle to reach Event 1 will cross Event 3 as the nth vehicle as well.

3) Event 3 is located at stop line. The recorded timestamps for Event 3 are the times that vehicles completely leave the stop line.

At the locations for the three events, the travel time for individual vehicles can be calculated by comparing the timestamps of each event. The average travel time between Event X and Event 1 was measured by using deterministic queuing principles. The average travel time between Event 1 and Event 3 was measured by using FIFO queuing principles. Based on the previous description, the travel time for turning movements also can be calculated by comparing the timestamps at Event 1 and Event 3.
These travel time measurements were converted to delays by subtracting the corresponding average free flow travel times, which were observed from the field (See Equation 5-1 from Event X to Event 1 and Equation 5-2 from Event 1 to Event 3). The average approach delay measurement can be determined by adding the average delay between Event X and Event 1 to the average delay between Event 1 and Event 3 (see Equation 5-3).

**Event X to 1**

\[
D_{X-1}^T = \left[ \frac{1}{V^T} \times \sum_{i=1}^{V^T} \left[ (t^T_1 (i))^T - (t^T_x (i))^T \right] \right] - FFTT_{X-1}^T \tag{5-1}
\]

Where

- \(D_{X-1}^T\): Average delay for automated delay measurement from Event X to Event 1 during time interval \(T\)
- \((t^T_1 (i))^T\): Video detection recorded time stamp of the \(i^{th}\) vehicle for Event 1 during time interval \(T\)
- \((t^T_x (i))^T\): Video detection recorded time stamp of the \(i^{th}\) vehicle for Event X during time interval \(T\)
- \(V^T\): Video detection recorded total traffic volume in time interval \(T\)
- \(FFTT_{X-1}^T\): Free flow travel time between Event X and Event 1 for time interval \(T\)

**Event 1 to 3**

\[
D_{1-3}^{T,(LT,TH,RT)} = \left[ \frac{1}{V_{LT,TH,RT}^T} \times \sum_{i=1}^{V_{LT,TH,RT}^T} \left[ (t^T_3 (i))^T - (t^T_1 (i))^T \right] \right] - FFTT_{1-3}^{T,(LT,TH,RT)} \tag{5-2}
\]

Where

- \(D_{1-3}^{T,(LT,TH,RT)}\): Average delay for automated delay measurement from Event 1 to Event 3 for different movements (LT, TH, and RT) (automated delay measurement)
- \((t^T_3 (i))^T\): Video detection recorded time stamp of the \(i^{th}\) vehicle for Event 3 during time interval \(T\)
- \((t^T_1 (i))^T\): Video detection recorded time stamp of the \(i^{th}\) vehicle for Event 1 during time interval \(T\)
- \(V_{LT,TH,RT}^T\): Video detection recorded total traffic volume for different movements during time interval \(T\)
Free flow travel time between Event 1 and Event 3 for different movement time interval $T$

**Average Approach Delay**

$$D_{approach}^{X-3} = D^{T}_{X-1} + D^{T}_{1-3}$$

Where

- $D_{approach}^{X-3}$: The average approach delay for automated delay measurement
- $D^{T}_{X-1}$: Average delay for automated delay measurement form Event X to Event 1 during time interval $T$
- $D^{T}_{1-3}$: Average delay for automated delay measurement form Event 1 to Event 3 for different movements (LT, TH, and RT)

### 5.4.2 Automated Delay Data Collection Methodology-Video Based Data Collection Methodology

The video detection device, AUTOSCOPE Rack Vision 8.3, produced by ECONOLITE Inc, was used for applying the automated traffic data collection method. In the following sections, the video detector placement guidelines and other related issues, which potentially influence the accuracy of recorded data, are addressed.

#### 5.4.2.1 Detector Placement Guidelines

**Camera Height:** According to the *Intersection Video Detection Handbook* (8), a minimum height of 20 ft is recommended in order to reduce adjacent lane occlusion and other factors that could affect field-of-view. Hence, in order to record an appropriate field-of-view, taking speed limit and the advance detector location into consideration, the camera height for this research was 33 ft and it was placed on a stable telescoping mast to avoid above-average errors that could be caused by unstable poles or masts.

**Detector Zone Location:** Detector zone locations followed the proposed event locations except Event 3, which was located on the stop line. However, based on the field observation, several drivers stopped on or beyond the stop line when they waited for the green signal indication. This
caused the video-detection device to record inaccurate timestamps. In order to avoid such errors, two detector zones were placed at Event 3. One was on the stop bar and the other was downstream of the stop bar and combined with a Boolean detector function to control these two detector zones. The distance between two detector zones was chosen to be equal to the average passenger vehicle length (15ft) in order to guarantee that time reported by the detector is the time when the vehicle is completely leaving the stop bar.

**Detector Type:** In any video data collection system, environmental factors and/or adjacent lane occlusion easily affect the accuracy of collected data. Appropriate detector type selection is important to mitigate the effect of these factors and increase the data collection accuracy. Three types of detectors were used: speed detector, directional presence detector, and cross lane presence detector. Different detector types were used at different event locations to ensure the most accurate event timestamps.

For Event X and Event 1, the advance detector locations, a speed detector and a cross lane presence detector combined with a Boolean detector function were used. After a series of video detection exercises, the speed detector showed the best result for blocking the shadow of adjacent lanes. The cross lane presence detector showed better performance and dealt with different volume levels and generated more accurate results. Directional presence detectors showed several detection errors, especially when the approach has successive slow moving vehicles. Due to detector setting restrictions, the directional presence detector could not detect every single vehicle and several miscounting errors occurred when two vehicles occupied the same directional presence detector and were detected as a single vehicle with one timestamp. Therefore, the directional presence detector seems not to be appropriate for Event X and Event 1 detector placements.

For Event 3, stop bar detector location, a count detector and a directional presence detector combined with a Boolean detector function were used. The detector function avoids miscounted vehicles caused by shadows of opposite turning vehicles or calls that could be caused by a tall vehicle. After adding the “AND” detector function for these two detectors, if only one detector turns “ON” the vehicle is not detected for that lane of traffic. Hence, if the count detector has been turned “ON” by pedestrian and the directional presence detector status still “Off”, the call...
will not be recorded. Using a directional presence detector instead of a cross lane presence detector avoids inaccurate detections such as pedestrian or the shadows of other conflict approach’s moving vehicles. On the other hand, when the green period begins, the saturation headway and the vehicle move-up time between queued vehicles could exceed two seconds which is greater than the detector detection time (from status turns “on” to “off”); therefore, the cross lane presence detector seems not to be appropriate for Event 3 detector placement.

Another important detector placement issue for the Event 3 detector was the setting of the left turn bay detector. This detector is easily affected by the shadows of opposite through movement vehicles or conflict turning heavy vehicles. In order to improve the selectivity and sensitivity of video detection, two parallel directional presence detectors combined with a function “AND” were used. Figure 5-2 and Figure 5-3 show examples of the detection zone layouts for two different intersection approaches.

![Figure 5-2 Detector Zone Layout Example (S.H 8 & Farm st)](image-url)
Detector Mode: In the AUTOSCOPE video detection device there is a useful function for limitless large number of calls from different detection zones. These calls can be combined and configured to control the intersection. Both pulse and presence mode detectors can be used for user desired detector schemes. Different types of detectors which are in the same detector channel can be combined by using different Boolean functions such as “OR” or “AND”. This function benefits the video detection by allowing detection to occur only if certain conditions are met, resulting in more accurate timestamps. For an example, refer to the detector function “AND” in Figure 5-2. The Event-3 detection used a count detector combined with a directional presence detector. After adding the “AND” detector function for these two detectors, if only one detector turns “ON”. The vehicle is not detected for that lane of traffic. For instance, if the count detector has been turned “ON” by a pedestrian, the call will not be recorded. On the other hand, the detector function “OR” has a different functionality. In this research, the “OR” detector function combined with the “AND” function was placed in the two through lanes at the Event 1 location, as shown in Figure 5-3. When the detectors of either lane were turned “ON” by way of the “AND” function, the “OR” function will record one vehicle for the approach. This reduced the likelihood of an approaching vehicle begin counted multiple times because of triggering detection in both lanes.

Figure 5-3 demonstrates the detection zone layouts. The setting and placement for each detection zone or detector function are based on the video detection guidelines as described before. All of the intersections for this research used a consistent detector zone placement concept to record reliable traffic timestamps.
5.4.2.2 Automated Data Processing Principles

Raw data were collected, either through video detection or manual vehicle tracking. The raw data were processed to obtain approach delay values by turning movements. Data processing involved the following three steps:

1) Measuring delay from Event X to Event 1
2) Measuring delay from Event 1 to Event 3 and
3) Calculating individual vehicle approach delay

**Step 1: Measuring Event X to Event 1 delay**

Delays between Event X and Event 1 were calculated by using Equation 4-1, which is presented in Section 5.4. The concept for the delay calculation from Event X to Event 1 is the time difference between two events for an individual vehicle, adjusting by the corresponding FFTT for that approach.

**Step 2: Measuring Event 1 to Event 3 Delay**

This delay measurement varies from the previous Event X to Event 1 delay measurement which was associated with all vehicles regardless of the movement. The delay process for Event 1 to Event 3 was needed to consider each turning movement. The validity of this association is dependent upon the validity of the lane change assumption mentioned earlier. Because the timestamps of turning movements were recorded for each vehicle, delay can be associated with turning movements of each vehicle. FFTT was subtracted from the total travel time to estimate delay. Equation 4-2 represents the delay measurement from Event 1 to Event 3.

**Step 3: Calculating Approach Delay**

The approach delay (see Equation 5-4 in section 5.4.1), including the delays from Event X to Event 1 and from Event 1 to Event 3, is calculated by summing the results of Equation 4-1 and Equation 4-2. Both benchmark and automated delay measurements can apply Equation 4-3 to calculate the approach delay.
5.5 Data Collection

5.5.1 Field Data Collection

The field data were collected by using a video-based data collection system. Data were collected at two actuated signalized intersections which are located within the city of Moscow, ID: one is a four-leg intersection, S.H.8 & Farm St (see Figure 5-4(Left) and the other one is a three-leg intersection, 6th St. & Deakin St (see Figure 5-4 (Right)). The speed limit for the three-leg intersection is 25 MPH and 35 MPH for the four-leg intersection. The four-leg intersection, S.H.8 & Farm St., operates in an actuated-coordinated mode and the coordinated phase is S.H.8. The field data were recorded simultaneously for each approach at the same intersection during the same time-of-day. Volume data were aggregated into a 15-minute time interval including non-peak and peak hours. Due to the limitations of recorded field-of-views, data from only five approaches’ were selected for measuring delay. Twenty 15-minute time intervals were used in this analysis, which covers peak and non-peak hour time intervals.

Figure 5-4 Intersection Geometry S.H.8 & Farm St (left) and 6th St & Deakin St (right).

5.5.2 Manual Vehicle Tracking Data – Benchmark/Ground Truth Delay Data

The vehicle tracking method is used for as the benchmark data in order to validate the results of the proposed delay measurement method. The vehicle tracking method involves manual tracking/recording of individual vehicle timestamps from a specific upstream point (usually the location of maximum queue length) to the stop line. For this research, vehicles were tracked and three timestamps were recorded at the same event locations as Event X, Event 1, and Event 3. In
addition, the time that vehicles were forced to stop, and that the vehicles leave the queue were also recorded.

