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Final Report

Manual on Performance of Traffic Signal Systems: Assessment of Operations and Maintenance

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Metric Conversion Table

SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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16. Abstract

The annual evaluation of traffic signal systems on an agency level can be of great importance for identifying problems, self-assessment, budgeting, creating the strategy for future steps, etc. The most famous similar effort of this type is the National Traffic Signal Report Card (NTSRC), which is used as an evaluation methodology for agencies country-wide. The main difference in the proposed methodology is that it steps away from qualitative evaluation and grading, and presents a new set of procedures for implementation of quantitative, therefore more unbiased, evaluation methodology. The proposed methodology should enable self-evaluation and comparison between different agencies in terms of agency management, traffic signal operations, signal timing practices, traffic monitoring, data collection, and maintenance. For two agencies, the numerical and logical values of the answers were used in the evaluation process to obtain the preliminary results, and together with the factor of confidence, they were displayed to explain the evaluation process. The annual evaluation is supported by weekly/monthly evaluation which was developed as a set of dashboards with relevant signal performance measures. The dashboards were created to reflect performance and reliability of a specific signal system on a weekly/monthly level. The authors used data from ATMS.now signal system central software to illustrate how similar dashboards could be developed from any central software to enable operators to promptly and efficiently monitor various parameters of traffic signals. The main outcome of the study is a set of Excel evaluation spreadsheets accompanied with relevant user manuals.

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Executive Summary

Investments in traffic signal equipment and staff can bring significant benefits to signal-operating agencies. However, such investments cannot easily be justified without a clear process of recording and documenting benefits of such investments. Such a process requires an evaluation methodology which should be based on quantifiable metrics that can reflect the true effects of the executed investments. Even in the cases where the annual expenditures, service areas (e.g., number of signals), and available staff are similar, operational and maintenance outcomes can vary considerably between different agencies. Therefore, if upper management of a city, county, or any other signal-operating agency wants to evaluate performance of its signal operations and the quality of service provided to citizens, it would need to have a clear procedure to evaluate strengths, weaknesses, and efficiency and reliability levels of its signal system. This need is further amplified if responsibility for operating and maintaining the traffic signals is awarded to private consultants. In such a case, a clear grading system becomes a mandatory component of any evaluation and compensation process.

The major requirements for successful evaluation of a traffic signal system's performance are available data and clearly defined performance measures. In a perfect situation, all of the data are fully available, and the performance measures can be clearly defined and based on quantitative inputs. However, in the real world, this is usually not the case. Lack of the available data is a major limiting factor, and it consequentially affects generation of the performance measures, which have to be based on the available data, some of which may be qualitative.

The objective of this research was to develop an evaluation methodology which would help agencies in Florida and across the country to consistently and comprehensively evaluate performance and reliability of the traffic signal systems under their jurisdictions. Evaluation of the traffic signal system's performance and reliability is a process that can be done in various (more or less frequent) time intervals. Depending on the frequency of the evaluation, the methodology for executing such an evaluation will vary. In other words, metrics which are appropriate for weekly monitoring of traffic signals may lose their significances if aggregated over the entire year and vice versa. This problem was recognized in the first half of this research project, and the scope of the work was modified to tackle both long-term (annual) and short-term (weekly/monthly) evaluations of traffic signal performance. Thus, the study consists of two major and quite distinctive components: annual evaluation of traffic signal assets (intended mostly for upper management of an agency as well as for external stakeholders (e.g., DOT)) and weekly/monthly evaluations of signals' performance and reliability, which are mostly duties of operators in Traffic Management Centers (TMCs).

Similarly, a spatial aggregation of the evaluation is dependent on the temporal aggregation of the system's outcomes. In other words, while it make sense to report annual evaluation for the performance of the entire signaling agency, the weekly/monthly evaluations have to be constrained to specific subnetworks or corridors. Thus, the latter options are best executed through performance (and reliability) dashboards, where TMC operators can observe historical data and derived performance measures and decide what actions (if any) to take to improve operations and maintenance of the system. Therefore, the final outcome of this research has two components: methodologies for both annual and weekly/monthly evaluations of traffic signals. Both

methodologies are practically executed through MS Excel tools/spreadsheets and accompanied with manuals which explain their use and logical flow of information.

For the annual evaluations, MS Excel spreadsheets prompt users to answer a set of predefined questions. Such inputs prohibit users from entering ambiguous answers, and enable head-to-head comparisons with the other users. A grading system for the annual evaluation is divided into five distinct categories (Management, Traffic signal operations, Signal timing practices, Traffic monitoring and data collection, and Maintenance), thus mimicking the grading system of the 2012 National Traffic Signal Report Card 2012. The annual evaluation methodology was tested on two pilot agencies which volunteered to provide data and answers in the relevant spreadsheets. The findings from these experiments show that it is possible to achieve unbiased grading by using more quantitative (versus qualitative) grades in the process. However, some limitations were observed, e.g., many entries cannot easily be quantified because they require large amounts of various data, which may not be easy to acquire. To overcome a problem with missing data, the FAU researchers introduced the concept of evaluation confidence, which assigns a level of confidence to the evaluation outcome based on how many entries were based on quantifiable data.

The proposed annual evaluation methodology can have a significant impact on the way traffic agencies evaluate their signal systems. However, it is necessary to: (1) standardize the types of the data that are collected and (2) calibrate the grading scale (e.g., by applying this methodology to a larger number of participating agencies). In the pilot studies, the participants were graded by comparing their entries to the virtual examples of the best and worst agencies. Inclusion of a higher number of agencies will make comparisons more realistic, which will lead to the development of a more accurate and meaningful grading scale. Another direction for improvement is development of a framework to connect weekly/monthly evaluations with annual evaluations, where data collected in shorter intervals would be aggregated and summarized by the end of a year.

Weekly/monthly evaluations do not rely on the tedious process of collecting vast amounts of data from agency staff, but they use (when available) data that might be already collected and stored by signal system central software. In such cases, a TMC (Traffic Management Center) operator can use custom-built macros (provided as deliverables of this project) to transfer the data from signal system central software (in this case, ATMS.now) into spreadsheets used to create Traffic Signal System Performance Dashboard and Traffic Signal System Reliability Dashboards (also provided as deliverables of this project). The abovementioned macros enable users to seamlessly, in few steps, prepare new databases for the dashboards and visualize some of the key performance measures based on the data from ATMS.now's reports.

The dashboards add a significant value to the entire project because they utilize, in an innovative way, the data that are already available. The Performance dashboard focuses on operational characteristics of traffic signals. Cycle lengths, numbers and percentages of phase activations, minimal, average, and maximal values of phases, green time distribution, and phase terminations are all displayed in one place, which allows the user to easily observe most of the important facts about signal operations. On the other hand, the Reliability dashboard shows the number and the percentage of alarm activations, total number of alarms, etc. Both dashboards introduce some new ways to observe signal operations. For example, the Reliability dashboard shows the top five intersections with the highest numbers of alarm activations and the top five alarm types for the selected system. Both dashboards allow user to filter out, spatially and temporally, intersections and periods that are important. Both dashboards are fully ready for field implementation and testing in the real TMC environments at the agencies that utilize the ATMS.now signal system central software.

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1 Introduction

1.1 Background Statement

Public agencies responsible for operations and maintenance of traffic signal systems spend significant funds each year for maintenance and operations of physical infrastructure and improvement of signals' operational performance. However, the driving factors, which guide decision makers when allocating these resources, are rarely based on measurable and quantifiable assessments. Instead, decisions are usually based on varied opinions and experiences which do not always lead to unanimous solutions. Further, it is not uncommon to see that the priority with which signals are maintained is based on the amount of traffic on the corridor (e.g., corridors with higher traffic receive more attention), predefined intervals (e.g., 3-5 years, although sometimes it should be sooner or later), and a limited amount of data collected from the field. Utilizing this approach of maintaining the signals does not always provide a clear picture of how conditions have changed since the last time the signal was maintained or retimed. This study examined existing practices, document current priorities, objectives, and needs and proposed a methodology (Excel spreadsheet and an accompanying manual) flexible enough to meet needs of various signal-operating agencies in Florida.

Signal asset management the retiming and maintenance of traffic signals have received enough attention in the past years from various national institutions and forums. The literature review shows availability of some of the key industry reports on this subject. However, most of these studies lack the level of detail and practicality, which are needed to simplify resource allocation and asset management of signal-operating agencies. Most of these studies have been conducted on a national level by adopting a top-down, highly aggregated, and generalized approach, which cannot address the needs of individual signal-operating agencies with idiosyncratic problems and needs. Thus, there was clearly a need to adopt a different approach (bottom-up) to describe practices and needs of various signal-operating agencies, before a generalized guide can be developed. The objective of this research is to develop a methodology, tool, and manual for monitoring (but also documenting and summarizing) operations and maintenance of various traffic signal agencies in Florida.

The purpose of the manual is to document a performance-based methodology for quantifying the level of physical and technological deterioration of traffic signals. In doing so, the outcomes of the methodology can help decision makers to prioritize the use of resources for operations and maintenance of traffic signals. In the case of signal retiming, the methodology should enable an agency to track performance of the signals from the last retiming date based on monitoring of certain performance measures (PMs) (answer of question "Which PMs?" should be based on literature review, agency's preference, availability of data, etc.). If a PM consistently exceeds a threshold (where the threshold is set by agency, mandated by FDOT, or taken from the national standards (if any), this will indicate a new retiming process is needed. The process of defining thresholds is a challenging endeavor as there is no federal or state document which defines such thresholds. When defining a set of thresholds, our team (in coordination with a panel consisting of several signal-operating practitioners from around FL) had to consider various external factors which create relevant circumstances for each specific system. For example, before judging the potential for improvement of a signalized system on a suburban arterial, one must take into consideration the level of traffic demand (signals are only effective up to a certain level of traffic demand), state of infrastructure (does the system fail often because infrastructure is obsolete), character of operations (e.g., multimodal streets/signals will have much harder time to address objectives of private traffic than those streets/signals which hardly have any pedestrians and transit vehicles) and other factors. After defining the maximum possible levels of operations and maintenance achievable (considering existing external factors), one should try to assess how close existing levels of operations and maintenance are to the maximum levels.

1.2 Objectives

The purpose of the manual is to document practices of using performance measures to monitor the quality of operations and maintenance of traffic signal systems, for various signal-operating agencies in Florida. The manual will also enable users to document their operational and maintenance profiles and practices in a manner that corresponds to the state/national standards and practices. The manual will be accompanied by a simple practical spreadsheet tools which will allow users to track performance of their systems and base their resource investment decision on a set of measurable and quantitative assessments.

1.3 Research Approach

The research approach is defined by the steps or tasks from the scope of the project. After the project kickoff teleconference and forming a technical review panel, the following group of tasks were designated to be performed:

1. Creating literature review and the questionnaire
2. Face-to-face interviews with selected agencies in Florida
3. Developing a methodology to track performance of traffic signal systems
4. Designing analytical spreadsheet tools and manuals
5. Summarizing all results and finds into report

The literature review documents and describes how other relevant national and state reports treated this subject and where the gaps exist to improve the practice in order to develop a tool and manual, which traffic signal agencies can use to track performance of their signals and define priorities in their needs.

The FAU team developed a questionnaire based on similar surveys done by others and knowledge acquired through the literature review. The questionnaire was modified and improved after receiving the remarks from technical review panel. After the modifications, the questionnaire is considered to be in accordance of the technical review panel and that it includes the question that panelists find relevant.

After preparing the final version of the questionnaire, the FAU team interviewed two selected agencies in Florida (The City of Boca Raton and Palm Beach County). Those meetings provided valuable knowledge about agency’s operations, maintenance and practices related to asset management of the traffic signals. Also, during the meetings, the FAU team members provided help for answering the defined questions in the questionnaire, collected the data and extracted the relevant reports from signal system central software and other available platforms. Technologies for traffic related data collection that agency possess and use were examined.

When the answers to the questionnaire were received and all relevant data that could be collected were obtained, the FAU research team proceeded with the development of a methodology to evaluate agencies' traffic signal systems. After the meeting and the consultations with the FDOT, it was decided that the development of the methodology will advance in two directions. One is an annual evaluation of the entire agency, and the other is a weekly or monthly evaluation on the corridor level.

The annual evaluation examines the operations and the maintenance by using the same sections like Traffic Signal Report Card (TSRC) from 2012: Management, Traffic signal operations, Signal timing practices, Traffic monitoring and data collection, and Maintenance. The proposed methodology should provide more quantitative and less qualitative evaluation, compared to aforementioned TSRC. The spreadsheet tool introduces weight factors, evaluation confidence, provides grades. Level of service as an output is created, and will be elaborated later in this report.

The monthly evaluation concentrated on tracking the performance and reliability indicators by using the newly developed dashboards. The dashboards use the data from signal system central software, process them in order to display various performance measures, considering both reliability and the performance.

Both tools for annual and monthly evaluation were created in MS Excel and are followed by corresponding user manuals whose purpose is to help the operators to understand and use the developed tools. In such a way, operators could perform both types of evaluation confidently and independently.

1.4 Research Goals

The goal of this research study is to develop a methodology and the actual MS Excel tools and manuals for annual or monthly evaluation of traffic signal systems based on the appropriate performance measures. The methodology needs to be comprehensive and detailed enough to be adequate for evaluation of traffic signal operations and maintenance for agencies in Florida. The tools need to enable the operator to efficiently and effectively perform the assessment process regardless the evaluation type.

1.5 Technical Review Panel Members

After a short discussion between FDOT Project Managers and the Principal Investigator, it was concluded that the technical review panel should consist of seven (7) representatives from various FDOT districts. Following FDOT districts' representatives were recommended to serve on the technical review panel for this project:

1. District 1: Donald Cashdollar (Donald.cashdollar@dot.state.fl.us) (an alternative is Renjan Joseph (Renjan.joseph@dot.state.fl.us))
2. District 2: Tony Falotico (Tony.falotico@dot.state.fl.us)
3. District 3: Cliff Johnson (Cliff.johnson@dot.state.fl.us)
4. District 4: Melissa Ackert (Melissa.ackert@dot.state.fl.us)
5. District 5: Jim Stroz (Jim.stroz@dot. state.fl.us)
6. District 6: Evelin Legcevic (Evelin.legcevic@dot. state.fl.us)
7. District 7: Elizabeth Wehle (Elizabeth.wehle@dot. state.fl.us) (alternatives are: Mark.hall@dot. state.fl.us and Sandra.gonzalzez@dot.state.fl.us)

2 Literature Review, Performance Metrics, and Data Collection Survey

2.1 Literature Review

A literature review has been made to understand and describe how other relevant national and state reports treated this subject and where they failed to provide enough technical details and clear methods to create practical manual/tool for traffic signal control agencies (to track performance of their signals and prioritize needs). Existing state of practice is summarized.

Sabra et al., 2003 developed a report that discusses five procedures associated with the entire signal timing process: optimization, deployment, evaluation, data management and documentation (Sabra, Wang & Associates, 2003). The report discusses interfaces between these procedures and opportunities to improve the overall signal timing process. Along with the signal timing performance evaluations (observed by engineers in field) the report discusses two other alternative ways of evaluation: simulation and "controller in the loop". However, it is noted that different simulation models might output different values for the same measures of effectiveness since the models use different assumptions and different algorithms to derive the estimates. Controller in the loop simulation is identified as an approach that helps to bridge the gap between the real-time world and the simulation world.

The South Dakota Department of Transportation (SDDOT) initiated a project that enabled the development of a reliable, systematic and qualitative monitoring of all the works that are performed on traffic signal systems (Schwinger and Sapkota, 2004). The monitoring includes verification, tracking, reviewing and recording an inventory of traffic signal maintenance along state routes, as well as the description of improved signal maintenance and management procedures. SDDOT, through its Office of Research, formulated new policies, agreements, and procedural standards for effective management and maintenance of state highway traffic signals. The research project involved a workshop to provide local and national insight and surveys of maintenance and management practices, as well as computer system needs at other state departments of transportation with similar operational needs to South Dakota. Fourteen issues were identified and seven specific recommendations were formulated including the development of a maintenance inspection checklist, a final acceptance checklist, revised maintenance agreements, a comprehensive policy and procedures for traffic signals on state highways, a traffic signal inventory and maintenance database, and updates to the existing standard specifications.

Two reports/white papers by Sunkari in 2004 and 2005 explained what is signal retiming and describe the resulting benefits (Sunkari, 2004 & 2005). Also, Sunkari listed the steps required for conducting signal retiming and the responsible parties if a failure occurs. The papers also discuss frequency and the cost of signal retiming. Finally, the descriptions of several successful retiming projects are provided.

Balke and Herrick documented the first year of research project during which the performance of traffic signal systems was measured using existing detector technology (Balke and Herrick, 2004). Several measures of reliability, efficacy and safety were proposed to be used to assess the performance of traffic signal timing at isolated intersections. The best-identified measures in terms of reliability were average number of phase activations, average number of vehicles served per cycle, average number of vehicles stopped per cycle, proportion of vehicles having to stop on an approach and percentage of overloaded cycles. The best measures in terms of efficacy were found to be average cycle time, average phase duration, average time to service and average proportion of green used to service queue. The best measures in terms of safety are average number of vehicles entering on yellow clearance per cycle, average number of vehicles entering on red clearance interval per cycle and percentage of cycle experience a red-clearance violation. The conclusions and recommendations are based on series of interviews that are conducted, analyzed and summarized which determined what measures the Texas Department of Transportation (TxDOT) is currently using when assessing the performance of their traffic signals and how data for these performance measures are collected.

The second year of research project during which the performance of traffic signal systems was measured using existing detector technology provided the definitions of the final measures for assessment of traffic signal timing performance (Balke et al., 2005). Based on the needs assessment and the limitations of the existing detection systems, a series of innovative performance measures to assess traffic operations and the effectiveness of the signal timing at intersections, were developed. The performance measures proposed and discussed in the report are: cycle time, time to service, queue service time, interval duration, number of vehicles entering per interval, yellow and all-red violation rates, phase failure rate. It was found that some of the traditionally used measures, such as intersection control delay, are difficult to measure accurately in the field since the individual vehicle tracking was not available. The system, called the Traffic Signal Performance Monitoring System (TSPMS) was developed to obtain information from the existing traffic signal and detection system to generate performance measures in real time. To enable automatic collection of the proposed performance measures, a prototype system was developed. The prototype system was installed in two different locations that exhibited different operating characteristics and assessed the ability of the system to collect meaningful and appropriate performance measures.

The Traffic Control Systems Handbook serves as a basic reference in planning, designing and implementing traffic control systems (Gordon, and Tighe, 1996). The document includes a chapter focused on traffic control systems management. It is pointed out that a set-it-and-forget-it policy does not prove sufficient and that managing of these systems should include four basic functional responsibilities: teamwork, operation, maintenance and evaluation. The discussion about the measures of effectiveness, including their graphical representation, used to analyze operational effectiveness of a system is included. To prevent system failure, each of the traffic control system maintenance activities, classified as functional, hardware and software, should be done on regular basis. It is noted that volume is a common measure used to evaluate a traffic control system. Additionally, it is suggested that using measures such as delay, stops and speed has to be done with caution since these MOE may contain estimation errors or may not truly represent conditions somewhat distant from the detector.

The conventional approach to signal timing optimization and field deployment requires current traffic flow data, experience with optimization models, familiarity with the signal controller hardware, and knowledge of field operations including signal timing fine-tuning. To avoid this time-consuming and expensive process, the FHWA publication examined the informal traffic signal timing and retiming process at the lowest possible cost (Henry, 2009). Various cost-effective techniques that can be used to generate good signal timing plans that can be employed when there are insufficient financial resources to generate the plans using conventional techniques were examined. The eight steps leading to new signal plans are defined to identify system intersections, collect and organize existing data, conduct a site survey, obtain turning movement data, calculate local timing parameters, identify signal groupings, calculate coordination parameters, and install and evaluate new plans. Each of these steps is discussed and the procedures that can be used to minimize costs in each of them are identified. Since it was noted that the highest cost for traffic signal retiming is for data collection, a 7-step "short count" method is given and discussed. Finally, the document presents the "signal timing tool box" of procedures to be used for various levels (moderate, modest, and minimum) of signal timing budget.

A team of signal operations engineers from the FHWA investigated traffic operation program assessments in the Puget Sound region on Washington State (US DOT, 2006). The review team found and recommended mechanisms to improve the operation of region-wide traffic signals, but they pointed out that there is no regional leadership for operation of traffic signals. The main recommended step in this regional operating program is to identify a regional champion who would focus on the regional operations. Besides the absence of regional leadership, the inadequate funding is mentioned as a problem since the funds are usually invested in construction projects without supporting the active operation and management of the infrastructure installed by those projects. The document also includes Puget Sound Regional Traffic Operations Self-Assessment Scoring Summary. The summary incorporates the results from the six agencies, the city, the county, the state and covers the national level data.

National Transportation Operations Coalition (NTOC) developed 2007 National Traffic Signal Report Card based on the questionnaires sent (from 2004 to 2006) to municipalities throughout the United States to obtain a self-assessment of traffic signal operations (NTOC, 2007). This report summarizes the results of the National Traffic Signal Report Card and gives suggestions on how to use the results. Compared to the 2005 National Traffic Signal Report Card, it was not possible to notice major improvements on the national basis. However, some agencies applied the suggestions from the earlier report card and reported significant improvements. The document includes the self-assessment survey, used to collect and assess traffic signal management and operations practices based on 417 agencies that collectively account for ownership of 45 percent of the nation's traffic signals. The assessment was divided into six topic sections: management, signal operations at individual intersections, signal operations in coordinated systems, signal timing practices, traffic monitoring and data collection and maintenance. Each section contains a number of questions concerning traffic signal operation policies and practices. Respondents are asked to score each question from one to six, based on its program's progress in each area. Overall, findings indicated that traffic signal operation in the United States has improved a very small amount since 2005, from a grade D- to a D.

Wolfe described methods for quantifying arterial performance using data from signal system loop detectors (Wolfe et al., 2007). Performance measures selected to evaluate arterial performance included traffic density, total delay, predicted travel time, and signal coordination effectiveness. The paper investigates potential methods to generate meaningful real-time information about arterial performance for traveler information. To assess them, methods are employed to analyze archived data for a segment of Barbur Blvd. in Portland, Oregon. Suggestions for future research are also included.

Day et al. investigated various performance measures that could be used to evaluate the performance of a signal (Day et al., 2008). The focus is primarily on the measures that can be extracted in real time on a cycle-by-cycle basis with an automatic traffic signal controller by logging detector actuations and phase information. The conversions of raw data, collected by a controller, into more meaningful information such as performance measures are discussed in the document. All of the calculations and analysis in this work is carried out in Excel using Visual Basic macros. Three groups of measures were derived to be used for three types of performance evaluations. To analyze the state of intersection, Day et al. used cycle length, green duration and volumes. Further, the performance measures identified as the best to analyze the intersection capacity are service flow rate, estimated capacity, observed capacity, volume-to-capacity (v/c) ratio, number of split failures and critical v/c ratio. Finally, to investigate the intersection's performance in coordination with vehicle progression along an arterial corridor, three derived measures were used: percent of arrivals on green, arrival type (defined by the Highway Capacity Manual) and platoon profile. Two comparative case studies demonstrated the effectiveness of the selected performance measures in evaluating operation at a traffic signal. The studies evaluated the impacts caused by actuating a portion of the coordinated phases and by retiming the signal timings on a coordinated arterial.

Koonce et al. developed Signal Timing Manual, a comprehensive report that, among other signal timing topics, reviewed issues related to maintenance and operations of traffic signals (Koonce et al., 2008). The report included description of the development of signal timing to provide safe and efficient intersection operations. In addition, the report emphasizes a concept of coordinating traffic signals with the examples from research and practice. Further, the summary of common techniques to assess the operational and safety performance of signal timing, as well as the various steps necessary to maintain effective traffic signal timing plans, are provided. The maintenance activities discussed in the document include signal retiming, traffic signal inventory, staff training and responding to public comments. The document also includes the highlight issues raised during the ITE traffic signal self-assessment. In general, the report is a comprehensive guide to traffic signal timing and focuses on traffic signal control principles, practices, and procedures.

In a doctorate dissertation, Ma discussed a real-time performance measurement system for arterial traffic signals. He noted that the main reason for insufficient signal retiming, to adjust to the new traffic patterns, is expensive manual data collection and performance measurements (Ma, 2008). The goal of his project was to develop a real-time arterial performance measurement system, which can automatically collect and archive high-resolution traffic signal data, and build a rich list of performance measures. The performance measures include queue length, delay and level of service (LOS) for individual intersections and travel time and number of stops for an arterial corridor. The SMART-SIGNAL (Systematic Monitoring of Arterial Road Traffic and Signals) system is developed to simultaneously collect "event-based" high-resolution traffic data from multiple intersections and generates arterial performance measures in real time. The field tests for an 11-intersections arterial in Hennepin County, Minnesota show that the proposed mathematical model can generate accurate-dependent queue lengths, travel times, numbers of stops, and other performance measures under various traffic conditions.

A collaborative effort between Denver Regional Council of Governments (DRCOG) staff, local agencies representatives, the FHWA and consultant staff documented the use of performance measures to evaluate how well a traffic signal system is working, information that may help in the decision-making process (Felsburg Holt & Ullevig, 2008). The objective was to demonstrate what performance-related information local traffic system operators need in order to assist in the management of their traffic systems. The document also discusses the methods required to collect accurately the appropriate data. Based on the state-of-the-practice review, two conclusions are presented. First, the commonly used performance measures, that are useful to traveling public and transportation professionals, are travel time and travel speeds. Second, the evaluation of arterial performance has been relying on advance detectors, stop bar detectors or AVI data from probe vehicles. Further, three performance measures were identified as the most important to start with: volume and occupancy, travel time and multi-modal data. In addition, three groups for which collected data and performance measure results should be tailored are signal system operators, public and elected officials. Finally, the document includes the summary of interviews with several local government agencies that shows the types of data that are currently being collected, the locations of collection devices, the frequency of collection, system requirements, and how the data is being used.

In 2009, Denney provided a guide for achieving a basic service model for traffic signal management and operations (Denney, 2009). The basic service model is based on simply stated and defensible operational objectives that consider the staffing level, expertise and priorities of the responsible agency. It was noted that so far the agencies have tended to demonstrate that they are doing all they can to alleviate congestion by undertaking prescribed activities. However, this report has adopted different approach, the one that rather focuses on results than activities as a measure of effectiveness. The report includes a literature review, which provides a review of the National Traffic Signal Report Card and self-assessment procedure. In addition, few case studies show how agencies deliver traffic signal management services based on their resources. Additionally, this report outlines key strategies that can help the agencies to articulate and maintain focus of their resources on their most important objectives. An explanation on how to incorporate those strategies into Traffic Signal Management Plan is also provided. Finally, the study suggests a better-than-the-traditional approach for signal retiming. The recommended approach, defined through seven steps, is claimed to be more versatile and more sensitive to available resources.

Gordon and Braud provided a guideline to estimate the staffing and resource needs required to effectively operate and maintain traffic signal systems (Gordon and Braud, 2009). It was concluded that agencies achieving a high level of signal system performance do so under a wide variety of conditions such as agency size, geography, system complexity and traffic conditions that do not adhere to the typical level of documented resource requirements. Accordingly, a set of performance-based criteria were developed to define requirements. The performance-based criteria are focused on establishing realistic and concise operations objectives and performance measures. Key management criteria included staff qualifications and periodic updating of management plans, periodic revision and retiming of signals, periodic review of functional changes in requirements and maintenance i.e. the recommendations for the up-time for detectors are provided.

Jones et al. investigated new concepts, new tools and emerging technologies that enhance traffic operations and safety on signalized urban arterials that operate under saturated conditions (Jones et al., 2009). Although not being researched widely, one of the most efficient and cost-effective way to determine the LOS of an intersection is the use of video surveillance for delay measurements. One of the objectives of this project was to investigate the feasibility of using video data for determining control delay on the approach to signalized intersections, where control delay is defined as the measure of delay a vehicle experiences due to the signalized intersection control. To capture the control delay experienced by vehicles, as they approach a traffic signal and stop at a red signal, the authors developed a technique that utilizes recorded video images of the investigated corridor. They also investigated use of VISTA as a simulation model for saturated arterial traffic flow analysis. In addition, various methods to optimize traffic flow at saturated intersections were examined through enhanced simulation models.

Koonce et al. documented a framework for a whole region to collectively face challenges of improving the traffic signal systems (Koonce et al., 2009). The framework shows agencies how to manage the signal system performance efficiently and consistently while cooperating on the efforts. In addition, an overview of practices related to developing and sustaining a Regional Traffic Signal Operations Program was developed. The main benefit of a regional program is the development of projects that can be included in a regional or state transportation improvement program (TIP). The traffic signal operations performance measures discussed in the document include number of signals retimed, frequency of a signal/corridor retiming, average corridor travel time, and average delay. However, it was noted that many agencies are in a reactive mode addressing public complaints instead of being proactive. Although the number of complaint phone calls represents valuable information, it should not be used as a sole indication of traffic signal performance.

Bonneson et al. documented the research conducted and the conclusions reached during the development of a Traffic Signal Operations Handbook (Bonneson et al., 2009A). This report includes the state-of-the-practice evaluations, TxDOT district interviews, the outline and the research plan for the final Handbook, and the description of the conducted research. One of the main findings is that, although the Texas Department of Transportation (TxDOT) has been operating thousands of traffic signals, some operational inconsistencies and, possibly sub-optimal performance, is created due to regional differences in signal timing and the fact that detection design practices have evolved. The goal was to document a range of effective settings and designs to allow traffic engineers to identify the "best" solution for his/her district conditions. It was concluded that a comprehensive signal timing resource guide would promote uniform and effective signal operations on a statewide basis.

Bonneson et al. provided guidelines for timing traffic control signals at both isolated and coordinated intersections (Bonneson et al., 2009B). The guidelines describe the best practices, as identified through interviews with TxDOT engineers and technicians. In addition, they identify conditions where alternative practices are equally workable. In summary, the Traffic Signal Operations Handbook provides quick-response cost-effective methods for maintaining or improving the operation of existing signalized intersections. The recommended methods ensure more consistent signal timing on an area-wide basis.

The case study from the City of Boston shows the magnitude of the benefits produced by the proposed signal improvements (Boston Transportation Department (BTD) and Howard/Stein-Hudson Associates, Inc., 2010). The Boston Transportation Department (BTD) collaborated with Howard/Stein-Hudson Associates (HSH) to assess the analysis results for each work order, to develop a methodology for quantifying the benefits and costs, and to calculate the associated benefit-cost ratio. Performance measures associated with delay, safety, emissions, and energy were evaluated for 60 study intersections in the Back Bay under existing and improved conditions. The conclusion was that the monetary investment in signal improvements can be recaptured many times over in terms of economic and social benefits.

Gordon provided the synthesis of the practices that operating agencies currently use to revise traffic signal timing, including the steps necessary to develop, install, verify, fine-tune, and evaluate the plans (Gordon, 2010). For various topics related to signal retiming, the corresponding literature reviews and the surveys of transit agencies are provided. Additionally, a series of project case studies is provided along with the in-depth questionnaire to solicit detailed information not addressed in the prior survey and to understand better the reasons for the choice of practices. Furthermore, the functions and the methods for obtaining the performance measures commonly used, i.e., user delay and safety, are discussed. The discussion about the measures usually used to evaluate the specific benefit associated with the signal retiming is included. Finally, one of the main conclusions was that the expensive system performance evaluation would be more cost-effective if a more automated process is implemented. Archived Data User Service (ADUS) coupled with Archived Data Management Systems (ADMS) technology is an emerging approach that may reduce the labor-intensive characteristics of evaluations and provide a basis for identifying retiming needs. However, relatively few implementations have been developed for signal systems, and these are not marketed in a convenient form for agencies to use. Another approach to automate signal system evaluation processes includes incorporation of software, which provides more useful measures such as delay, into controllers.

Day et al. quantified and presented the user benefits resulting from signal retiming activities (Day et al., 2010). Two tools performed these quantifications: high-resolution signal event data and travel time measurement using Bluetooth device MAC address matching. In the first case study, the impact that offsets optimization had on vehicle demand was measured. In the second study, the impact that the implementation of an exclusive pedestrian phase had on demand for pedestrian service was assessed. Finally, the third case study demonstrated the use of travel time data in quantifying changes in user costs and environmental impact (tons of carbon). A method of describing changes in travel time reliability was also presented.

Pennsylvania DOT (PennDOT) published the guidance for activities that are required to maintain traffic signals and improve current signalized operations (PennDOT, 2010). Traffic signal maintenance and operations responsibilities are classified as responsive (emergency) maintenance, preventive (routine) maintenance, operational maintenance, and design maintenance. To evaluate the overall quality of the traffic signal operation with respect to current traffic volumes, two measures of effectiveness (MOEs) are identified: average delay per vehicle per intersection and average number of stops per day per intersection. The document points out that a good preventive maintenance program will almost eliminate the need for emergency maintenance. It also identifies eight possible MOEs to be used: annual number of emergency calls per intersection, number of burnout/non-functioning lights replaced per year, average response time for emergency calls, average time to complete an emergency repair, percent of response calls that were fixed with all new parts from inventory, percent of loop detectors online, maintenance records showing all maintenance performed at each signal, including the technician and the date and number of traffic signal operational improvements to existing traffic signals. Besides maintenance of traffic signals, the document discusses the need for signal retiming and/or upgrade every three to five years. This reexamination would improve traffic flow and safety while providing timings adjusted to the new traffic volumes and to the new technologies developed. Since many municipalities are not equipped to perform the necessary maintenance, they obtain the services of a traffic signal contractor to maintain their traffic signals. This document provides municipal guidance on items that should be considered when selecting a contractor, and includes a sample maintenance contract.

2012 National Traffic Signal Report Card provided summary of the results of the national survey on traffic signal management and operations (NTOC, 2012). The results are based on the 2011 Traffic Signal Operations Self Assessment survey from 241 local and state agencies in the United States and Canada (NTOC, 2011). The 2012 grade of D+ is a slight improvement over grades of a D- in 2005 and a D in 2007. The continuing slow improvement in the national score is meaningful in showing the ongoing progress by agencies that operate the majority of traffic signals in the United States. However, the low scores show that traffic signal management and operations still require the continued attention and additional resources. The new self-assessment consisted of one topic area less than the previous self-assessment survey since the sections for signal operations for both individual intersections and coordinated systems were merged. Thus, the new self-assessment survey had five sections: management, traffic signal operations, signal timing practices, traffic monitoring and data collection, and maintenance. Respondents were asked to rate the extent to which a particular policy or practice had been adopted by their agency (on a scale from one to five) based on their program’s progress through the end of 2011. It is noted that it was not anticipated that any agency would have a perfect score, but rather that the results will provide an agency with a potential target for improving their own traffic signal operations.

Gettman et al. presented generic measures of effectiveness and validation tools that were developed for agencies to validate that selected Adaptive Signal Control Technology (ASCT) meet their performance objectives (Gettman et al., 2013). The identified measures and tools can be also used to evaluate the traditional coordinated-actuated signal timings. For each measure of effectiveness, its source and the corresponding operational objectives are given. To demonstrate the application of these validation measures and methodology to a real world implementation of ASCT, the presented approach was tested at a field site in Mesa, Arizona where an ASCT system has been deployed for over one year. The test phase included 30 days during which the ASCT was turned off and background coordination patterns were used instead. Tube counters and Bluetooth detectors were used for volume and travel time data collection. In addition, GPS probe data and phase timing and detector status data were collected during the test period. The derived measures used in the validation analysis were green occupancy ratio, percent arrivals on green, platoon ratio, and route travel times and reliability metrics. The main operational objectives were to smooth flow, maximize throughput, manage queues, and provide access equity.

Grossman and Bullock designed and developed a sustainable framework for implementing traffic signal performance measures to facilitate the assessment if signal changes will make a positive impact (Grossman and Bullock, 2013). The new framework should stop anecdotal and observational assessments that have been common practice due to the expensive and time-consuming processes to gather the data and perform the evaluation analysis. The performance measures discussed in the document (and subsequently deployed in Elkhart County and Lafayette, IN) were results of the first commercial deployment of real-time traffic signal performance measures recommended by NCHRP 3-79a. It was suggested that these performance measures are used (by local agencies): cycle length, equivalent hourly flow rate, green time plot, volume-to-capacity ratio, split failures, Purdue coordination diagram and percentage of phases with pedestrians. Three main elements are required to allow implementation of the suggested performance measures in a local agency system. First, the local signal controllers have to be capable of collecting high-resolution event data. Second, the system will need to have an Ethernet based communication system to allow data from the controllers to be uploaded to the central system. Finally, the central system has to be capable to use the collected and stored data to produce the performance measure graphics. In addition to the investigation of performance measures, this project evaluated the emerging thermal and video technologies for assessment of vehicle detection performance measures. It was determined that the state of practice of video detection has improved in the previous decade. For origin-destination and travel time data collection the Bluetooth technique was used. Additionally, this research project examined the feasibility of deploying adaptive traffic signal control in the near term (next 12-18 months). The given recommendation is to pursue a hybrid approach of scheduled review of traffic signal performance measures to identify performance improvement opportunities and the use of the link-pivot algorithm developed by Purdue.

The National Highway Institute (NHI) developed and organized a course on Successful Traffic Signal Management: The Basic Service Approach. This two-day course aimed at helping professionals involved in traffic signal programs develop objectives with a management approach that focuses on outcomes and is prioritized to be consistent with capabilities and resources (FHWA, 2013). A document used in this course was participant workbook that serves multiple roles. First, the workbook provided background and contemporary case studies on the traffic management issues that the signal agencies have been facing. Further, the workbook discussed the need to understand maintenance resources and their proper utilization. In addition, the workbook helped professionals to define clearly unique operational objectives that are ideally suited for a specific agency. The description of high-level requirements and strategies to achieve operational objectives were also included. Finally, hands-on development of a Traffic Signal Management Plan was provided.

Day et al. compiled a set of performance measures to be used for analyzing the actual operation of any traffic signal system for all types of operations (Day et al., 2014). The document also provides an overview of signal operations and the methodology for recording and collecting data required to analyze and evaluate performance of a traffic signal system. The description of the infrastructure required to make such an analysis possible, is included. Various types of performance measures that can be used for such analysis are presented and discussed. The mentioned performance measures are based on high-resolution discreet controller event data such as changes in detector and signal phase states. These performance measures are classified depending on a type of traffic signal system performance intended to be evaluated: capacity, progression, multi-modal or maintenance performance. Measures listed for vehicle capacity allocation and vehicle progression evaluate signal operations. Measures related to maintenance can be used to evaluate system maintenance and asset management. Multi-modal measures cover the non-vehicle modes, including pedestrians, and modes that require signal preemption and priority features. The document also demonstrates the use of travel time as a measure to evaluate system operations and to assess the impact of signal retiming activities.

The Table 2.1-1 and Table 2.1-2 summarize the performance measures, which were covered in the reviewed studies. They have been categorized based on major topics of the NTSRC (Management, Operations, Signal Timing Practices, Traffic Monitoring and Data Collection, and Maintenance). Based on reviewed studies one can note that traffic signal operations is the prevalently and comprehensively discussed NTSRC topic area. To evaluate signal operations the researchers mostly used performance measures such as cycle length, delay, travel time, stops, phase duration and capacity-related measures. Regarding the signal-timing, most common performance measures were number of phase activations, number of vehicles served per cycle etc. Performance measures to evaluate management, maintenance, and traffic monitoring and data collection have been much less emphasized in the previous research work although some of the most notable ones were provided in the aforementioned tables.

Table 2.1-1. Investigated performance measures

NTSRC Topic Area	Performance Measure	Required Technology	Publication
Management	Incident clearance time, information dissemination time	TMC records, Road-ranger crew records, etc.	Robert L. Gordon, 2010
	Data for planning and evaluation	Review process to consider traffic signal operations and maintenance	
	Staffing qualifications and levels	HR records, training certifications	
Traffic Signal Operations	Cycle length	Central Traffic Signal System (connected to the field controllers)	Balke and Herrick, 2004; Balke et al., 2005; Day et al., 2008; Grossman and Bullock, 2013;
	Phase duration	Central Traffic Signal System (connected to the field controllers)	Balke and Herrick, 2004; Day et al., 2008; Gettman et al., 2013;
	Delay, travel time	HCM method, GPS data, Virtual probe trajectories, High-resolution data logging system, Point-to-point travel time measurements	Wolfe et al., 2007; Ma, 2008; Felsburg Holt & Ullevig, 2008; Day et al., 2010; PennDOT, 2010; Gettman et al., 2013;
	Stops	HCM method, GPS data, Virtual probe trajectories	Ma, 2008; PennDOT, 2010;
	Estimated capacity, observed capacity, volume-to-capacity (v/c) ratio	High-resolution data logging system	Day et al., 2008; Grossman and Bullock, 2013;
Signal Timing Practices	Number of phase activations, number of vehicles served per cycle, number of vehicles stopped per cycle, proportion of vehicles having to stop on an approach, percentage of overloaded cycles	Eagle EPAC300 Actuated Controller Autoscope Solo® system ORACLE /2 dual channel inductive loop system	Balke and Herrick, 2004

Table 2.1-1 Investigated performance measures - continued

	Phase failure rate	High-resolution data logging system	Balke et al., 2005
	Number of signals retimed, frequency of a signal/corridor retiming	Agency records	Koonce et al, 2009
Traffic Monitoring & Data Collection	Quality and amount of collected data	High-resolution data logging system	Day et al., 2014
Maintenance	Annual # of emergency calls per intersection, # of burnout/non-functioning lights replaced per year, response time for emergency calls, time to complete an emergency repair, percent of response calls that were fixed with all new parts from inventory, percent of loop detectors online, maintenance records showing all maintenance performed at each signal.	Various databases and agency records (asset management systems, systems for recording emergency calls, central traffic signal system, system for maintenance records, etc.)	PennDOT, 2010

2.2 Performance Metrics from Various Signal Management Platforms

2.2.1 Introduction

In order to present and summarize the current state-of-practice in monitoring operations and maintenance of traffic signal systems, first part of this document investigates the signal system central software and other tools that can provide data related to traffic flows. For each signal system central software, the possibilities for reporting the useful performance metrics were examined and documented. Every defined performance measure was explained by using text and figures and other outputs from the signal system central software. In the following chapter, the technologies and processes for monitoring and data collection (BlueTOAD, Sensys, Acyclica) are described.

FAU research team conducted the interviews and survey with two selected agencies under the jurisdiction of Florida Department of Transportation, District 4: The City of Boca Raton and the Palm Beach County. The goal was to acquire better understanding about agency's operations, maintenance, data collection capabilities, technologies used and other practices related to asset management of the traffic signal systems. A set of questions was prepared for all defined sections in the evaluation methodology and handed over to the agencies in order to obtain as much data as possible so that the evaluation is as comprehensive and realistic as possible.

The example of reports from external systems for data collection using different technologies (Wi-Fi, Bluetooth, magnetic sensors…), were displayed in the following chapter. Finally, the future steps for this research project were explained by using the examples of two types of reports from ATMS.now signal system central software. Both reports were displayed in their original state, along with the necessary transformations and macros to execute such transformations. The document is concluded by introducing preliminary performance measures that FAU research team selected to use in annual or weekly/monthly evaluations. After investigating possibilities for using those performance measures, the FAU team and FDOT will decide what measures will be part of the final methodology.

2.2.2 Signal System Central Software

The need for central signal system platform was identified due to complexity of the signal systems and challenges that various agencies have while operating, monitoring and maintaining signals. Development of signal system central software (SSCS), enabled the rising of the management and the control of traffic signals on a new level, also enabled the improvement of the performance of the operators and the entire agencies.

Many different companies developed their own products in order to offer the comprehensive platform for dealing with traffic signals. Each of those platforms have their own options, capabilities and different characteristics. Although various teams tried to create systems with different characteristics, the major functionalities of SSCSs are more or less similar. Most of them have the possibility to collect, aggregate, process and report various performance measures. Performance measures are crucial in determining the traffic flow status and efficiency on the intersection, corridor or the entire network.

The SSCS's have the ability of adding different specialized modules which increases the usefulness and introduces new options in terms of traffic signal control, monitoring, data collection and reporting. Some of those additional module types are listed below:

1. Camera and CCTV modules
2. VMS (Variable Message Signs) module
3. Inventory module
4. Transit signal priority
5. Backup module
6. Modules for the external detection systems
7. Uninterrupted Power Supplies modules
8. Adaptive System modules
9. High Resolution data modules
10. Connected vehicles modules
11. Module for wireless access to the controllers on the field

Not all SSCS's have the same capabilities or modules, and detailed explanations on that topic are given in the following chapters.

2.2.3 ACTRA

ACTRA is not just a transportation management system, it is also a robust, adaptable, configurable and modular ATMS platform developed by Eagle/Siemens. It is an MS Windows-based software for monitoring and traffic control from a control center. It allows the user to enter, monitor and maintain information for intersections and groups of intersections from a central computer workstation. ACTRA has modular design which enables it to handle simple or large complex systems. This system has many options like preemption (priority for emergency vehicles, public transport vehicles and trains), interface with other traffic systems, for example dynamic traffic signs, video cameras, highway advisory radio or telephone system, ramp metering controllers, adaptive traffic control systems (SCOOT) or third party systems like parking guidance and incident detection functions. [1]

ACTRA can be deployed as a closed-loop system, where ACTRA communicates with local controllers via master controllers, or as a central system for traffic management where such communication is being conducted directly. System has the capacity for 8,192 controllers (256 master controllers per computer and 32 controllers per master). The system operates over a Local Area Network capable of supporting multiple client workstations. Main interface components of the system are: [2]

1. **Intersection lists –** where every intersection is listed to monitor phase data, unit, coordination, preemption, access, system detector data, reports, graphics, status and configuration.
2. **Masters list –** every master can be listed to monitor intersection lists, Time-of-Day schedules, groups, users, unit data and coordination data.
3. **Graphic user interface maps –** it is possible to pick the intersection on the map and access the intersection map. Maps can be imported from other map programs, aerial photos or CAD maps.

4. **Intersection graphics –** displaying the real time information about one or more intersections. Maps can be imported from different CAD or drawing programs or from ACTRA library of intersections. Can be modified to display functional status of the intersection operation.
5. **System reports –** a collection of reports. Customized reports can be created using Crystal reports wizard. ACTRA can generate various historical system reports at Master Group level and Local level for a user selected time range:
   a. **Master Historical Reports**
      - Critical alarm
      - Master alarm
      - On-line / Off-line
      - Communications alarm
      - Traffic responsive pattern change
      - Group pattern change
      - System detector – Volume and Occupancy
      - Traffic responsive – Volume and Occupancy

   b. **Local Historical Reports**
      - Local alarm
      - Measures of Effectiveness (MOE)
      - Communications alarm
      - Detector alarm
      - System detector
      - Speed trap
      - Detector volume
      - Cycle Measures of Effectiveness
      - TS/1 Conflict monitor
      - TS/2 MMU (Malfunction Monitor Unit)

The reports can be predefined with user selected reporting intervals and can be scheduled to run automatically. They can be displayed on-screen, printed or saved to a file. Reports can be made using only database values or including the data from the controller. Reports can be presented in table or plot format.

Considering the **Measures of Effectiveness (MOE)** ACTRA's reporting capabilities are limited to:

1. Vehicle Volume
2. Vehicle Detector Occupancy
3. Speed
4. Delay
5. Split Usage Monitoring
6. Time Space Diagram (Corridor Performance Measure)
7. Green Splits

8. Average Green Time Utilization
9. Gap out/Force out/Max out (Split Failures)

It is important to note that ACTRA does not have the possibility to report some MOEs such as queue length, travel time or number of stops. Regarding the function of each controller software, ACTRA can log and plot detector data (Volume, raw occupancy and speed). It is possible to setup cycle data logging or raw data file. Some of the MOEs reporting and presenting are shown below.

2.2.3.1 Vehicle Volume, Vehicle Detector Occupancy, and Speed

Figure 2.2-1 and Figure 2.2-2 show the summary of the vehicle volume, raw occupancy (the amount of time when the detector is on), speed, average volume and average occupancy (the percentage of detector occupancy time divided by time interval) on each detector for a specified period of time are provided by Detector log files from Intersection System Detector Report. The data are collected by local detectors and the report is presented in plot format.

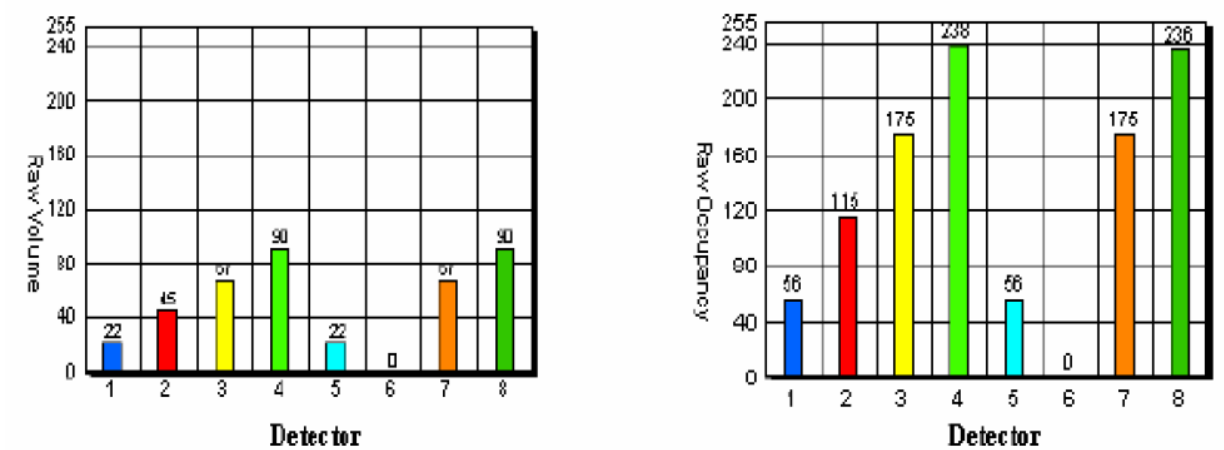


Figure 2.2-1. ACTRA detector log file report (raw volume and raw occupancy)

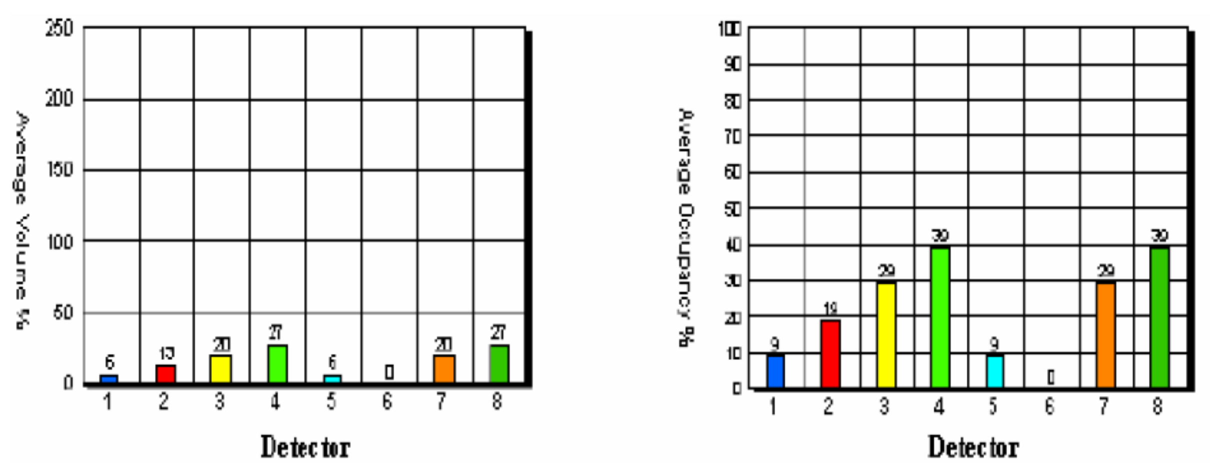


Figure 2.2-2. ACTRA presentation of average volume and average occupancy

ACTRA can generate a series of historical system reports at master and local level for a user selected interval of time (Event log files).

2.2.3.2 Phase Utilization

Report of the cycle phase utilization (Intersection Cycle MOE Report) – reported in seconds in which the correspondence of negative value to actual phase usage time is less than the programmed usage time. In cycle MOE report list shown below (Figure 2.2-3), different symbols were used to present the **phase utilization status** (“#”: means that phase split time is greater than the used time and “#F”: that the phase was forced off). **Max out** and **Gap out** frequencies may be identified from this report by comparing the different values of programmed phase usage time and the actual split time.

11/29/1999 **Cycle Measurement of Effectiveness Report** 12:46:23PM

Local Name: 6th Street & 1st Ave
MODE: DBASE = Database
CORR-/CORR+ = Correcting
TRANS = Transition Cycle

TIME: #- = Used < Split
#F = Forced
#f = Used < Split & Forced

Report Start: 10/01/1999 12:45:00
Report End: 11/29/1999 12:45:00

Date/Time: 11/29/1999 5:58:11AM **Dial/Split/Offset:** 1/ 1/ 1 **Mode:** COORD

Phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Forced	Y		Y	Y	Y		Y	Y								
Utilization	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 2.2-3. Cycle MOE report in ACTRA

2.2.3.3 Intersection Delay, Number of Stops, and Green Time Utilization

MOE Report in ACTRA displays the intersection delay calculated as a product of number of cars waiting and the waiting time in seconds. Also volume, number of stops, and green time utilization are MOEs provided by this report. Volume, number of stops, delay and green time utilization per phase are shown on the Figure 2.2-4.

Measure of Effectiveness Report

Local Name: 6th Street & 1st Ave 11/29/1999 12:53:44PM

Volume = total cars
Stops = number of cars waiting
Delay = number of cars waiting * time in seconds
Utilization = green used time in seconds

Start Time: 10/20/1999 12:06PM **Dial/Split/Offset:** 1/1/1

Phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Volume	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stops	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Delay * 10	34	28	34	29	34	28	34	29	0	0	0	0	0	0	0	0
Utilization	71	130	72	121	72	130	72	121	0	0	0	0	0	0	0	0

Figure 2.2-4. MOE report in ACTRA

2.2.3.4 Green Split Usage, Force Off, Max Out, and Gap Out

Split monitoring report shows actual split usage for each controller. That data can be obtained from multiple intersections at the same time. Bar graphs are used to compare programed and actual splits, local time zero points, phases in dual ring configuration and utilization percentage of each phase.

Split monitoring compares actual and programmed split times for an intersection for a certain time period. The average split data for the cycle and the phases with detailed phase timing data (min green, gap outs, max outs, etc.) are displayed graphically and statistically (Figure 2.2-5).

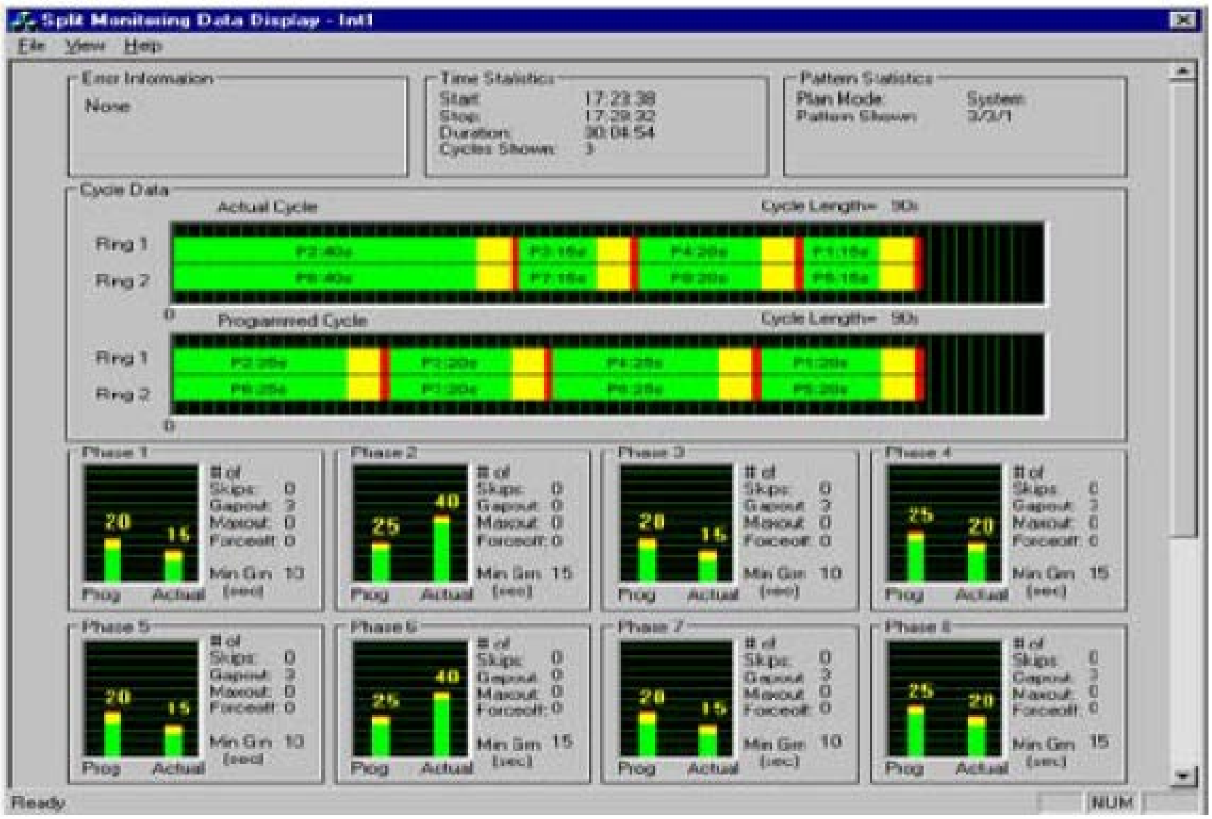


Figure 2.2-5. ACTRA split monitor report

The ACTRA allows integration of traffic analysis optimization tools like Passer, Transyt and Synchro, and can provide visualization of progression by using time-space diagrams.

2.2.3.5 SCOOT

Split Cycle Offset Optimization Technique (SCOOT) adaptive traffic control system is not a part of ACTRA system by default, but can be installed as an optional module. It can be used with other signal system central software (for example Siemens Tactics) but in Florida it is used only with ACTRA. If SCOOT is installed, some additional performance measures can be recorded.

On a network level SCOOT can report the congestion levels for the entire network, congestion levels inside a certain region and the controller statuses. For the intersection level, it is possible to extract various measures that will be mentioned below.

Traffic demand and queue can be showed in LPUs (Link Profile Units) which are SCCOTs internal measure and is a hybrid of flow and occupancy. LPUs can be related to traffic flow by using certain conversion factors. Demand and queue profiles are available through Vega profiles (Figure 2.2-6).

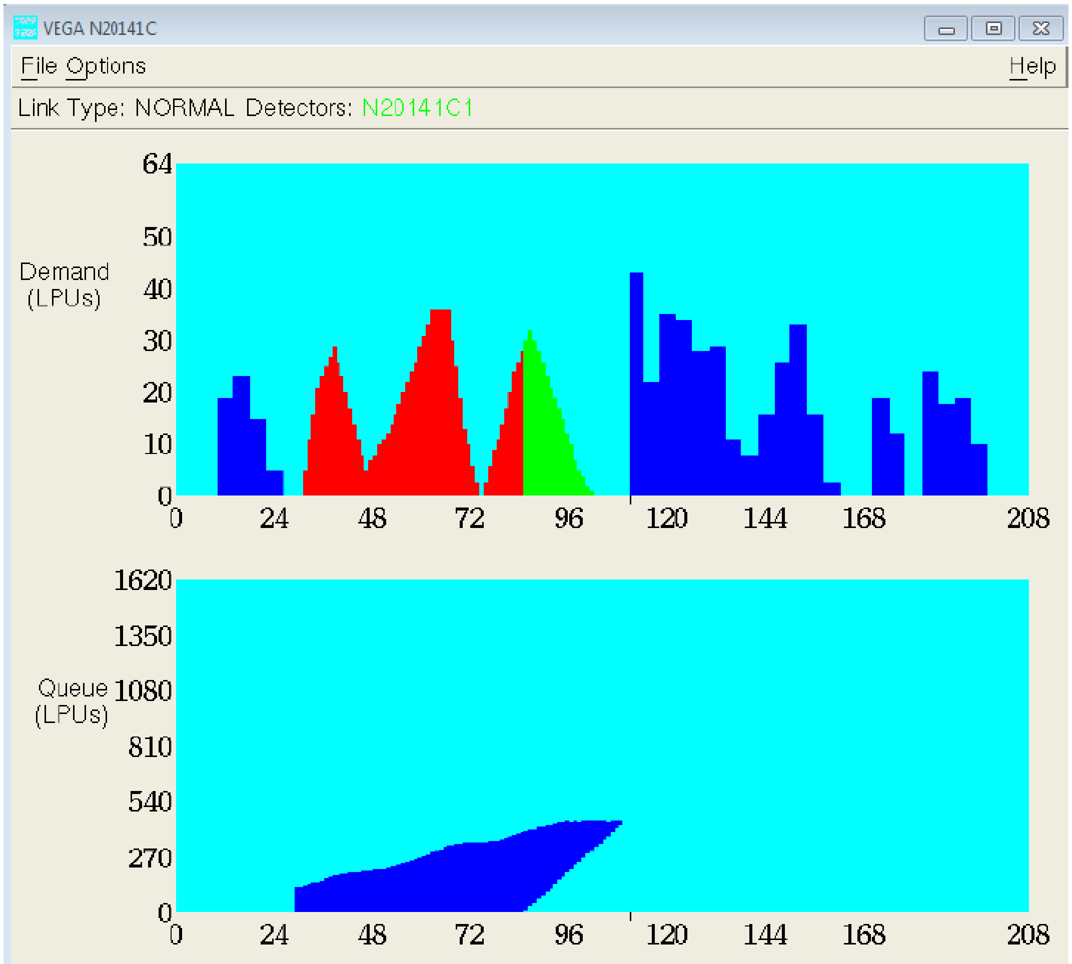


Figure 2.2-6. SCOOT Vega profiles for traffic demand and queue profiles representation

The traffic flow can be displayed in a form of a report that can provide information about the traffic volumes for every hour of every day which is clearly visible in the Figure 2.2-7.

WEEK D10331

Flow Report D10331 (vehicles per hour) **Report date** 21-Jan-15

Hr	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Hr	Wed	Thu	Fri	Sat	Sun	Mon	Tue
00	474	579	529	667	723	294	307	12	1249	1280	1604	872	771	689	697
01	264	343	394	442	512	120	144	13	1295	1340	1682	912	807	635	609
02	175	183	251	308	362	83	53	14	1506	1483	1971	1060	883	746	663
03	60	87	121	134	168	43	64	15	1671	1630	2104	1180	840	795	879**P**
04	78	81	88	126	98	66	62	16	1622	1596	1602	1168	829	742	1321**P**
05	137	136	206	149	119	110	94	17	1664	1586	1358	1093	971	826	1388**P**
06	334	289	299	231	196	222	184	18	2010	1893	1183	1180	876	933	1413**P**
07	646	632	607	475	328	332	311	19	1867	1465	1143	1149	919	918	1305**P**
08	837	971	984	689	626	544	524	20	1403	1177	1216	1152	834	804	1208**P**
09	1115	1132	1300	756	809	696	662	21	1203	1202	1126	1281	828	780	1164**P**
10	1126	1181	1224	842	785	634	631	22	1361	1226	1165	1226	683	655	1157**P**
11	1169	1091	1287	840	825	651	630	23	947	967	869	956	467	482	886**P**

Figure 2.2-7. SCOOT traffic flow report

The estimated percent of saturation and delay, derived by using Automatic SCOOT Traffic Information Database (ASTRID), are also available MOEs (Figure 2.2-8 and Figure 2.2-9). By using these MOEs, a user can keep track of the degree of congestion on specific portions or the entire network, changes during the time, interrelations with some special events occurring in the vicinity of the subject network etc. Also, level of service can be monitored in real time (but also historically), and appropriate actions can be taken if necessary.

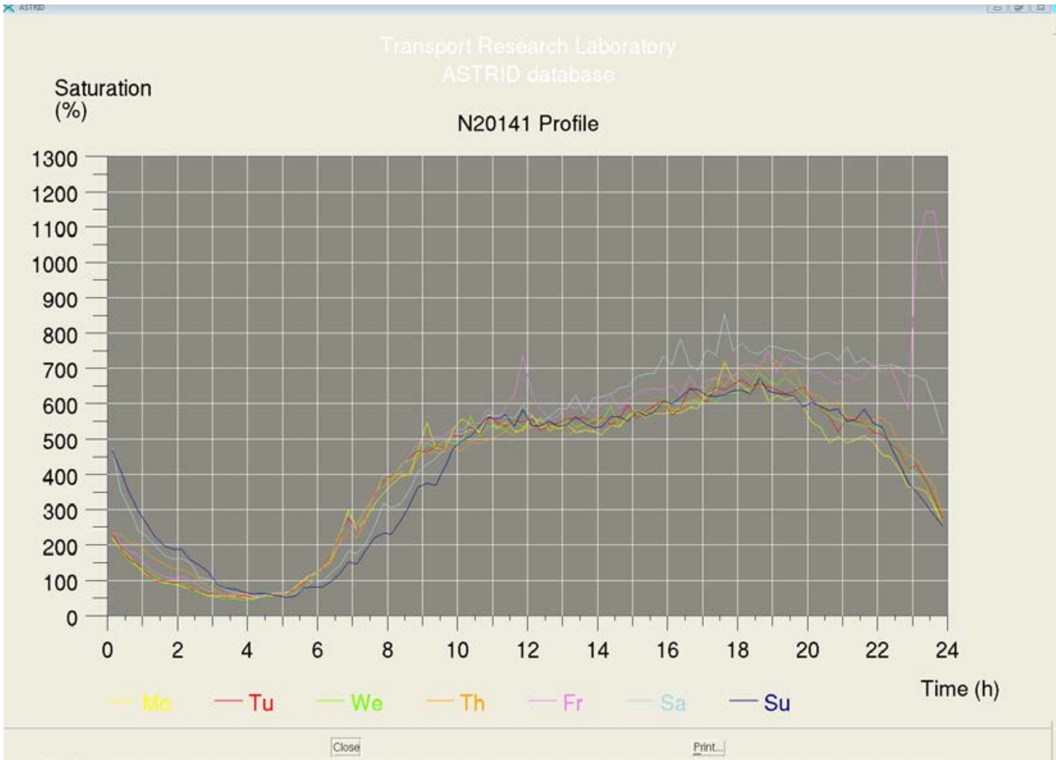


Figure 2.2-8. SCOOT-ASTRID estimated percentage of saturation

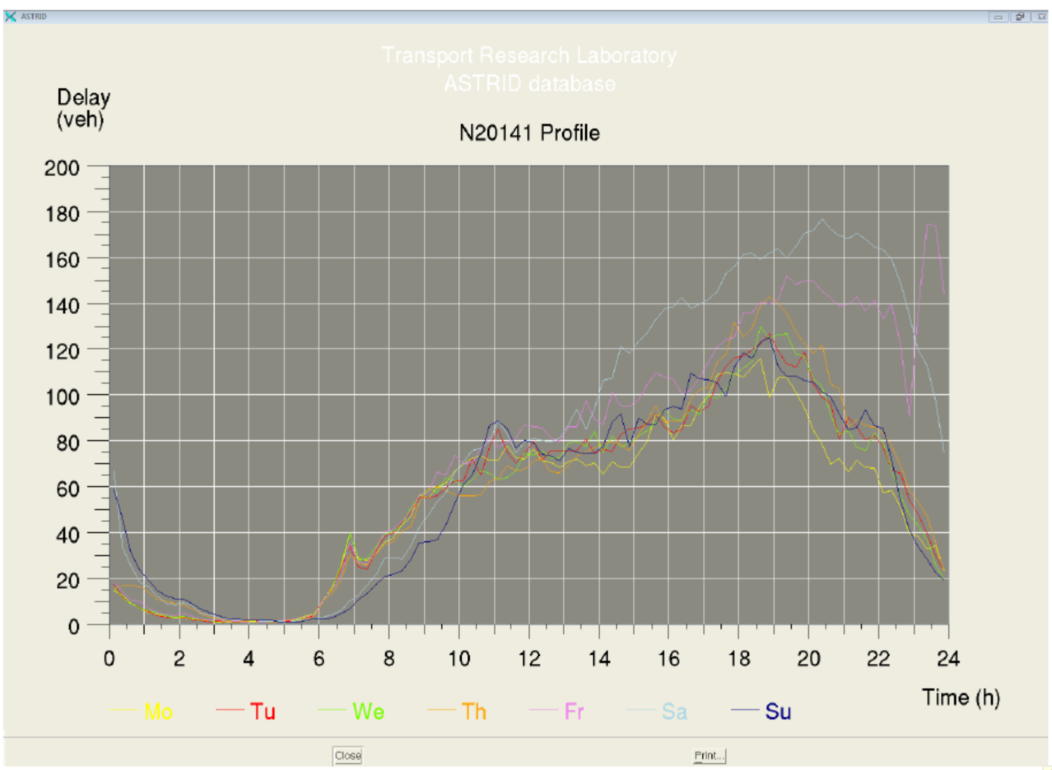


Figure 2.2-9. SCOOT-ASTRID estimated vehicle delay

2.2.4 ATMS.now

ATMS.now is an Advanced Traffic Management System developed by Trafficware. It is a modular, fully integrated platform for continuous real-time system monitoring, traffic and data management that can use TCP/IP or NTCIP protocols. The system has an ability to create various reports considering various categories given in the Table 2.2-1, shown below (taken from the ATMS.now User Manual).