For the benchmark data, travel time for individual vehicles was measured using the timestamps from Event X, to Event 1, to Event 3. Then the FFTT was subtracted from the total travel time for each vehicle to calculate the vehicle’s approach delay. The average approach delays were calculated as the sum of the combined approach delays from Event X to Event 1 and from Event 1 to Event 3 (see Equation 5-5):

\[
D_{\text{approach}}^{X-3} = D_{X-1}^T + D_{1-3}^{T, (LT, TH, RT)}
\]

Where

- \(D_{\text{approach}}^{X-3}\): The average approach delay for manual delay measurement
- \(D_{X-1}^T\): Average delay for manual delay measurement from Event X to Event 1 during time interval T
- \(D_{1-3}^{T, (LT, TH, RT)}\): Average delay for manual delay measurement from Event 1 to Event 3 for different movements (LT, TH, and RT)

### 5.5.3 HCM Queue Delay Measurement

The HCM method was applied simultaneously so that its performance and that of the method proposed here could be evaluated. Queue delay and the proposed method delay were observed at the same analyzed approaches and for the same time intervals. For occasions where queues blocked left or right turning movements from entering their desired turn bay, the zoned-survey technique was used by subdividing the approach into segments, consistent with guidelines given in the HCM.

**Adjusting HCM Queue Delay**

To compare the proposed method and the HCM method, the queue delay was adjusted to approach delay. For a given time interval, the average deceleration delay experienced by vehicles joining the queue for the time interval was added to the corresponding queue delay obtained from the HCM method (Equation 5-6):
\[ d_{ap(n,m)}^k = d_{q(n,m)}^k + d_{d(n,m)}^k \]

Where

\( d_{ap(n,m)}^k \) Approach delay at time interval \( k \), at intersection \( n \) and for movement \( m \),

\( d_{q(n,m)}^k \) Queue delay at time interval \( k \), at intersection \( n \) and for movement \( m \), and

\( d_{d(n,m)}^k \) Deceleration delay at time interval \( k \) (obtained using the vehicle tracking method) at intersection \( n \) and for movement \( m \).

### 5.5.4 Free Flow Travel Time Measurement

As mentioned before, the proposed (automated) delay and vehicle tracking delay measurement are calculated by subtracting the free flow travel time (FFTT) from recorded total travel time for each vehicle. Free flow vehicles were identified as vehicles that drive through the approach under unimpeded traffic conditions. For each time interval, the FFTT from Event X to Event 1 and from Event 1 to Event 3 were recorded. For free flow travel time from Event 1 to Event 3, the measurements were categorized by turning movement. Thirty vehicles, which drove through the approach under free flow condition, were sampled for each time interval. However, in some particular movements, the total volume did not reach the desired sample size. In these cases, all free flow vehicles were observed and recorded. Table 5-1 lists the observed FFTT for each intersection and approach.

**Table 5-1 Observed Free Flow Travel Time**

<table>
<thead>
<tr>
<th>Posted speed (MPH)</th>
<th>Approach</th>
<th>FFTT (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lane group FFTT</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>NB</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td>WB</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>EB</td>
<td>9.1</td>
</tr>
</tbody>
</table>

(--) Movement does not exist

### 5.6 Analysis of Results

In this section, collected and calculated data for this research are analyzed. This section is divided into two sub-sections. In section 5.6.1, automated delay measurement is compared with
vehicle tracking delay by using an Analysis of variance (ANOV) test. In section 5.6.2, three delay measurements are compared. The three delay measurements that were used for this research (Vehicle Tracking delay, HCM delay and Automated delay) are compared using two statistical error measurements - Mean Percent Error (MPE) and Mean Absolute Percent Error (MAPE).

**5.6.1 Comparison with Vehicle Tracking and Automated Delay Measurements**

After collecting data, automated delays were compared with vehicle tracking delays to analyze the correlation by using statistical analyses, as statistical analyses can determine how accurate the automated method relative to the vehicle tracking delay.

Figure 5-5 (a-d) illustrates the approach delay comparison between HCM and Automated delay measurements and the correlation coefficient values for all movements and the individual turning movements. For the comparison of overall movement delay results, an Analysis of variance (ANOVA) test comparing the HCM method to the automated method with a 0.05 level of significance was used. From the ANOVA result, an F-value was found of 0.0012 (smaller than the F-critical value of 2.13), which means the statistical test fails to reject the null hypothesis of equality of the mean values for these two data collection methods. Furthermore, the distribution of the automated and vehicle tracking delay data are close to a 45-degree line with no outliers and near perfect fit. On the other hand, the value of coefficient of determination (R-square) was 0.9869 (see Figure 5-5 (a). The same results were found for three individual movements. They all represented high correlation with the vehicle tracking results. The R-square values for automated delay for the through phase, LT phase, and RT phase were 0.9665, 0.9702, and 0.8942 respectively. Therefore, after a series of statistical tests, the approach delay results for these two delay measurements were found to be similar and available for further delay comparison with HCM delay results.
5.6.2 Comparison with the Delay Results for Three Delay Measurements

The comparison of the results between three delay measurements – vehicle tracking, automated, and HCM delay is discussed here. Two statistical error methods MAPE and MPE and an R-square test were used to compare the results and from the result it can be seen that HCM results slightly overestimate delay for the through and right turn movements. However a strong correlation exists between the automated delays and vehicle tracking delays. Table 5-2 presents the results of these delay measurements. The data were collected for twenty 15-minute intervals. Where right turning movements share the same lane with through movements, delay estimates were reported for through and right vehicles together, because it was not possible to distinguish between the through and right turning vehicles in the HCM delay measurement or in the automated delay measurement.
The data in Table 5-2 shows a comparison between the accuracies of the automated method and the HCM method. For the approach with a shared through and right lane (NB of S.H.8 and Farm Street), turning movement delays from the automated and vehicle tracking delay measurements were aggregated to obtain average approach delay by lane group. The measured approach delays, by lane group, for the HCM and automated delay measurements are plotted against the vehicle tracking delays. The plotted graph is presented in Figure 5-5(a-d). From the plots for the left and right turn movements, it can be seen that the HCM method measurements follow the same patterns as the automated method. The automated delay measurement for the through movement closely fits the actual data, where most of the automated method data points lie on the 45° line, as shown in Figure 5-5(c). In Figure 5-5(a) and Figure 5-5(c) it shows that most of the HCM delay data are distributed above the 45° line. It demonstrates that the HCM seems to have overestimated the delay when compared with the actual and automated delay values. Comparing

### Table 5-2 Measured Approach Delay per Lane Group

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Intervals</th>
<th>Actual (Vehicle Tracking)</th>
<th>HCM</th>
<th>Automated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lane group Delay</td>
<td>Lane group Delay</td>
<td>Lane group Delay</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LT</td>
<td>TH</td>
<td>RT</td>
</tr>
<tr>
<td>6th &amp; Deakin</td>
<td>EB</td>
<td>1</td>
<td>--</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>--</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>--</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>--</td>
<td>16</td>
</tr>
<tr>
<td>6th &amp; Deakin</td>
<td>WB</td>
<td>1</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>30</td>
<td>11</td>
</tr>
<tr>
<td>NB</td>
<td></td>
<td>1</td>
<td>36</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>39</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>36</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>49</td>
<td>26</td>
</tr>
<tr>
<td>SH &amp; Farm Rd</td>
<td>WB</td>
<td>1</td>
<td>27</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>43</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>38</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>42</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>33</td>
<td>19</td>
</tr>
</tbody>
</table>

(--) Movement does not exist (1) Share lane (2) three-leg intersection
overall lanes delay measurement, in Figure 5-5(a), the proposed method represents a close fit to the actual data. These observations can be verified by statistical analysis.

Two statistical error measurements were used for the verification of these observations. One was Mean Percent Error (MPE) and the other one was Mean Absolute Percent Error (MAPE). These two statistical error measurements were used to measure the errors between corresponding actual values and other delay measurement values. The MPE can be used for measuring the overall bias of different delay measurements. The MAPE can be used for measuring the error magnitudes of different delay measurements (i.e. HCM and automated method) relative to the corresponding actual values. The MPE and MAPE were calculated as shown in Equation 5-7 and in Equation 5-8.

\[
MPE = \frac{1}{n} \sum_{T=1}^{n} \left( \frac{XT_p - XT_o}{XT_o} \right) \times 100
\]

5-7

\[
MAPE = \frac{1}{n} \sum_{T=1}^{n} \left| \frac{XT_p - XT_o}{XT_o} \right| \times 100
\]

5-8

Where,

\[XT_o\] Actual average delay value for interval \(T\),

\[XT_p\] Experiment average delay value for interval \(T\), and

\[n\] The total number of data points in each delay measurement for different movement.

First delay measurements for the through movements were analyzed. The MPE was used to determine which delay measurement for the through movement had a strong unbiased correlation with the vehicle tracking values. The MPE value for \(HCM\) measurement was found to be 24.29 percent, compared with the automated method MPE of 1.37 percent. It indicates that the \(HCM\) through delay measurements values were much more biased than the automated delay measurements. These statistical analysis results also support the fact that most of the \(HCM\) delay data points were located above the 45\(^\circ\) line. In addition, it can also be seen that the R-square value for automated measurement was higher than the \(HCM\) measurement. These values indicate...
that the automated delays had a stronger correlation with the vehicle tracking values and less bias than the HCM delays.

Aggregated delay measurements across all movements of an approach (Overall delay) were then analyzed. The error magnitude was measured by the MAPE. The calculated MAPE was found to be 17.83 percent for the HCM method, whereas it was 5.74 percent for automated method. The MAPE result indicates that the automated delay measurement more closely fit the vehicle tracking data than the HCM delay measurements. The percentage bias for the overall delay results can be measured by using the MPE statistic, which was 16.57 percent for the HCM method and 2.41 percent for the automated method. In addition, the R-square value for the automated measurement was slightly higher than the HCM measurement (R square (automated) =0.9869 and R-square (HCM) =0.9651). These results again demonstrate that the automated method produces measurements that are much less biased. However, from the perspective of overall delay, the two methods have similar correlation.

In summary, from the results of statistical analyses and R square values, apparently a strong correlation between the automated delays and vehicle tracking delays exists. Compared to the automated delays, the HCM results were less accurate and more biased.

6. CONCLUSION

The main purpose of this research was to determine and develop different new automated measures of performance for green time utilization, cycle failure and delay to improve performance in signalized intersections. This chapter summarizes the important achievements of this research related to the above mentioned issues.

6.1 Green Time Utilization

Green Time Utilization can be measured at an intersection and used as an index for unused capacity. To accomplish this, GU would need to be used as a surrogate of v/c ratio and translations between GU and v/c ratio would be according to the linear model developed. From the simulation experiment of green time utilization, it was possible to produce a statistically significant model for a linear relationship between green utilization and v/c ratio as well as GU
and delay. So, it is possible to measure GU and use it to represent trends in v/c and delay. Based on the research for GTU, the following can be concluded:

- **GU Calculation** The Simple GU (described in Section 3.4.1) measure provides a well-documented, easy to use method for determining GU. However, very little guidance is given for the calculation of GU. In addition, current methods that use a GU measure to estimate v/c rely on specialized detector configurations. The Simple GU measure accurately calculates the percentage of green time used during a phase or cycle. Furthermore, although the Simple GU method utilizes standard ITD detector configurations in this research, only a stop bar detector is required in order to calculate GU using this method. Thus, any detector configuration including a stop bar detector would be appropriate for measurement of GU.

- **GU as a surrogate for v/c ratio and/or delay** The Simple GU method as presented in green time utilization section addresses the need for documentation of the relationship between GU and v/c ratio. In addition, the research verifies and documents the relationship between GU and delay. The statistically significant relationships developed in this experiment prove that there is a relationship between GU and v/c ratio and between GU and delay.

- **GU Target Values** The relationship between GU and v/c ratio developed in this experiment coupled with the ability to use GU as a surrogate for v/c ratio provides the ability to set GU target values. Using the linear relationship between GU and v/c ratio, it is possible to translate a desired range of v/c ratio to a desired range of GU values. From the result, 95% confidence interval for v/c ratio ranges from 85% to 88% and the average v/c ratio for simple GU was found 87%.