By choosing Auto Reports user may schedule that the report is generated at the time scheduled and at the same time it will be e-mailed in .pdf format. Graphical interface for selection of the reports is presented by Figure 2.2-10.

Table 2.2-1. List of all reports in ATMS.now with brief explanations

Report Type	Description
Alpha UPS Alarm/Fault Report	**A report of the Alpha UPS Alarms and Faults**
Detected Speed	**A report of vehicle speed as detected in the field.**
Vehicle Classification	**A report of vehicle classification.**
Vehicle Travel Time Report	**A report of vehicle travel time between fences**
Vehicle Trigger Status Report	**A report of vehicle trigger status**
Daktronics CMS Sign Report	**A report of the messages downloaded to the CMS**
Compare Controllers Database Configurations	**A report to compare controllers database configurations**
Conflict/MMU Report	**A report of controllers conflict/mmu upload reports**
Controller Communication Errors	**A report of the controller communication errors. (On and Off)**
Controller Pattern	**A report of controller pattern changes.**
Controller Pattern Graph	**A Graph of controller pattern changes.**
Database Comparison	**Results of compared databases with the server.** *****Requires Upload/Compare Database Report**
Detector Failure Report	**A report of controller detector failure**

Table 2.2-1. List of all reports in ATMS.now with brief explanations - Continued

Detector Failure Report Threshold	**A report of controller Detector Failure**
Field Alarms	**A history of alarms generated by a controller.**
Flex Group Participation	**A list of each flex groups and their assignment.**
Incident Trigger Report	**A report of Incidents triggers.**
Inventory by Drop	**A list of controllers assigned to each drop.**
Inventory by Group	**A list of controllers assigned to each group.**
Inventory by IP Address	**A list of Controller and their associate IP Address.**
Inventory by Master	**A list of Controllers assigned to each Field Master.**
Inventory by Type	**A list of Controllers and their associated device type.**
Logins	**A history of user logins to a controller.**
Opticom(TM) Report	**A history of controllers Opticom(TM) log**
Ped Failure Report	**A report of controller ped failure**
Preemption	**Preempts activated by the controller.**
Real-Time Status	**The current real-time status of controllers.**
RealTime Congestion Data	**A report of Realtime Congestion Data**
Split History	**A report of controller Split History** ****Reports only the GREEN time of the Split**
Temperature Probe Report	**A report of controller temperature probe**
TR Master Pattern Change	**A report of TR Master Pattern change**
Transit Priority Report	**Transit Priority Report**
Weekly Road Tube Detector Output	**A report of controller Weekly Road Tube Detector Output**
Timing Sheet – Chronomax	**A chronomax timing sheet layout**

Table 2.2-1. List of all reports in ATMS.now with brief explanations - Continued

Timing Sheet - Condensed Layout	**A timing sheet layout with only essential information**
Timing Sheet - Field Operator Layout	**A timing sheet layout organized for controller data entry**
Timing Sheet - Field Operator Layout 2	**A timing sheet layout organized for controller data entry**
Incident Report	**A report of Accident/Construction Incidents.**
Trip Comparison Report	**A report of the Trip Comparison**
Logins	**A history of user logins to the server.**
Transactions	**A history of user downloads to the controller.**
AVL Location	**A history of vehicle locations based on GPS data.**
AVL Speed	**A history of vehicle speeds based on GPS data.**
External Detector Report	**External Detector Report--- A Vol/Occ/Speed Report from External Detectors (Wavetronix)**
LOS Average by Day	**A report of controllers LOS average by day**
LOS Hourly Day Graph	**A report of controller LOS hourly day Graph**
LOS Multi Day Graph	**A report of controller LOS Multi day Graph**
Turning Movement Volume/Occupancy Graphic	**Graphic of turning movements volume/occupancy per controller.**
Turning Movement Volume/Occupancy Report	**Report of turning movement volume/occupancy per controller.**
Volume In/Out per Day	**Chart that plots intersection throughput within a 24-hour period**
Volume In/Out per Multiple Days	**Chart that plots intersection throughput during a multi-day period**
Volume/Occupancy per Day Graph	**Graph of volume/occupancy per day.**
Volume/Occupancy per Lane Graphic	**Graphic of volume/occupancy per lane.**

Table 2.2-1. List of all reports in ATMS.now with brief explanations - Continued

Volume/Occupancy per Lane Report	**Report of volume/occupancy per lane.**
Volume/Occupancy per Multiple Days Graph	**Graph of volume/occupancy over multiple days.**
Volume/Occupancy Report	**Report showing either volume or occupancy per controller.**

Figure 2.2-10. Navigation through ATMS.now reports

Not all the ATMS.now reports are available in every agency due to various versions of ATMS.now, which facilitate different additional modules installed (Adaptive - SynchroGreen, BlueToad, Alpha Battery Backup – UPS, TSP.now – Transit vehicles Signal Priority, Wavetronix, High resolution Data, Fleet.now and others), different external equipment setup and connection.

ATMS.now has the possibility to extract, produce or to report various **Measures of Effectiveness (MOE's)** listed below:

1. Vehicle Volume
2. Vehicle Detector Occupancy
3. Vehicle Speed
4. Effective Cycle length
5. Green Time Distribution
6. Green-to-Cycle Ratio
7. Volume-to-Capacity Ratio and Level of Service (LOS)
8. Green Time Utilization (in Free mode)
9. Delay (caused by traffic signals only)
10. Time-Space Diagram
11. High resolution Flow and Phase Diagrams
    a. Purdue Coordination Diagrams
    b. Purdue Phase Termination Charts

Other measures available from ATMS.now are:

1. Vehicle Detector Failures
2. Travel Times
3. Number of Cycle Failures,
4. The Number of Cycle Faults
5. Number of Cycle Fault/failure-to–total Number of Cycles Ratio
6. The number of Max-outs
7. The number of Gap-outs
8. The number of Force-offs
9. Max-out/Gap-out/Force-off-to-total Number of Cycles Ratio
10. The Number of Phase Activations
11. The Number and the Duration of Pedestrian Detector Malfunctions
12. The Number and the Duration of Communication Failures
13. The Number and the Duration of Congestion Incidents
14. The Number of Controller Faults
15. The Number and Duration of the Coordination faults
16. The Number and the Duration of the Coordination Failures
17. The Number and the Duration of the Preemptions

2.2.4.1 Vehicle Volume, Vehicle Detector Occupancy, and Vehicle Speed

Data for vehicle volumes, detector occupancies and vehicle speed are available through several reports created by the ATMS.now. Those reports can use tables or graphs to show the relevant information about the aforementioned values. It is possible to show vehicle volumes and vehicle detector occupancies per lane (using graphic or the tables – Figure 2.2-11 and Figure 2.2-12), the same information per multiple days (Figure 2.2-13) and the same set of information (vehicle volumes, detector occupancies) with the addition of speed is possible to report using external detectors, for example Wavetronix (Figure 2.2-14).

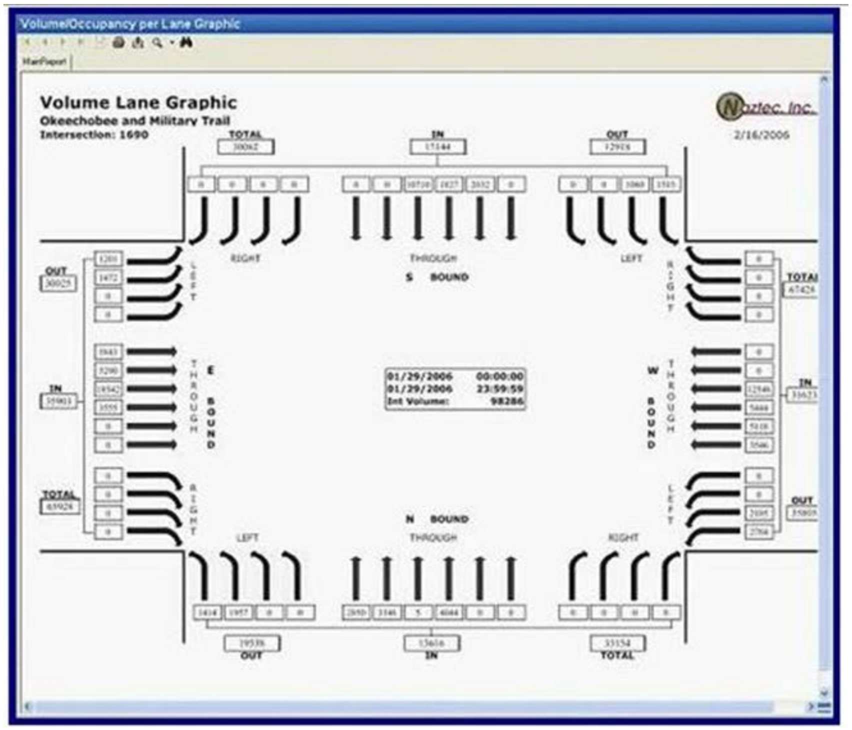


Figure 2.2-11. Volume/Occupancy per lane graphic

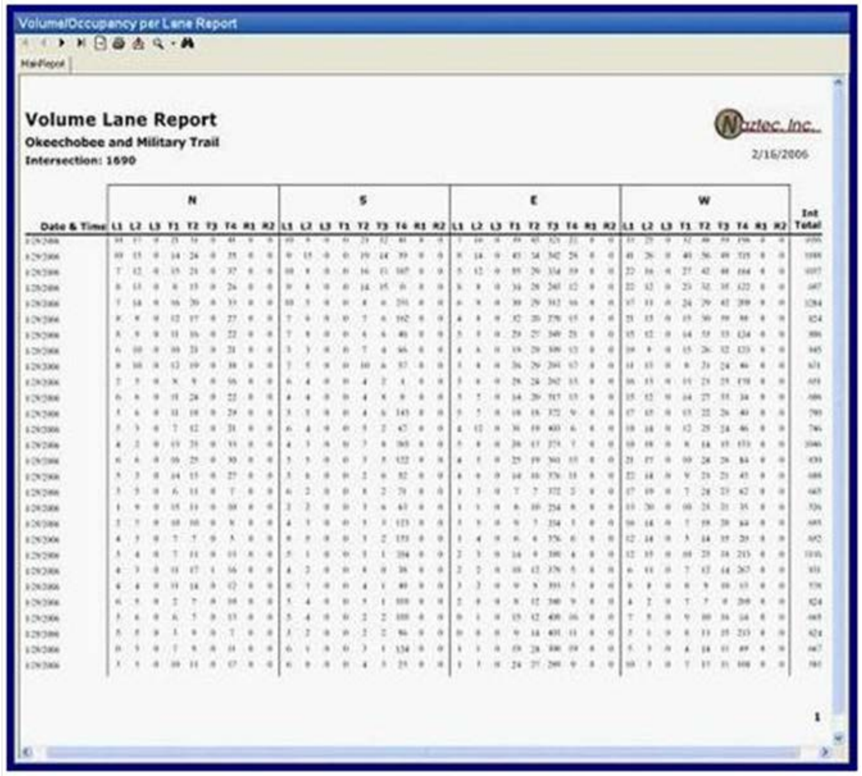


Figure 2.2-12. Volume per lane report

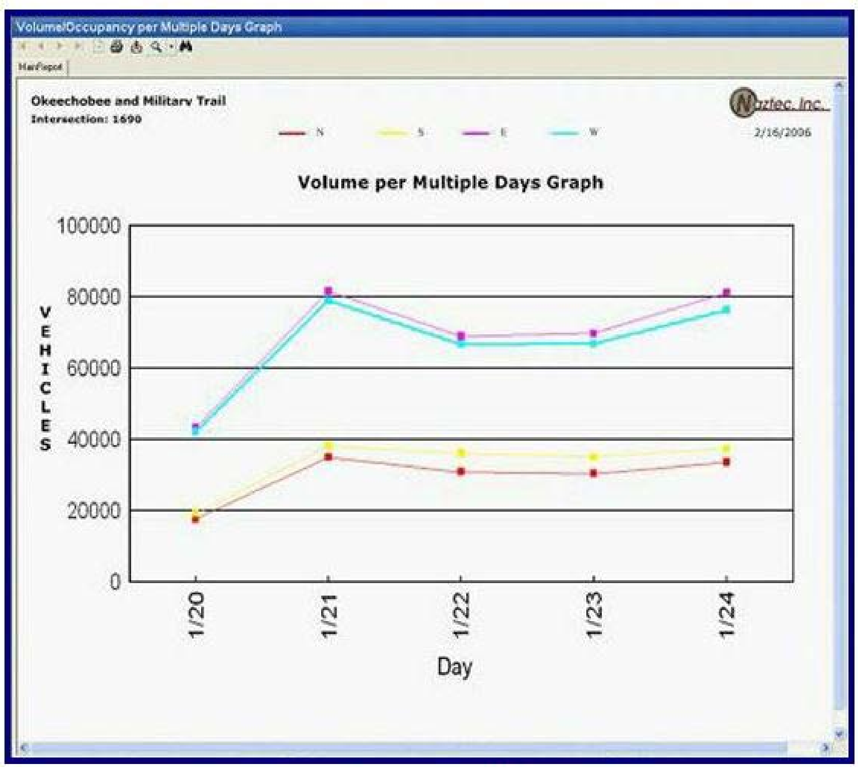


Figure 2.2-13. Volume/occupancy per multiple days graph

External Detector Report

4/13/2009

ID : 1775
Begin Date : 04/09/2009
End Date : 04/10/2009

Name : Demo Wavetronix
Begin Time : 0:00.00
End Time : 23:59.59

Date/Time	Lane 1 Vol	Lane 1 Occ	Lane 1 Spd	Lane 2 Vol	Lane 2 Occ	Lane 2 Spd	Lane 3 Vol	Lane 3 Occ	Lane 3 Spd	Lane 4 Vol	Lane 4 Occ	Lane 4 Spd	Lane 5 Vol	Lane 5 Occ	Lane 5 Spd	Lane 6 Vol	Lane 6 Occ	Lane 6 Spd
4/9/2009 12:00:00AM	100	17	51	100	17	50	100	17	50	101	18	50	100	17	50	100	17	50
4/9/2009 12:05:00AM	100	17	51	100	17	50	100	17	50	100	17	50	101	17	50	100	17	50
4/9/2009 12:10:00AM	101	17	51	100	17	50	100	17	50	100	17	50	100	17	50	101	17	50
4/9/2009 12:15:00AM	100	17	51	101	17	50	101	18	50	100	17	50	100	17	50	100	17	50
4/9/2009 12:20:00AM	100	17	51	100	17	50	100	17	50	101	17	50	100	17	50	100	17	50
4/9/2009 12:25:00AM	100	17	51	100	17	50	100	17	50	100	17	50	101	17	50	101	17	50
4/9/2009 12:30:00AM	101	17	51	101	17	50	100	17	50	100	17	50	100	17	50	100	17	50
4/9/2009 12:35:00AM	100	17	51	100	17	50	101	17	50	101	17	50	100	17	50	100	17	50
4/9/2009 12:40:00AM	100	17	51	100	17	50	100	17	50	100	17	50	101	17	50	101	17	50
4/9/2009 12:45:00AM	101	17	51	101	17	50	101	17	50	100	17	50	100	17	50	100	17	50
4/9/2009 12:50:00AM	100	18	51	100	17	50	100	17	50	101	17	50	100	17	50	101	17	50
4/9/2009 12:55:00AM	100	18	51	100	17	50	100	17	50	100	17	50	100	17	50	100	17	50
4/9/2009 1:00:00AM	101	17	50	100	18	50	100	17	50	100	17	50	100	17	50	100	17	50
4/9/2009 1:05:00AM	100	17	51	100	18	50	100	17	50	100	17	50	100	17	50	100	17	50
4/9/2009 1:10:00AM	100	17	51	100	18	50	100	17	50	100	17	50	100	17	50	100	17	50
4/9/2009 1:15:00AM	100	17	51	101	18	50	100	18	50	100	17	50	100	17	50	100	17	50
4/9/2009 1:20:00AM	100	17	51	100	17	50	100	18	50	100	17	50	100	17	50	100	17	50
4/9/2009 1:25:00AM	100	17	51	100	17	50	100	17	50	100	17	50	100	17	50	100	17	50
4/9/2009 1:30:00AM	100	17	51	100	17	50	101	17	50	100	18	50	100	17	50	100	17	50
4/9/2009 1:35:00AM	100	17	51	100	17	50	100	17	50	100	18	50	100	17	50	100	17	50
4/9/2009 1:40:00AM	100	17	51	100	17	50	100	17	50	100	17	50	100	17	50	100	17	50
4/9/2009 1:45:00AM	100	17	51	100	17	50	100	17	50	101	17	50	100	18	50	100	17	50
4/9/2009 1:50:00AM	100	17	51	100	17	50	100	17	50	100	17	50	100	18	50	100	17	50
4/9/2009 1:55:00AM	100	17	51	100	17	50	100	17	50	100	17	50	100	17	50	100	18	50
4/9/2009 2:00:00AM	100	17	51	100	17	50	100	17	50	100	17	50	101	17	50	100	18	50
4/9/2009 2:05:00AM	100	17	51	100	17	50	100	17	50	100	17	50	100	17	50	100	18	50
4/9/2009 2:10:00AM	100	17	51	100	17	50	100	17	50	100	17	50	100	17	50	100	17	50
4/9/2009 2:15:00AM	100	18	51	100	17	50	100	17	50	100	17	50	100	17	50	101	17	50

Date/Time	Lane 7 Vol	Lane 7 Occ	Lane 7 Spd	Lane 8 Vol	Lane 8 Occ	Lane 8 Spd	Lane 9 Vol	Lane 9 Occ	Lane 9 Spd	Lane 10 Vol	Lane 10 Occ	Lane 10 Spd
4/9/2009 12:00:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 12:05:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 12:10:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 12:15:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 12:20:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 12:25:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 12:30:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 12:35:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 12:40:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 12:45:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 12:50:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 12:55:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:00:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:05:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:10:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:15:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:20:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:25:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:30:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:35:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:40:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:45:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:50:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 1:55:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 2:00:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 2:05:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 2:10:00AM	0	0	0	0	0	0	0	0	0	0	0	0
4/9/2009 2:15:00AM	0	0	0	0	0	0	0	0	0	0	0	0

1

Figure 2.2-14. Wavetronix radar counter report

2.2.4.2 Effective Cycle Length, Green Time Distribution, and Green-To-Cycle Ratio

One of the most frequently used reports from ATMS.now is Split History Report (Figure 2.2-15). This report enables the operator to get information about active pattern, cycle length and the duration of every signal phase per cycle per intersection. By using this report, it is possible to calculate the indirect measures like green time distribution, by comparing the green times for every signal phase and green-to-cycle ratio by comparing the green times with cycle lengths. Comparison between programmed and actual green times per phase can also be performed by using the Split History Report.

Split History

6/6/2016

ID: 101

Name: PALMETTO PARK ROAD & NW 9 AVE (CMU)

Begin Date/Time: 04/23/2016 12:00 AM **End Date/Time:** 04/30/2016 11:59 PM

DateTime		Pattern	Cycle	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10	SP11	SP12	SP13	SP14	SP15	SP16
4/23/2016	00:00:00 AM	48	58	14	24	0	20	0	38	0	20	0	0	0	0	0	0	0	0
4/23/2016	00:01:00 AM	48	39	13	26	0	0	0	39	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:02:00 AM	48	38	13	25	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:02:00 AM	48	37	13	24	0	0	0	37	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:03:00 AM	48	38	14	24	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:04:00 AM	48	38	14	24	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:04:00 AM	48	26	12	14	0	0	13	13	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:05:00 AM	48	44	1	23	0	20	0	24	0	20	0	0	0	0	0	0	0	0
4/23/2016	00:05:00 AM	48	38	14	24	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:06:00 AM	48	40	14	26	0	0	0	40	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:07:00 AM	48	39	14	25	0	0	0	39	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:07:00 AM	48	38	13	25	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:08:00 AM	48	38	13	25	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:09:00 AM	48	38	13	25	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:09:00 AM	48	42	14	28	0	0	0	42	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:10:00 AM	48	38	14	24	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:11:00 AM	48	38	13	25	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:11:00 AM	48	39	13	26	0	0	0	39	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:12:00 AM	48	37	13	24	0	0	0	37	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:12:00 AM	48	38	14	24	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:13:00 AM	48	38	14	24	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:14:00 AM	48	58	13	25	0	20	0	38	0	20	0	0	0	0	0	0	0	0
4/23/2016	00:15:00 AM	48	38	13	25	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:15:00 AM	48	37	13	24	0	0	0	37	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:16:00 AM	48	38	14	24	0	0	0	38	0	0	0	0	0	0	0	0	0	0
4/23/2016	00:17:00 AM	48	38	14	24	0	0	0	38	0	0	0	0	0	0	0	0	0	0

Figure 2.2-15. Split history report

2.2.4.3 Volume-to-Capacity Ratio and Level of Service

In the report module of ATMS.now, the Level of Service (LOS) reports can be created. Namely, those are Real-time Congestion Data, or reports for congestion levels using LOS values (Figure 2.2-16, Figure 2.2-17 to Figure 2.2-18). For each approach of the intersection, two congestion level thresholds (medium and high) can be assigned. Values below the medium threshold gets classified as low, the values between medium and high threshold are classified as medium, and values higher than high threshold will be classified as high congestion. The operator can specify Volume, Occupancy, or Speed to measure congestion, and it is assumed that one detector per each lane will be installed.

If the congestion is being calculated by *Occupancy*, the values for medium and high will be a percent value between 1 and 100 that represents sum of the occupancy detectors actuations for the collection period. If the congestion level is being calculated by using *Volume*, the crucial values will be a number of vehicles for each threshold for the entire collection period. If calculation of the congestion is being realized by using *Speed*, the congestion will report based on the most recently reported speed value for that direction. ATMS.now allows the user to complete values for all three aforementioned methods even though it will only utilize one selected method for each approach. This is useful for minimizing the effort and time required to change from one method to another.

The reports show Volume-to-Capacity ratio (V/C) in numerical values between 0 and 1. If the intersection is oversaturated the value of the V/C would be presented as > 1.00 and the exact value will not be shown.

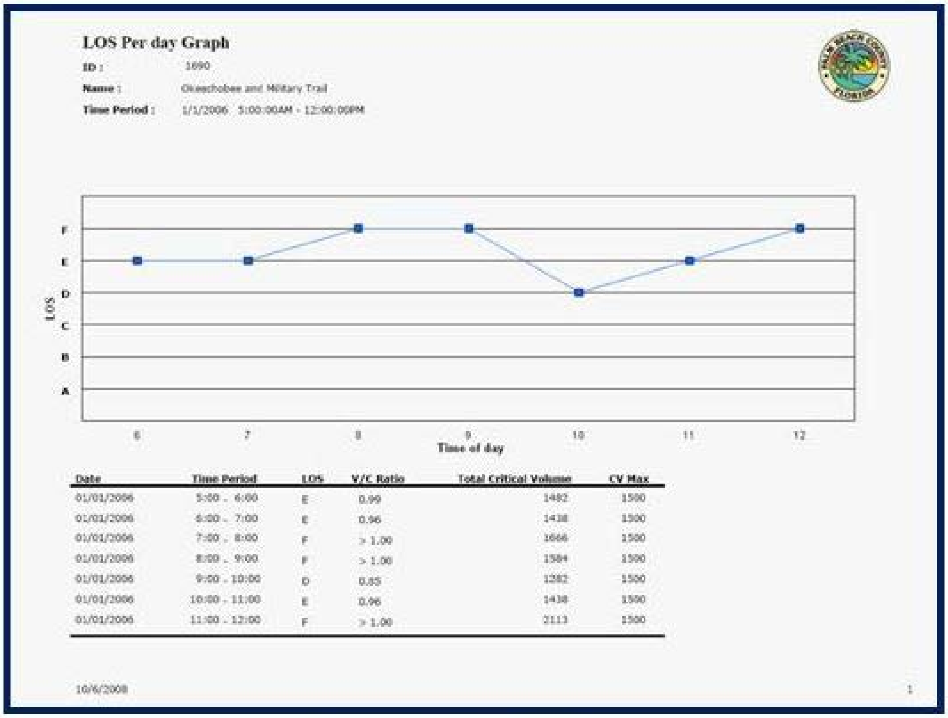
Intersection LOS Average

Time Period : 1/1/2006 12:00:00PM - 3:00:00PM

Movements	CV Max
2	1600
3	1500
4	1450

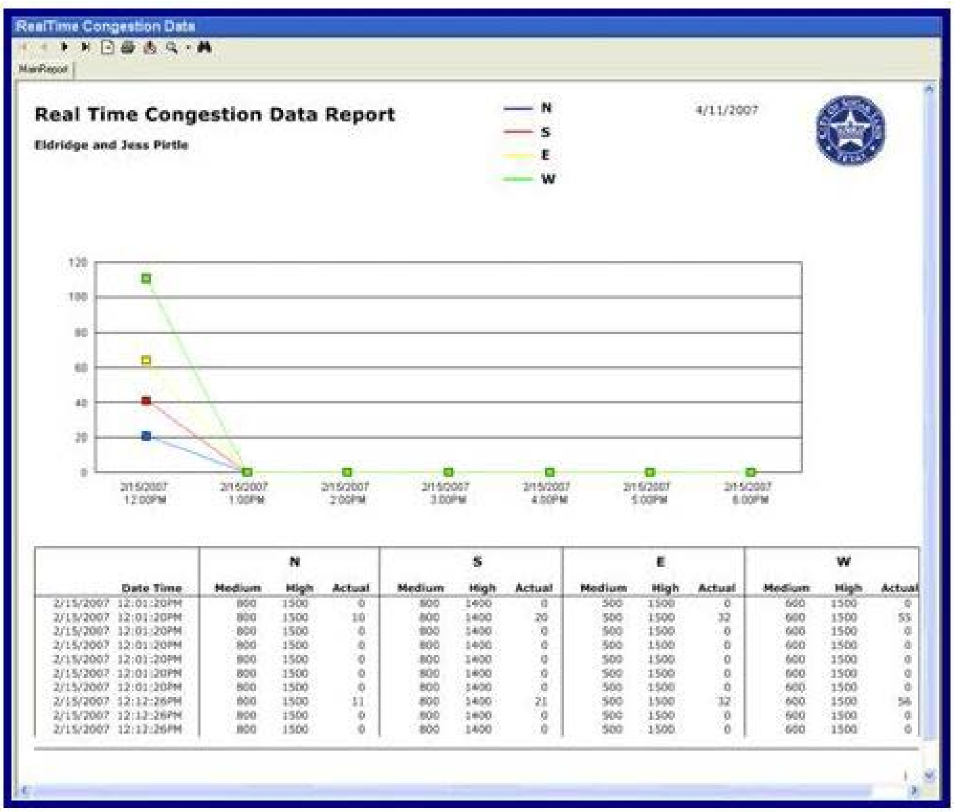
ID	Name	LOS	V/C Ratio	Total Critical Volume	CV Max
1665	Okeechobee and Fl Turnpike	D	0.903	1309	1450
1670	Okeechobee and Meridian	F	> 1.00	1502	1450
1680	Century Corners and Haverhill Rd		No Movements		
1685	Okeechobee and Haverhill	F	> 1.00	1810	1450
1690	Okeechobee and Military Trail	F	> 1.00	3219	1500
1695	Okeechobee and Biscayne	F	> 1.00	1781	1450
1705	Okeechobee and Palm Beach Lakes	A	0.449	651	1450
1710	Okeechobee and Spencer Drive	F	> 1.00	3676	1450
1715	Okeechobee and Loxahatchee Dr.	F	> 1.00	2159	1450
1720	Okeechobee and Congress Ave.	A	0	0	1450
1725	Okeechobee and Church Street	F	> 1.00	3749	1450
1730	Okeechobee and I-95 West	C	0.732	1098	1500
1735	Okeechobee and I-95 East	F	> 1.00	2066	1500

Figure 2.2-16. Intersection average level of service report



Date	Time Period	LOS	V/C Ratio	Total Critical Volume	CV Max
01/01/2006	5:00 - 6:00	E	0.99	1482	1500
01/01/2006	6:00 - 7:00	E	0.96	1438	1500
01/01/2006	7:00 - 8:00	F	> 1.00	1666	1500
01/01/2006	8:00 - 9:00	F	> 1.00	1584	1500
01/01/2006	9:00 - 10:00	D	0.85	1282	1500
01/01/2006	10:00 - 11:00	E	0.96	1438	1500
01/01/2006	11:00 - 12:00	F	> 1.00	2113	1500

Figure 2.2-17. Intersection average level of service per day graph



	N			S			E			W		
Date Time	Medium	High	Actual	Medium	High	Actual	Medium	High	Actual	Medium	High	Actual
2/15/2007 12:01:20PM	800	1500	0	800	1400	0	500	1500	0	600	1500	0
2/15/2007 12:01:20PM	800	1500	10	800	1400	20	500	1500	32	600	1500	55
2/15/2007 12:01:20PM	800	1500	0	800	1400	0	500	1500	0	600	1500	0
2/15/2007 12:01:20PM	800	1500	0	800	1400	0	500	1500	0	600	1500	0
2/15/2007 12:01:20PM	800	1500	0	800	1400	0	500	1500	0	600	1500	0
2/15/2007 12:01:20PM	800	1500	0	800	1400	0	500	1500	0	600	1500	0
2/15/2007 12:01:20PM	800	1500	0	800	1400	0	500	1500	0	600	1500	0
2/15/2007 12:12:26PM	800	1500	11	800	1400	21	500	1500	32	600	1500	56
2/15/2007 12:12:26PM	800	1500	0	800	1400	0	500	1500	0	600	1500	0
2/15/2007 12:12:26PM	800	1500	0	800	1400	0	500	1500	0	600	1500	0

Figure 2.2-18. Real-time congestion data report

2.2.4.4 Green Time Utilization

As of ATMS.now version 1.5.4., the Split Monitor has the possibility to track the green time utilization only while the FREE mode is active.

2.2.4.5 Time-Space Diagram and Delay

ATMS.now has the possibility of creating the Time-Space Diagrams which allow the user to plot real-time signal data for multiple intersections that are in coordination. Such diagrams can be used to improve traffic signal coordination. The *Time Space* utility provides a bi-directional Green Band calculation and Delay-Flow calculations. The Delay-Flow band is created to illustrate the delay time of the vehicles in the platoon that did not stay within the Green Band, instead they were stopped or delayed in the coordination operation. All calculations are automatically updated in real-time at a user-defined rate of 15, 30, 45, and 60 seconds intervals, or can be previously set to calculate from historical values that have been saved on the server.

2.2.4.6 High Resolution Flow and Phase Diagrams

ATMS.now has multiple additional modules that enable new functions inside this system, and one particularly important from a performance measures standpoint is High Resolution Data module. Those modules enable logging of the traffic data from the high resolution traffic controllers in 0.1 second frequency. Some of the logged data are detector actuations, phase states, split changes and others. The module has the capability of creating several, user-customized, reports like Purdue Coordination Diagrams, Phase Termination Charts, etc.

2.2.4.7 Vehicle Detector Failures

The number of vehicle detector failures is available through Controller Detector Failure Report displayed in the Figure 2.2-19. This information, alongside with the duration of the vehicle detector failure can also be extracted from Field Alarm Report (Figure 2.2-20) by counting the number of occurrences for detector failure and calculation of the duration by subtracting the time when the failure was no longer present from the time when the detector failure was noted.