- **GU as an index of unused capacity** Closely related to the use of GU as a surrogate for v/c ratio, this research experiment addresses the concern for using GU as an index for unused capacity.

6.2 Cycle Failure

The Texas Method is one way to estimate cycle failure. It is simple and only requires the conventional stop bar detection. The Texas Method was tested varying numerous intersection and approach parameters. The Texas Method did work well in identifying which cycles did not experience cycle failure without introducing many commission errors. In low volume, high permitted left-turn percentage approaches the Texas Method was able detect nearly all of the cycle failures.

The effectiveness of the Texas Method was reduced as a result of queue spillbacks and large following gaps during saturation flow. When cycle failure occurs, queue spill backs are very
common causing lanes to be inaccessible. These un-used lanes leave the stop bar detectors to become un-occupied although demand is still present. To address this issue, the length of the turning bays could be increased or upstream detectors could be used to determine when there are queue spillbacks.

During saturation flow, it is common for the distance gap between vehicles to be larger than the stop bar detector length. Currently a cycle is flagged as a failed cycle whenever the detector becomes un-occupied for anytime greater than zero seconds. This issue can be addressed without increasing the length of the stop bar detector by increasing the un-occupancy threshold from zero to between 2 and 5 seconds before a cycle is flagged as failed.

6.3 Delay

The automated delay measurement data collection used a video detection method to record the timestamps at some specific data collection points of individual approaches. The data were recorded from all of the approaches at each proposed intersection. Then, the data were post processed by using a data filtering process to rectify the erroneous data. Delays were calculated as the difference between the recorded total travel time and the free flow travel time for each movement. The HCM delay measurement and the vehicle tracking method were applied by using the same time intervals in order to compare with the automated method. Then, the automated method and the HCM method were validated with the vehicle tracking (actual) data to determine which delay measurement most highly correlated with the vehicle tracking delays.

In contrast with HCM or vehicle tracking delay measurements, the automated delay measurement method is advantageous. Based on the comparison results, the following can be concluded, given the field data used in this research:

- The statistical results show strong correlations between automated and vehicle tracking delays. The value for coefficient of determination (overall movements) for automated delay was 0.9869, relative to 0.9651 for HCM delay measurement). As a result, the automated delay measurement method has the potential for becoming a major delay measurement method for future studies.
- The automated method measured more accurate and much less biased results than the HCM method for through lane group delay. The MPE for HCM delay measurement was 24.29 percent, and 1.37 percent for proposed (automated) method.
• The HCM method required less time than the proposed (automated) method to perform unless queuing was extensive. However, the additional accuracy and detail that the proposed method provided may be worth the additional data collection time.

7. RECOMMENDATION FOR FUTURE RESEARCH

To develop the automated measures for using in a general signalized intersection, further research and analyses is required and this chapter provides a guideline for future research.

7.1 Green Time Utilization

Further research should continue in the area of GU. In addition to the Simple GU, two other measures of GU should be examined. The primary purpose of this research should be to establish stronger relationships with v/c ratio and delay. Since the relationship between GU and v/c ratio contains less variability than the relationship between GU and delay, GU may be used as a surrogate for v/c ratio with more confidence than as a surrogate for delay.

7.2 Cycle Failure

Current research detects the cycle failure at an isolated intersection. Additional research should be completed expand existing research to assess and mitigate cycle failure at neighboring intersections. The Texas Method sometimes fails to detect cycle failure when one occurs. To fix this problem, further study is required. In addition, cycle failure due to a through movement spillback should also be examined. In addition, current research tests cycle failure detection at an isolated intersection subjected to different traffic volume scenarios. It does not provide solutions that ameliorate the cycle failure problem. So, future research should be done to solve the cycle failure problem, using the cycle failure detection as feedback to the controller and expanding on the controller logic to result in a beneficial control response.

7.3 Delay

From different statistical results, a strong correlation was found between vehicle tracking delay measurement and automated delay measurement. If users apply the automated method to other intersections, the camera location/height and detector placement will need to be changed by applying different intersection geometries and posted speed limit.
Different video detector types will result in different detection errors, which were caused by adjacent lane vehicle shadows or other environment factors. Therefore, choosing the correct detector type combined with a Boolean detector function should be considered in future research as it will likely increase the accuracy of the delay measurements.
8. REFERENCES


9. APPENDIX A: GREEN TIME UTILIZATION VAP SCRIPT

PROGRAM Measure Performance;

    /*This VAP collects a performance measure, green time utilization.
    It's written for an Intersection with eight phases following the
    standard NEMA conventions*/

    VAP_Frequency 10;

    CONST

        /***************************************************************************/
        /******************CONSTANTS******************/
        /***************************************************************************/

        StepLength = 0.1,        /*Controller Frequency is 10 time step per second*/
        SubIntervalLength= 1.0;

        /***************************************************************************/
        /********Signal Status Communication**********/
        /***************************************************************************/

        /* Obtain signal status from the HILS controller. 0- red, 1- green, 2- yellow*/

        Sg1:=marker_get(101);
        Sg2:=marker_get(102);
        Sg3:=marker_get(103);
        Sg4:=marker_get(104);
        Sg5:=marker_get(105);
        Sg6:=marker_get(106);
        Sg7:=marker_get(107);
        Sg8:=marker_get(108);

        /***************************************************************************/
        /***Record phase starting status ****/
        /***************************************************************************/

        /*If the current signal status is green and the previous signal status was red,
        then it is the start of green time. Similarly, we can determine starting time step
        of yellow and red time.*/

        /*Phase 2*/

        IF (Sg2=2) AND (SignalWasYellow2=0) Then
            YellowStarted2:=1;
        End;
        IF Sg2=1 AND (SignalWasGreen2=0) THEN
            GreenStarted2:=1;
        End;

        If Not((Sg2=1) And (SignalWasGreen2=0)) Then
            GreenStarted2:=0;
End;

If Not((Sg2=2) And (SignalWasYellow2=0)) Then
    YellowStarted2:=0;
End;

/******************************************************************************/
/***Green time utilization****/  
/******************************************************************************/

/*Clear variable values at the beginning of the green time*/

If GreenStarted2=1 Then
    S2:=0.0;
    Utilized2:=0;
    TotalUsedSubInterval2:=0;
    TotalSubInterval2:=0;
End;

/*Record utilized sub intervals and total sub intervals during the green time*/

If Sg2=1 Then
    S2:=S2+StepLength;
    If (S2<=SubIntervalLength) Then
        If Detection(2)=1 Then
            Utilized2:=1;
        End;
    End;
    If (S2>=SubIntervalLength) Then
        TotalUsedSubInterval2:=TotalUsedSubInterval2+Utilized2;
        TotalSubInterval2:=TotalSubInterval2+1;
        S2:=0.0;
        Utilized2:=0;
    End;
End;

/*If the last sub interval during the green is less than the sub interval length,
then it is examined whether it has been utilized at the onset of yellow.
The green time utilization is recorded as 100 times of its value.*/

If YellowStarted2=1 Then
    If (S2<SubIntervalLength)And (S2>0) Then
        TotalUsedSubInterval2:=TotalUsedSubInterval2+Utilized2;
        TotalSubInterval2:=TotalSubInterval2+1;
    End;

    /*GreenUtilizationRatio2 is 100 times the true green utilization*/
    GreenUtilizationRatio2:=100.0*TotalUsedSubInterval2/TotalSubInterval2;
    Record_value(3, GreenUtilizationRatio2);
End;

/******************************************************************************/
/***Determine phase status****/  
/******************************************************************************/

/*This section should always be the last in the code*/

If Sg2=1 Then
    SignalWasGreen2:=1;
End;
If Sg2<>1 Then
  SignalWasGreen2:=0;
End;

If Sg2=2 Then
  SignalWasYellow2:=1;
End;

If Sg2<>2 Then
  SignalWasYellow2:=0;
End

10. APPENDIX B: CYCLE FAILURE VBA SCRIPT

Dim NUM_SIGNALS, ROW, COLUMN, NUM_SCHANGES As Integer
Dim END_RED_TIMES(), BEG_RED_TIMES(), T, P, P_, L, I, I2(), R, V, COUNT, VR As Integer
Dim INS, INST, TOTAL, TIME1, Time, PHI(), TI(), VEHNO As Integer
Dim LA(), VN(), PO(), VE(), E(), VE_ As Integer
Dim ACTIVE_COUNT(), FCOUNT(), UCOUNT(), VEHN(), TIM() As Integer
Dim CURRENTROWS, T1, P1, I_(), LT, COUNT1, COUNT2, COUNT3, COUNT4, COUNT5 As Integer
Dim CURRENTVEHICLE, VCOUNT(), VEHICLE(), TOTALVEHICLES(), X(), RCOUNT(), R2COUNT(),
R3COUNT(), R4COUNT(), R5Count(), X_ As Integer
Dim LAST(), myphase As Integer
Dim SIG_STATUS(), STIME(), textline, CHECK, PHASE(), q(), STATUS, S() As String
Dim TRANSFER As Variant
Dim A, A1, A2, A3, B, B1, B2, C, C1, C2, MYROW As Integer
Dim w As Long
Dim strLDPName, strFZPName, strMERName, Speed As String, Phase_assign(10000) As Integer
Dim c_1(10000, 9) As Variant

Sub Speeds()
  temp = ActiveCell.Offset(MYROW, myphase)
  If Len(temp) = 4 Then
    ' Number is 4 digits long, so read 1 digit from right
    temp2 = Right(temp, 1)
    If (temp2 >= 1 And temp2 <= 8) Then
      Speed = "Low"
    End If
    If (temp2 = 9) Then
      Speed = "Medium"
    End If
  ElseIf Len(temp) = 5 Then
    ' Number is 5 digits long, so read 2 digits from right
    temp2 = Right(temp, 2)
    If (temp2 >= 17 And temp2 <= 24) Then
      Speed = "High"
    End If
    If (temp2 >= 10 And temp2 <= 16) Then
      Speed = "Medium"
    End If
  Else
    ' Not sure how many digits in the field
  End If
End Sub
End Sub
Sub Move()
    Const strName As String = "D:\lab110-05\My Documents\Guillermo\"
    myphase = 1
    CHECK = "ok"
    Range("A1").Select
    MYROW = 1
    Do Until CHECK = ""
        Workbooks("Run All_m.xlsm").Activate
        Range("A1").Select
        Call Speeds
        strFZPName = strName & "Modification of Original Network" & Speed & ":Modification of Original Network" & ActiveCell.Offset(MYROW, myphase) & ".fzp"
        strLDPName = strName & "Modification of Original Network" & Speed & ":Modification of Original Network" & ActiveCell.Offset(MYROW, myphase) & ".ldp"
        strMERName = strName & "Modification of Original Network" & Speed & ":Modification of Original Network" & ActiveCell.Offset(MYROW, myphase) & ".mer"
        FileCopy strFZPName, "C:\Documents and Settings\padi4545\Desktop\Project\Runs1" & "Modification of Original Network" & ActiveCell.Offset(MYROW, myphase) & ".fzp"
        FileCopy strLDPName, "C:\Documents and Settings\padi4545\Desktop\Project\Runs1" & "Modification of Original Network" & ActiveCell.Offset(MYROW, myphase) & ".ldp"
        FileCopy strMERName, "C:\Documents and Settings\padi4545\Desktop\Project\Runs1" & "Modification of Original Network" & ActiveCell.Offset(MYROW, myphase) & ".mer"
        Workbooks("Run All_m.xlsm").Activate
        Range("A1").Select
        Call Speeds
        strFZPName = strName & ":2 Phase Network" & Speed & ":2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".fzp"
        strLDPName = strName & ":2 Phase Network" & Speed & ":2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".ldp"
        strMERName = strName & ":2 Phase Network" & Speed & ":2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".mer"
        FileCopy strFZPName, "C:\Documents and Settings\padi4545\Desktop\Project\Runs1" & ":2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".fzp"
        FileCopy strLDPName, "C:\Documents and Settings\padi4545\Desktop\Project\Runs1" & ":2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".ldp"
    Loop
    End If
    " THIS IS DOING THE EXACT SAME THING AS THE STEPS ABOVE, BUT IT IS FOR PHASE 2. THIS WILL ONLY RUN IF THERE IS STUFF IN THE "LIST OF PHASE 2" COLUMN."
    myphase = 6
    CHECK = "ok"
    Range("A1").Select
    MYROW = 1
    Do Until CHECK = ""
        Workbooks("Run All_m.xlsm").Activate
        Range("A1").Select
        Call Speeds
        strFZPName = strName & ":2 Phase Network" & Speed & ":2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".fzp"
        strLDPName = strName & ":2 Phase Network" & Speed & ":2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".ldp"
        strMERName = strName & ":2 Phase Network" & Speed & ":2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".mer"
        FileCopy strFZPName, "C:\Documents and Settings\padi4545\Desktop\Project\Runs1" & ":2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".fzp"
        FileCopy strLDPName, "C:\Documents and Settings\padi4545\Desktop\Project\Runs1" & ":2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".ldp"
Copy source to target.
   Workbooks.Open strFName