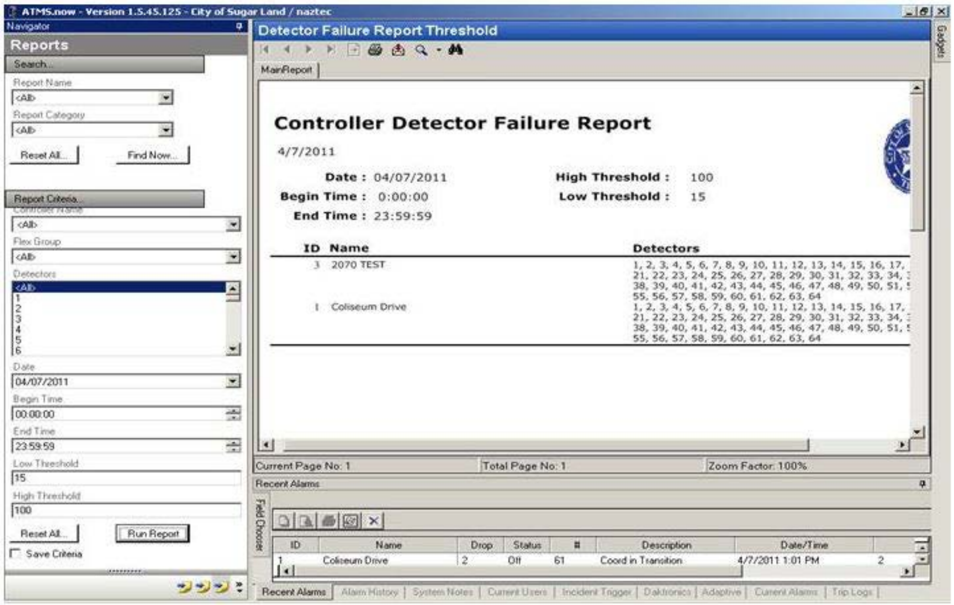


Figure 2.2-19. Controller detector failure report

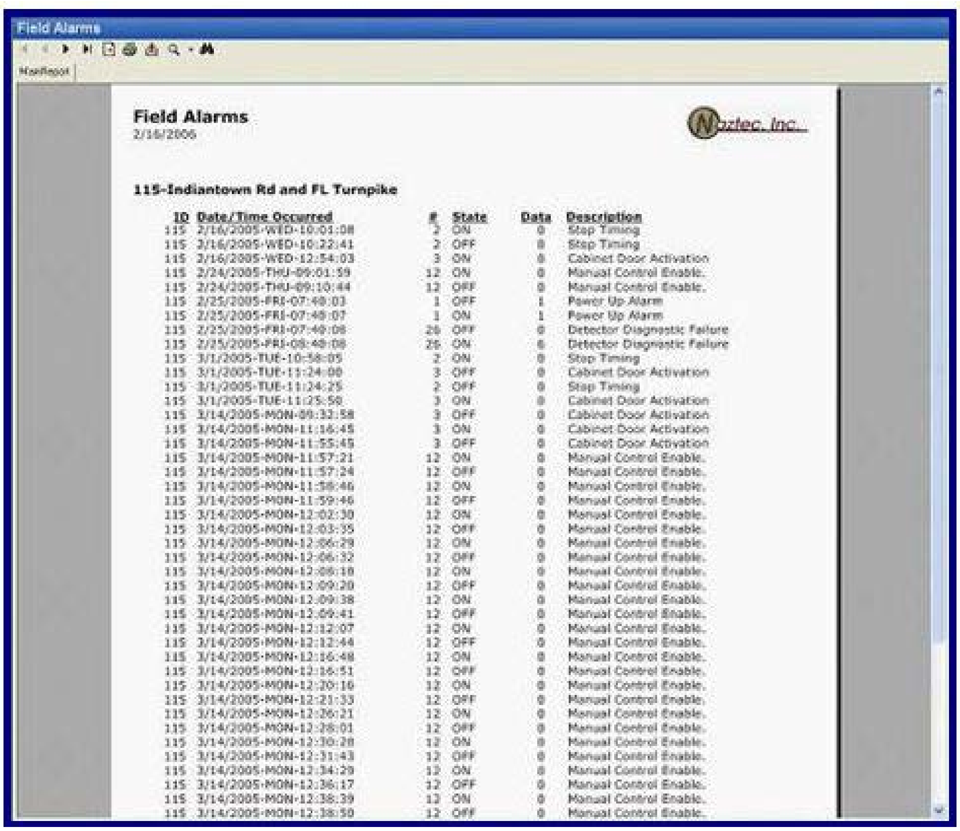


Figure 2.2-20. Field alarms report

2.2.4.8 Travel Time

If the Trip Comparison Report (Figure 2.2-21) shows the data, it is possible to use it to extract travel times and speed on covered road section. Comparison of travel times and speeds on the same sections during the operation of signals can give valuable insight into the quality of signal timings used.

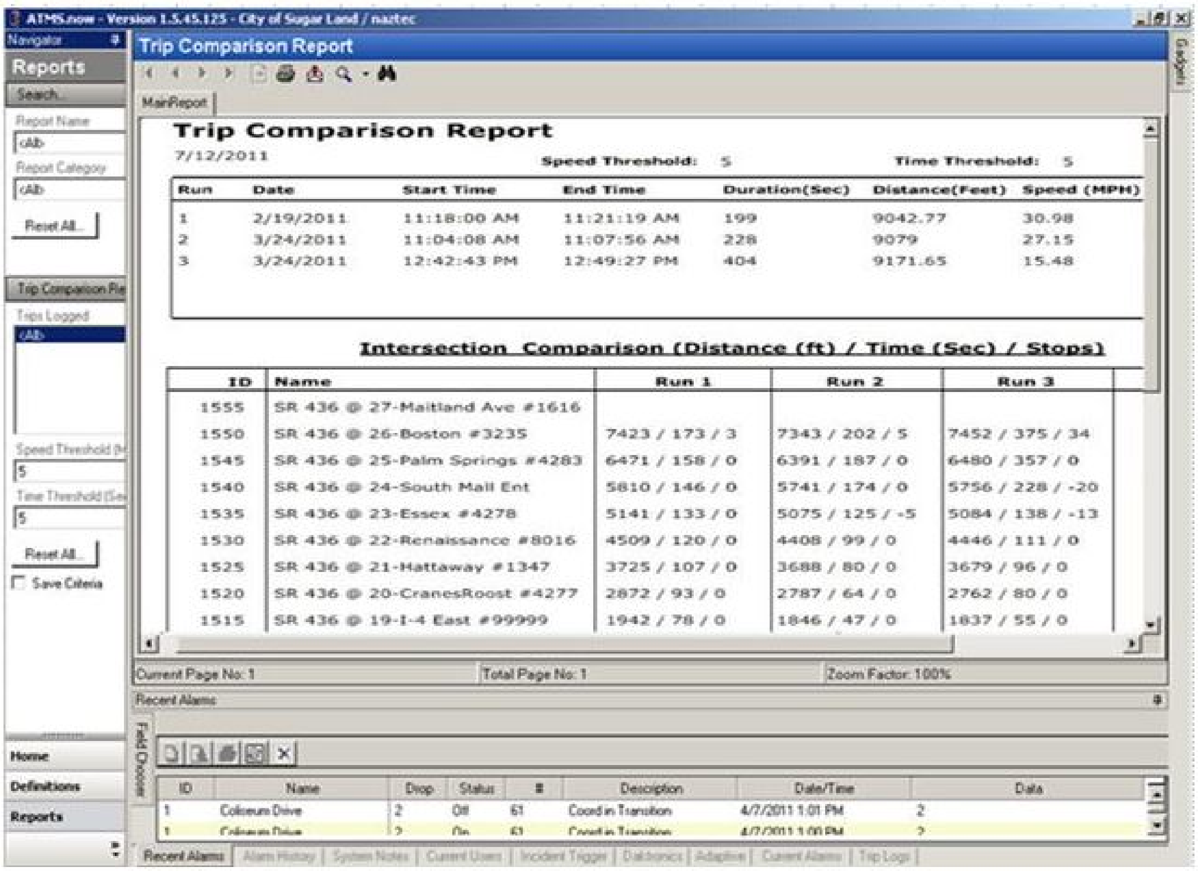


Figure 2.2-21. Comparison report

2.2.4.9 Traffic Signal Operations Performance Indicators

Following traffic signal operations indicators can be derived from Split History report by counting the number of occurrences of different events and calculation of the duration of the individual events:

- Number of cycle failures
- Number of cycle faults
- Number of cycle fault/failure-to–total number of cycles batio
- Number of max-outs
- Number of gap-outs
- Number of force-offs
- Max-out/gap-out/force-off-to-total number of cycles ratio
- Number of phase activations

By using these indicators, a selected corridor or zone can be monitored more effectively. It is very important to explain the meaning of cycle failures and faults in ATMS.now. The cycle fault is an event which indicates that a serviceable call has not been serviced in approximately two cycle times and that coordination was active at that time. The cycle failure represents the same event as the cycle fault but with the difference that coordination was not active at the time.

The number of Max-outs, Gap-outs, and Force-offs is given at the end of the Split History report. The values of those indicators can as well be compared to total number of cycles in an observing period.

2.2.4.10 The Field Alarm Report Performance Indicators

The following performance indicators can be extracted from Field Alarm report:

- Number and the duration of pedestrian detector malfunctions
- Number and the duration of communication failures
- Number and the duration of congestion incidents
- Number of controller faults
- Number and duration of the coordination faults
- Number and duration of the coordination failures
- Number and duration of preemptions
- Number and duration of the service interventions in terms of opening the cabinet doors

The Field Alarm report shows a large number of events noted by ATMS.now. After filtering, counting, and comparison of the moments between when an event started and finished, the number and the duration of the events can be defined. That way, it is possible to track reliability, performance, and frequency of certain events of interest.

2.2.5 KITS

The Kimley-Horn Integrated Transportation System (KITS) is a traffic control system developed by Kimley-Horn and Associates. KITS enables continuous monitoring of traffic signal operations and traffic conditions on a second-by-second basis. KITS allows the operators and traffic engineers the use of modern technology during the development, implementation, selection of signal timing plans, and monitoring. Besides the operations segment, the maintenance aspect is improved by immediate notification of the responsible staff in case of signal malfunction. The system enables the editing of signal controller databases with download, upload, and import functions. The history reports menu allows the operator to view, filter, and print historical data about system events, user activities, system detector data, count detector data, link data, controller communications statistics, and preemption logs.

Performance measures and their components registered by KITS:

1. Vehicle Volume
2. Vehicle Detector Occupancy
3. Vehicle Speed
4. Malfunctioning Detectors
5. Pedestrian Volume

6. Number of Stops
7. Queue Lengths
8. Delays
9. Effective Cycle Length
10. Green-to-Cycle Ratio
11. Green Time Distribution
12. Volume to Capacity Ratio
13. Level of Service
14. Time-Space Diagram

In terms of maintenance and reliability, the following measures can be collected:

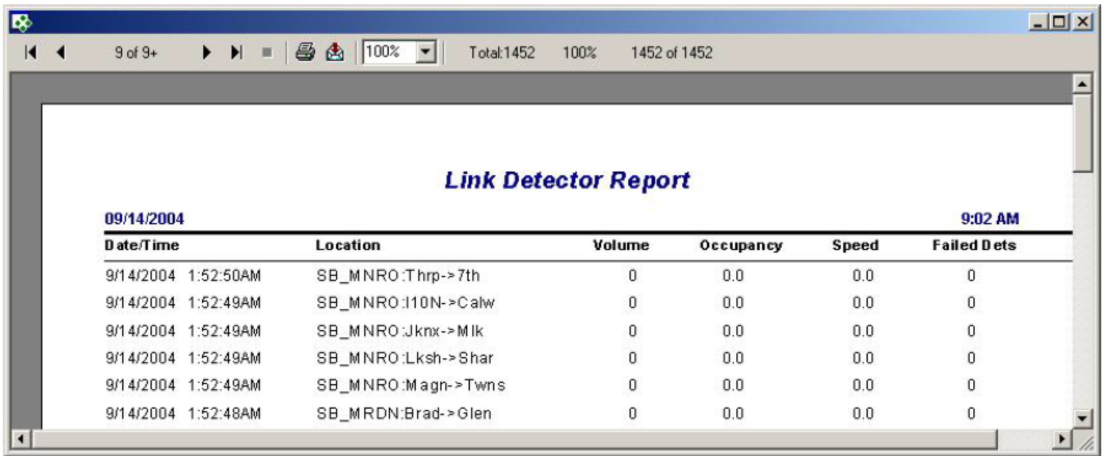
1. Status Events Occurrence (System Status Report)
2. Incident Management (Event Log Report and Communications Statistics Report)
3. Equipment Maintenance
4. Communication Failures

Other:

1. Alarms when turning movement count change exceeds preset threshold.
2. TRSP Improvement Factor **-** shows the minimum improvement percentage (between 1 and 100) between the current timing plan and the optimal traffic responsive selected timing plan. This improvement factor must be met prior to implementing a new plan.
3. Scheduling Failure Threshold defines the percentage (between 1 and 100) of non-responding intersections that will cause a section's scheduled plan to be overridden by standby. The default value is 30%.
4. Scheduling Failure Threshold defines the percentage (between 1 and 100) of non-responding intersections that will cause a section's scheduled signal plan to be overridden by a standby signal plan. Default 25%

2.2.5.1 Vehicle Volume Speed and Detector Occupancy

Link Detector Reports and System Detector Reports (Figure 2.2-22 and Figure 2.2-23), can show the date, time when the data was generated and intersection that contains that detector, failed detectors or their status, smoothed traffic volume, detector occupancy (percentage of the time detector was occupied by the vehicles) and smoothed speed (average vehicle speed over the detector). The average vehicle speed over the detector can be also obtained by using Speed Trap History Report shown in the Figure 2.2-24.

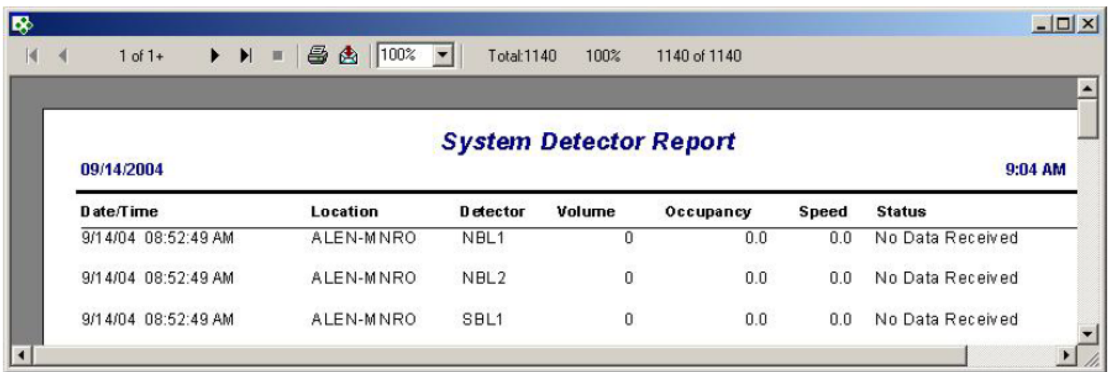


Link Detector Report

09/14/2004 9:02 AM

Date/Time	Location	Volume	Occupancy	Speed	Failed Dets
9/14/2004 1:52:50AM	SB_MNRO:Thrp->7th	0	0.0	0.0	0
9/14/2004 1:52:49AM	SB_MNRO:I10N->Calw	0	0.0	0.0	0
9/14/2004 1:52:49AM	SB_MNRO:Jknx->Mlk	0	0.0	0.0	0
9/14/2004 1:52:49AM	SB_MNRO:Lksh->Shar	0	0.0	0.0	0
9/14/2004 1:52:49AM	SB_MNRO:Magn->Twns	0	0.0	0.0	0
9/14/2004 1:52:48AM	SB_MRDN:Brad->Glen	0	0.0	0.0	0

Figure 2.2-22. Link detector report

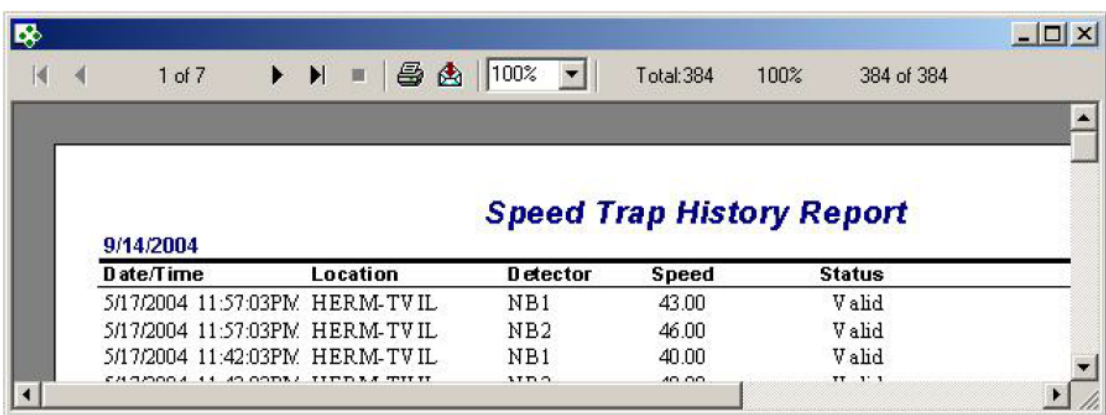


System Detector Report

09/14/2004 9:04 AM

Date/Time	Location	Detector	Volume	Occupancy	Speed	Status
9/14/04 08:52:49 AM	ALEN-MNRO	NBL1	0	0.0	0.0	No Data Received
9/14/04 08:52:49 AM	ALEN-MNRO	NBL2	0	0.0	0.0	No Data Received
9/14/04 08:52:49 AM	ALEN-MNRO	SBL1	0	0.0	0.0	No Data Received

Figure 2.2-23. System detector report



Speed Trap History Report

9/14/2004

Date/Time	Location	Detector	Speed	Status
5/17/2004 11:57:03PM	HERM-TVIL	NB1	43.00	Valid
5/17/2004 11:57:03PM	HERM-TVIL	NB2	46.00	Valid
5/17/2004 11:42:03PM	HERM-TVIL	NB1	40.00	Valid

Figure 2.2-24. Speed trap history report

2.2.5.2 Pedestrian Volume

Number of activations of pedestrian detectors can be obtained (example in Figure 2.2-25), however pedestrian volume cannot be measured exactly due to the fact that during the single detector activation, more than one person can cross the crosswalk.

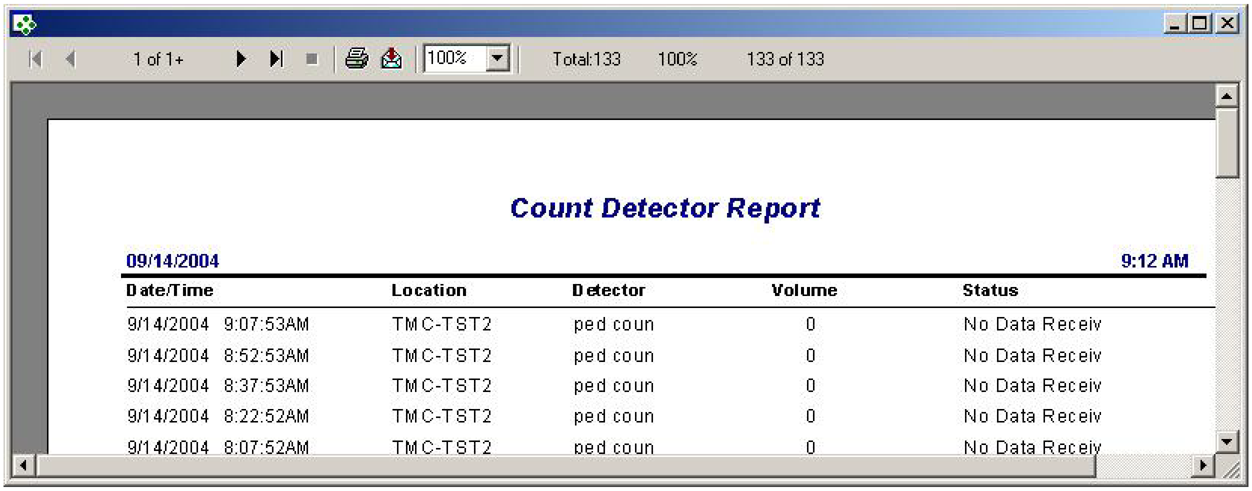


Figure 2.2-25. Count detector report

2.2.5.3 Time-Space Diagram

One of the corridor performance measures that KITS is able to show is Time-space diagram (Figure 2.2-26) presented by Real-time coordination logic display. That enables the monitoring and controlling of the progression.

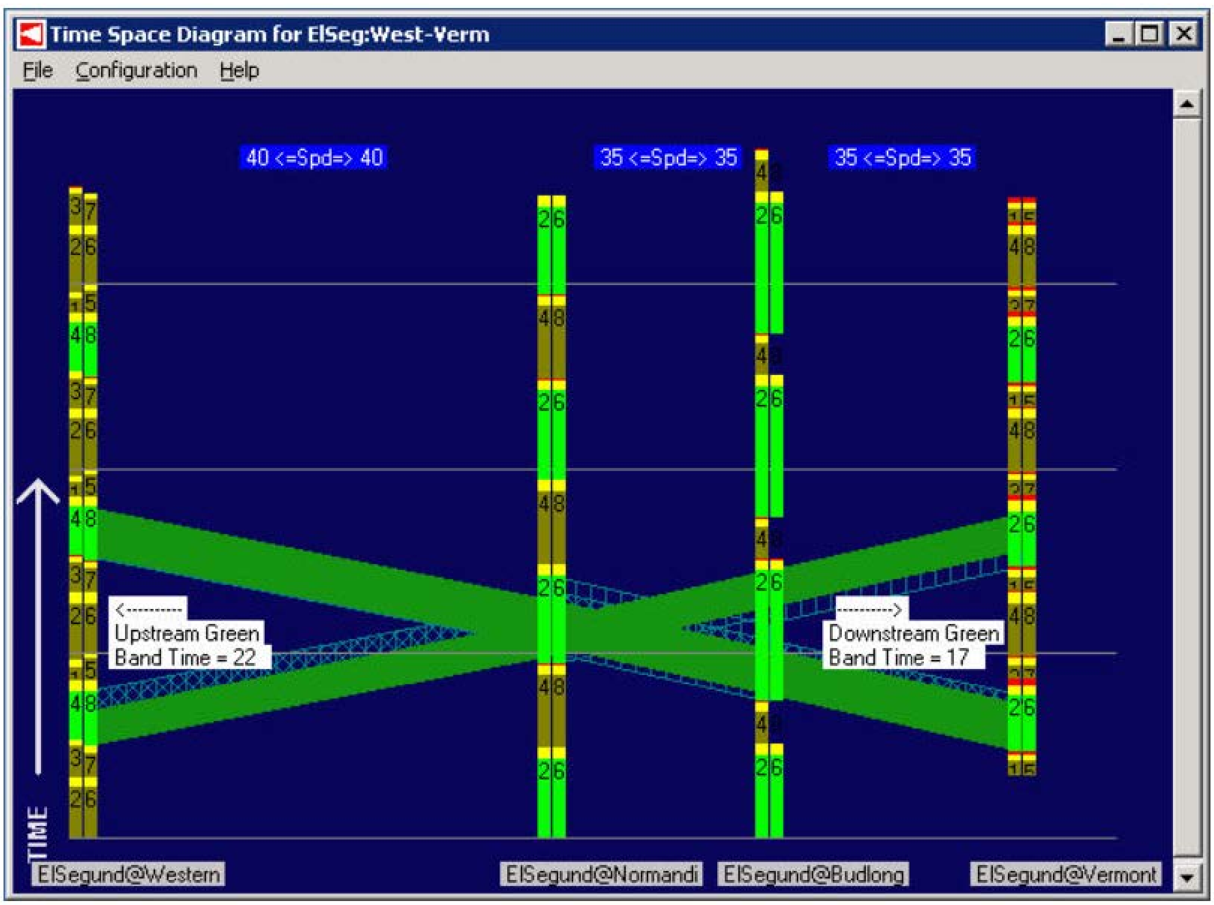


Figure 2.2-26. Time-space diagram in KITS

2.2.5.4 Green Time Distribution

By using a KITS Cycle Summary Report (Figure 2.2-27) it is possible to monitor the durations of all splits sorted by phases. In that way, the history of green time distributions can be checked for each intersection throughout the system.

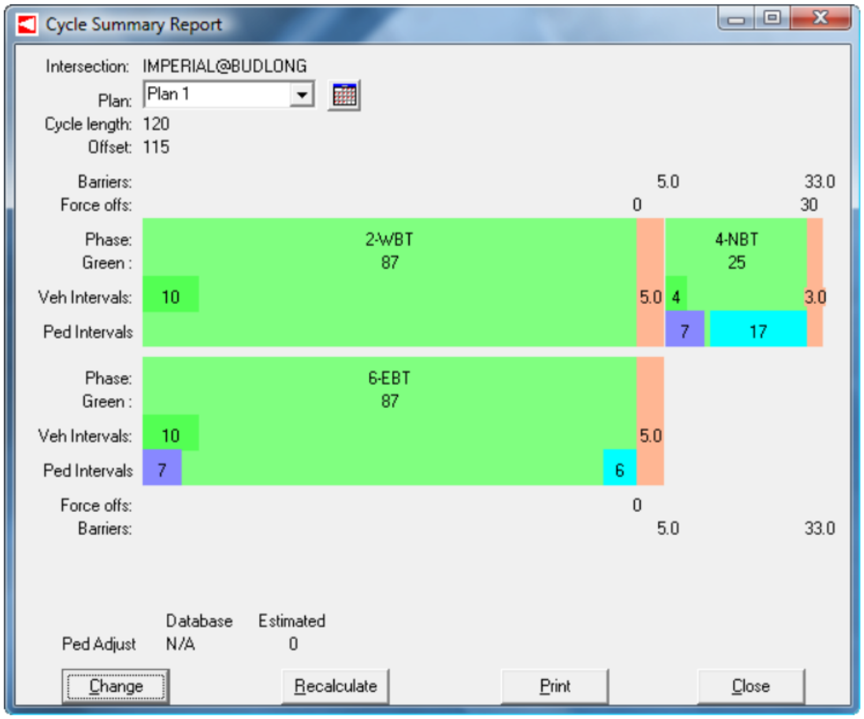


Figure 2.2-27. KITS cycle summary report

2.2.5.5 Volume-To-Capacity Ratio and Level of Service

The Level of Service (LOS) Report displays the overview of the following data: date and time when the data were collected, name of the intersection, LOS for all four intersection approaches and the Volume over Capacity ratio. Extent of the area that should be considered in the report can be changed, so instead of the single intersection, a user can select either a certain subnetwork of intersections or the entire system (Figure 2.2-28).

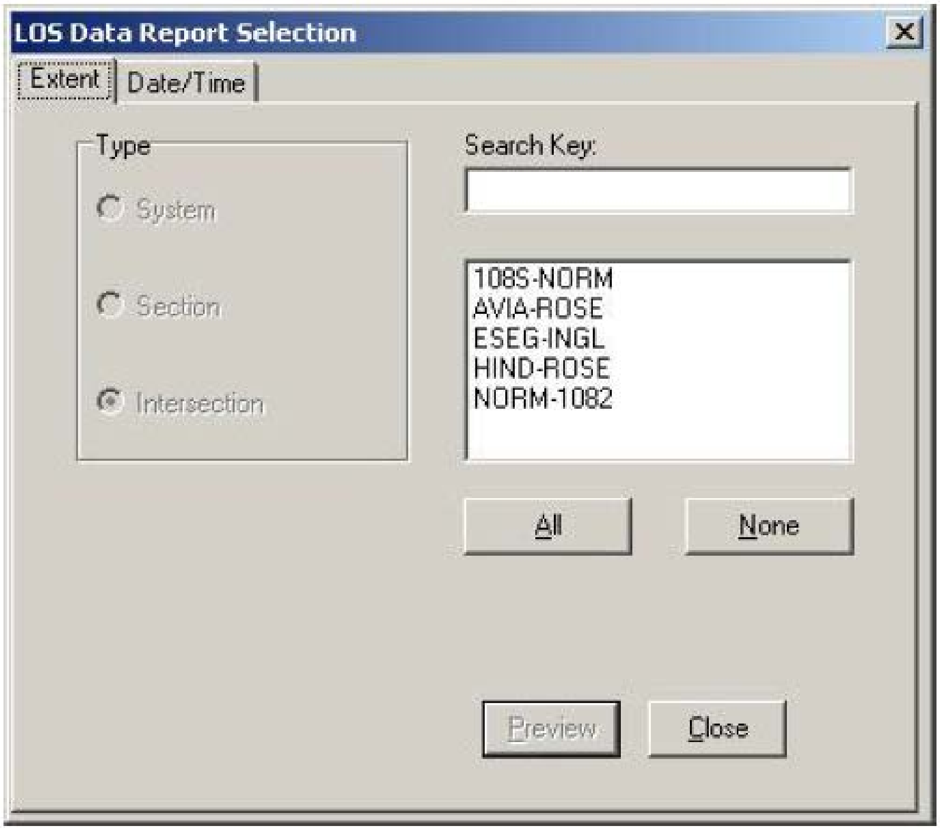


Figure 2.2-28. KITS LOS data report selection

2.2.5.6 Measures of Effectiveness (MOE) Cycle Data

Measures of Effectiveness (MOE) Cycle Data report include Cycle Length, Force Offs, Wait Time, Average Queue, Green Time on Approach and the Delay Time on Approach. These reports can display various types of the data at the interval specified in the System Parameters form. These reports can present: the name of the intersection where MOE data were collected, date, time, the intersection phase and the current timing plan when the data were collected, phase cycle length, information if the phase was forced off, whether the pedestrian button was pushed, the wait time, the average queue, green time on approach and the delay time on approach.

MOE Plan Data Report Selection is used to generate the report where the data can be viewed or printed after filtering the MOEs. In this type of report, similar MOEs are presented except that it is possible to show the percentages of force-offs, the percentage of how many times the pedestrian detectors were pushed, the average wait time, the average green time and the average delay time (Figure 2.2-29).

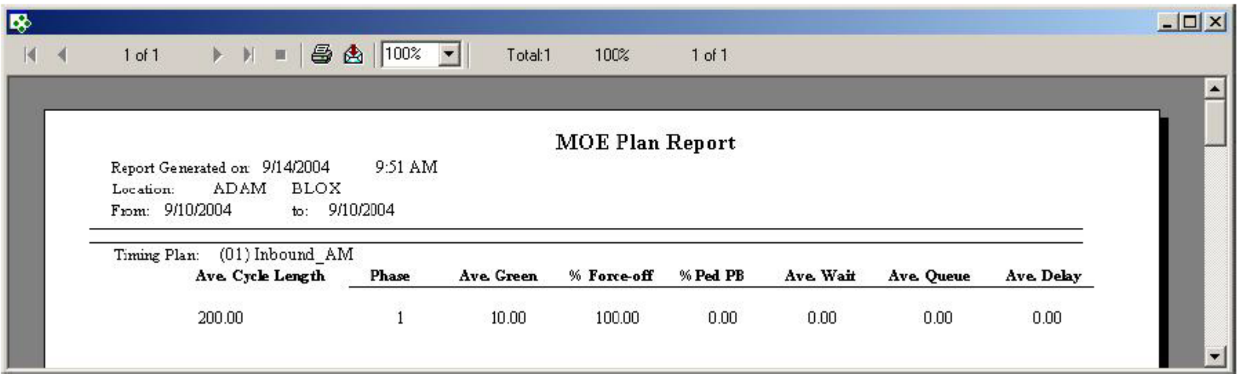


Figure 2.2-29. MOE plan report

2.2.5.7 Status Events Occurrence

Real-time system status report enables the operators to select which types of conditions will be reported. Conditions that can be reported are Coordination failures, Cabinet flash, Conflict Flash, Communications Flash, Preemption, Transition and if the controller is online or not (Figure 2.2-30).

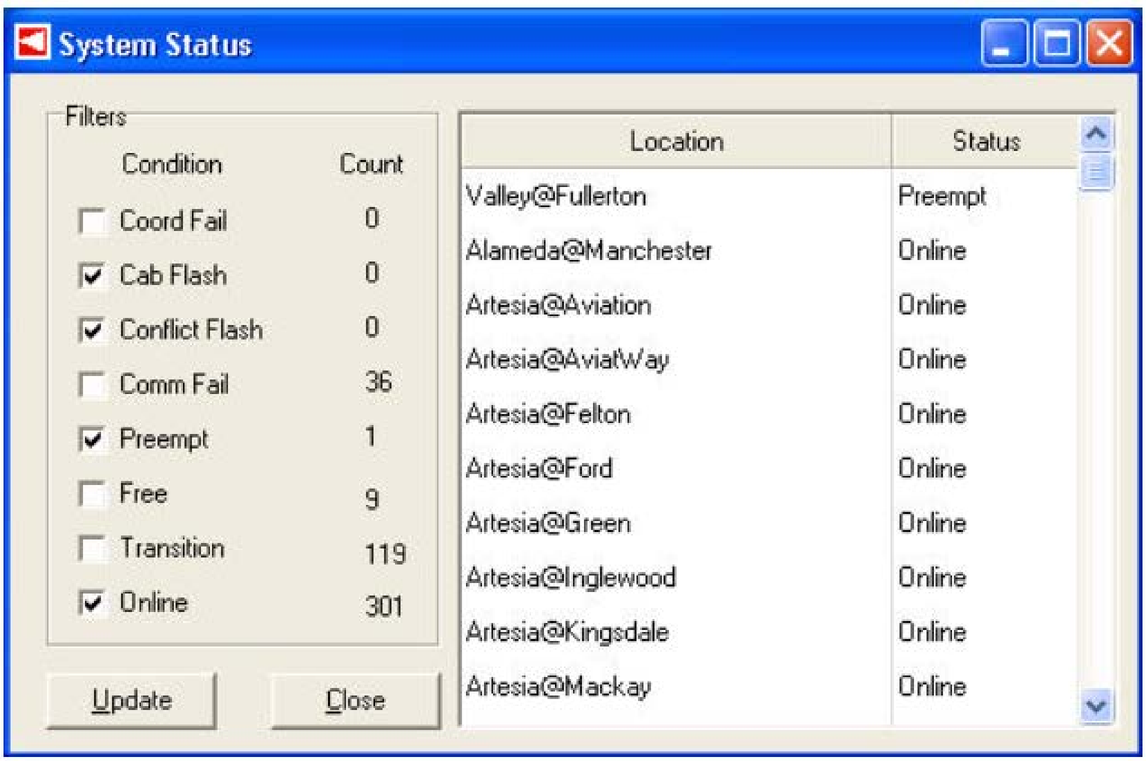


Figure 2.2-30. Real-time system status report

2.2.5.8 Incident Management

KITS has a comprehensive capability for recording and tracking the incidents in the network over time. Broad range of information about incidents (events, not crashes) can be stored or edited by the operators. Two different Report types can be used for that purpose: Event Log

Report and Communications Statistics Report that are shown in the following figures (Figure 2.2-31, Figure 2.2-32 and Figure 2.2-33). For example, the first enables the data collection about when and where the event occurred, the type of event and the equipment that generated the event, the actions taken for the event and optionally the event descriptions. In the Communications Statistics Reports it is possible to extract the information about the percentage of time when communications were functional.