   Call main()

   "THIS IS THE CODE THAT DOES ALL THE COPYING FROM VISSIM INTO EXCEL. THIS PART IS WHAT WE WILL DEFINITELY USE IF"
"WE DECIDEED TO USE NEW CODE"

ActiveWorkbook.Save
ActiveWindow.Close
MYROW = MYROW + 1
Workbooks("Run All_m.xlsm").Activate
CHECK = ActiveCell_Offset(MYROW, 6)
Loop
End If
Next k

For k = 13 To 16
'Dim strFirstName As String
strFirstName = "C:\Documents and Settings\madr5173\Desktop\MotherFolder\runs" & k & ";"  
'need to change the folder name here
Workbooks("Run All_m.xlsm").Activate
ActiveSheet.Range("B2:B5600").Clear
Workbooks.Open strFirstName & "Run All.xls"
Workbooks("Run All.xls").Activate
Range("G2").Select
Range(Selection, Selection.End(xlDown)).Select
Selection.Copy
Workbooks("Run All_m.xlsm").Activate
Range("G2").Select
ActiveSheet.Paste Destination:=Worksheets("Sheet1").Range("G2")
Workbooks("Run All.xls").Activate
ActiveWindow.Close
'Dim strFName As String, wbk As Workbook
myphase = 6
CHECK = "ok"
Workbooks("Run All_m.xlsm").Activate
Range("A1").Select
If Not ActiveCell_Offset(1, 6) = "" Then
MYROW = 1
Do Until CHECK = ""
Workbooks("Run All_m.xlsm").Activate
Range("A1").Select
strFName = strFirstName & ActiveCell_Offset(MYROW, 6) & ".xlsm"
strFZPName = strFirstName & "2 Phase Network" & ActiveCell_Offset(MYROW, myphase) & ".fzp"
strLDPName = strFirstName & "2 Phase Network" & ActiveCell_Offset(MYROW, myphase) & ".ldp"
strMERName = strFirstName & "2 Phase Network" & ActiveCell_Offset(MYROW, myphase) & ".mer"

" FileCopy Range("a40").Select, strFName " GUILLERMO TRIED TO ADD THIS LINE TO GET RID OF NEXT LINE BUT HAVING ISSUES
"FileCopy "C:\Documents and Settings\padi4545\Desktop\Project\Runs\PracticeCode4.xls", strFName  
Copy source to target.
Workbooks.Open strFName

Call main

"THIS IS THE CODE THAT DOES ALL THE COPYING FROM VISSIM INTO EXCEL. THIS PART IS WHAT WE WILL DEFINATLY USE IF
"WE DECIDE TO USE NEW CODE

ActiveWorkbook.Save
ActiveWindow.Close
MYROW = MYROW + 1
Workbooks("Run All_m.xlsm").Activate
CHECK = ActiveCell.Offset(MYROW, 6)
Loop
End If
Next k
For k = 21 To 24
  Dim strFirstName As String
  strFirstName = "C:\Documents and Settings\madr5173\Desktop\MotherFolder\runs" & k & "\"
  Workbooks("Run All_m.xlsm").Activate
  ActiveSheet.Range("B2:B5600").Clear
  Workbooks.Open strFirstName & "Run All.xls"
  Workbooks("Run All.xls").Activate
  Range("G2").Select
  Range(Selection, Selection.End(xlDown)).Select
  Selection.Copy
  Workbooks("Run All_m.xlsm").Activate
  Range("G2").Select
  ActiveSheet.Paste Destination:=Worksheets("Sheet1").Range("G2")
  Workbooks("Run All.xls").Activate
  ActiveWindow.Close
  Dim strFName As String, wbk As Workbook
  myphase = 6
  CHECK = "ok"
  Workbooks("Run All_m.xlsm").Activate
  Range("A1").Select
  If Not ActiveCell.Offset(1, 6) = ""
  MYROW = 1
  Do Until CHECK = ""
    Workbooks("Run All_m.xlsm").Activate
    Range("A1").Select
    strFName = strFirstName & ActiveCell.Offset(MYROW, 6) & ".xlsm"
    strFZPName = strFirstName & "2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".fzp"
    strLDPName = strFirstName & "2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".ldp"
    strMERName = strFirstName & "2 Phase Network" & ActiveCell.Offset(MYROW, myphase) & ".mer"
  " I AM NOT SURE WHY SHE IS COPYING TO PRACTICECODE4.XLS, I THINK THAT SHE NEVER UPDATED THIS PART"
  " STUFF LIKE THIS LEADS ME TO BELIEVE SHE NEVER FINALIZED A MASTER CODE"
  " FileCopy Range("a40").Select, strFName " GUILLERMO TRIED TO ADD THIS LINE TO GET RID OF NEXT LINE BUT HAVING ISSUES"
  "FileCopy "C:\Documents and Settings\padi4545\Desktop\Project\Runs\PracticeCode4.xls", strFName " Copy source to target.
  Workbooks.Open strFName
  Call main

  "THIS IS THE CODE THAT DOES ALL THE COPYING FROM VISSIM INTO EXCEL. THIS PART IS WHAT WE WILL DEFINATLY USE IF"
  "WE DECIDE TO USE NEW CODE"
ActiveWorkbook.Save
ActiveWindow.Close
MYROW = MYROW + 1
Workbooks("Run All.xlsm").Activate
CHECK = ActiveCell.Offset(MYROW, 6)
Loop
End If
Next k
End Sub

Sub main()

" THIS PART CALLS ALL THE INDIVIDUAL PARTS OF COPYING THE VISSIM OUTPUT

Call Clear
Call Times
Call Import_Signal_Data
If myphase = 6 Then
   Call Arrange_Signal_Data
End If
Call Import_Data_Collection
Call Read_Signal_Data
Call Output_Signal_Data
Call Important_Signal_Data
Call Signal_Phase
Call Read_Vehicle_Data
Call Sort
Call Failure
Call Output_Failure
Call Sort2
Call Cycle_Headings
Call Fails
Call Sort3
'Call Unique_Fails
Call Final
Call Occupancy
Call Green_Occupancy
Call Texas_Method
Call Points
Call Method2
Call omission_comission
End Sub
Sub Clear()

" CLEARING ALL THE VARIABLES THAT HAVE BEEN USED SO FAR. THIS IS JUST PART OF
INITILLIZING EVERYTHING TO ZERO AGAIN.

NUM_SIGNALS = ROW = COLUMN = NUM_SCHANGES = T = P = P_ = P__ = L = 0
R = CURRENTVEHICLE = A = A1 = A2 = A3 = B = B1 = B2 = C = C1 = C2 = 0
V = VE_ = CURRENTROWS = T1 = P1 = LT = COUNT1 = COUNT2 = COUNT3 = COUNT4 = COUNT5 = 0
COUNT = VR = INS = INST = TOTAL = TIME1 = Time = VEHNO = X_ = 0

' Erase END_RED_TIMES, BEG_RED_TIMES, I, I2, PH, RCOUNT, R2COUNT, R3COUNT, R4COUNT, R5Count

Development of New Actuated Signalized Intersection Performance . . .
ReDim END_RED_TIMES(100000, 8), BEG_RED_TIMES(100000, 8), I(8), I2(8), PH(20000)
ReDim VE(20000), E(20000), ACTIVE_COUNT(8), FCOUNT(8), UCOUNT(8), VEHN(20000), TIM(20000)
ReDim I(8, 50), VCOUNT(8), VECOUNT(8), TOTALVEHICLES(8), X(8, 20000), RCOUNT(8),
R2COUNT(8), R3COUNT(8), R4COUNT(8), R5Count(8)
ReDim LAST(8), SIG_STATUS(200000, 8), STIME(20000), PHASE(8), q(20000), S(8), TI(20000), LA(20000),
VN(200000)
ReDim PO(20000), VE(20000), q(20000)
For P = 1 To 8
    Worksheets("Phase " & P).Select
    Worksheets("Phase " & P).Range("S2:U56000").Clear
Next P
End Sub
Sub Times()
    'Workbooks("PracticeCode4.xls").Activate
    Worksheets("Times").Select
    Range("A1:D20").Clear
    Range("B2") = Format(Now(), "hh:mm:ss")
    Range("B1") = "Begin Time"
    Range("C1") = "End Time"
    Range("D1") = "How Long"
    Range("A2") = "Time"
    Range("A3") = "Import_Signal_Data"
    Range("A4") = "Import_Data_Collection"
    Range("A5") = "Read_Signal_Data"
    Range("A6") = "Output_Signal_Data"
    Range("A7") = "Important_Signal_Data"
    Range("A8") = "Signal_Phase"
    Range("A9") = "Read_Vehicle_Data"
    Range("A10") = "Sort"
    Range("A11") = "Failure"
    Range("A12") = "Output_Failure"
    Range("A13") = "Sort2"
    Range("A14") = "Cycle_Headings"
    Range("A15") = "Fails"
    Range("A16") = "Occupancy"
    Range("A17") = "Green_Occupancy"
    Range("A18") = "Data_Points"
    Range("C2") = Format(Now(), "hh:mm:ss")
End Sub
Sub Import_Signal_Data()
    Worksheets("Times").Select
    Range("B3") = Format(Now(), "hh:mm:ss")
    Worksheets("Signal_Record").Select
    Range("A1").Select
    Worksheets("Signal_Record").Range("A1:Q56000").Clear
w = 0
    Open strLDPName For Input As #2
    Do While Not EOF(2)
        Line Input #2, textline
        ' Read line into variable.
        split_line = Trim(Replace(textline, ",", ""))
        ...
'Do While InStr(Split_line, " ")
'Split_line = Replace(Split_line, " ", " ")
'Loop
split_line = Split(split_line)
w = w + 1
If w >= 25 Then
   If myphase = 1 Then
      For COLUMN = 0 To 16
         ActiveCell.Offset(ROW + w - 25, COLUMN) = split_line(COLUMN)
      Next
   End If
   If myphase = 6 Then
      For COLUMN = 0 To 8
         ActiveCell.Offset(ROW + w - 25, COLUMN) = split_line(COLUMN)
      Next
   End If
End If
Loop
Close #2
Worksheets("Times").Select
Range("C3") = Format(Now(), "hh:mm:ss")
End Sub
Sub Arrange_Signal_Data()
   Worksheets("Signal Record").Select
   Columns("F:M").Select
   Range("M1").Activate
   Selection.Cut
   Range("N1").Select
   ActiveSheet.Paste
   Columns("B:B").Select
   Selection.Insert Shift:=xlToRight
   Columns("E:E").Select
   Selection.Copy
   Range("B1").Select
   ActiveSheet.Paste
   Columns("D:D").Select
   Application.CutCopyMode = False
   Selection.Insert Shift:=xlToRight
   Columns("G:G").Select
   Selection.Copy
   Columns("D:D").Select
   ActiveSheet.Paste
   Range("I1").Select
   ActiveSheet.Paste
   Columns("G:G").Select
   Application.CutCopyMode = False
   Selection.ClearContents
   Columns("E:E").Select
   Selection.Copy
   Range("H1").Select
   ActiveSheet.Paste
   Columns("F:F").Select
   Application.CutCopyMode = False
   Columns("F:F").Select
   Selection.Cut
   Range("G1").Select
ActiveSheet.Paste
Columns("C:C").Select
Selection.Copy
Range("F1").Select
ActiveSheet.Paste
Range("K5").Select
Columns("P:W").Select
Application.CutCopyMode = False
Selection.Cut
Range("J1").Select
ActiveSheet.Paste
End Sub

Sub Import_Data_Collection()
Worksheets("Times").Select
Range("B4") = Format(Now(), "hh:mm:ss")
Worksheets("Data Collection Points").Select
Range("A1").Select
Worksheets("Data Collection Points").Range("A1:L56000").Clear
ROW = 0
w = 0
Open strMERName For Input As #3
Do While Not EOF(3)
    Line Input #3, textline
    split_line = Trim(Replace(textline, ",", ","))
    Do While InStr(split_line, "  ")
        split_line = Replace(split_line, "  ", ","")
    Loop
    split_line = Split(split_line)
    w = w + 1
    If w >= 50 Then
        If split_line(1) >= 300 Or split_line(2) >= 300 Then '' This is the amount of "warm up time" that elaps before
data is collected
            For COLUMN = 0 To 11
                ActiveCell.Offset(w - 50 - ROW, COLUMN) = split_line(COLUMN)
            Next
        Else
            ROW = ROW + 1
        End If
    End If
Loop
Close #3
Range("A1").Select
Range(Selection, Selection.End(xlToRight)).Select
Range(Selection, Selection.End(xlDown)).Select
Selection.Sort Key1:=Range("A1"), Order1:=xlAscending, Header:=xlGuess, _
    OrderCustom:=1, MatchCase:=False, Orientation:=xlTopToBottom, _
    DataOption1:=xlSortNormal
Worksheets("Times").Select
Range("C4") = Format(Now(), "hh:mm:ss")
End Sub

Sub Read_Signal_Data()
Worksheets("Times").Select
Range("B5") = Format(Now(), "hh:mm:ss")
Worksheets("Signal Record").Select
Range("A1").Select
NUM_SIGNALS = 8
ROW = 0
ActiveCell.Offset(ROW, 1).Select
COUNT = 0

CHECK = "ok"
Do Until CHECK = ""
    ROW = ROW + 1
    COLUMN = 0
    If ActiveCell.Offset(ROW, -1) >= 300 Then
        Do Until COLUMN = NUM_SIGNALS
            COLUMN = COLUMN + 1
            Signaltime = ActiveCell.Offset(ROW, -1)
            SIG_STATUS(Signaltime, COLUMN) = ""
            STIME(20000) = 0
            If ActiveCell.Offset(ROW, COLUMN - 1) = "." And ActiveCell.Offset(ROW - 1, COLUMN - 1) = "/" Then
                COUNT = COUNT + 1
                STIME(COUNT) = ActiveCell.Offset(ROW, -1)
                Signaltime = ActiveCell.Offset(ROW, -1)
                SIG_STATUS(Signaltime, COLUMN) = "Beg Red"
                End If
            If ActiveCell.Offset(ROW, COLUMN - 1) = "." And ActiveCell.Offset(ROW + 1, COLUMN - 1) = "I" Then
                COUNT = COUNT + 1
                STIME(COUNT) = ActiveCell.Offset(ROW, -1)
                Signaltime = ActiveCell.Offset(ROW, -1)
                SIG_STATUS(Signaltime, COLUMN) = "End Red"
                End If
            Loop
        End If
    CHECK = ActiveCell.Offset(ROW + 1, 0)
    NUM_SCHANGES = COUNT
    Loop
    Worksheets("Times").Select
    Range("C5") = Format(Now(), "hh:mm:ss")
End Sub
Sub Output_Signal_Data()
    Worksheets("Times").Select
    Range("B6") = Format(Now(), "hh:mm:ss")
    Worksheets("Signal Data").Select
    Worksheets("Signal Data").Range("A1:J56000").Clear
    Range("A1").Select
    ActiveCell.Offset(0, 0).Select
    ROW = 0
COUNT = 1
COLUMN = 0
For COUNT = 1 To NUM_SCHANGES
    If Not STIME(COUNT - 1) = STIME(COUNT) Then
        ROW = ROW + 1
        ActiveCell.Offset(ROW, 0) = STIME(COUNT)
    End If
Next

ROW = 0
Do Until ROW > NUM_SCHANGES
    ROW = ROW + 1
    For COLUMN = 1 To 8
        Signaltime = ActiveCell.Offset(ROW, 0)
        'OUTPUT SIGNAL STATUS - "END RED" or "BEG RED"
        If Not SIG_STATUS(Signaltime, COLUMN) = "" Then
            ActiveCell.Offset(ROW, COLUMN) = SIG_STATUS(Signaltime, COLUMN)
        End If
    Next
Loop

For COLUMN = 1 To NUM_SIGNALS
    ActiveCell.Offset(0, COLUMN) = "Phase " & COLUMN
Next

Worksheets("Times").Select
Range("C6") = Format(Now(), "hh:mm:ss")

End Sub

Sub Important_Signal_Data()
    Worksheets("Times").Select
    Range("B7") = Format(Now(), "hh:mm:ss")
    Worksheets("Signal Data").Select
    Range("A1").Select
    ActiveCell.Offset(0, 0).Select
    ROW = 1
    COLUMN = 0
    CHECK = "ok"
    T = 0
    For COLUMN = 1 To 8
        ACTIVE_COUNT(COLUMN) = 0
        Do Until CHECK = ""
            If ActiveCell.Offset(Row, COLUMN) = "End Red" Then
                P = COLUMN
                T = ActiveCell.Offset(Row, 0) * 10
                END_RED_TIMES(T, P) = T
                X(P, T) = 1
            End If
            COUNT = ROW + 1
            Do Until BEG_RED_TIMES(T, P) = T Or CHECK = ""
                If ActiveCell.Offset(COUNT, COLUMN) = "Beg Red" Then
                    T = ActiveCell.Offset(COUNT, 0) * 10
                    X(P, T) = 2
                    BEG_RED_TIMES(T, P) = T
                End If
            End Do
            ACTIVE_COUNT(P) = ACTIVE_COUNT(P) + 1          'Counts number of times a phase is active
        End Do
        CHECK = "ok"
    Next
End Sub
End If
COUNT = COUNT + 1
CHECK = ActiveCell.Offset(COUNT, 0)
Loop
COUNT = 0
End If
ROW = ROW + 1
CHECK = ActiveCell.Offset(ROW, 0)
Loop
ROW = 1
CHECK = ActiveCell.Offset(ROW, 0)
Next
Worksheets("Times").Select
Range("C7") = Format(Now(), "hh:mm:ss")
End Sub
Sub Signal_Phase()
Worksheets("Times").Select
Range("B8") = Format(Now(), "hh:mm:ss")
Worksheets("Phase 1").Range("A1:T56000").Clear
Worksheets("Phase 2").Range("A1:T56000").Clear
Worksheets("Phase 3").Range("A1:T56000").Clear
Worksheets("Phase 4").Range("A1:T56000").Clear
Worksheets("Phase 5").Range("A1:T56000").Clear
Worksheets("Phase 6").Range("A1:T56000").Clear
Worksheets("Phase 7").Range("A1:T56000").Clear
Worksheets("Phase 8").Range("A1:T56000").Clear
Worksheets("Signal Data").Select
Range("A1").Select
ActiveCell.Offset(0, 0).Select
ROW = 1
R = 0
COLUMN = 0
COUNT = 0
CHECK = "ok"
For COLUMN = 1 To 8
Do Until CHECK = ""
If ActiveCell.Offset(ROW, COLUMN) = "End Red" Then
T = ActiveCell.Offset(ROW, 0)
Do Until ActiveCell.Offset(ROW, 0) = "" 'ActiveCell.Offset(ROW - 1, COLUMN) = "Beg Red" Or
ROW = ROW + 1
If ActiveCell.Offset(ROW, COLUMN) = "Beg Red" Then
T1 = ActiveCell.Offset(ROW, 0)
COUNT = COUNT + 1
Worksheets("Phase " & COLUMN).Select
Range("B1").Select
ActiveCell.Offset(0, 0).Select
R = R + 1
ActiveCell.Offset(R, 0) = T
ActiveCell.Offset(R, 1) = T1
ActiveCell.Offset(R, -1) = COUNT
End If
Loop
End If
ROW = ROW + 1
Worksheets("Signal Data").Select
Range("A1").Select
ActiveCell.Offset(0, 0).Select
CHECK = ActiveCell.Offset(ROW, 0)
Loop
CHECK = "ok"
ROW = 1
R = 0
COUNT = 0
Next
Worksheets("Times").Select
Range("C8") = Format(Now(), "hh:nn:ss")
End Sub