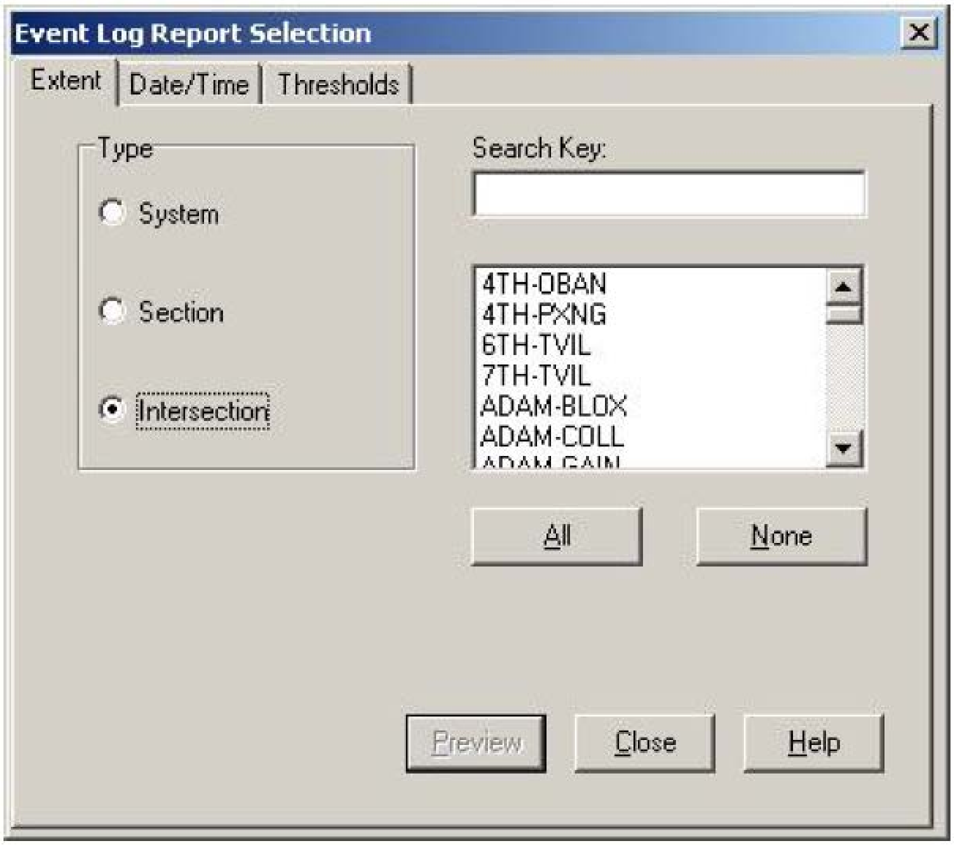
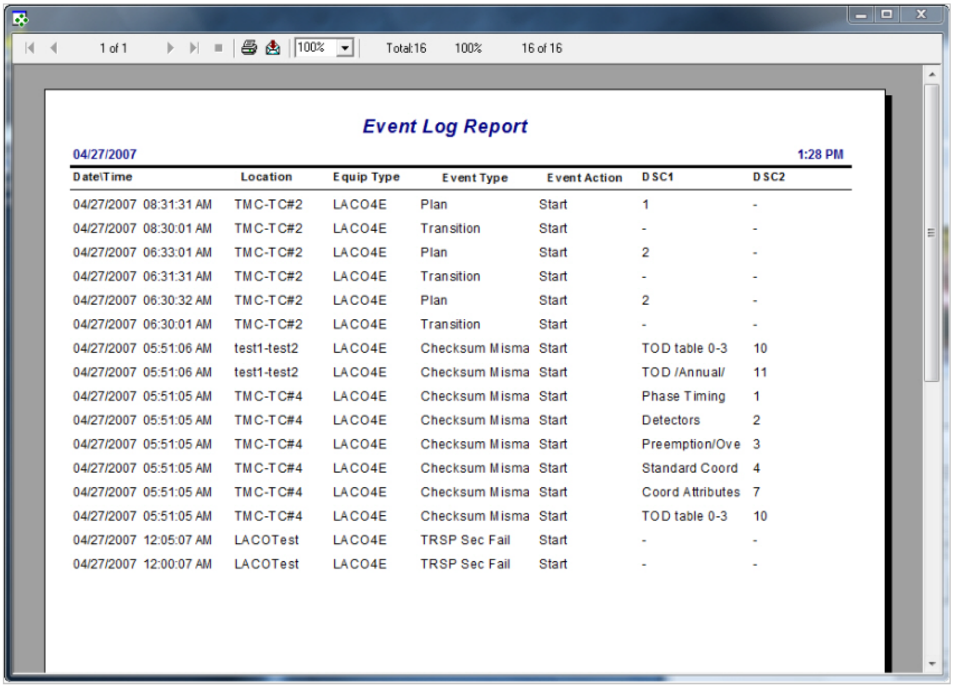


Figure 2.2-31. Event log report selection



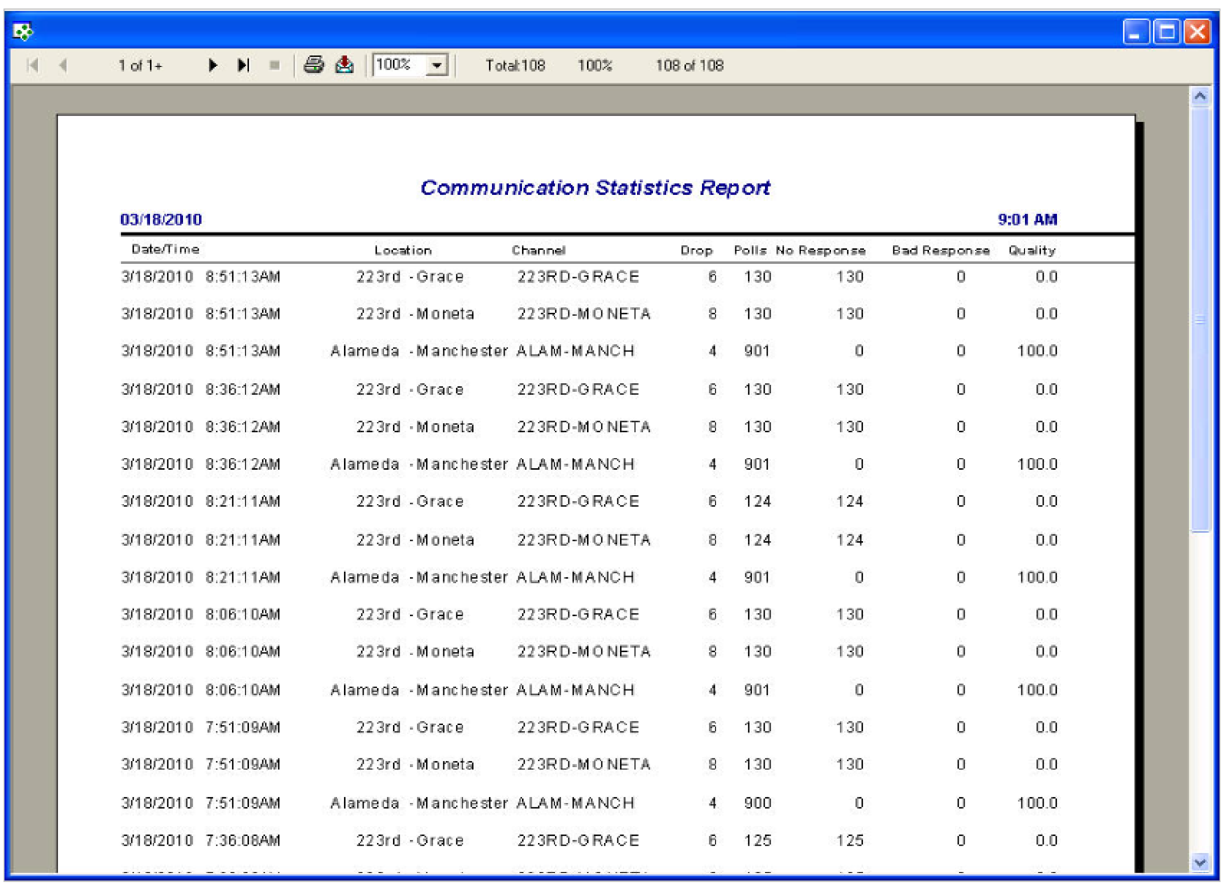
1 of 1 | Total:16 | 100% | 16 of 16

Event Log Report

04/27/2007 | 1:28 PM

Date\Time	Location	Equip Type	Event Type	Event Action	DSC1	DSC2
04/27/2007 08:31:31 AM	TMC-TC#2	LACO4E	Plan	Start	1	-
04/27/2007 08:30:01 AM	TMC-TC#2	LACO4E	Transition	Start	-	-
04/27/2007 06:33:01 AM	TMC-TC#2	LACO4E	Plan	Start	2	-
04/27/2007 06:31:31 AM	TMC-TC#2	LACO4E	Transition	Start	-	-
04/27/2007 06:30:32 AM	TMC-TC#2	LACO4E	Plan	Start	2	-
04/27/2007 06:30:01 AM	TMC-TC#2	LACO4E	Transition	Start	-	-
04/27/2007 05:51:06 AM	test1-test2	LACO4E	Checksum Misma	Start	TOD table 0-3	10
04/27/2007 05:51:06 AM	test1-test2	LACO4E	Checksum Misma	Start	TOD /Annual/	11
04/27/2007 05:51:05 AM	TMC-TC#4	LACO4E	Checksum Misma	Start	Phase Timing	1
04/27/2007 05:51:05 AM	TMC-TC#4	LACO4E	Checksum Misma	Start	Detectors	2
04/27/2007 05:51:05 AM	TMC-TC#4	LACO4E	Checksum Misma	Start	Preemption/Ove	3
04/27/2007 05:51:05 AM	TMC-TC#4	LACO4E	Checksum Misma	Start	Standard Coord	4
04/27/2007 05:51:05 AM	TMC-TC#4	LACO4E	Checksum Misma	Start	Coord Attributes	7
04/27/2007 05:51:05 AM	TMC-TC#4	LACO4E	Checksum Misma	Start	TOD table 0-3	10
04/27/2007 12:05:07 AM	LACOTest	LACO4E	TRSP Sec Fail	Start	-	-
04/27/2007 12:00:07 AM	LACOTest	LACO4E	TRSP Sec Fail	Start	-	-

Figure 2.2-32. Event log report



1 of 1+ | Total:108 | 100% | 108 of 108

Communication Statistics Report

03/18/2010 | 9:01 AM

Date/Time	Location	Channel	Drop	Polls	No Response	Bad Response	Quality
3/18/2010 8:51:13AM	223rd - Grace	223RD-GRACE	6	130	130	0	0.0
3/18/2010 8:51:13AM	223rd - Moneta	223RD-MONETA	8	130	130	0	0.0
3/18/2010 8:51:13AM	Alameda - Manchester	ALAM-MANCH	4	901	0	0	100.0
3/18/2010 8:36:12AM	223rd - Grace	223RD-GRACE	6	130	130	0	0.0
3/18/2010 8:36:12AM	223rd - Moneta	223RD-MONETA	8	130	130	0	0.0
3/18/2010 8:36:12AM	Alameda - Manchester	ALAM-MANCH	4	901	0	0	100.0
3/18/2010 8:21:11AM	223rd - Grace	223RD-GRACE	6	124	124	0	0.0
3/18/2010 8:21:11AM	223rd - Moneta	223RD-MONETA	8	124	124	0	0.0
3/18/2010 8:21:11AM	Alameda - Manchester	ALAM-MANCH	4	901	0	0	100.0
3/18/2010 8:06:10AM	223rd - Grace	223RD-GRACE	6	130	130	0	0.0
3/18/2010 8:06:10AM	223rd - Moneta	223RD-MONETA	8	130	130	0	0.0
3/18/2010 8:06:10AM	Alameda - Manchester	ALAM-MANCH	4	901	0	0	100.0
3/18/2010 7:51:09AM	223rd - Grace	223RD-GRACE	6	130	130	0	0.0
3/18/2010 7:51:09AM	223rd - Moneta	223RD-MONETA	8	130	130	0	0.0
3/18/2010 7:51:09AM	Alameda - Manchester	ALAM-MANCH	4	900	0	0	100.0
3/18/2010 7:36:08AM	223rd - Grace	223RD-GRACE	6	125	125	0	0.0

Figure 2.2-33. Communications statistic report

2.2.5.9 Equipment Maintenance

Equipment malfunction and other important events can be monitored via KITS Alert Viewer shown in Figure 2.2-34. In that way, operators can be alerted about activities that require their attention.

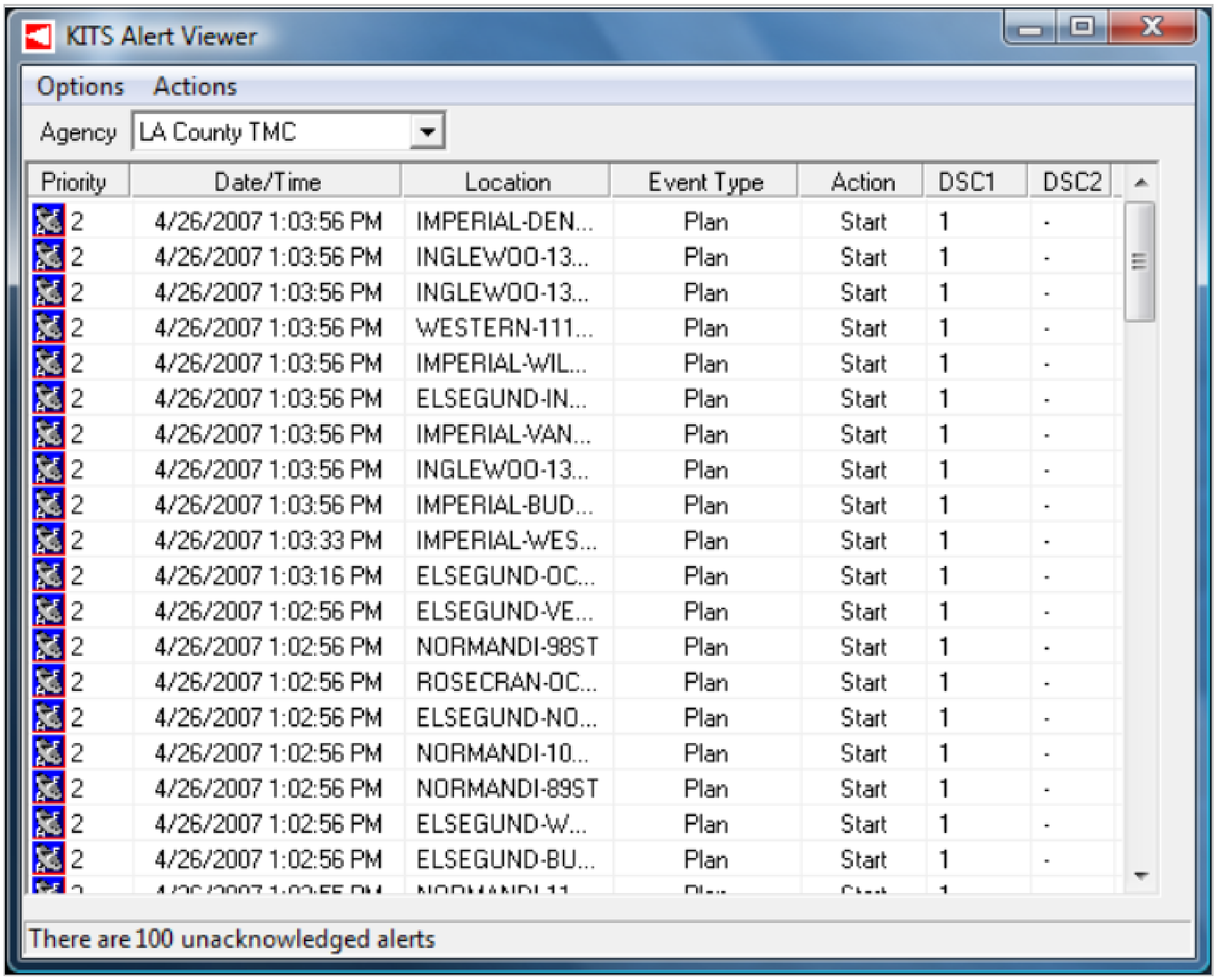


Figure 2.2-34. KITS alert viewer

2.2.5.10 Communication Failures

The Communication Statistics Report summarizes the statistics for communications in 15 minutes intervals (Figure 2.2-35). Those reports show the number of poll messages, number of bad responses, number of no responses, percent of correct poll message responses for the intersection during the summary period alongside with the general data (date and time when the summary was generated, intersection, channel and drop address of the intersection).

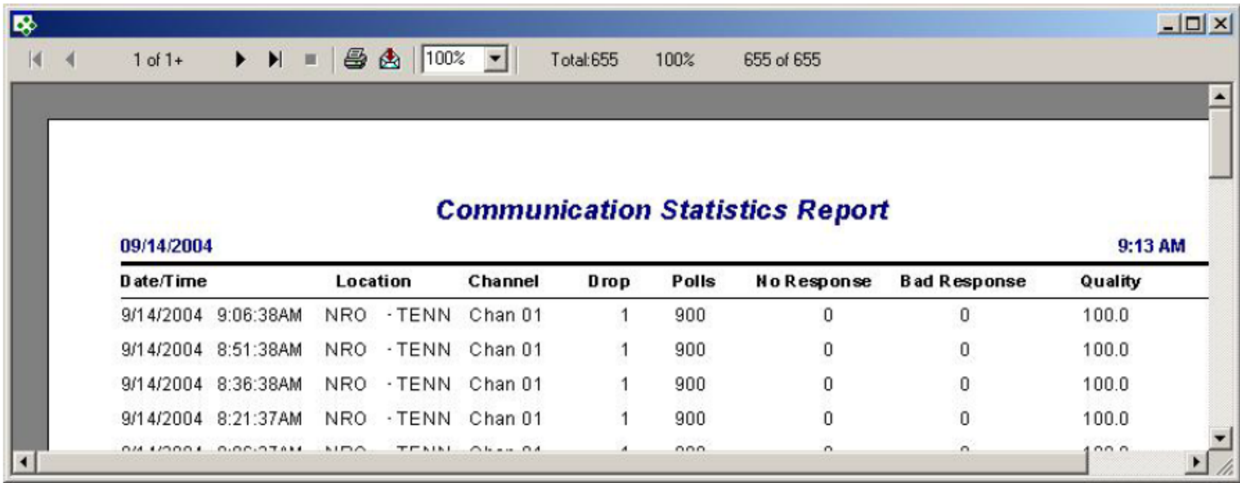


Figure 2.2-35. KITS communication statistics report

All the reports can be periodically generated by using the Scheduled reports option in KITS (Figure 2.2-36). There it is possible to find name of the report and the description used to identify the scheduled report entry, but also the frequency or the exact days for the report generation.

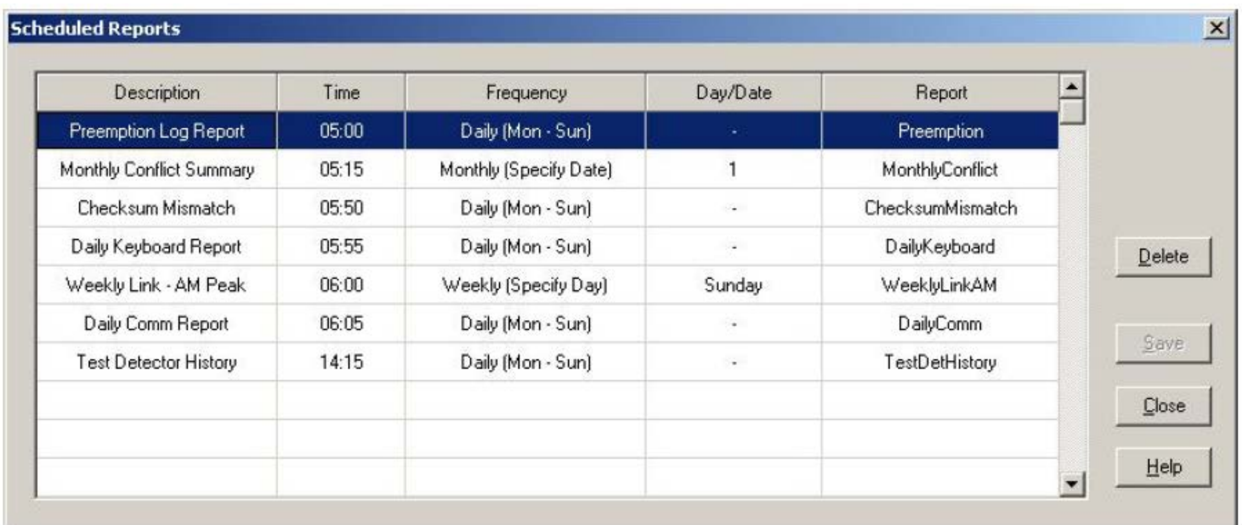


Figure 2.2-36. KITS scheduled reports

2.2.6 MIST

The Management Information System for Transportation (MIST) is a traffic management software created by Telvent. This system enables management of the urban traffic and the traffic on expressways by using a centralized platform. MIST provides the operators with the possibility to monitor and control traffic and other assets with the goal of alleviating congestion, air pollution or increase mobility. The operators have a real-time insight in traffic operations, and can react in a fast and coordinated manner to traffic conditions in the network. The integration of applications for air quality evaluation (TRACE) and adaptive traffic control systems (OPAC and ITACA) into MIST platform is enabled. MIST uses NTCIP communication protocols.

Traffic signal MOEs available from MIST:

1. Vehicle Volume
2. Vehicle Detector Occupancy
3. Speed
4. Cycle lengths
5. Green splits
6. Time-space diagram (Corridor performance measure)

2.2.6.1 Vehicle Volume, Occupancy, and Speed

MIST has the possibility to collect, process and display the volume, occupancy and the speed information provided by detectors in the field. Each detector is providing the measurements, and MIST enables seamless presentation and further usage of that data.

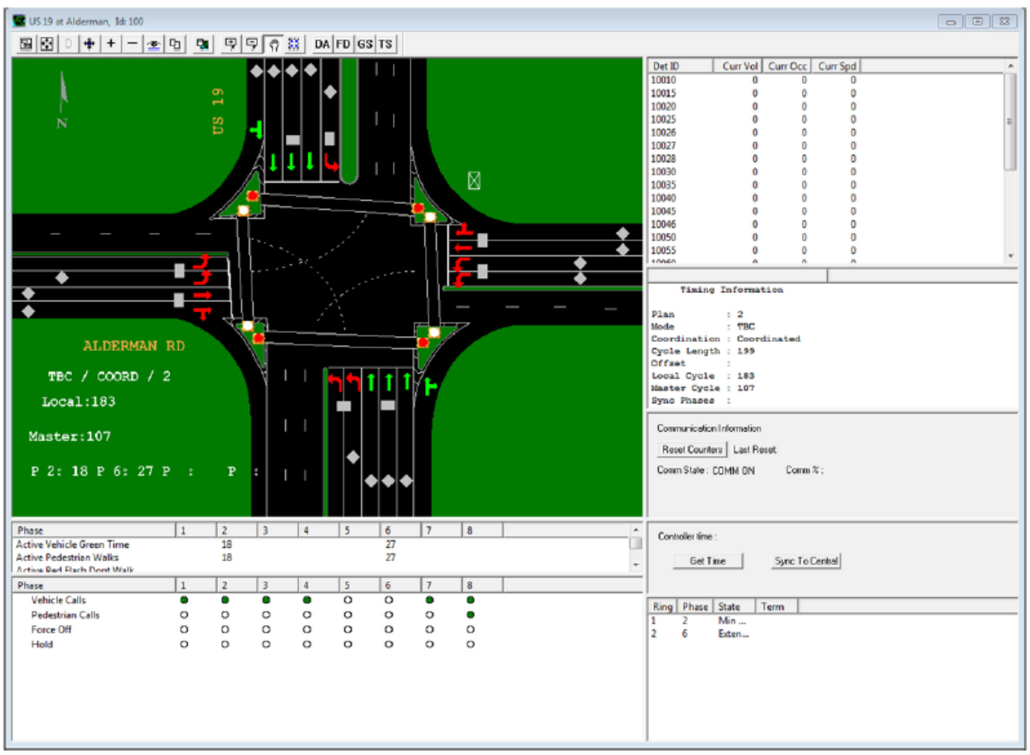


Figure 2.2-37. MIST user interface

2.2.6.2 Green Splits, Cycle Lengths, and Volume

Green or Phase splits are available to obtain trough Green Split Report in MIST. Site Activity Reports from OPAC via MIST, also provide traffic volumes. In this way, it is possible to track if the changing of the split durations follows changes in traffic volumes.

2.2.6.3 Time-Space Diagram

Considering the corridor performance measures, a time-space diagram (Figure 2.2-38) is available for operators to track the progression. If the signals were synchronized correctly, the virtual vehicular trajectories in MIST would maximally utilize available green bands.

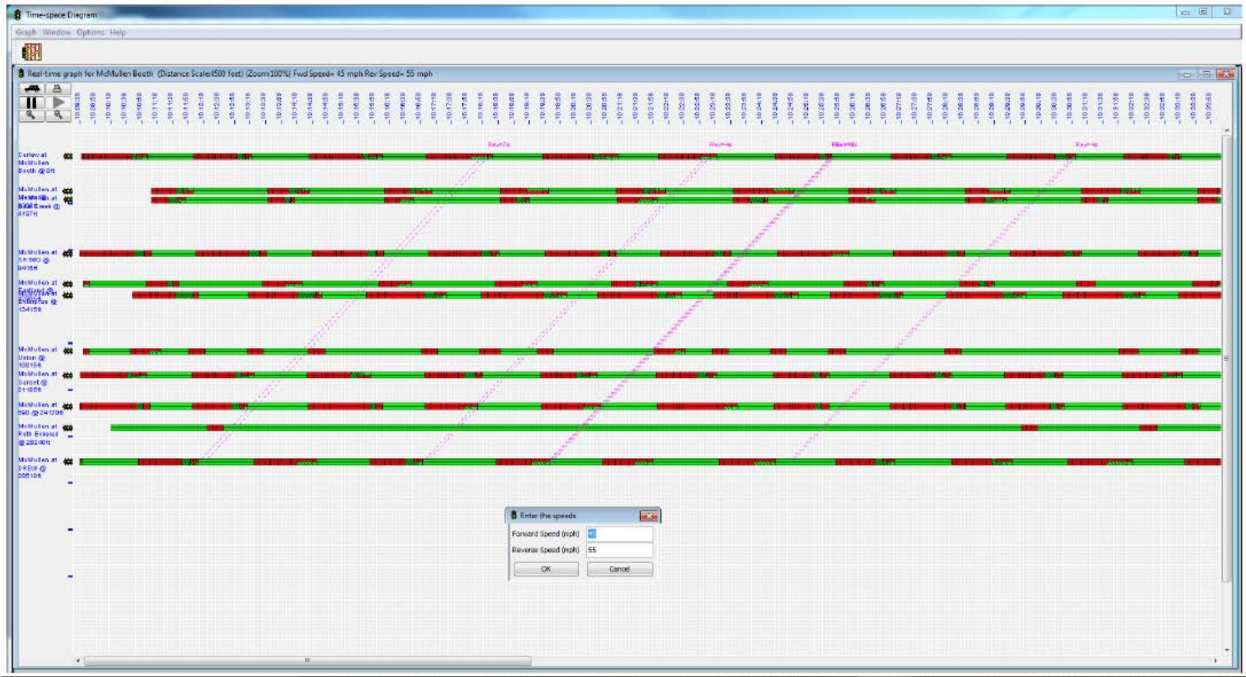


Figure 2.2-38. Time-space diagram

2.2.7 External Systems for Data Collection and Performance Measure Calculation

Even though the SSCSs regularly have a vast variety of possibilities, options, indicators, and reports available, additional tools are used to complement those systems and to bring new data not available from the SSCS. The data can be used in real-time or later by using historical values for the decision making, trend analysis, and performance evaluation. Most often, those systems are used for collecting the travel time or speed data, but other indicators can be measured and reported depending on the system configuration and technology used.

The technologies that those packages use to collect specific data about traffic flows are different. The most frequent types of detectors used are:

- Bluetooth
- Wi-Fi
- Automatic License Plate Recognition (ALPR)
- Toll tag readers and similar

What all these systems have in common, apart from the technology used, is that the part of the total number of vehicles in the traffic flow gets identified at starting point when the timestamp is assigned to that event, and then on the ending point vehicles are identified again and given a second timestamp. In such a way, by comparing the locations and the timestamps, it is possible to calculate travel times, average speeds and other measures. The number and the precision of the tools depends mostly on the detection type used and that is the reason why some of the systems can provide more categories of the data, in higher resolution and in more detail.

For this report only tools using Bluetooth and Wi-Fi technology were used. Acyclica, Trafficcast's BlueToad (and BlueARGUS), and Sensys networks package of tools were selected as valid representatives of that group of systems, and because pilot agencies selected for this research use them

Systems using tag readers are more frequently used on the freeways because of the possibility to pay the tolls with the tag inside the vehicle. On urban network Bluetooth or Wi-Fi technology is more popular due to higher penetration rates. Each system will be explained in more detail in the following chapters. ALPR systems were not investigated as part of this research project.

2.2.8 Acyclica

There are many Bluetooth and WiFi-enabled devices out there including mobile phones, cameras, laptops – even vehicles with their GPS navigation systems – all of which meet protocols for the wireless transmission of data. Each device transmits a unique identifier called a MAC (Media Access Control) address.

Acyclica Go is a package created for traffic data collection. Depending on the detection devices used, the features and the functions of the systems differ. Three devices currently are available:

1. BlueCompass – using only Bluetooth data
2. BlackCompass – using WiFi data
3. CrossCompass – dual Bluetooth and WiFi data

The Compass sensors anonymously scan and collect MAC addresses, matching them from point to point, providing stable, accurate, and reliable travel times, along with the ability to analyze traffic flows at a high level of detail.

The Acyclica software enables the users not only to view real-time data but also to download .csv files of the records in form of a report or .xml data feed. The hardware has the capability to encrypt the data in the device so that anonymity is guaranteed. Considering the signal strength profile, the web interface provides a way to monitor the signal strength transferred along with Wi-Fi MAC address detections. In that way the user can check if the device is set up optimally. Signal strength readings are presented on a logarithmic scale and higher negative values represent weaker signal whereas lower negative values represent stronger signal strength (Figure 2.2-39). Use of these charts is useful to determine if antennas are oriented and connected in a proper way, and if the location of the devices is too far from the site that is being analyzed.

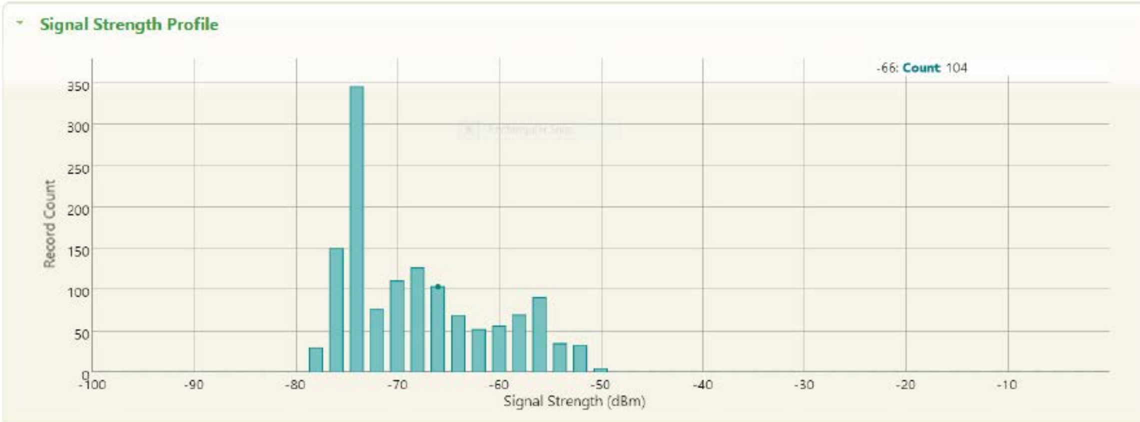


Figure 2.2-39. Signal strength profile chart

Performance metrics available through Acyclica software and valuable for signal timing analysis and traffic flow status analysis are:

1. Vehicle Volume
2. Speed
3. Travel Times by segment
4. Queue lengths
5. Route and Segment Delay
6. Intersection Delay by Approach
7. Congestion Index
8. Idle emission
9. Progression diagram
10. Purdue Coordination Diagram
11. LA Route Intersection Coordination Metrics

BlackCompass device is created to optimize the data collection process. It can collect over 240,000 records per one hour. By collecting only Wi-Fi data, the device passively collects MAC addresses which allows calculation of the vehicle distances from the measuring device and enables measuring the queues in the intersections. The BlackCompass capabilities enable congestion measurements beside the travel times. With the Wi-Fi, the ability to detect intersection delay is introduced. That is possible by using one sensor on a distances of maximum 1/8 miles from the intersections. By using the Acyclica Analyzer Software, the delay can be analyzed for each phase. Bluetooth technology for data collection relies on the interrogation and response in order to collect data. On the other hand, using Wi-Fi is different in terms that the sensor only listens, which means that it is the passive data collection. That type of data collection removes the possibility of interference with other 2.4 GHz equipment.