Sub Read_Vehicle_Data()
Worksheets("Times").Select
Range("B9") = Format(Now(), "hh:nn:ss")
'Start(xlWorkbook).Activate
Worksheets("Sheet3").Range("A1:J56000").Clear
Worksheets("Sheet3").Select
ROW = 0
w = 0
Open strFZPName For Input As #1
textline = "ok"
Do While Not EOF(1) ' Loop until end of file.	Line Input #1, textline ' Read line into variable.	split_line = Trim(Replace(textline, ",", ", "))
	Do While InStr(split_line, " ")		split_line = Replace(split_line, " ", " ")
	Loop
	split_line = Split(split_line)
w = w + 1
If Not textline = "" Then
If w >= 17 Then
T = split_line(0) * 10
Worksheets("Sheet3").Range("B1").Select
If split_line(1) = 1 Or split_line(1) = 2 Or split_line(1) = 3 Or split_line(1) = 4 Or split_line(1) = 5 Or split_line(1) = 6 Or split_line(1) = 7 _
Or split_line(1) = 8 Or split_line(1) = 10000 Or split_line(1) = 10001 Or split_line(1) = 10002 Or split_line(1) = 10003 Then
ROW = ROW + 1
For COLUMN = 0 To 6
	ActiveCell.Offset(Row, COLUMN) = split_line(COLUMN)
Next
End If
End If
End If
End If
Loop
Close #1
Range("B4").Select
Range(Selection, Selection.End(xlToRight)).Select
'Strart(xlWorkbook).Activate
Range(Selection, Selection.End(xlToRight)).Select
Range(Selection, Selection.End(xlDown)).Select
Selection.Sort Key1:=Range("E4"), Order1:=xlAscending, Header:=xlGuess, _
OrderCustom:=1, MatchCase:=False, Orientation:=xlTopToBottom,
DataOption1:=xlSortNormal
'Application.ScreenUpdating = False
Range("E4").Select
check1 = Selection.Value
Do Until check1 = ""
        If Selection.Offset(1, -2) = 10000 Or Selection.Offset(1, -2) = 7 Then
            Selection.Offset(0, 5) = 1
            Phase_assign(check1) = 1
        ElseIf Selection.Offset(1, -2) = 10001 Or Selection.Offset(1, -2) = 6 Then
            Selection.Offset(0, 5) = 5
            Phase_assign(check1) = 5
        ElseIf Selection.Offset(1, -2) = 10002 Or Selection.Offset(1, -2) = 8 Then
            Selection.Offset(0, 5) = 3
            Phase_assign(check1) = 3
        ElseIf Selection.Offset(1, -2) = 10003 Or Selection.Offset(1, -2) = 5 Then
            Selection.Offset(0, 5) = 7
            Phase_assign(check1) = 7
        ElseIf Selection.Offset(1, -2) = 2 Then
            Selection.Offset(0, 5) = 2
            Phase_assign(check1) = 2
        ElseIf Selection.Offset(1, -2) = 1 Then
            Selection.Offset(0, 5) = 6
            Phase_assign(check1) = 6
        ElseIf Selection.Offset(1, -2) = 3 Then
            Selection.Offset(0, 5) = 4
            Phase_assign(check1) = 4
        ElseIf Selection.Offset(1, -2) = 4 Then
            Selection.Offset(0, 5) = 8
            Phase_assign(check1) = 8
        End If
    End If
Else
    Select Case Selection.Offset(0, -2).Value
        Case 2:
            Selection.Offset(0, 5) = 2
            Phase_assign(check1) = 2
        Case 1:
            Selection.Offset(0, 5) = 6
            Phase_assign(check1) = 6
        Case 3:
            Selection.Offset(0, 5) = 4
            Phase_assign(check1) = 4
        Case 4:
            Selection.Offset(0, 5) = 8
            Phase_assign(check1) = 8
        Case 7:
            Selection.Offset(0, 5) = 1
            Phase_assign(check1) = 1
        Case 6:
            Selection.Offset(0, 5) = 5
            Phase_assign(check1) = 5
        Case 8:
            Selection.Offset(0, 5) = 3
            Phase_assign(check1) = 3
        Case 5:
End Select
Selection.Offset(0, 5) = 7
Phase_assign(check1) = 7
Case 10000:
Selection.Offset(0, 5) = 1
Phase_assign(check1) = 1
Case 10001:
Selection.Offset(0, 5) = 5
Phase_assign(check1) = 5
Case 10002:
Selection.Offset(0, 5) = 3
Phase_assign(check1) = 3
Case 10003:
Selection.Offset(0, 5) = 7
Phase_assign(check1) = 7
End Select
End If
Selection.Offset(1, 0).Select
check1 = Selection.Value
Loop
Range("E4").Select
check1 = Selection.Value
Do Until check1 = ""
Selection.Offset(0, 5) = Phase_assign(check1)
Selection.Offset(1, 0).Select
check1 = Selection.Value
Loop
Range("B4").Select
check1 = Selection.Value
T = check1 * 10
COUNT = 0
Do Until check1 = ""
P = Selection.Offset(0, 8).Value
If Selection.Offset(0, 6) = "+" And (T = END_RED_TIMES(T, P) Or T = BEG_RED_TIMES(T, P)) Then
COUNT = COUNT + 1
For j = 1 To 9
If Not j = 7 Then
   c_1(COUNT, j) = Selection.Offset(0, j - 1)
Else
   c_1(COUNT, j) = "+"
End If
Next j
c_1(COUNT, 8) = X(P, T)
End If
Selection.Offset(1, 0).Select
check1 = Selection.Value
T = check1 * 10
Loop
Range("B4:J4").Select
Range(Summary, Selection.End(xlDown)).Select
Selection.Clear
Range("B4").Select
For j = 1 To COUNT
   For k = 1 To 9
Selection.Offset(0, k - 1) = c_1(j, k)
Next k
Selection.Offset(1, 0).Select
Next j

' Application.ScreenUpdating = True
Range("B3") = "Time"
Range("C3") = "Link"
Range("D3") = "Lane"
Range("E3") = "VehNo"
Range("F3") = "Pos"
Range("G3") = "Vel"
Range("H3") = "Queue"
Range("I3") = "Phase"
Worksheets("Times").Select
Range("C9") = Format(Now(), "hh:mm:ss")

End Sub
Sub Sort()
Worksheets("Times").Select
Range("B10") = Format(Now(), "hh:mm:ss")
Worksheets("Sheet3").Select
Range("B4").Select
Range(Selection, Selection.End(xlToLeft)).Select
Range(Selection, Selection.End(xlToLeft)).Select
Range(Selection, Selection.End(xlDown)).Select
Selection.Sort Key1:=Range("E4"), Order1:=xlAscending, Header:=xlGuess, _
OrderCustom:=1, MatchCase:=False, Orientation:=xlTopToBottom, _
DataOption1:=xlSortNormal
Worksheets("Times").Select
Range("C10") = Format(Now(), "hh:mm:ss")
End Sub
Sub All()
Call Copy " CALLS THE COPY PROCEDURE THAT EXTRACTS THE OUTPUT FROM THE VISSIM FILES AND PUTS IT INTO THE EXCEL WORKSHEETS"
End Sub
Sub Failure()
Worksheets("Times").Select
Range("B11") = Format(Now(), "hh:mm:ss")
Worksheets("Sheet3").Select
Range("A1").Select
ROW = 0
COLUMN = 0
COUNT = 0
INST = 1
INS = 0
VN0 = 0
P = 0
CHECK = "ok"
Do Until CHECK = ""
If ActiveCell.Offset(ROW + 3, 8) = 1 Then 'If Vehicle is there at the end of red
V = ActiveCell.Offset(ROW + 3, 4)
TIME1 = ActiveCell.Offset(ROW + 3, 1)
If Not V = VEHN(V) Or Not TIME1 = TIM(V) Then
COUNT = ROW + 1
STATUS = "OK"
End If
End Do
"
Do Until CHECK = "" Or STATUS = "Fail" Or ActiveCell.Offset(COUNT + 3, 4) > V
If ActiveCell.Offset(COUNT + 3, 8) = 2 Then 'And is Still there at the beg of red
    L = ActiveCell.Offset(COUNT + 3, 2) 'Link Associated with Vehicle Position
    VEHNO = ActiveCell.Offset(COUNT + 3, 4) 'at the beg of red
    P = ActiveCell.Offset(COUNT + 3, 9)
    STATUS = "Fail"
    PHASE(P) = "Fail"
Worksheets("Phase " & P).Select '****** begining of modification by MONSUR*********
    'Worksheets("Phase " & P).Range("T2:T56000").Clear
    Range("B1").Select
    m = ActiveCell.Offset(1, 0)
    roww = 1
    Do Until m = ""
        If m = TIME1 Then
            ActiveCell.Offset(roww, 18) = STATUS
            End If
        roww = roww + 1
        m = ActiveCell.Offset(roww, 0)
    Loop
Worksheets("Sheet3").Select
    Range("A1").Select '****** end of modification by MONSUR*********
    INS = INS + 1
    TI(INS) = ActiveCell.Offset(COUNT + 3, 1)
    E(INS) = ActiveCell.Offset(COUNT + 3, 8)
    If E(INS) = 2 Then
        lee = 0
    End If
    PH(INS) = P
    LA(INS) = ActiveCell.Offset(COUNT + 3, 3)
    VN(INS) = ActiveCell.Offset(COUNT + 3, 4)
    PO(INS) = ActiveCell.Offset(COUNT + 3, 5)
    VE(INS) = ActiveCell.Offset(COUNT + 3, 6)
    q(INS) = ActiveCell.Offset(COUNT + 3, 7)
    VEHN(VEHNO) = VEHNO
    TIM(VEHNO) = Time
    End If
End If
End If
COUNT = COUNT + 1
CHECK = ActiveCell.Offset(COUNT + 3, 1)
Loop
End If
End If
ROW = ROW + 1
CHECK = ActiveCell.Offset(ROW + 3, 1)
Loop
TOTAL = INS
Worksheets("Times").Select
Range("C11") = Format(Now(), "hh:mm:ss")
End Sub
Sub Output_Failure()
    Worksheets("Times").Select
    Range("B12") = Format(Now(), "hh:mm:ss")
    Worksheets("Aggregate").Select
    Worksheets("Aggregate").Range("A1:N50000").Clear
    Range("A1").Select
    'INST = -1
    INS = 0

    'OUTPUT ROW AND COLUMN NAMES
    ActiveCell.Offset(1, 0) = "Times Fail"
    ActiveCell.Offset(2, 0) = "Times Active"
    ActiveCell.Offset(3, 0) = "% Phase Failures"
    ActiveCell.Offset(5, 0) = "Texas Method Times Fail"
    ActiveCell.Offset(6, 0) = "Texas Method % Fails"
    ActiveCell.Offset(8, 0) = "Method 2 Times Fail"
    ActiveCell.Offset(9, 0) = "Method 2 % Fails"
    ActiveCell.Offset(10, 0) = "Commission_M2&GT"
    ActiveCell.Offset(11, 0) = "Omission_M2&GT"
    ActiveCell.Offset(12, 0) = "Correctly fail detection_M2&GT"
    ActiveCell.Offset(13, 0) = "Correctly no-fail detection_M2&GT"
    ActiveCell.Offset(10, 9) = "Commission_TM&GT"
    ActiveCell.Offset(11, 9) = "Omission_TM&GT"
    ActiveCell.Offset(12, 9) = "Correctly fail detection_TM&GT"
    ActiveCell.Offset(13, 9) = "Correctly no-fail detection_TM&GT"
    ActiveCell.Offset(14, 0) = "Cases Help Up"

    ActiveCell.Offset(16, 0) = "% of Veh. Failed"
    ActiveCell.Offset(17, 0) = "Ave. No. Veh. in queue"
    ActiveCell.Offset(18, 0) = " when a phase fails"

    For COLUMN = 1 To NUM_SIGNALS
        ActiveCell.Offset(0, COLUMN) = "Phase " & COLUMN
    Next

    'OUTPUT NUMBER OF TIMES A PHASE IS ACTIVE
    For COLUMN = 1 To NUM_SIGNALS
        ActiveCell.Offset(2, COLUMN) = ACTIVE_COUNT(COLUMN)
    Next

    'OUTPUT OF ALL FAILED VEHICLES
    ActiveCell.Offset(20, 1) = "Time"
    ActiveCell.Offset(20, 2) = "Phase"
    ActiveCell.Offset(20, 3) = "Lane"
    ActiveCell.Offset(20, 4) = "Veh No."
    ActiveCell.Offset(20, 5) = "Position"
    ActiveCell.Offset(20, 6) = "Velocity"
    ActiveCell.Offset(20, 7) = "Queue"

    Do Until INS = TOTAL
        INS = INS + 1
        'If E(INS) = 2 Then
        ActiveCell.Offset(INS + 20, 1) = TI(INS)
        ActiveCell.Offset(INS + 20, 2) = PH(INS)
    'OUTPUT ALL THE BEG RED CASES
    End Sub
ActiveCell.Offset(INS + 20, 3) = LA(INS)
ActiveCell.Offset(INS + 20, 4) = VN(INS)
ActiveCell.Offset(INS + 20, 5) = PO(INS)
ActiveCell.Offset(INS + 20, 6) = VE(INS)
ActiveCell.Offset(INS + 20, 7) = q(INS)
ActiveCell.Offset(INS + 20, 8) = E(INS)
'End If
Loop

Worksheets("Times").Select
Range("C12") = Format(Now(), "hh:mm:ss")
End Sub
Sub Sort2()
Worksheets("Times").Select
Range("B13") = Format(Now(), "hh:mm:ss")
Worksheets("Aggregate").Select
Range("B22").Select
Range(Selection, Selection.End(xlToRight)).Select
Range(Selection, Selection.End(xlDown)).Select
Range("B22").Select
Range(Selection, Selection.End(xlToRight)).Select
Range(Selection, Selection.End(xlDown)).Select

'OUTPUT CASE NUMBERS
Range("A1").Select
ROW = 21
CHECK = "ok"
Do Until CHECK = 
    ActiveCell.Offset(ROW, 0) = ROW - 20
    ROW = ROW + 1
    CHECK = ActiveCell.Offset(ROW, 1)
Loop