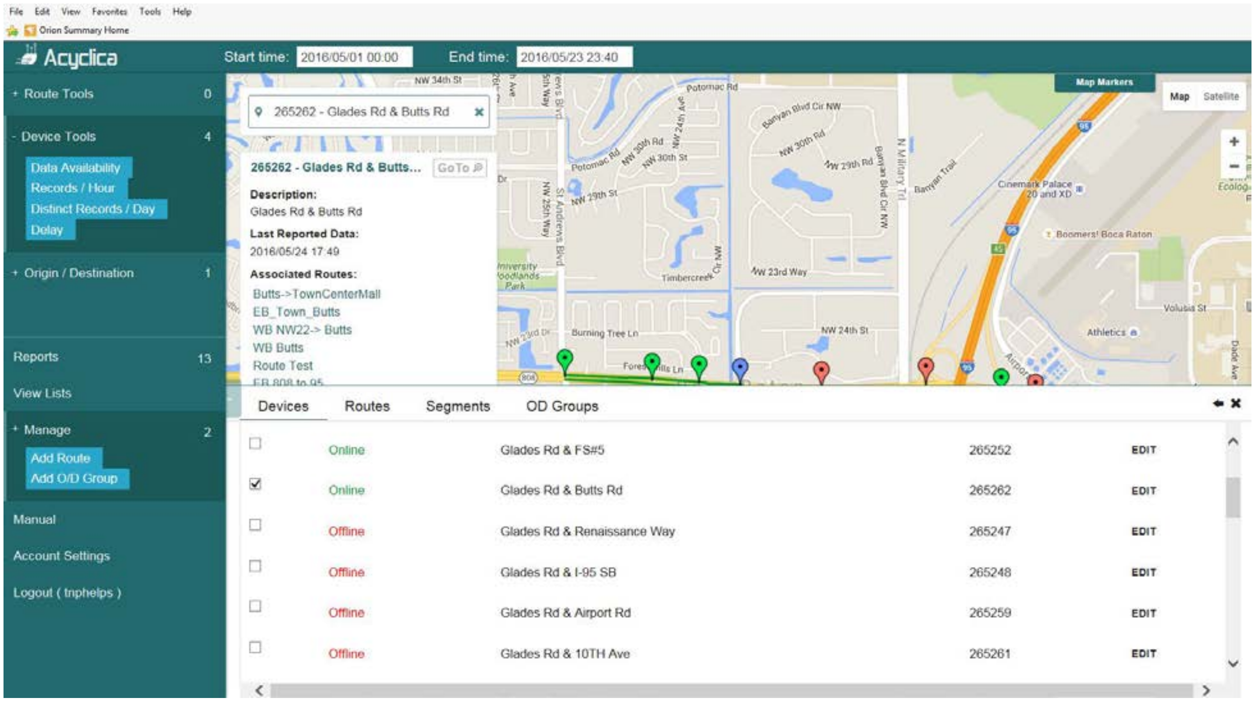


Figure 2.2-40. Acyclica Go User interface

CrossCompass combines the Bluetooth and WiFi data collection. Higher sample rates obtained in this way cause more accurate origin-destination, travel times and higher quality of the data overall. The data can be downloaded in form of graphs or raw data in Microsoft Excel files.

2.2.8.1 Vehicle Volume

Acyclica Go Software can provide vehicle volume counts and display in form of a graphic (Figure 2.2-41 and Figure 2.2-42). This option can be used as primary or additional source of that type of data.

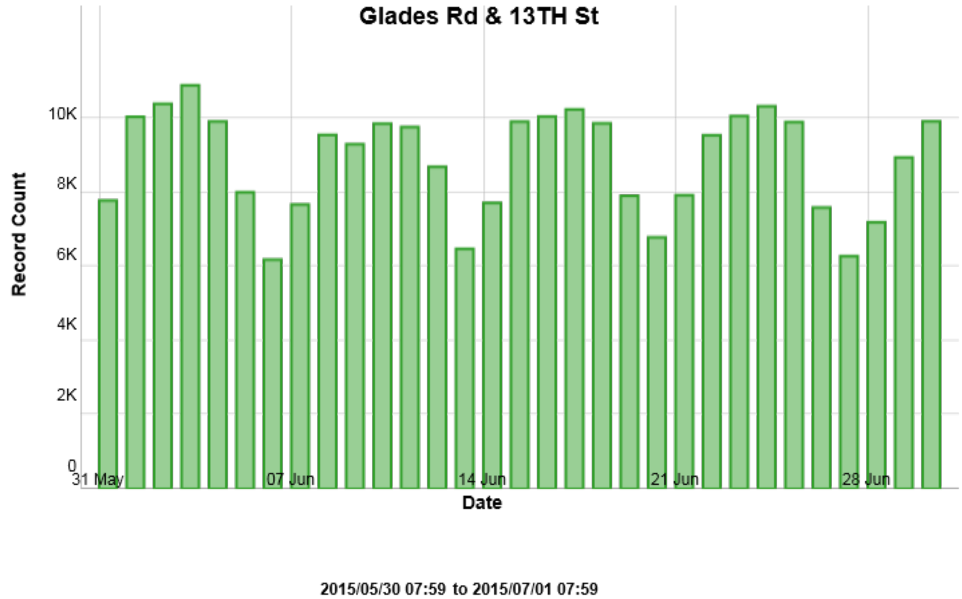


Figure 2.2-41. Vehicle volumes bar chart

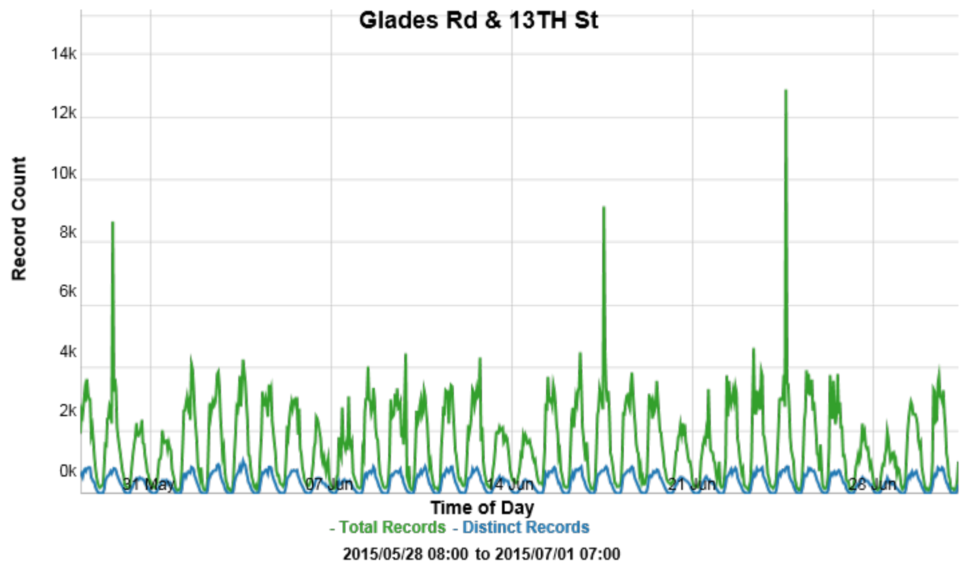


Figure 2.2-42. Vehicle volume graph

2.2.8.2 Travel Times per Segment

The basic purpose of the Acyclica Go software are travel time measurements. A user can monitor and compare the travel times as an indicator of traffic flow status. By utilizing various types of graphics (Figure 2.2-43 and Figure 2.2-44) and a table (Table 2.2-2), it is possible to observe travel times for the first vehicle, last vehicle, minimal, maximal and total travel times for the particular segment.

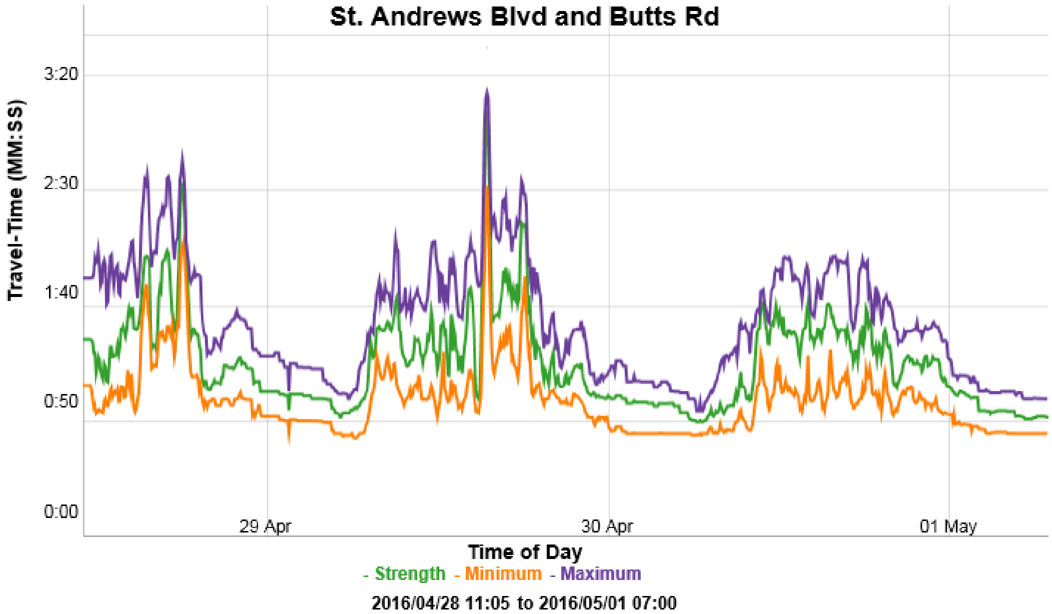


Figure 2.2-43. Strength, minimum and maximum travel times by segment chart

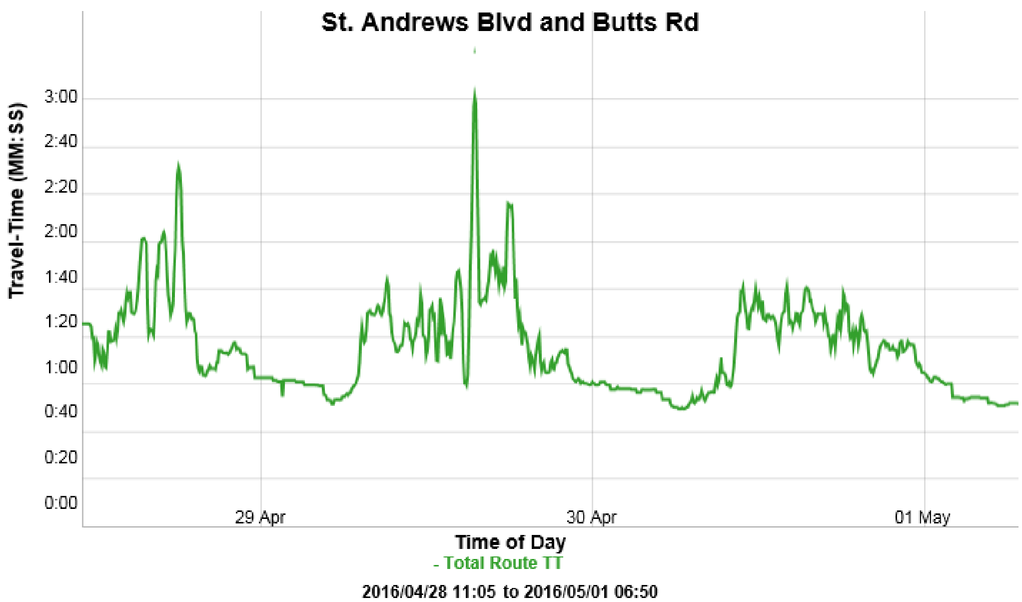


Figure 2.2-44. Total route travel times chart

Table 2.2-2. Travel times table

Time	Strength	Firsts	Lasts	Minimum	Maximum
Thu Apr 28 11:00:00 EDT 2016	1:24	1:41	1:16	1:03	1:53
Thu Apr 28 12:00:00 EDT 2016	1:12	1:40	1:03	0:56	1:55
Thu Apr 28 13:00:00 EDT 2016	1:23	1:39	1:09	1:02	1:53
Thu Apr 28 14:00:00 EDT 2016	1:33	1:46	1:16	1:02	1:57
Thu Apr 28 15:00:00 EDT 2016	1:46	2:03	1:42	1:29	2:15
Thu Apr 28 16:00:00 EDT 2016	1:42	1:49	1:35	1:22	2:15
Thu Apr 28 17:00:00 EDT 2016	1:48	1:57	1:41	1:30	2:19

2.2.8.3 Speed

Similar to the travel time, speed is also being calculated and presented in form of a chart (Figure 2.2-45) or a table (Table 2.2-3). Speed of the first vehicle, last vehicle, minimal and maximal speed can be shown.

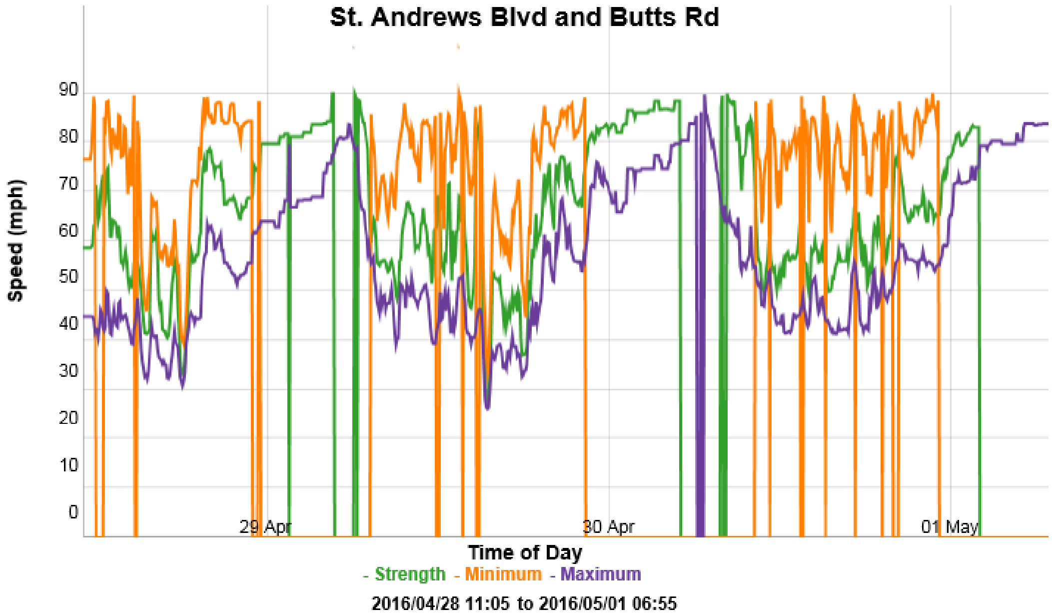


Figure 2.2-45. Speed chart for one segment

Table 2.2-3. Speed table

Time	Strength	Firsts	Lasts	Minimum	Maximum
Sun May 1 00:00:00 EDT 2016	77.06	78.7	80.01	0	65.3
Sun May 1 00:05:00 EDT 2016	77.6	79.42	81.33	0	65.3
Sun May 1 00:10:00 EDT 2016	78.2	79.88	81.67	0	67.07
Sun May 1 00:15:00 EDT 2016	79.67	81.7	82.08	0	71.57
Sun May 1 00:20:00 EDT 2016	79.92	81.7	81.99	0	71.68
Sun May 1 00:25:00 EDT 2016	81.44	81.7	82.27	0	71.87
Sun May 1 00:30:00 EDT 2016	81.7	81.7	82.27	0	71.87

2.2.8.4 Delay

The delay per intersection is presented on the graph below (Figure 2.2-46). Dwell values for vehicles are noted in the form of dots, and the averages of all dwell times are represented with a blue line.

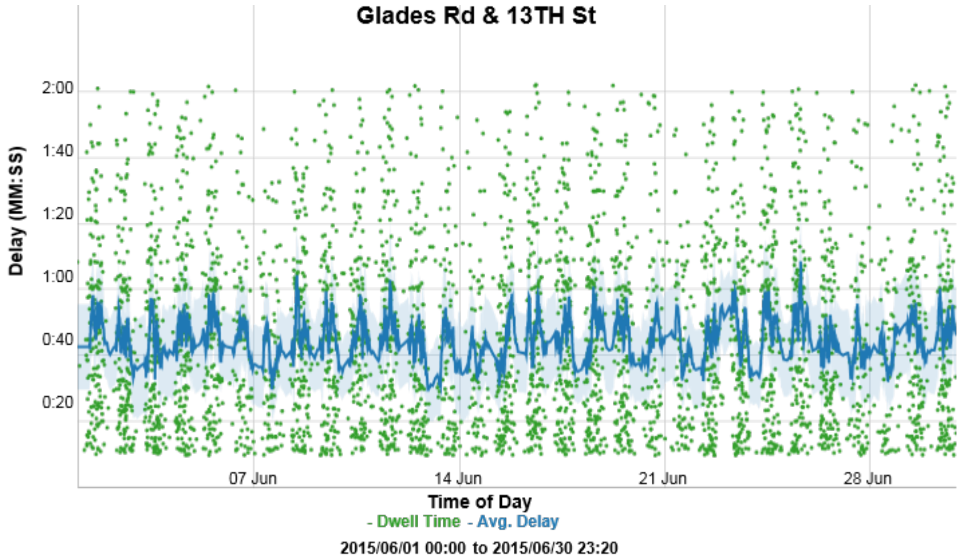


Figure 2.2-46. Delay chart for one intersection

2.2.9 BlueTOAD

BlueTOAD is the traffic-monitoring system which directly and accurately measures travel times using cost-effective and non-intrusive roadside technology. Bluetooth is well-known technology to the general public, and nowadays, it is being used for travel time data collection. BlueTOAD (Bluetooth Travel-time Origination And Destination) searches for the signals emanating from Bluetooth-enabled devices in a vehicle by using sensor boxes mounted on light poles. Those sensors get the media access control (MAC) addresses from different types of Bluetooth-capable devices like cell phones, navigation systems, laptops inside vehicles, and finally, from the Bluetooth enabled vehicles. The procedure for calculating travel times is conducted when the devices detect the Bluetooth signal; a time stamp is generated, and the same Bluetooth signal gets picked up on the next checkpoint downstream and also timestamped. With that information, the computation of the travel time and the speed can be performed. The system calculates travel time through analysis of subsequent detections. BlueTOADs can be positioned to provide travel times on entire routes, not only segments, as each device can be paired with multiple devices; device-detector pairs can create routes together.

The BlueTOAD technology platform securely processes collected data to calculate travel times and speeds in real time, providing route management capabilities through a private Web interface and direct data feeds. The data is also archived, including travel times, road speeds**,** and MAC address detection counts, to enable a range of robust planning efforts, including Origin-Destination Studies, Trip Length Analysis, Travel Demand Modeling and Signal Timing Optimization.

The TrafficCast processes the data collected by BlueTOAD devices. Data can be viewed in real-time or analyzed historically through a BlueTOAD Web interface, which provides travel times, road speeds, and MAC address detection counts.

The privacy of the users of Bluetooth devices is guaranteed, because all MAC addresses are being deleted shortly after a short time and only travel time data is saved. BlueTOAD Spectra detector increases the number of detections and matches, and also improves the privacy by using only 6 characters of the MAC addresses and not the usual 12 characters. The data can be viewed in real-time or analyzed historically using the BlueTOAD Web interface.

BlueTOAD has more than 2000 users and it is active on about 6000 locations. By its functionalities, the system enables many Traffic engineers, ITS engineers or Planners to have an accurate overview of the several indicators of the traffic flow listed below.

The Performance measures that can be collected using BlueTOAD are:

1. Travel times
2. Speed
3. Detection counts

BlueARGUS is data manipulation software optimized for travel time data and dashboard styled visualizations. Multiple views of travel time data, and derived measures of travel time reliability like travel time index can be calculated. Users have the possibility to create a pair or route report about speed or travel times in 5 or 15 minute increments. These reports can be saved in HTMS, .csv or graph format (Figure 2.2-47).

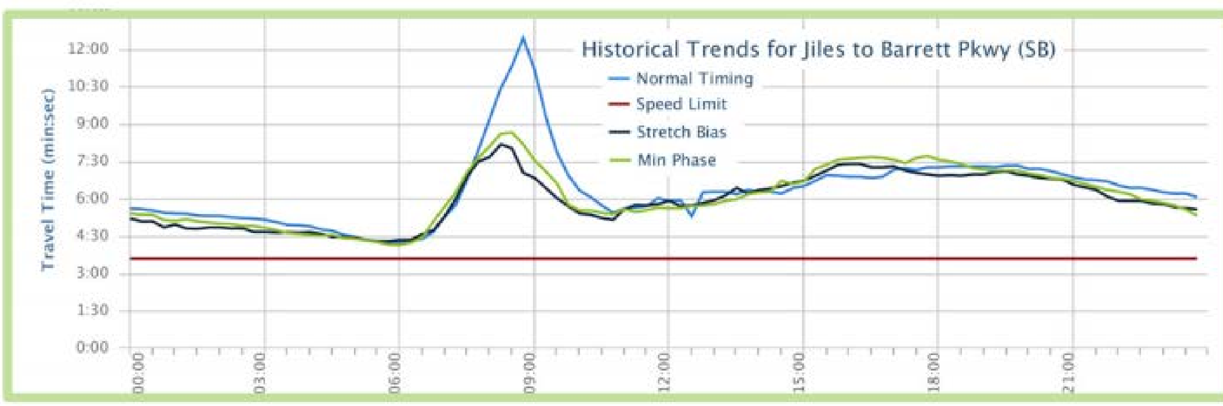


Figure 2.2-47. Travel time graph

Option of creating an overlay of the two sets of the data for direct comparison also exists. The operator can compare two or multiple pairs or routes between themselves or the same pair/route for the different dates by utilizing the comparison report (Figure 2.2-48).

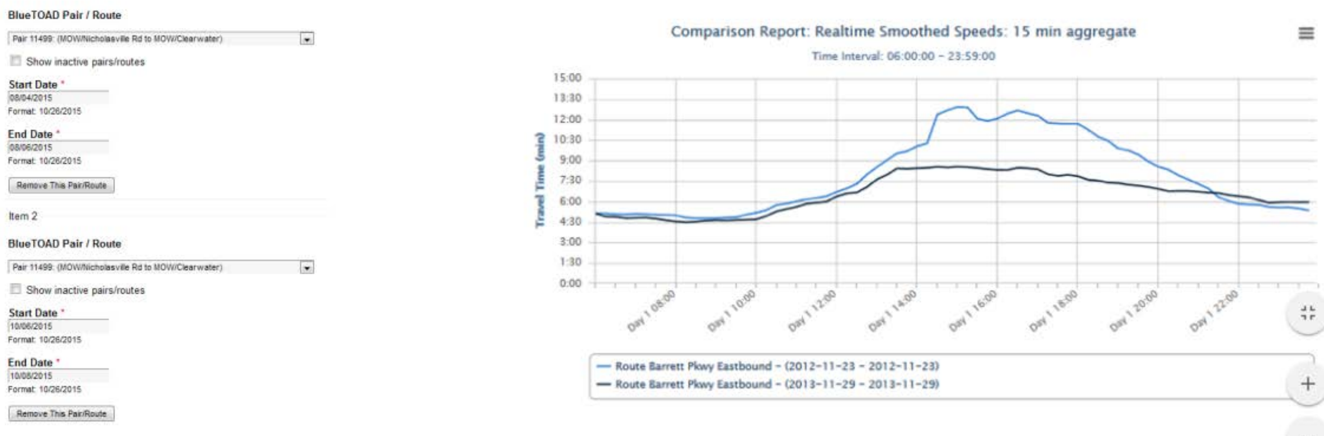


Figure 2.2-48. Comparison report

Travel time reliability is an indicator to show a driver's experience by quantifying variability and providing the average travel time. By using the travel time report, the users have the ability to analyze network performance in terms of volatility, reoccurring congestion and non-reoccurring congestion. Travel time reliability is an index based on three factors: Travel Time Index (TTI), Buffer Time Index (BTI), and Planning Time Index (PTI). The results can be displayed in form of a table (Table 2.2-4) or a chart (Figure 2.2-49).

Figure 2.2-49. Travel time reliability diagram

Table 2.2-4. Travel time reliability table

Day/Time	TTI	BTI	PTI
	From 06-01-2015 to 08-31-2015 (Weekdays 06:00 to 12:00 every month)		
06-2015	1.14 (5:15)	0.38 (1:58)	1.56 (7:14)
07-2015	1.14 (5:16)	0.49 (2:36)	1.7 (7:51)
08-2015	1.33 (6:08)	0.9 (5:31)	2.52 (11:38)

When a link is selected on the speed map, the color of the link, changes into purple and on the right side, real-time information are shown. That information can include historical speed (average for last 12 weeks, last 48 hours…). The graphical part can show travel times or speed (the display mode), and on the right side it is possible to see summary with information about pair ID, current speed, speed limit, historical speed and travel time, and the real-time status of each device displayed in the heartbeat (HB), MAC address inputs, lag and the voltage (Figure 2.2-50). If any of the status indicators fall below the acceptable threshold, the indication shows the red dot, otherwise the dot will be green. The information can also be shown in form of a chart (Figure 2.2-51).

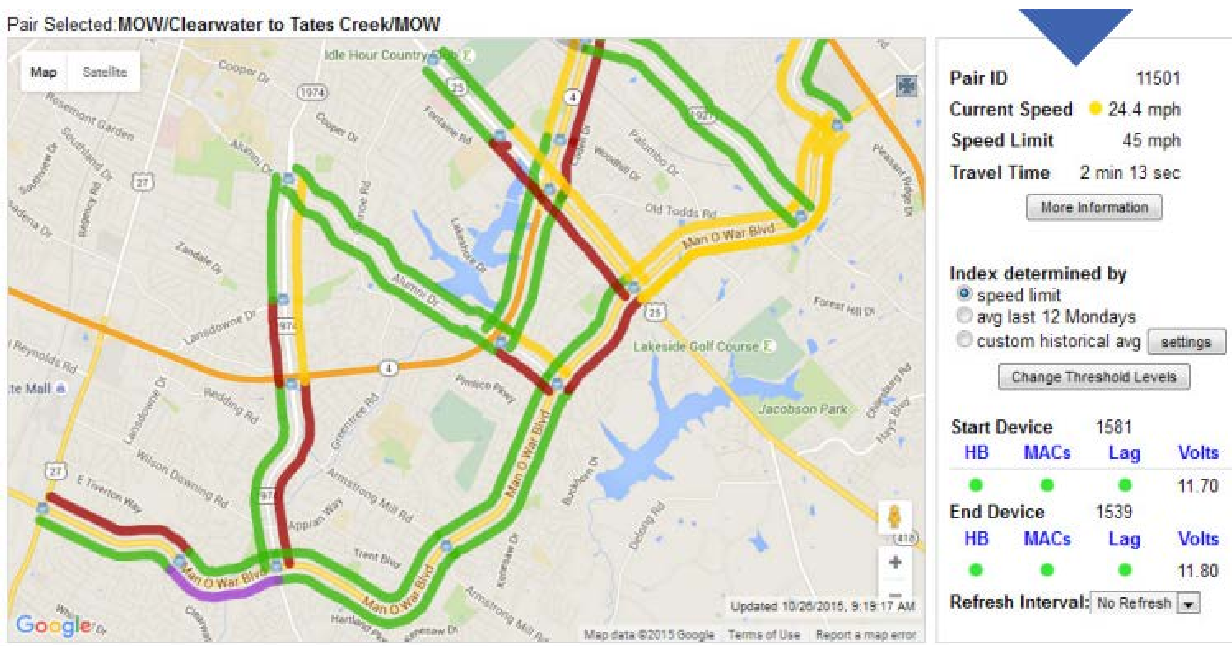


Figure 2.2-50. Real-time speed map

Figure 2.2-51. Speed diagram

The BlueARGUS Dashboard enables the user to see pairs and routes in a single table (Figure 2.2-52). In that table, information about type (pair or route), ID number, entry measuring point, exit measuring point, speed, time and the date/time of the last match are obtained.

Dashboard - City of Memphis

☑ Show Pairs ☑ Show Routes

Type	ID	From	To	*	Name	Speed	Time	Last Match
Pair	18868	1879	1935	●	Airways at Ketchum (Bypass) (SB)	30 mph	7:41	10-07 07:57
Pair	18869	1935	1879	●	Airways at Ketchum (Bypass) NB)	34 mph	6:52	10-07 07:56
Pair	12945	1935	1880	●	Airways Blvd-Winchester Rd to E. Pkwy-Ketchum Rd	41 mph	2:45	10-07 08:00
Pair	12954	1935	1956	●	Airways Blvd-Winchester Rd to Lamar Ave-Winchester Rd	35 mph	6:45	10-07 07:59
Pair	12946	1935	1934	●	Airways Blvd-Winchester Rd to Shelby Dr-Airways Blvd	38 mph	3:28	10-07 07:51
Pair	14403	1935	1966	●	Airways Blvd-Winchester Rd to Shelby Dr-Boeingshire Dr - Bypass for u1934	31 mph	4:58	10-07 07:50
Pair	23053	1935	5072	●	Airways Blvd-Winchester Rd to Winchester & Elvis Presley (u5072)	31 mph	3:54	10-07 07:57
Route	19647	1934	1888	●	Airways/ E. Parkway NB	35 mph	18:08	10-07 07:58
Route	19648	1888	1934	●	Airways/ E. Parkway SB	35 mph	17:56	10-07 07:51
Route	13466	1941	1895	●	American Way (EB)	35 mph	6:44	10-07 07:58
Pair	13083	1899	1895	●	American Way (Getwell to Mt. Moriah) (Bypass) (EB)	36 mph	4:43	10-07 07:59
Pair	16245	1895	1899	●	American Way (Mt. Moriah to Getwell) (Bypass) (WB)	33 mph	5:05	10-07 07:59
Route	13467	1895	1941	●	American Way (WB)	33 mph	7:11	10-07 07:56
Pair	12970	1895	1897	●	American Way-Mount Moriah Rd to Mount Moriah Rd-Hickory Hill Rd	30 mph	3:10	10-07 07:57
Pair	13106	1895	1943	●	American Way-Mount Moriah Rd to Perkins Road-American Way	29 mph	2:29	10-07 07:56
Pair	12517	1883	1886	●	E. Pkwy-Central Ave to Central Ave-Goodwyn	39 mph	2:00	10-07 07:54
Pair	12513	1883	1891	●	E. Pkwy-Central Ave to E. Pkwy-Poplar Ave	47 mph	2:18	10-07 07:58
Pair	12512	1883	1882	●	E. Pkwy-Central Ave to Spottswood-Airways	12 mph	3:54	10-07 07:39
Pair	12944	1880	1935	●	E. Pkwy-Ketchum Rd to Airways Blvd-Winchester Rd	35 mph	3:13	10-07 08:00
Pair	19280	1880	953	●	E. Pkwy-Ketchum Rd to Lamar Ave @ Airways Blvd	29 mph	3:49	10-07 08:00
Pair	12507	1880	1879	●	E. Pkwy-Ketchum Rd to Park Ave-Airways Blvd	27 mph	4:27	10-07 07:58
Pair	19286	1891	955	●	E. Pkwy-Poplar Ave to E Pkwy @ North Pkwy	20 mph	2:08	10-07 07:58
Pair	12514	1891	1883	●	E. Pkwy-Poplar Ave to E. Pkwy-Central Ave	54 mph	2:01	10-07 08:01
Pair	12521	1891	1885	●	E. Pkwy-Poplar Ave to Highland-Poplar Ave	28 mph	4:56	10-07 08:00

* Black => no data Colors => speed relative to ○ speed limit ◉ historical avg ○ custom [settings] [Change Thresholds]

Figure 2.2-52. Dashboard table

The alarms in BlueARGUS enable notifications about certain events via text message or email, usually when a pair or route speed drops below a user-defined level constituted on a percentage of the historical speed or absolute number (Figure 2.2-53). All alarms are saved and reports can be generated to review the when and on what locations the alarms were triggered. Also, alarms can be based on the lack of Heartbeat of the system, no MAC addresses discovered, Low Voltage or latency issue.

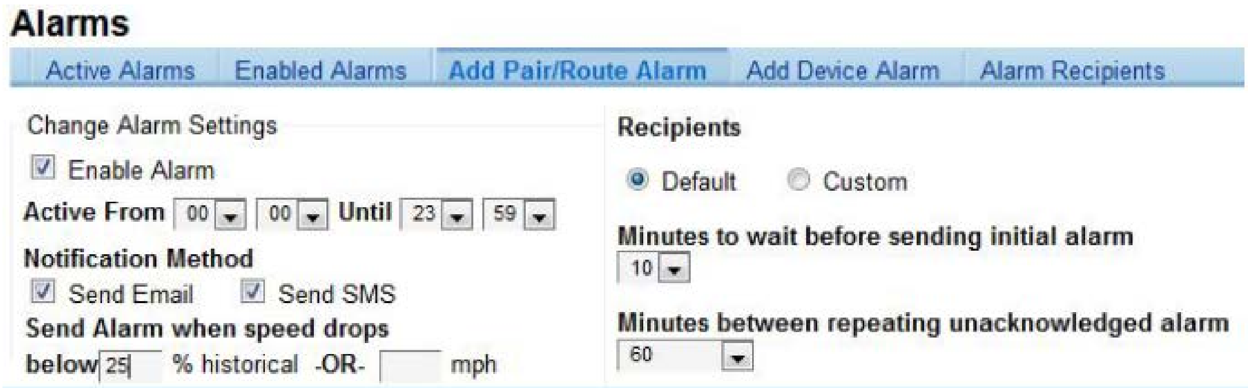


Figure 2.2-53. Field hardware and route threshold alarm

2.2.10 Sensys Networks

For a long period of time, floating car studies were the primary tool for assessing the traffic flow conditions. A major drawback of this type of data collection are it expensiveness, tediousness and unpracticality. That is the reason why with the development of new technologies, several products for traffic data collection emerged. Kwong et al. (2009) addressed the difficult task of estimating of the probability distribution of travel time across segment with several intersections. On the bases of vehicle re-identification using wireless sensors, many tools were created with the goal of collecting the traffic data.

Sensys Networks has designated its own wireless sensor protocol to meet the demanding system level requirements for vehicle detection and traffic monitoring. Sensys Networks offer a variety of products which enable collecting and representation of various traffic flow data. Cloud-based application makes the deployment very easy, and software wise the user does not have to put significant effort in maintenance or upgrades. The system uses Bluetooth or WiFi technology to identify vehicles and their positions in the network. The comparison between match rates for those two technologies showed that Wi-Fi has better match rate up to ten times, which allows real-time updates of the vehicle positions. Additional advantage of using Wi-Fi technology is that higher signal strength enables generation of the reports about the delay at the intersection.

Performance measures available when using some of the Sensys tools are listed below:

1. Vehicle Volumes
2. Bicycle Volumes
3. Vehicle Detector occupancy
4. Speed
5. Travel times
6. Intersection delay (available only if WiFi technology is used, not with Bluetooth)
7. Volume-to-Capacity Ratio
8. Arrivals on Green
9. Purdue Coordination Diagrams
10. Red Light Violations

2.2.10.1 SensID

SensID is an application based on the Sensys Networks wireless platform. The wireless devices are installed to match Bluetooth or Wi-Fi data, more precisely they perform the re-identification of Media Access Control (MAC) addresses to determine the position of the vehicle containing the device with BlueTooth or Wi-Fi turned on. This tool is capable of creating reports for travel time, speed reports, intersection delay analysis and origin/destination patterns for the time intervals and the routes selected by the user. Congestion sports can be mapped so the operator can focus on that zones.

2.2.10.2 SensFlow

SensFlow is the tool created for arterial and freeway traffic data collection. It provides Volume, Occupancy and Speed reports. Thereby, the user can have the overview of the traffic flow status on the subject arterial.

2.2.10.3 SensMetrics

SensMetrics is a high resolution data analysis platform which based on wireless technology for vehicle detection. It continuously collects and reports the traffic data from the intersection or the entire corridor. SensMetrics is able to accurately note turning movement counts and other important data, for example, volumes, V/C ratio, percentage of arrivals on green or create Purdue Coordination diagrams. Additional safety measures like red light violations can also be collected.

The collected vehicle volume data can be displayed in form of a graph (Figure 2.2-54) so operators can easily track changes and take appropriate actions, if necessary. Beside the daily changes, also changes by week, month or year can easily be observed.

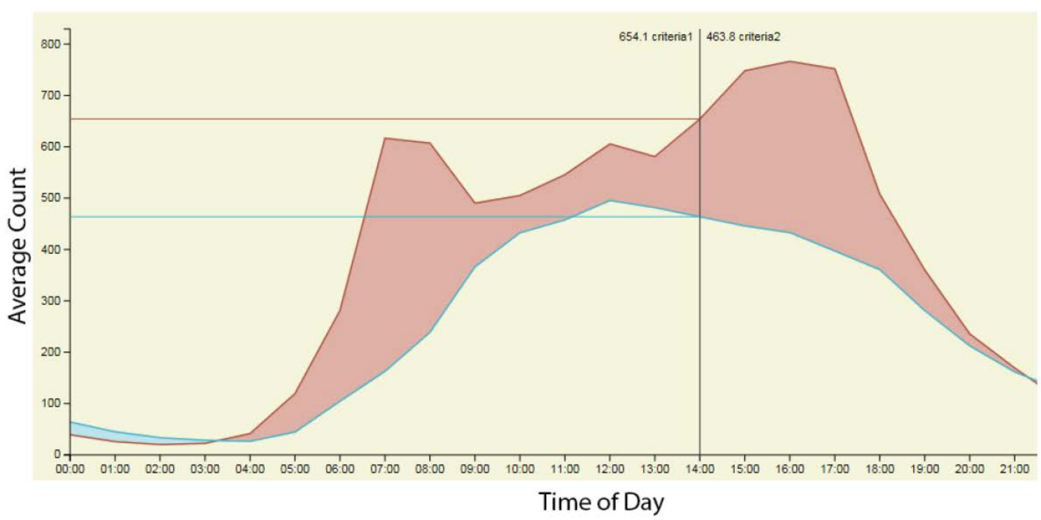


Figure 2.2-54. Performance comparison report

Purdue Coordination Diagrams offer a graphical view of signal coordination. Percentage of arrivals on green in addition to waiting time by approach are also summarized and displayed to the user. Thus, high resolution traffic data can be collected by using external equipment where hi-resolution controllers are not available.

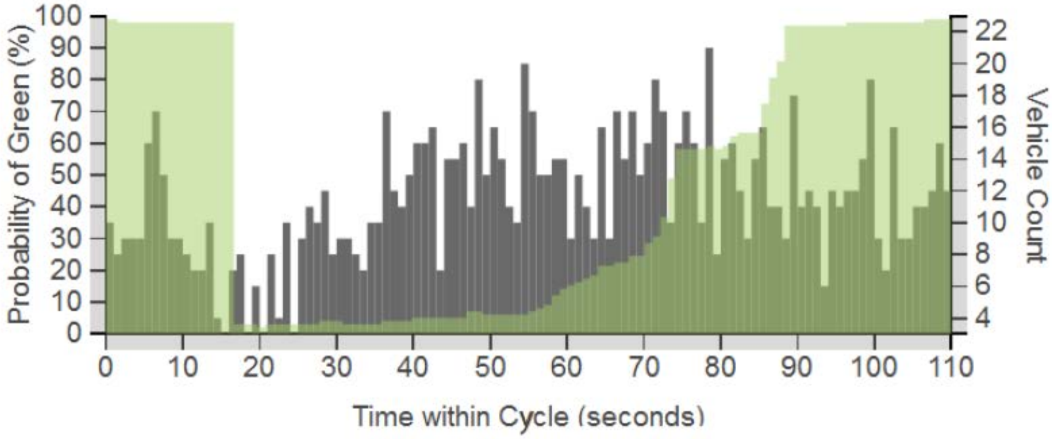


Figure 2.2-55. Purdue coordination diagram

The tool is capable of measuring congestion levels by comparing the measured volumes with the capacity per each lane on an approach per 60 minutes. Indication of the protected and permissive movements is also given on the graph below (Figure 2.2-56).

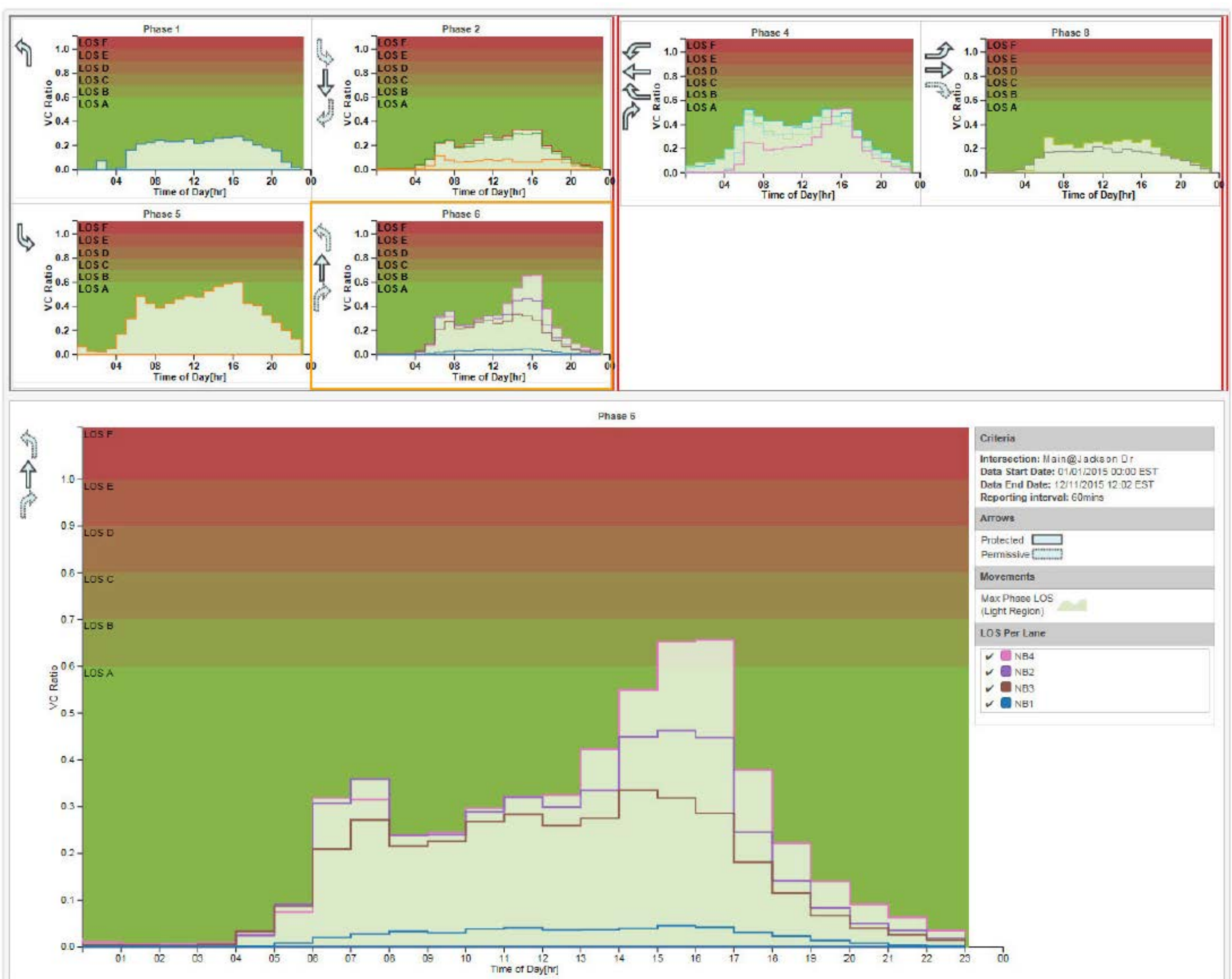


Figure 2.2-56. Volume-to-capacity (V/C) ratio by phase per hour per approach per lane

The average number of red light violations per 15 minutes per approach can also be reported (Figure 2.2-57). Thereby, the operators have a possibility to keep track about red light violations as an indicator of safety at the intersections. Red light violations are being documented separately for each approach and later being displayed on the graph using different colors. In that case, isolation of the most problematic location, approach or time interval can be easily monitored.

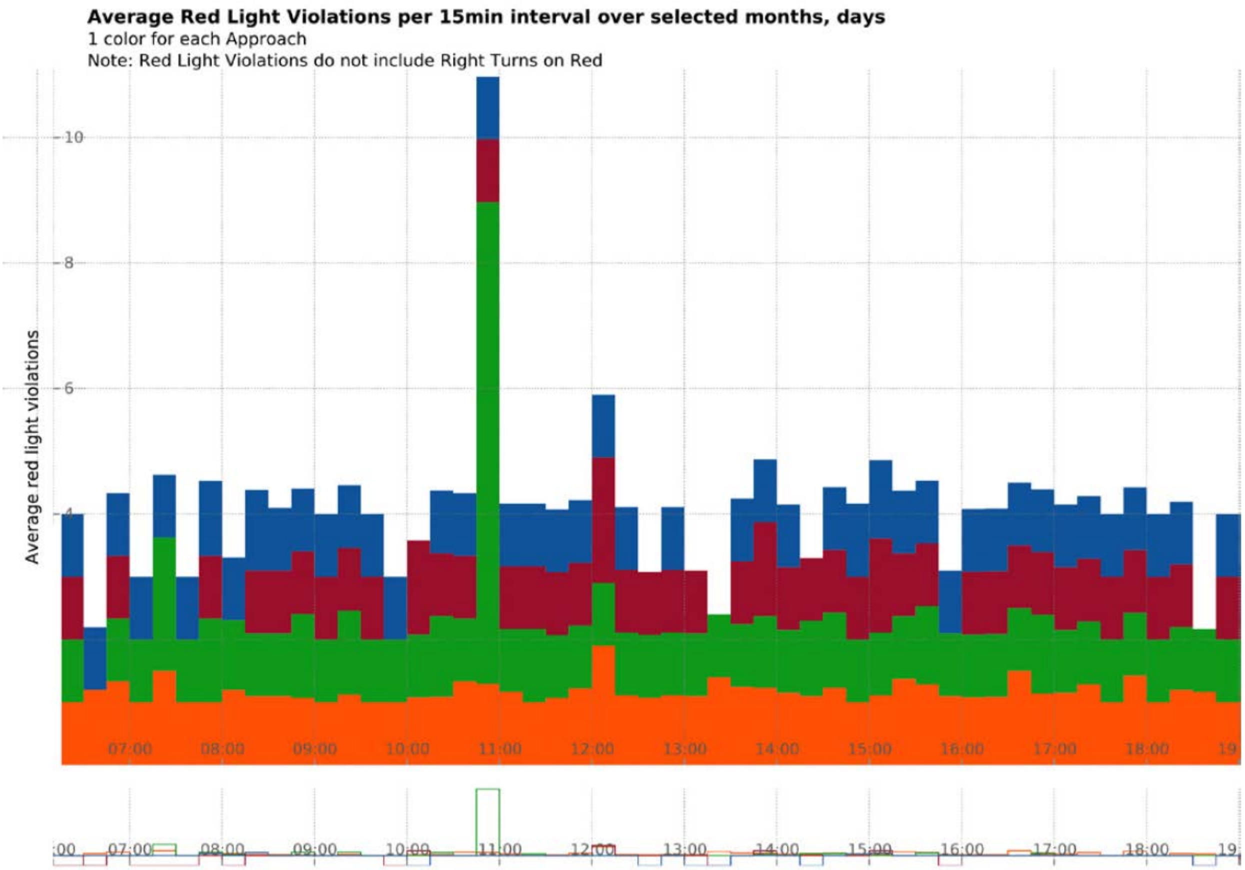


Figure 2.2-57. Red light violations graph

Beside volume, occupancy and speed, the Sensys has the capability to calculate and report travel times (Figure 2.2-59). The available data are median travel time, 80th percentile, 90th percentile, length of segment, number of detections in the segment and level of service. All those measures enable comprehensive overview of the traffic flow status on the subject segment.

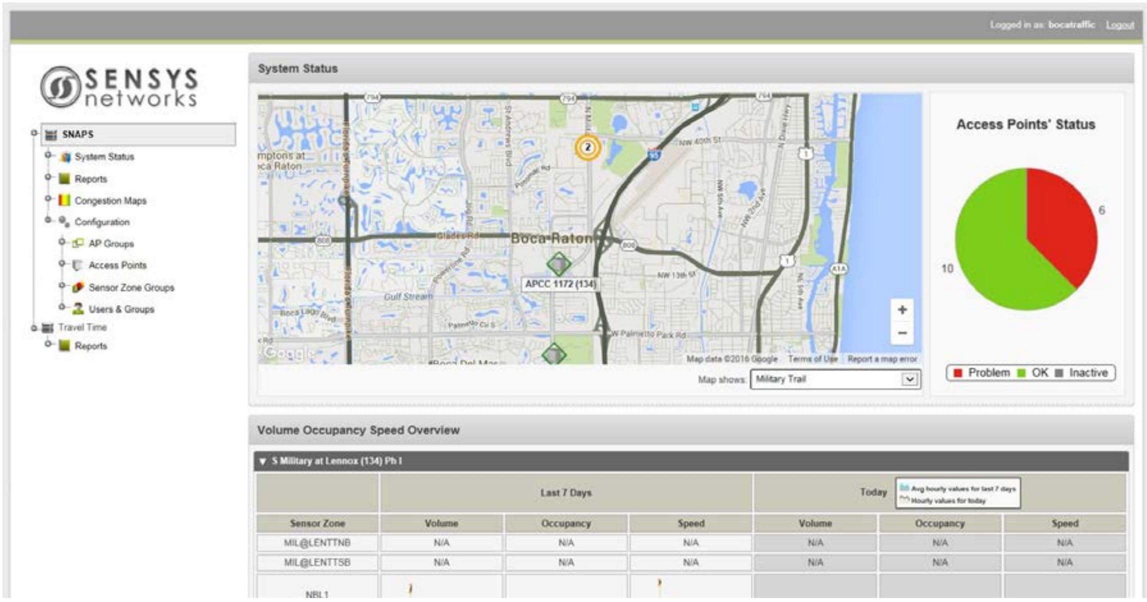


Figure 2.2-58. Volume, occupancy, and speed overview

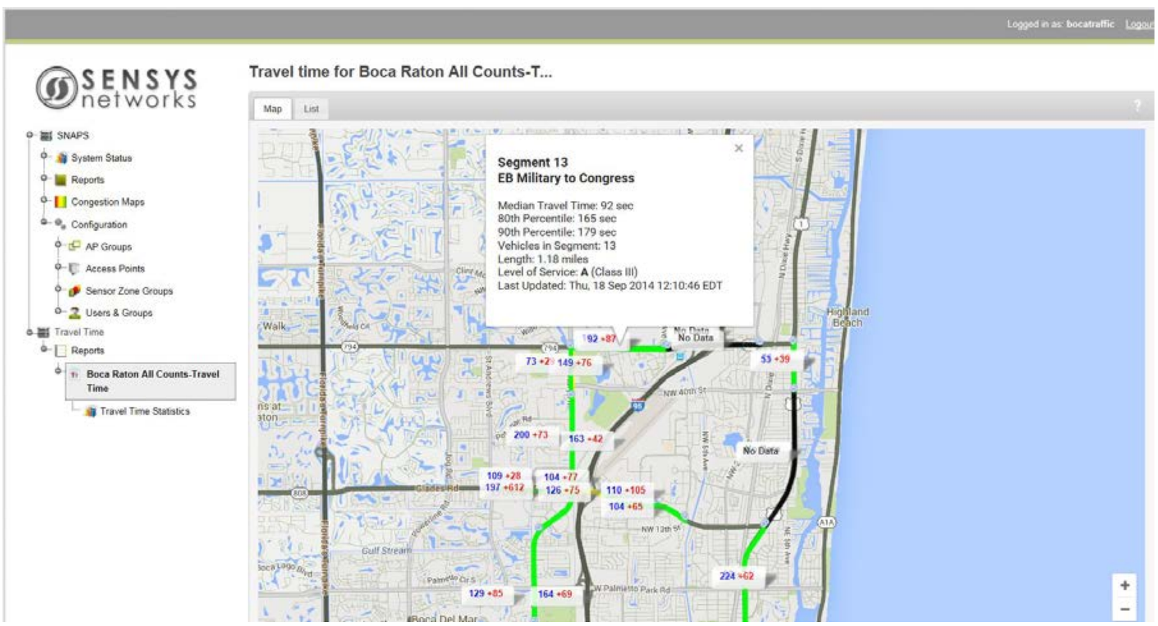


Figure 2.2-59. Travel time screen for one segment

2.3 Data Collection Survey – Two Agencies

After reviewing the possibilities for the data collection of SSCSs and external systems, the next step was to interview the agencies that operate traffic signals in the local counties or cities. This was done to determine what data and performance measures are actually available onsite. The agencies might have only some of the performance measures available due to differences in system types, versions, equipment used or modules installed even within the same type of SSCS.

Two agencies that were selected to participate in this interview are Traffic Divisions from Palm Beach County and City of Boca Raton. A difference in agency's jurisdiction size can cause variances in procedures, number of personnel, level of equipment etc. They are provided as inputs in the spreadsheet tool (used to assess agency operations).

Variability in the characteristics of traffic signal agencies can help to test practicality and feasibility of the evaluation methodology in the real-world environment. Data availability, ease of extraction, data aggregation, interfacing, etc., are the types of issues that are addressed in the following part of the report.

After the FAU research team defined the questions for the survey (upon an extensive literature review), those questions were given to the agencies to provide their inputs. The agencies did not have answers to all of the questions – in some cases, the data were not available whereas, in some cases, the data existed but required significant effort from the agency staff to extract and process in order to answer the survey questions. In the latter case, the representative of the FAU research team visited agency's office and performed all the necessary actions regarding the data extraction.

The agency inputs are provided in five different sections (see below) following the format from the National Traffic Signal Report Card (NTSRC):

1. Management
2. Traffic Signal Operations
3. Signal Timing Practices
4. Traffic Monitoring and Data Collection
5. Maintenance

The additional "General and Contact information" section was added, and the data availability and the results can be shown separately per section for both "pilot" agencies. This addition makes comparison between the grades, acquired by NTSRC's qualitative methodology, more reasonable. Weekly/monthly evaluation using various performance measures was also developed for two selected corridors operated by these two agencies.

Finally, FAU research team would like to express its gratitude to staff of both City of Boca Raton and Palm Beach County agencies for their collaboration, cooperation and help during the data collection process. By using their experience in Traffic Management Center operations and signal systems in general, their insights, suggestions and explanations contributed to the quality of this task of the research project.

2.3.1 General and Contact Information

The survey spreadsheet starts with General and contact information section. In the first part, name and address of the agency as well as name, title and the email address of a contact person are required. That information should be always available, and the reason for the collecting this information is to enable potential communication with the person in charge. General information section consists of the questions about county population (available on the web site www.census.gov), number of the registered vehicles, number of neighboring signal control agencies, number of streets with shared signal jurisdiction, estimated annual funding for signal operations and management, estimated annual funding for signal related capital investments and number of signals that agency has under its jurisdiction. Some of the required information may seem of low relevance but their true importance is revealed later in calculations and comparisons. If some of the necessary information were not available, the values were approximated by agency staff, where possible, and those fields were marked in yellow. If approximation was performed by someone outside of the agency staff, those cases are separately explained in the text of this deliverable. Where the values could not be approximated, impossible to collect without creating a new method for data extraction or processing, or do not exist at all, those fields are marked in red. Data sources are given in the tables or additionally explained in the text (Table 2.3-1 and Table 2.3-2).

Number of the registered vehicles is available for all counties in Florida on the website www.flhsmv.gov. However, considering the number of registered vehicles in the cities, neither the agency staff nor FAU research team were able to acquire that information. That is the reason why approximation was performed by using proportion ratio between population values for both Palm Beach County and City of Boca Raton, to approximate the number of registered vehicles in Boca Raton by using the number of registered vehicles in the Palm Beach County.

Table 2.3-1. General and contact information - Boca Raton

	Contact information	Data	Source
0.1	Name of the contact person	Rasem Awwad/Tracy Phelps	
0.2	Title of the contact person	Traffic Ops Eng/Transportation Eng	
0.3	Agency	City of Boca Raton	
0.4	Address	201 W. Palmetto Park Rd, Boca Raton, FL 33432	
0.5	Email address	rawwad@myboca.us	
	General information		
0.6	County population	91,332	www.census.gov
0.7	Number of registered vehicles	72,600	www.flhsmv.gov
0.8	Number of neighboring signal control agencies	2	
0.9	Number of streets with shared signal jurisdiction	0	
0.10	Total length of road by the jurisdiction (miles)	220	

Table 2.3 1. General and contact information - Boca Raton - continued

0.11	Estimated annual funding for signal operations and management	$150,000	
0.12	Estimated annual funding for signal related capital investments	$80,000	
0.13	Number of signalized intersections (full signals)	136	

For Palm Beach County, all the data were available except estimated annual funding for signal operations and management, and estimated annual funding for signal related capital investments.

Table 2.3-2. General and contact information - Palm Beach County

General and contact information - Palm Beach County			
	Contact information	**Data**	**Source**
0.1	Name of the contact person	Giri Jeedigunta, PE, PTOE	
0.2	Title of the contact person	Signal Systems Manager - Traffic Division	
0.3	Agency	Palm Beach County	
0.4	Address	2300 N. Jog Road, 3rd floor East, West Palm Beach, FL 33411	
0.5	Email address	gjeedigu@pbcgov.org	
	General information		
0.6	County population	1,422,789	www.census.gov
0.7	Number of registered vehicles	1,135,116	http://www.flhsmv.gov/html/reports_and_statistics/cvr/15-16/cvr_04_2016.pdf
0.8	Number of neighboring signal control agencies	5	
0.9	Number of streets with shared signal jurisdiction	25	
0.1	Total length of roads by the jurisdiction	1549	http://www.dot.state.fl.us/planning/statistics/gis/road.shtm
0.11	Estimated annual funding for signal operations and management	NA	Not available at this time.
0.12	Estimated annual funding for signal related capital investments	NA	Not available at this time.
0.13	Number of signalized intersections (full signals)	1,047	ATMS.now

2.3.2 Management

The following section in the evaluation methodology is the Management, and the answers for both agencies are given in the Table 2.3-3. The questions are divided into subgroups addressing relevant topics regarding the management section. First four questions (1.1 to 1.4) are related to the number and expertise of the staff, in-house and outsourced, staff training and their involvement in monitoring of the traffic flows and signals. These questions help to get a better idea about size of the agency in terms of personnel and quantifying the efforts to improve skills and abilities of the staff.

In the next step, the data considering public relations were collected including publicized telephone number or website which public can use to report malfunctions, and quantifying the complaints per year. An average time from receiving a memo or a call to answering the call is investigated. Furthermore, some of the questions addressed were about types of information and means of communication to the public to determine the level of interaction between the agency and public.

The level of cooperation with the neighboring agencies is determined by number of agencies with whom the data or information are being exchanged to total number of neighboring agencies, and by determining the number of streets with traffic signals that are inter-coordinated. On the other hand, the number and the extent of the work zones were not available for either agency involved in this research project. Those data are not being collected or documented, the staff members from both agencies were unable to make an expert estimation, and hence there is a possibility for removal the question 1.10 from the methodology (Table 2.3-3).

Number of accidents near traffic signals was selected as a safety measure. For collecting that data, Signal Four Analytics Software was installed with the help of Florida Department of Transportation (FDOT). In order to exclude some of the accidents that happen throughout the city or county network, some additional conditions were added. After selecting a city or county of interest, the network extent should be set to Intersection, intersection offset distance to 150 feet, road circumstances to None, Other and Unknown, and Road System Identifier to U.S., State, County and Local. In this way only accidents which occurred near intersection (within the zone of 150 feet) were considered. Also, road circumstances conditions setup exclude the conditions that can cause the accidents and are not related to the traffic signals. Finally, Road System Identifier setup excludes interstate highways, and private roads where should be no traffic signals. As an additional measure, accidents involving the running of the red lights were separately displayed as a value in the brackets.

Before finally reaching the questions addressing the existence, type, extent, functionality, alarms and other characteristics of signal system central software (ATMS.now for both agencies), two sets of questions considering inventory and intervention vehicles are prepared. First, it is important to check if the agency has an updated inventory about all traffic signal related equipment with spares, which gives a slightly better insight about level of organization of the agency. Second, number of intervention vehicles and the amount of using them in terms of time, mileage and coverage. The coverage can be explained as the area in which all traffic signals will be assigned to one vehicle/team for maintenance or similar.

Table 2.3-3. Section 1 - Management

#	Number and expertise of staff	City of Boca Raton	Palm Beach County
1.1	**Number of FTE for regular staff per expertise (Engineer, Technician, Administrative…)**	10	27
1.1.1	Manager	0	1
1.1.2	*Engineer*	2	3
1.1.3	*Technician*	6	22
1.1.4	*Administrative staff*	2	1
1.2	**Number of FTE for outsourced staff per expertise (Engineer, Technician, Administrative…)**	0	4
1.2.1	Manager	0	1
1.2.2	*Engineer*	0	2
1.2.3	*Technician*	0	1
1.2.4	*Administrative staff*	0	0
	Staff training		
1.3	**Number of training hours in the last year for (hours x persons):**	176	
1.3.1	*Basic Signal Timing*	0	NA
1.3.2	*Advanced Signal Timing*	32	NA
1.3.3	*ITS Courses*	64	NA
1.3.4	*Hardware and Communications*	64	NA
1.3.5	*Other (what)*	16	NA
1.4	**Monitoring**		
1.4.1	Number of staff designated to monitoring	1	3
1.4.2	Number of hours per week they are designated to monitoring	10	20
1.4.4	Average number of work hours per week for that personnel	40	40
1.5	**Quantified goals**		
1.5.1	Number of complaints per year	248	Approx. 900
1.5.2	Is there a publicized call-in telephone number and web site that the public can use to report malfunctions, ask questions and suggest operational improvements?	YES	YES
	Public relations		
1.6	**Average time from receiving of memo or call until answering**	48h	NA
1.7	**Information being made available to public:**		
1.7.1	*Traffic lights failures*	NO	NO
1.7.2	*Congestion*	NO	YES
1.7.3	*Incidents on signalized intersections*	NO	YES
1.7.4	*Lane closures at signalized intersections*	YES	YES
1.7.5	*Reaction time for reparations of traffic signals*	NO	NO
1.7.6	*Frequency of malfunctions*	NO	NO

Table 2.3 3. Section 1 – Management - continued

#		City of Boca Raton	Palm Beach County
1.7.7	*Goals of the agency (write the goals in the comment)*	NO	NO
1.7.8	*Other (what)*	NO	NO
1.8	**Means of communication with the public:**		
1.8.1	*PR person*	YES	NO
1.8.2	*Head of department*	YES	NO
1.8.3	*Memos or letters*	YES	NO
1.8.4	*Television*	NO	NO
1.8.5	*Radio*	NO	NO
1.8.6	*Web site*	YES	NO
1.8.7	*Telephone*	YES	YES
1.8.8	*Other*	NO	511
1.9	**Cooperation with adjacent agencies**		
1.9.1	Number of neighboring county agencies with whom the information and data are being exchanged	1	5
1.9.2	Number of streets with signals being shared with the neighboring agencies that are inter-coordinated	0	Approx .25
1.10	**Work zones**		
1.10.1	Number of work zones on signalized intersections per year	NA	NA
1.10.2	Number of lane-mile-hours closed due to work zones per year	NA	NA
	Safety and accidents		
1.11	**Number of accidents on streets with traffic signals (number of running the red light incidents in brackets)**	2960 (98)	29964 (921)
	Inventory		
1.12	**Is there an up-to date inventory about all signal equipment including spares?**	YES	YES
1.13	**Service vehicles number and activation**		
1.13.1	Number of vehicles in operation by shift	6	15
1.13.2	Miles travelled per vehicle (in thousands)	NA	15
1.13.3	Hours in service per vehicle	5.33	NA
1.13.4	Miles of coverage per vehicle (in thousands)	NA	NA
1.14	**From Signal System Central Software (ATMS.now)**		
1.14.1	Do you have a SSCS software?	YES	YES
1.14.2	How many intersections are connected to SSCS?	136	817
1.15	**Type of SSCS software:**		
1.15.1	*ACTRA*		
1.15.2	*ATMS.now*	YES	YES
1.15.3	*Centracs*		
1.15.4	*KITS*		

Table 2.3 3. Section 1 – Management - continued

#		City of Boca Raton	Palm Beach County
1.15.5	*MIST*		
1.15.6	*QuicNet*		
1.15.7	*Sitraffic Concert*		
1.15.8	*Sitraffic Tactics*		
1.15.9	*Other*		
1.16	**Functionality of SSCS:**		
1.16.1	*Video monitoring*	YES	YES
1.16.2	*Functionality monitoring*	YES	YES
1.16.3	*Signal plans changing*	YES	YES
1.16.4	*Special events management*	YES	YES
1.16.5	*Corridor management/traffic signal coordination or control*	YES	YES
1.16.6	*Disaster management and traffic coordination*	YES	YES
1.16.7	*Emergency services traffic control coordination*	YES	YES
1.16.8	*Ramp management and control*	NO	NO
1.16.9	*Network performance monitoring, evaluation and reporting*	YES	YES
1.16.10	*Other (what)*		
1.17	**Number of staff that actively use SSCS software**	2	12
1.18	**Does the agency have set the alarms for malfunctions that inform persons in charge?**	YES	YES
1.19	**The existing mediums that are used for informing persons in charge about events causing alarms:**		
1.19.1	*On SSCS software interface*	YES	YES
1.19.2	*SMS message*	NO	NO
1.19.3	*E-mail*	YES	YES
1.19.4	*Pager*	NO	NO
1.19.5	*Other (what)*		

The data collected from the questionnaires will be imported into spreadsheet tool, Management section sheet, and further used for calculation of the section score. For the questions and sets of questions user will have the possibility to select the level of importance, and therefore increase or decrease the influence of certain questions based on priorities set or local conditions. The five section scores will at the end be used to calculate the final score explaining the level of quality the agency reached in terms of traffic signal operations and maintenance.

2.3.3 Traffic Signal Operations

In the second section of the manual/methodology, the traffic signal operations are addressed (Table 2.3-4). The questions in this section are separated in two groups, general questions and those questions whose answers can be obtained using SSCS. The questions include use of responsive or adaptive traffic control, frequency of signal retiming, number of coordinated signals, etc. For all of the questions, the agencies provided the answers although the answers for questions 2.6, 2.7 and 2.8 were estimated.

As far as data from SSCS is concerned, number of special signal timings and total number of signal timings were estimated by agency's staff. The total number of signal timings for Palm Beach County was hard to estimate, having in mind that there are 1047 signalized intersections under jurisdiction of that agency. The inventory of signal timings is not kept and updated in electronic form. The exact number of signal timings could be counted if every of the 1047 intersections were accessed via ATMS.now and then counted, but that would be long and tedious process and thus not suitable to become regular practice by the agency staff.

Giving priority to public transit vehicles on signalized intersections does not exist in neither of the agencies that were subject to the survey. By comparing the number of school zone flashers with the number of schools, it is possible to calculate the percent of coverage. Although there is a Real-time congestion report in ATMS.now, both agencies failed to provide this information in the ATMS.now reports (they were blank).

Considering the cycle failures, it is important to emphasize that in ATMS.now cycle failure is an alarm that indicates that a serviceable call has not been serviced in approximately two cycle times and that coordination was not active at the time. In general, as a cycle failure is considered a case when after finishing the green time queue formed in front of the intersection has not discharged completely. Cycle fault in ATMS.now is similar to cycle failure with the difference that the coordination was active at the time. The cycle faults, failures and coordination failures are the events that are being noted in the ATMS.now and can be reported by Field Alarms. One of the future efforts of this research project will be creating a semi-automatized macro in Excel that can calculate frequency and durations of those events. After finishing that step, some of the fields currently marked red will be cleared and the exact values could be used.