Worksheets("Times").Select
Range("C13") = Format(Now(), "hh:mm:ss")

End Sub
Sub Cycle_Headings()
Worksheets("Times").Select
Range("B14") = Format(Now(), "hh:mm:ss")
For COLUMN = 1 To 8
    Worksheets("Phase " & COLUMN).Select
    Range("A1").Select
    ActiveCell.Offset(0, 0) = "Cycle"
    ActiveCell.Offset(0, 1) = "Beg Time"
    ActiveCell.Offset(0, 2) = "End Time"
Next
COLUMN = 1
Do Until COLUMN > 7
    Worksheets("Phase " & COLUMN).Select
<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. Veh. Failed</td>
</tr>
<tr>
<td>2</td>
<td>Occ.</td>
</tr>
<tr>
<td>3</td>
<td>Green Occ.</td>
</tr>
<tr>
<td>4</td>
<td>Stopbar Count</td>
</tr>
<tr>
<td>5</td>
<td>Advanced Count</td>
</tr>
<tr>
<td>6</td>
<td>Queue Count</td>
</tr>
<tr>
<td>7</td>
<td>Discharge</td>
</tr>
<tr>
<td>8</td>
<td>Method2</td>
</tr>
<tr>
<td>9</td>
<td>Texas Method</td>
</tr>
<tr>
<td>10</td>
<td>Ground truth</td>
</tr>
<tr>
<td>11</td>
<td>Error type_M2&amp;GT</td>
</tr>
<tr>
<td>12</td>
<td>Error type_TM&amp;GT</td>
</tr>
<tr>
<td>13</td>
<td>Total</td>
</tr>
<tr>
<td>14</td>
<td>Z2</td>
</tr>
<tr>
<td>15</td>
<td>Z3</td>
</tr>
<tr>
<td>16</td>
<td>Z4</td>
</tr>
<tr>
<td>17</td>
<td>Z5</td>
</tr>
<tr>
<td>18</td>
<td>Occ.</td>
</tr>
<tr>
<td>19</td>
<td>Green Occ.</td>
</tr>
<tr>
<td>20</td>
<td>Stopbar Count Lane 1</td>
</tr>
<tr>
<td>21</td>
<td>Advanced Count Lane 1</td>
</tr>
<tr>
<td>22</td>
<td>Queue Count Lane 1</td>
</tr>
<tr>
<td>23</td>
<td>Stopbar Count Lane 2</td>
</tr>
<tr>
<td>24</td>
<td>Advanced Count Lane 2</td>
</tr>
<tr>
<td>25</td>
<td>Queue Count Lane 2</td>
</tr>
<tr>
<td>26</td>
<td>Discharge Lane 1</td>
</tr>
<tr>
<td>27</td>
<td>Discharge Lane 2</td>
</tr>
<tr>
<td>28</td>
<td>Method2</td>
</tr>
<tr>
<td>29</td>
<td>Texas Method</td>
</tr>
<tr>
<td>30</td>
<td>Ground truth</td>
</tr>
<tr>
<td>31</td>
<td>Error type_M2&amp;GT</td>
</tr>
<tr>
<td>32</td>
<td>Error type_TM&amp;GT</td>
</tr>
</tbody>
</table>

Loop

COLUMN = COLUMN + 2
Do Until COLUMN > 8
  Worksheets("Phase " & COLUMN).Select
  ActiveCell.Offset(0, 3) = "Total"
  ActiveCell.Offset(0, 4) = "Z2"
  ActiveCell.Offset(0, 5) = "Z3"
  ActiveCell.Offset(0, 6) = "Z4"
  ActiveCell.Offset(0, 7) = "Z5"
  ActiveCell.Offset(0, 8) = "Occ."
  ActiveCell.Offset(0, 9) = "Green Occ."
  ActiveCell.Offset(0, 10) = "Stopbar Count Lane 1"
  ActiveCell.Offset(0, 11) = "Advanced Count Lane 1"
  ActiveCell.Offset(0, 12) = "Queue Count Lane 1"
  ActiveCell.Offset(0, 13) = "Stopbar Count Lane 2"
  ActiveCell.Offset(0, 14) = "Advanced Count Lane 2"
  ActiveCell.Offset(0, 15) = "Queue Count Lane 2"
  ActiveCell.Offset(0, 16) = "Discharge Lane 1"
  ActiveCell.Offset(0, 17) = "Discharge Lane 2"
  ActiveCell.Offset(0, 18) = "Method2"  ******beg of mod. ******
  ActiveCell.Offset(0, 20) = "Texas Method"
  ActiveCell.Offset(0, 19) = "Ground truth"  ******end of mod. ******
  COLUMN = COLUMN + 2
Loop

Worksheets("Times").Select
  Range("C14") = Format(Now(), "hh:mm:ss")
End Sub
Sub Fails()
  Worksheets("Times").Select
  Range("C15") = Format(Now(), "hh:mm:ss")
  Worksheets("Aggregate").Select
  Range("A1").Select
  If Not Range("B22") = "" Then
    ROW = 21
    CHECK = "ok"
    For P = 1 To 8
      R = 0
      VCOUNT(P) = 0
      RCOUNT(P) = 0
R2COUNT(P) = 0
R3COUNT(P) = 0
R4COUNT(P) = 0
R5Count(P) = 0
I(P) = 0
VECOUNT(P) = 0
Do Until CHECK = "" Or Not ActiveCell.Offset(ROW, 2) <= P
  VCOUNT(P) = 0
  RCOUNT(P) = 0
  R2COUNT(P) = 0
  R3COUNT(P) = 0
  R4COUNT(P) = 0
  R5Count(P) = 0
  Do Until CHECK = ""
    T = ActiveCell.Offset(ROW, 1)
    T1 = ActiveCell.Offset(ROW + 1, 1)
    'FIND NUMBER OF TIMES A PHASE FAILS
    If (Not T = T1) Then
      I(P) = I(P) + 1
    End If
    'FIND NUMBER OF VEHICLES FAILED
    VECOUNT(P) = VECOUNT(P) + 1
    VCOUNT(P) = VCOUNT(P) + 1
    'FIND ZONE
    If ActiveCell.Offset(ROW, 2) = 2 Or ActiveCell.Offset(ROW, 2) = 4 Or ActiveCell.Offset(ROW, 2) = 6 Or
      ActiveCell.Offset(ROW, 2) = 8 Then
      If ActiveCell.Offset(ROW, 5) < 850 Then
        If ActiveCell.Offset(ROW, 3) = 1 Then
          R5Count(P) = R5Count(P) + 1
        End If
        If ActiveCell.Offset(ROW, 3) = 2 Then
          R4COUNT(P) = R4COUNT(P) + 1
        End If
      End If
      If ActiveCell.Offset(ROW, 5) >= 850 Then
        If ActiveCell.Offset(ROW, 3) = 1 Then
          R3COUNT(P) = R3COUNT(P) + 1
        End If
        If ActiveCell.Offset(ROW, 3) = 2 Then
          R2COUNT(P) = R2COUNT(P) + 1
        End If
      End If
      If Not ActiveCell.Offset(ROW, 1) = ActiveCell.Offset(ROW + 1, 1) Then
        CHECK = ""
      End If
    ROW = ROW + 1
  Loop
  Worksheets("Phase " & P).Select
  Range("B2").Select
  If P = 1 Or P = 3 Or P = 5 Or P = 7 Then
    Do Until ActiveCell.Offset(R, 0) > T Or ActiveCell.Offset(R, 0) = ""
      If ActiveCell.Offset(R, 1) = T Then
        ActiveCell.Offset(R, 2) = VCOUNT(P)
      End If
    End If
  End If
R = R + 1
Loop
End If
If P = 2 Or P = 4 Or P = 6 Or P = 8 Then
Do Until ActiveCell.Offset(R, 0) > T Or ActiveCell.Offset(R, 0) = ""
If ActiveCell.Offset(R, 1) = T Then
ActiveCell.Offset(R, 2) = VCOUNT(P)
ActiveCell.Offset(R, 3) = R2COUNT(P)
ActiveCell.Offset(R, 4) = R3COUNT(P)
ActiveCell.Offset(R, 5) = R4COUNT(P)
ActiveCell.Offset(R, 6) = R5Count(P)
End If
R = R + 1
Loop
End If
Worksheets("Aggregate").Select
Range("A1").Select
CHECK = ActiveCell.Offset(ROW, 0)
'ROW = ROW + 1
Loop
'OUTPUT AGGREGATE DATA
Next
For P = 1 To 8
If Not I(P) = 0 Then
FCOUNT(P) = I(P)
End If
If I(P) = 0 Then
FCOUNT(P) = 0
End If
ActiveCell.Offset(1, P) = FCOUNT(P)
Next
For P = 1 To 8
If Not VECOUNT(P) = 0 Then
ActiveCell.Offset(14, P) = VECOUNT(P)  '**********Mod by Monsur**********
End If
If VECOUNT(P) = 0 Then
ActiveCell.Offset(14, P) = 0
End If
Next
End If
Worksheets("Times").Select
Range("C15") = Format(Now(), "hh:mm:ss")
End Sub
Sub Sort3()
Worksheets("Aggregate").Select
Range("B22").Select
Range(Selection, Selection.End(xlToRight)).Select
Range(Selection, Selection.End(xlDown)).Select
Selection.Sort Key1:=Range("E22"), Order1:=xlAscending, Header:=xlGuess, _
OrderCustom:=1, MatchCase:=False, Orientation:=xlTopToBottom, _
DataOption1:=xlSortNormal
End Sub
Sub Unique_Fails()
Worksheets("Multiple Fails").Range("A1:K65300").Clear
Worksheets("Aggregate").Select
Worksheets("Aggregate").Range("J22:J65300").Clear

'FIND Repeat Vehicles

Range("E22").Select
R = 0
ROW = 0
Do Until ActiveCell.Offset(ROW, 0) = ""
    If ActiveCell.Offset(ROW + 1, 0) = ActiveCell.Offset(ROW, 0) Then
        T = ActiveCell.Offset(ROW, -3)
        P = ActiveCell.Offset(ROW, -2)
        L = ActiveCell.Offset(ROW, -1)
        V = ActiveCell.Offset(ROW, 0)
        POS = ActiveCell.Offset(ROW, 1)
        T1 = ActiveCell.Offset(ROW + 1, -3)
        P1 = ActiveCell.Offset(ROW + 1, -2)
        L1 = ActiveCell.Offset(ROW + 1, -1)
        V1 = ActiveCell.Offset(ROW + 1, 0)
        POS1 = ActiveCell.Offset(ROW + 1, 1)
        Worksheets("Multiple Fails").Select
        Range("B2").Select
        ActiveCell.Offset(R, 0) = T
        ActiveCell.Offset(R, 1) = P
        ActiveCell.Offset(R, 2) = L
        ActiveCell.Offset(R, 3) = V
        ActiveCell.Offset(R, 4) = POS
        ActiveCell.Offset(R + 1, 0) = T1
        ActiveCell.Offset(R + 1, 1) = P1
        ActiveCell.Offset(R + 1, 2) = L1
        ActiveCell.Offset(R + 1, 3) = V1
        ActiveCell.Offset(R + 1, 4) = POS1
        R = R + 2
    End If
    Worksheets("Aggregate").Select
    ROW = ROW + 1
Loop

Worksheets("Multiple Fails").Select

End Sub
Sub Final()
Worksheets("Aggregate").Select
Range("A1").Select

'OUTPUT % PHASE FAILURES = FAILED PHASES/TOTAL TIMES PHASE IS ACTIVE
For COLUMN = 1 To NUM_SIGNALS
    If ActiveCell.Offset(2, COLUMN) = 0 Then
        ActiveCell.Offset(3, COLUMN) = "N/A"
    Else
        ActiveCell.Offset(3, COLUMN) = ActiveCell.Offset(1, COLUMN) / ActiveCell.Offset(2, COLUMN) * 100
    End If
Next

nd Sub
Sub Occupancy()
Worksheets("Times").Select
Range("B16") = Format(Now(), "hh:mm:ss")
COLUMN = 1
Do Until COLUMN > 7
    Worksheets("Phase " & COLUMN).Range("E2:E56000").Clear
    COLUMN = COLUMN + 2
Loop
COLUMN = 2
Do Until COLUMN > 8
    Worksheets("Phase " & COLUMN).Range("I2:I56000").Clear
    COLUMN = COLUMN + 2
Loop
COLUMN = 1
Do Until COLUMN > 7
    Worksheets("Phase " & COLUMN).Select
    Range("B2").Select
    R = 0
    CHECK = "ok"
    COUNT = 0
    Do Until CHECK = ""
        T = ActiveCell.Offset(R, 0)
        T1 = ActiveCell.Offset(R + 1, 0)
        Worksheets("Signal Record").Select
        Range("A1").Select
        ROW = 1
        For ROW = T To T1 - 1
            If ActiveCell.Offset(ROW, COLUMN + 8) = "+" Or ActiveCell.Offset(ROW, COLUMN + 8) = "|" Then
                COUNT = COUNT + 1
            End If
        Next
        Worksheets("Phase " & COLUMN).Select
        Range("B2").Select
        If Not (T1 = 0 And T = 0) Then
            ActiveCell.Offset(R, 3) = Round((COUNT / (T1 - T)), 2)
        End If
        CHECK = ActiveCell.Offset(R + 1, 0)
        R = R + 1
        COUNT = 0
    Loop
COLUMN = COLUMN + 2
Loop
COLUMN = 2
Do Until COLUMN > 8
    Worksheets("Phase " & COLUMN).Select
    Range("B2").Select
    R = 0
    CHECK = "ok"
    COUNT = 0
    Do Until CHECK = ""
        T = ActiveCell.Offset(R, 0)
        T1 = ActiveCell.Offset(R + 1, 0)
        Worksheets("Signal Record").Select
        Range("A1").Select
        ROW = 1
        For ROW = T To T1 - 1
            If ActiveCell.Offset(ROW, COLUMN + 8) = "+" Or ActiveCell.Offset(ROW, COLUMN + 8) = "|" Then
                COUNT = COUNT + 1
            End If
        Next
        Worksheets("Phase " & COLUMN).Select
        Range("B2").Select
        If Not (T1 = 0 And T = 0) Then
            ActiveCell.Offset(R, 3) = Round((COUNT / (T1 - T)), 2)
        End If
        CHECK = ActiveCell.Offset(R + 1, 0)
        R = R + 1
        COUNT = 0
    Loop
If ActiveCell.Offset(ROW, COLUMN + 8) = "+" Or ActiveCell.Offset(ROW, COLUMN + 8) = "|

     COUNT = COUNT + 1

   End If

Next
Worksheets("Phase " & COLUMN).Select
Range("B2").Select
If Not (T1 = 0 And T = 0) Then
   ActiveCell.Offset(R, 7) = Round((COUNT / (T1 - T)), 2)
End If
CHECK = ActiveCell.Offset(R + 1, 0)
R = R + 1
COUNT = 0
Loop
COLUMNS = COLUMNS + 2
Loop
Worksheets("Times").Select
Range("C16") = Format(Now(), "hh:mm:ss")
End Sub
Sub Green_Occupancy()
Worksheets("Times").Select
Range("B17") = Format(Now(), "hh:mm:ss")
COLUMNS = 1
Do Until COLUMNS > 7
   Worksheets("Phase " & COLUMNS).Range("F2:F56000").Clear
   COLUMNS = COLUMNS + 2
Loop
COLUMNS = 2
Do Until COLUMNS > 8
   Worksheets("Phase " & COLUMNS).Range("J2:J56000").Clear
   COLUMNS = COLUMNS + 2
Loop
COLUMNS = 1
Do Until COLUMNS > 7
   FCOUNT(COLUMN) = 0
   Worksheets("Phase " & COLUMNS).Select
   Range("B2").Select
   R = 0
   CHECK = "ok"
   COUNT = 0
Do Until CHECK = ""
   T = ActiveCell.Offset(R, 0)
   T1 = ActiveCell.Offset(R, 1)
   Worksheets("Signal Record").Select
   Range("A1").Select
   ROW = 1
   For ROW = T To T1 - 1
      If ActiveCell.Offset(ROW, COLUMN + 8) = "+" Or ActiveCell.Offset(ROW, COLUMN + 8) = "|

      COUNT = COUNT + 1

   End If
Next
Worksheets("Phase " & COLUMNS).Select
Range("B2").Select
If Not (T1 = 0 And T = 0) Then
   ActiveCell.Offset(R, 4) = Round((COUNT / (T1 - T)), 2)
End If
' If ActiveCell.Offset(R, 4) = 1 Then
'   FCOUNT(COLUMN) = FCOUNT(COLUMN) + 1
' End If
CHECK = ActiveCell.Offset(R + 1, 0)
R = R + 1
COUNT = 0
Loop
COLUMN = COLUMN + 2
Loop

COLUMN = 2
Do Until COLUMN > 8
   FCOUNT(COLUMN) = 0
   Worksheets("Phase " & COLUMN).Select
   Range("B2").Select
   R = 0
   CHECK = "ok"
   COUNT = 0
   Do Until CHECK = ""
      T = ActiveCell.Offset(R, 0)
      T1 = ActiveCell.Offset(R, 1)
      Worksheets("Signal Record").Select
      Range("A1").Select
      ROW = 1
      For ROW = T To T1 - 1
         If ActiveCell.Offset(ROW, COLUMN + 8) = "+" Or ActiveCell.Offset(ROW, COLUMN + 8) = "|" Then
            COUNT = COUNT + 1
         End If
      Next
      Worksheets("Phase " & COLUMN).Select
      Range("B2").Select
      If Not (T1 = 0 And T = 0) Then
         ActiveCell.Offset(R, 8) = Round((COUNT / (T1 - T)), 2)
      End If
' If ActiveCell.Offset(R, 9) = 1 Then
'   FCOUNT(COLUMN) = FCOUNT(COLUMN) + 1
' End If
   CHECK = ActiveCell.Offset(R + 1, 0)
   R = R + 1
   COUNT = 0
Loop
COLUMN = COLUMN + 2
Loop

Worksheets("Aggregate").Select
Worksheets("Times").Select
Range("C17") = Format(Now(), "hh:mm:ss")
End Sub
Sub Texas_Method()

COLUMN = 1
Do Until COLUMN > 7
   FCOUNT(COLUMN) = 0
   Worksheets("Phase " & COLUMN).Select
   'Worksheets("Phase " & COLUMN).Range("U2:U56000").Clear

Range("B2").Select
R = 0
CHECK = "ok"
COUNT = 0
Do Until CHECK = ""
    If ActiveCell.Offset(R, 4) = 1 Then
        FCOUNT(COLUMN) = FCOUNT(COLUMN) + 1
        ActiveCell.Offset(R, 19) = "Fail"
    End If
    CHECK = ActiveCell.Offset(R + 1, 0)
    R = R + 1
    COUNT = 0
Loop
COLUMN = COLUMN + 2
Loop

COLUMN = 2
Do Until COLUMN > 8
    FCOUNT(COLUMN) = 0
    Worksheets("Phase " & COLUMN).Select
    'Worksheets("Phase " & COLUMN).Range("U2:U56000").Clear
    Range("B2").Select
    R = 0
    CHECK = "ok"
    COUNT = 0
    Do Until CHECK = ""
        If ActiveCell.Offset(R, 8) = 1 Then
            FCOUNT(COLUMN) = FCOUNT(COLUMN) + 1
            ActiveCell.Offset(R, 19) = "Fail"
        End If
        CHECK = ActiveCell.Offset(R + 1, 0)
        R = R + 1
        COUNT = 0
    Loop
    COLUMN = COLUMN + 2
Loop

Worksheets("Aggregate").Select
For COLUMN = 1 To 8
    ActiveCell.Offset(5, COLUMN) = FCOUNT(COLUMN)
    If Not ActiveCell.Offset(2, COLUMN) = 0 Then
        ActiveCell.Offset(6, COLUMN) = ActiveCell.Offset(5, COLUMN) / ActiveCell.Offset(2, COLUMN)
    Else
        ActiveCell.Offset(6, COLUMN) = "N/A"
    End If
Next
End Sub

'********* Added by Monsur **********

Sub omission_comision()
For P = 1 To 8
    Worksheets("Phase " & P).Select
    Worksheets("Phase " & P).Range("V2:W56000").Clear
    Range("B1").Select
    no_fail_count = 0
    fail_count = 0
    Commission_count = 0
End Sub

Development of New Actuated Signalized Intersection Performance . . .
Omission_count = 0
m = ActiveCell.Offset(1, 0)
roww = 1
Do Until m = ""
    If ActiveCell.Offset(roww, 18) = "" And ActiveCell.Offset(roww, 17) = "" Then
        ActiveCell.Offset(roww, 20) = "Correctly no-fail detect"
        no_fail_count = no_fail_count + 1
    Else
        If ActiveCell.Offset(roww, 17) = "Fail" And ActiveCell.Offset(roww, 18) = "Fail" Then
            ActiveCell.Offset(roww, 20) = "Correctly fail detect"
            fail_count = fail_count + 1
        Else
            If ActiveCell.Offset(roww, 17) = "Fail" And ActiveCell.Offset(roww, 18) = "" Then
                ActiveCell.Offset(roww, 20) = "Commission"
                Commission_count = Commission_count + 1
            Else
                ActiveCell.Offset(roww, 20) = "Omission"
                Omission_count = Omission_count + 1
            End If
        End If
    End If
    roww = roww + 1
m = ActiveCell.Offset(roww, 0)
Loop

Worksheets("Aggregate").Select
Range("A1").Select
ActiveCell.Offset(10, P) = Commission_count
ActiveCell.Offset(11, P) = Omission_count
ActiveCell.Offset(13, P) = no_fail_count
ActiveCell.Offset(12, P) = fail_count

Worksheets("Phase " & P).Select
Range("B1").Select
no_fail_count = 0
fail_count = 0
Commission_count = 0
Omission_count = 0
m = ActiveCell.Offset(1, 0)
roww = 1
Do Until m = ""
    If ActiveCell.Offset(roww, 19) = "" And ActiveCell.Offset(roww, 18) = "" Then
        ActiveCell.Offset(roww, 21) = "Correctly no-fail detect"
        no_fail_count = no_fail_count + 1
    Else
        If ActiveCell.Offset(roww, 19) = "Fail" And ActiveCell.Offset(roww, 18) = "Fail" Then
            ActiveCell.Offset(roww, 21) = "Correctly fail detect"
            fail_count = fail_count + 1
        Else
            If ActiveCell.Offset(roww, 19) = "Fail" And ActiveCell.Offset(roww, 18) = "" Then
                ActiveCell.Offset(roww, 21) = "Commission"
                Commission_count = Commission_count + 1
            Else
                ActiveCell.Offset(roww, 21) = "Omission"
                Omission_count = Omission_count + 1
            End If
        End If
    End If
End If

End If
End If
roww = roww + 1
m = ActiveCell.Offset(roww, 0)
Loop
Worksheets ("Aggregate").Select
Range("A1").Select
ActiveCell.Offset(10, P + 9) = Commission_count
ActiveCell.Offset(11, P + 9) = Omission_count
ActiveCell.Offset(13, P + 9) = no_fail_count
ActiveCell.Offset(12, P + 9) = fail_count
Next P
End Sub