Table 2.3-4. Section 2 - Traffic signal operations

2	General	City of Boca Raton	Palm Beach County
2.1	Do you use responsive or adaptive traffic control?	YES	YES
2.2	Frequency of signal operations reviews?	Twice a year	On as needed basis
2.3	Are ad-hoc changes triggered complaint calls performed for all legitimate requests?	YES	YES
2.4	Reviewing the sights distances to intersections with new traffic signal installations	YES	YES
2.5	Are advanced warning indications installed where limited site distances exist?	YES	YES
2.6	Number of signalized intersections adjusted for visually impaired persons	13	Approx. 70 -100
2.7	Actual time to implements, evaluate and calibrate the new timing settings or strategy	4 weeks	Approx. 4 -8 weeks
2.8	Expected time to implement, evaluate and calibrate the new timing settings or strategy	4 weeks	Approx. 4 - 8 weeks
2.9	What is the frequency of signal retiming in your agency?		
2.9.1	*Less than 1 year*	*YES*	
2.9.2	*1-2 years*		For Critical Corridors
2.9.3	*2-3 years*		All other coordinated corridors
2.9.4	*3-5 years*		Isolated signals
2.9.5	*More than 5 years*		
2.10	Number of coordinated traffic signals	103	61% (639)
	From Signal System Central Software		
2.11	Number of special events, disasters, VIP routes and emergency signal timings	48	375
2.12	Total number of signal timings	589	YES
2.13	Number of school zone manual flash signals	39	Approx. 200
2.14	Number of schools	17	168
2.15	Number of intersections with preemption capability	64	100%
2.16	Number of intersections with Public transit prioritization capability	0	0
2.17	Total number of signalized intersections along PT routes.	0	0
2.18	Average number of hours per day when adaptive system is active	12	24X7X365
2.19	Number of hours with congestion (per day, week, month)	8	NA
2.20	Total number of hours per observed period (in days, weeks, months)	24	NA
2.21	Number of cycle failures	NA	NA
2.22	Total number of cycles per observed period	YES	YES
2.23	Number of cycle faults (AM, PM, Midday, Night)	NA	YES
2.24	Time that coordination has been in transition	NA	YES
2.25	Time the coordination is active (per day)	15	YES
2.26	Coordination failure	NA	YES

2.3.4 Signal Timing Practices

In the third section, Signal Timing Practices, the intention is to investigate what types of input data, procedures or software are used when creating new signal timing plans or strategies. Are records of vehicle conflicts on intersections taken into consideration before creating a new signal plan? What performance measures and what signal timing parameters do the agencies use when creating new signal plans? The set of general questions is finalized after examining if the staff uses some of the signal timing optimization software to develop new signal timings. All of the necessary data were available and collected by both agencies (Table 2.3-5).

From SSCS, the necessary data are duration of splits in different time periods, duration of programmed splits, the number of times a certain phase was activated during an evaluation period and what is the maximum number of times that phase could be activated. Those data can be retrieved from Split History reports in ATMS.now, but due to nature and the quantity of the data (split history logs data per cycle and per intersection), it is possible to perform the collection and calculation only for certain selected intersections, corridors or small zones. That is the reason why it is suggested that answers from questions 3.5 to 3.8 (Table 2.3-5) should be used for weekly/monthly evaluation only.

Table 2.3-5. Section 3 - Signal timing practices

	General	**City of Boca Raton**	**Palm Beach County**
3.1	Are records of vehicle conflict situations collected and available?	NO	NO
3.2	What performance measures your agency collects?		
3.2.1	*Number of vehicles served*	*NO*	YES
3.2.2	*Delay per vehicle*	*YES*	YES
3.2.3	*Total delay*	*YES*	YES
3.2.4	*Travel time*	*YES*	YES
3.2.5	*Number of stops*	*YES*	YES
3.2.6	*V/C*	*NO*	YES
3.2.7	*Other*	*NO*	NO
3.3	Do you use signal timing optimization software (Synchro, PASSES, TRANSYT, etc.) to develop new signal timings?	YES	YES
3.4	What parameters do you use to develop new signal timings?		
3.4.1	*Cycle lengths*	*YES*	YES
3.4.2	*Offsets*	*YES*	YES
3.4.3	*Splits*	*YES*	YES
3.4.4	*Phasing sequence*	*YES*	YES
3.4.5	*Discharge time*	*YES*	YES
3.4.6	*Two-way progression*	*YES*	YES
3.4.7	*Turning movements*	*YES*	YES
3.4.8	*Time space diagrams*	*YES*	YES
3.4.9	*Other*		YES

Table 2.3 5. Section 3 - Signal timing practices - continued

	From Signal System Central Software	City of Boca Raton	Palm Beach County
3.5	Average duration of splits per AM, Midday and PM period	NA	YES
3.6	Duration of programmed splits per AM, Midday and PM period	NA	YES
3.7	The number of times a phase was activated in a given evaluation period	NA	YES
3.8	Maximum number of times that phase could be activated	NA	YES

2.3.5 Traffic Monitoring and Data Collection

The traffic monitoring and data collection are very important especially nowadays when Intelligent Transportation Systems are widely present and detection, data collection and storage capacities are easily available. The entire section is divided into several sets of questions (Table 2.3-6). From 4.1 to 4.7 are questions related to the detection. That is the most problematic set in this section, because of the answers on the questions related to the detection inventory. Neither of the agencies has exact inventory of all of the detection components. Admittedly, The City of Boca Raton has the inventory list about number of cameras for video detection and pedestrian detectors, but not the number of inductive loops installed. The City of Boca Raton was an easier case because of a smaller number of signals and corresponding detectors. After reviewing majority of the intersection as built drawings and using Google map street view, the approximate number of detectors per type was determined. Palm Beach County agency does not keep that kind of updated information. For larger agencies, inventory that would be updated regularly would make that process very easy. Currently, the inventory about detectors was not available so only rough approximations can be made. For the question 4.1, Palm Beach County responded with YES but provided an additional explanation that they have detectors on all signalized intersections with either video detection or loop detectors (typically 4 cameras per intersection, or 1 loop in each lane). Still, the exact number of the detectors is not known. Other questions were much easier to answer for both agencies.

Questions from 4.8 to 4.11 address the data collection and storage. Archiving methods, data types, sharing of the data and the technologies used for data collection are the fields covered by this set of questions, and they all were answered.

Questions 4.12 to 4.15 are referring to data quality and investigate correctness, consistency and the resolution of the data collection. That is very important because misleading information can sometimes be even worse case compared to the total lack of the data.

Number of requests for data by media or other agencies, number of weather stations and number of actions taken based on information from those stations, and turning movement counts in terms of frequency and number of locations represent the set from question numbers 4.16 to 4.21.

Table 2.3-6. Section 4 - Traffic monitoring and data collection

4	Detection	City of Boca Raton	Palm Beach County
4.1	**Total number of detectors**	1167	Approx. 7545
4.2	**Detection distribution by type of detector**		
4.2.1	*Inductive loop*	928	Approx. 6700
4.2.2	*Video*	239	Approx. 838
4.2.3	*Microwave*	0	7
4.2.4	*Infrared*	0	0
4.3	**Choose system detectors that are being used in your agency:**		
4.3.1	*Midblock*	0	0
4.3.2	*Near upstream intersections*	0	0
4.3.3	*Other*	0	Stop-bar
4.4	**What data do those system detectors collect?**		
4.4.1	*Speed*	NO	YES
4.4.2	*Volume*	NO	YES
4.4.3	*Occupancy*	NO	YES
4.4.4	*Progression speed*	NO	
4.4.5	*Other*		
4.5	**Does your agency use queue detectors?**	NO	YES
4.6	**If video detectors are used, is their operation calibrated for real conditions on the field**		
4.6.1	*Lighting*	YES	NO
4.6.2	*Weather*	YES	YES
4.6.3	*Wind*	YES	YES
4.6.4	*Occlusion*	YES	YES
4.6.5	*Lense cleaning*	YES	YES
4.6.6	*Zone adjustments*	YES	YES
4.6.7	*Other*		
4.7	**How often video detectors are being calibrated?**		
4.7.1	*More often than once per month*		
4.7.2	*Every month*		
4.7.3	*Every three months*	YES	
4.7.4	*Every six months*		YES
4.7.5	*Once per year*		
4.7.6	*Less often than once per year*		
	Data Collection and storage		
4.8	**Choose the used archiving methods for the data:**		
4.8.1	*Paper copy database*	YES	YES
4.8.2	*Electronic database*	YES	YES

Table 2.3 6. Section 4 - Traffic monitoring and data collection - continued

#		City of Boca Raton	Palm Beach County
4.8.3	*GIS*	YES	YES
4.8.4	*Other*	NO	YES
4.8.5	*Not at all*	NO	NO
4.9	**Select the data types that are saved in the signal inventory system (database):**		
4.9.1	*Volume*	NO	YES
4.9.2	*Occupancy*	NO	
4.9.3	*Travel time*	YES	YES
4.9.4	*Queue lengths*	NO	
4.9.5	*Work zones*	NO	YES
4.9.6	*Events*	YES	YES
4.9.7	*Weather*	YES	
4.9.8	*Location*	YES	YES
4.9.9	*Hardware*	YES	YES
4.9.10	*Controller*	YES	YES
4.9.11	*Timing plans*	YES	YES
4.9.12	*Time space diagrams*	YES	YES
4.9.13	*Travel time intervals*	YES	YES
4.9.14	*Maintenance activity*	NO	YES
4.9.15	*Other*		
4.10	**With who are those reports shared?**		
4.10.1	*Limited group inside the agency*	YES	YES
4.10.2	*All agency personnel*	YES	YES
4.10.3	*Public*	NO	
4.10.4	*Universities*	YES	YES
4.10.5	*Research institutes*	YES	YES
4.10.6	*Agencies at the same state*	NO	YES
4.10.7	*Agencies in other states*	NO	
4.10.8	*Other*	FHWA	
4.11	**Select the technologies used to collect vehicle travel times:**		
4.11.1	*Field runs - manually with probe vehicle*	NO	
4.11.2	*Field runs - with GPS*	YES	YES
4.11.3	*Video cameras with ALPR (Automatic license plate recognition)*	NO	NO
4.11.4	*Tag readers (E-Z Pass)*	NO	NO
4.11.5	*Bluetooth/Wi-Fi (MAC address matching)*	YES	YES
4.11.6	*Other*	NO	YES
4.11.7	*Travel time not collected*	NO	

Table 2.3 6. Section 4 - Traffic monitoring and data collection - continued

	Data quality	**City of Boca Raton**	**Palm Beach County**
4.12	Are the collected data checked for quality, consistency and correctness?	YES	YES
4.13	The resolution of collected data regarding travel times	As needed	5min, 15 min and 1h intervals
4.14	The resolution of collected data regarding vehicle delay	NO	NO
4.15	The resolution of collected data regarding actual signal timings	Cycle by cycle	Cycle by cycle
	Other		
4.16	Number of requests for data by other agencies per year	5	NA
4.17	Number of requests for data by media	0	NA
4.18	Number of weather stations located on the territory under agency's jurisdiction	0	NA
4.19	Number of actions or responses due to weather detection	0	NA
4.20	On how many locations, the turning movement counts are being collected?	Where needed	Where needed
4.21	Frequency of turning movement counts collection	4 years	once in 1.5 years

2.3.6 Maintenance

Final section for annual evaluation methodology is maintenance, with the answers for both agencies shown in the Table 2.3-7. Although the majority of the questions were answered without significant issues, there are few groups of the questions whose answers were not easy to develop. In the set of questions regarding equipment, the data about number and the duration of the detector failures is not readily available. Rough estimation could be made, but other options could be to analyze the Detector failure report (did not provide any data for either of the agencies) or to analyze the Field Alarm reports from ATMS.now. More about this issue will be explained in the final chapter of the report.

Total cost of all reparations per year was not available either. Approximation by using the yearly budget is one option for answering, but the exact value is not available. Number of all malfunctions for Palm Beach County was approximated by their staff, and for City of Boca Raton it was taken from Signal shop tables where they keep track about number of activations for intervention. Total number of lightbulbs was unknown because there is no detailed inventory, and regarding the number of changed lightbulbs only rough approximation could be made.

In the set of questions about inventory, City of Boca Raton keeps also the detailed information about every intervention that their signal technicians or engineers performed in the field. The downside is that data is stored in paper reports filled and returned by teams involved after every shift. Going through every hard copy report and transcription of all data for the entire network and entire year would not be feasible for the staff to perform even if it was once per year. If that kind of information was stored in digital database, this process could be properly integrated in the agency assessment methodology. On the other hand, Palm Beach County agency stores the data about some of the daily field alarms, data changes report, locations and type of work performed because those data are part of the work orders they create for field teams. Other data such as about equipment, spare parts, duration of the interventions, and number of workers are not stored.

The value of lane-mile-hours near signalized intersections which were closed due to routine maintenance and non-routine maintenance of traffic signals is not available in either of the agencies, and it is not possible to make expert estimation based on the available data. This set of questions might be excluded from the evaluation methodology if data about these activities will not be updated and stored.

Considering the last set of questions, answers on questions from 5.26 to 5.30 do exist and those data are available indirectly after significant post-processing of the reports available from ATMS.now. FAU research team will try to create a tool for automatization of that process. Question from 5.31 to 5.35 are either currently not available in the electronic form, or not available at all.

Table 2.3-7. Section 5 - Maintenance

	Performance	**City of Boca Raton**	**Palm Beach County**
5.1	Does maintenance agreement require performance monitoring and report?	YES	YES
5.2	Does agency uses performance measures to evaluate its signal system maintenance?	YES	YES
	Equipment		
5.3	Number of detectors out of function per year.	NA	500 to 700 intersections
5.4	Duration of detectors failure per year.	NA	NA
5.5	Are adjustment made to reflect changes required due to the characteristics of the new equipment?	YES	YES
5.6	Frequency of checking alignment and position of all signal heads and signs.	Yearly	2 PMS a year
5.7	Frequency of checking operability of signal controllers.	Daily	Daily
5.8	Frequency of checking operability of communication infrastructure.	Daily	Daily
5.9	Frequency of checking operability of Signal System Central Software.	Daily	Continuously
5.10	Frequency of checking operability of signal heads.	Monthly	During PM activities
5.11	Frequency of implement methods for synchronizing controllers' clocks.	Hourly	Daily
5.12	Total cost of all reparations per year.	150000	NA
5.13	Number of all malfunctions per year.	1581	Approx. 12,000
5.14	Number of changed lightbulbs.	NA	Approx. 2,000
5.15	Total number of lightbulbs.	NA	YES

Table 2.3 7. Section 5 – Maintenance - continued

	Reaction time	**City of Boca Raton**	**Palm Beach County**
5.16	The average response time (time from problem occurrence to beginning of solving) to critical failures (e.g. controller malfunction, communications failure, physical damage of equipment on site…).	12 hours	2 Hours for Critical 24 Hours for Non critical
5.17	The average time to complete the intervention (time to resolving the problem) to critical failures (e.g. controller malfunction, communications failure, physical damage or equipment on site…).	Less than 3 day	NA
5.18	The average response time to all reported failures:	Less than 3 day	NA
5.19	The average response time regarding user complaints:	NA	within a day
	Inventory and report		
5.2	Is there a record of maintenance activity available?	YES	YES
5.21	Does your agency creates maintenance reports about the following:		
5.21.1	*Communication failures*	*NO*	YES
5.21.2	*Vehicle detector failures*	*YES*	YES
5.21.3	*Pedestrian detector failures*	*YES*	YES
5.21.4	*UPS device failures*	*NO*	NA
5.21.5	*Controller device failures*	*NO*	YES
5.21.6	*Signal system central software*	*NO*	YES
5.21.7	*Signal system central hardware*	*NO*	YES
5.22	How frequent the maintenance reports are being made in your agency?		
5.22.1	*Hourly*		
5.22.2	*Daily*	*YES*	YES
5.22.3	*Weekly*		
5.22.4	*Monthly*		
5.22.5	*Annually*		
5.22.6	*Never*		
5.22.7	*Other*		
5.23	Does your agency keep record of the following specifics of each maintenance task and work order about:		
5.23.1	*Locations (where was maintenance performed)*	*YES*	YES
5.23.2	*Equipment (hardware and software which was affected by work order)*	*YES*	NA
5.23.3	*Type of work defined by work order*	*YES*	YES
5.23.4	*Type of work not defined by work order*	*YES*	YES
5.23.5	*Duration of work*	*YES*	NA
5.23.6	*Used parts for reparations*	*YES*	NA

Table 2.3 7. Section 5 – Maintenance - continued

5.23.7	*Number of workers active on that specific reparation*	*YES*	NA
5.23.8	*Other*		
	Other	**City of Boca Raton**	**Palm Beach County**
5.24	Lane-mile-hours near signalized intersections closed due to routine maintenance	NA	NA
5.25	Lane-mile-hours near signalized intersections closed due to non-routine maintenance	NA	NA
	From Signal System Central Software		
5.26	Duration of coordination failure	YES	YES
5.27	Total time while signals should be coordinated	YES	YES
5.28	Time while communications errors were present (per year)	YES	YES
5.29	Number of vehicle detector malfunctions	YES	YES
5.30	Number of pedestrian detector malfunctions	YES	YES
5.31	Total number of pedestrian detectors	NA	NA
5.32	Duration of all reparations per year	NA	NA
5.33	Total duration of routine and non-routine reparations	YES	NA
5.34	Number of routine and non-routine reparations	YES	NA
5.35	Average duration of routine and non-routine reparations	YES	NA

2.4 Reports from External Systems for Data Collection — Examples

In one of the previous chapters, external systems for data collection and performance measures calculation were presented and explained. In this chapter, the real example reports extracted by FAU team member in City of Boca Raton are presented and analyzed for all three selected systems. Their possibilities and options differ from those explained in the earlier chapters.

2.4.1 Acyclica Go

In one pilot agency Acyclica reports are able to display data about travel times (Table 2.4-1) and speed (Table 2.4-2) for different segments and for different time intervals. That gives the opportunity to keep track how changes in signal operations and traffic flows affect those parameters as well as to optimize the signal timings for better performance.

Table 2.4-1. An excerpt from Acyclica travel times – St. Andrews Blvd to Butts Rd

Time	Strength	Firsts	Lasts	Minimum	Maximum
Thu Apr 28 11:00:00 EDT 2016	1:24	1:41	1:16	1:03	1:53
Thu Apr 28 12:00:00 EDT 2016	1:12	1:40	1:03	0:56	1:55
Thu Apr 28 13:00:00 EDT 2016	1:23	1:39	1:09	1:02	1:53
Thu Apr 28 14:00:00 EDT 2016	1:33	1:46	1:16	1:02	1:57
Thu Apr 28 15:00:00 EDT 2016	1:46	2:03	1:42	1:29	2:15
Thu Apr 28 16:00:00 EDT 2016	1:42	1:49	1:35	1:22	2:15
Thu Apr 28 17:00:00 EDT 2016	1:48	1:57	1:41	1:30	2:19
Thu Apr 28 18:00:00 EDT 2016	1:56	1:59	1:53	1:37	2:11
Thu Apr 28 19:00:00 EDT 2016	1:14	1:27	1:09	1:02	1:39
Thu Apr 28 20:00:00 EDT 2016	1:06	1:14	1:03	0:58	1:22
Thu Apr 28 21:00:00 EDT 2016	1:14	1:18	1:03	0:59	1:34
Thu Apr 28 22:00:00 EDT 2016	1:16	1:24	1:08	1:00	1:34

Table 2.4-2. An excerpt from Acyclica speeds - St Andrews Blvd to Butts Rd

Time	Strength	Firsts	Lasts	Minimum	Maximum
Thu Apr 28 11:00:00 EDT 2016	1:24	1:41	1:16	1:03	1:53
Thu Apr 28 12:00:00 EDT 2016	1:12	1:40	1:03	0:56	1:55
Thu Apr 28 13:00:00 EDT 2016	1:23	1:39	1:09	1:02	1:53
Thu Apr 28 14:00:00 EDT 2016	1:33	1:46	1:16	1:02	1:57
Thu Apr 28 15:00:00 EDT 2016	1:46	2:03	1:42	1:29	2:15
Thu Apr 28 16:00:00 EDT 2016	1:42	1:49	1:35	1:22	2:15
Thu Apr 28 17:00:00 EDT 2016	1:48	1:57	1:41	1:30	2:19
Thu Apr 28 18:00:00 EDT 2016	1:56	1:59	1:53	1:37	2:11
Thu Apr 28 19:00:00 EDT 2016	1:14	1:27	1:09	1:02	1:39
Thu Apr 28 20:00:00 EDT 2016	1:06	1:14	1:03	0:58	1:22
Thu Apr 28 21:00:00 EDT 2016	1:14	1:18	1:03	0:59	1:34
Thu Apr 28 22:00:00 EDT 2016	1:16	1:24	1:08	1:00	1:34
Thu Apr 28 23:00:00 EDT 2016	1:06	1:10	1:04	0:54	1:20
Fri Apr 29 00:00:00 EDT 2016	1:03	1:06	1:03	0:52	1:18

It is possible to take data from these reports, process them, and draw certain conclusions about performance measures. Hence, it is possible to compare the changes of the signal timings or historical results and the current values.

2.4.2 BlueTOAD

The City of Boca Raton also has BlueTOAD installed and it is used to collect, summarize and report data about travel times and speeds on segments of the route or the entire route. The examples of the available reports are given below in the Table 2.4-3. In Data Comparison Report information about observed pairs or routes, start time and end time of the observed interval, type of data provided, date and time for each measurement, travel times for pairs or routes and the difference between travel times for two pairs/routes expressed in percents.

Table 2.4-3. BlueTOAD data comparison report

BlueTOAD Data Comparison Report

Pairs/Routes

1. Military Trl_SB: Banyan to Verde - 2016-04-24 - 2016-05-24
2. Military Trl_NB: Verde to Banyan - 2016-04-24 - 2016-05-24

Start Time 0:00:00

End Time 23:55:00

Type Smoothed Speed (15-min)

Day	Time	Pair 1 Date	Pair 1 Travel Time (sec)	Pair 2 Date	Pair 2 Travel Time (sec)	% Diff 1 - 2
1	0:00	4/24/2016	161	4/24/2016	153	-5
1	0:15	4/24/2016	161	4/24/2016	153	-5
1	0:30	4/24/2016	161	4/24/2016	Not enough matches	-100
1	0:45	4/24/2016	161	4/24/2016	Not enough matches	-100
1	1:00	4/24/2016	161	4/24/2016	Not enough matches	-100
1	1:15	4/24/2016	161	4/24/2016	153	-5
1	1:30	4/24/2016	Not enough matches	4/24/2016	Not enough matches	
1	1:45	4/24/2016	160	4/24/2016	Not enough matches	-100
1	2:00	4/24/2016	160	4/24/2016	Not enough matches	-100
1	2:15	4/24/2016	Not enough matches	4/24/2016	Not enough matches	
1	2:30	4/24/2016	158	4/24/2016	Not enough matches	-100
1	2:45	4/24/2016	156	4/24/2016	152	-2.6
1	3:00	4/24/2016	156	4/24/2016	150	-3.8
1	3:15	4/24/2016	157	4/24/2016	148	-5.7

BlueTOAD Historical report (example given in the Table 2.4-4) is used to compare changes in measurements (speed or travel time) in function of time. That allows the analysis of performance measures changes due to special events, accidents, traffic signal control changes and other, if their start and end times are known.

Table 2.4-4. BlueTOAD historical report

BlueTOAD Historical Report		
Pair/Route	13692: (Military Trl_NB: Verde to Banyan)	
Speed Limit	45mph	
Comparison Index #1	Historical Avg of all days: From 2015-05-24 to 2016-05-24	
Time	Comparison Index #1 (speed)	Comparison Index #1 (time)
0:00	36.9	150
0:15	37	150
0:30	37	150
0:45	37.1	149
1:00	37.2	149
1:15	37.3	149
1:30	37.3	149
1:45	37.4	148
2:00	37.5	148
2:15	37.4	148
2:30	37.5	148
2:45	37.6	147
3:00	37.7	147
3:15	37.7	147
3:30	37.9	146
3:45	38	146
4:00	38.2	145
4:15	38.3	145
4:30	38.4	144

2.4.3 Sensys

The City of Boca Raton has Sensys system installed as well. That system has the ability to show data about travel times, but it was not in operation at the time when FAU team member was collecting data due to technical issues. Nevertheless, the examples of Sensys interface are given on the Figure 2.4-1 and Figure 2.4-2 below.

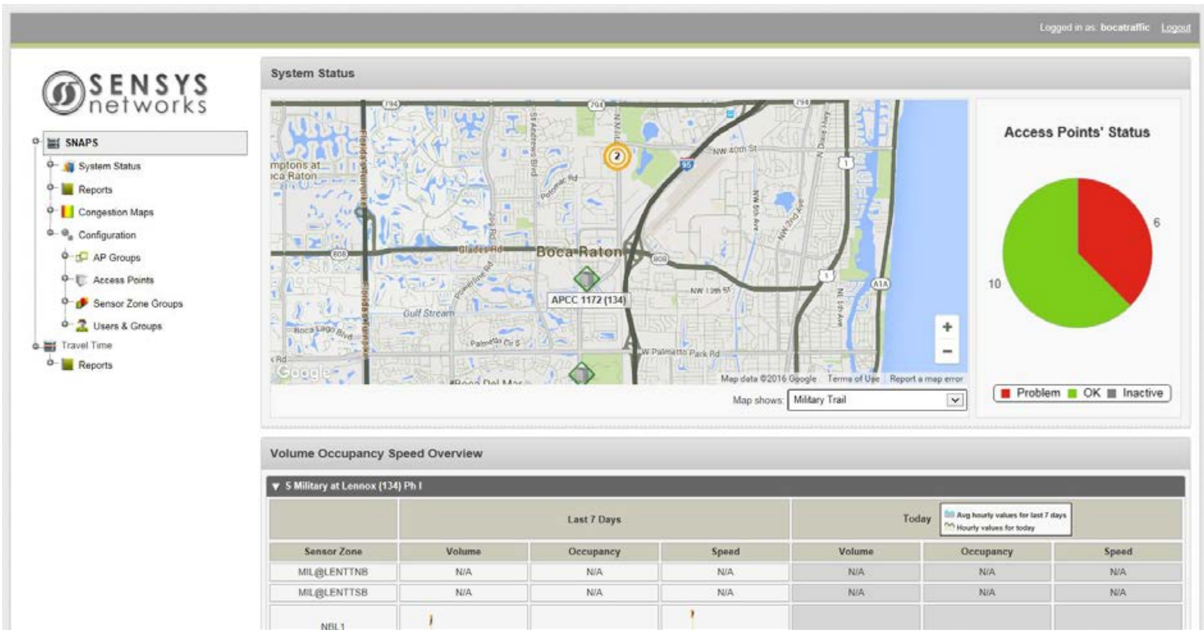


Figure 2.4-1. Sensys interface — system status

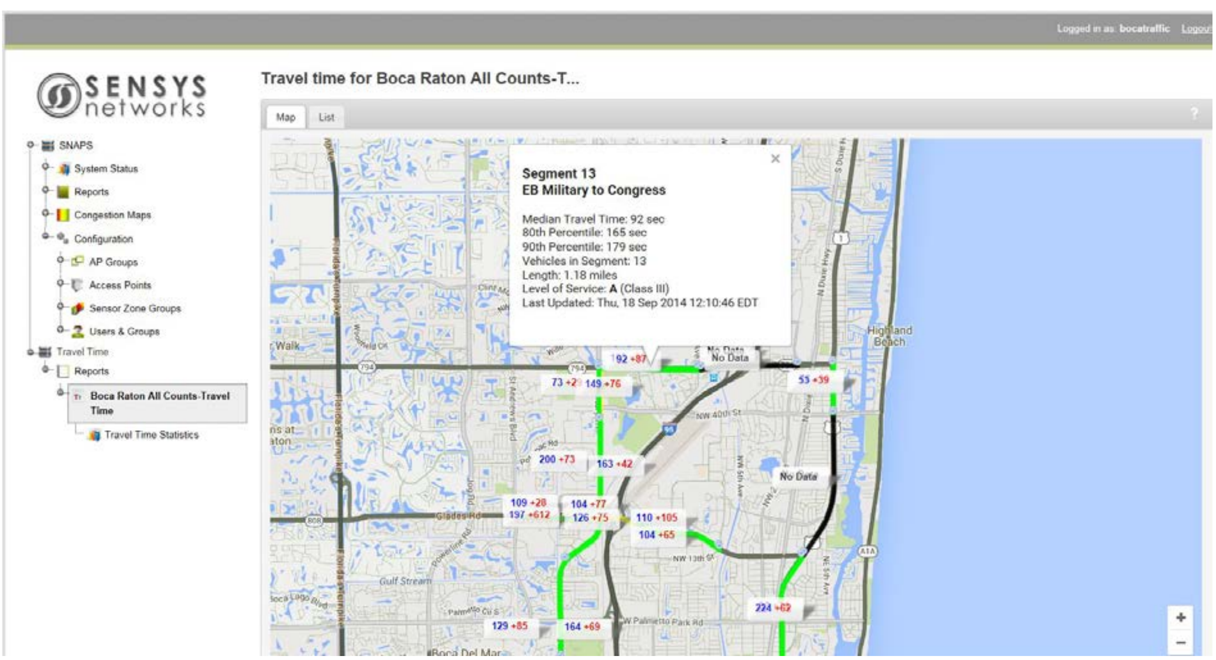


Figure 2.4-2. Sensys interface — travel time

3 Methods Developed for Analytical Signal Operations and Maintenance Assessment Tool

The assessment of traffic signal systems of an agency can help to identify signal-related issues, perform self-evaluation, define future strategies, etc. Tracking performance of traffic signal systems, in terms of reliability and performance, is not an easy task. The goal of this study is to identify and propose the appropriate performance measures to accurately and appropriately assess annual performance of the traffic signal system for a public agency. Those performance measures have to be obtainable, but also have to provide an overview of the agency's performance. The methodology needs to be universal enough to be applicable for the multiple agencies across the state of Florida. On the other hand, the methodology needs to have sufficient level of detail to adequately represent the performance and the condition of the traffic signals' operations and maintenance and to evaluate the main weaknesses, strengths and opportunities.

The evaluation was originally intended to be performed only on annual basis, but later the focus of the study included also weekly/monthly evaluations. Also, the number of the participating agencies was adjusted to make the data collection more manageable than originally intended. Two of the local agencies which were selected to be investigated under this project are: the City of Boca Raton and Palm Beach County.

Therefore, in this deliverable we present framework for annual evaluation methodology that was originally developed and the performance measures that can be used for weekly/monthly evaluation. The MS Excel tool, that can be used to perform annual evaluations, is also attached populated with the data from two agencies and two hypothetical cases. Similar MS Excel spreadsheets for weekly/monthly evaluations are being developed as well and will be provided in the next deliverable.

3.1 Annual Evaluation Framework

The main reasoning behind decision to create a method for annual evaluation of signal performance and maintenance was to make previous evaluation efforts more quantitative than they are right now. Until now, the best known methodology in this area is the National Traffic Signal Report Card (NTSRC), but there is a feeling that it relies mostly on qualitative assessments. It is possible that subjective opinions of the respondents impact the final grade, which is placed between 1 and 5. The estimation of the difference between the ideal case (which deserves a grade 5) and the existing state of practice/repaid is the critical for a fair evaluation as potential bias of the respondents can lead to different grades for the same agency.

The FAU research team proposes here a methodology which may not be fully quantitative, but a lot of efforts was applied to decrease the level of subjective assessments and make the methodology as quantitative as possible, under the constraints of this project. Instead of using the subjective assessments of agency staff, the proposed methodology for the annual evaluation relies on numerical and logical (true/not true or yes/no) values as answers to the sets of predefined questions. However, the sections defined in the NTSRC are kept in the proposed methodology to provide compatibility with the NTSRC grades. The first section where contact and general information are obtained is followed by the same five sections which are defined in 2012 NTSRC: Management, Traffic Signal Operations, Signal timing Practices, Traffic Monitoring and Data Collection, and Maintenance.

All six sections of the methodology are presented graphically in this chapter by using different colors for fields containing the questions for agency staff. In this way, the flow of the annual evaluation methodology can be conveniently visualized and information from the other sections is easy to spot. The boxes with black borders do not belong to any section but are known facts, values or explanations. All aforementioned sections are divided into subsections that represent sets of questions related to various topics of interest.

The grading is conducted by calculating partial grades for each of the subsections in all of the five defined sections from NTSRC, and those partial grades are used to obtain the final grade for the subject section. The mean value of the partial grades multiplied with weight factors is used to get the final grade for the subject section.

Weight factors are introduced to determine the importance of the different answer options on lower level, the subsections, or the entire sections in the process of calculating the final sectional grade on a higher level. By introducing the weight factors, the agencies get more flexibility to accentuate sections, topics or questions that are more important to them. On the other hand, if the weight factors are different, the comparison between different agencies becomes more difficult. On the example of two agencies, given below, all weight factors were the same for all of the subsection or section grades. The reason for adopting this approach is that because it was not possible to determine reliable values for weight factors due to small sample size (only two agencies).

The grading scale for this assessment was developed by virtually creating the worst and the best agencies by inserting all of the worst and the best answers in the evaluation spreadsheet. In this way, minimal and maximal values for each subsection are obtained. After the actual answers from two sampled agencies were entered, the resulting values are normalized and translated into the scale from 0 to 100 in order to make the grading process uniform and easy. Considering that not all topics/questions are answered, it was necessary to introduce another measure which evaluates quality of the assessment. It is called "Evaluation confidence", and it was calculated as a percentage/ratio of the number of answered questions over the total number of questions. The "Evaluation confidence" shows how reliable the assessment is. Also, the questions where the input data are the result of an approximation or assumption can be considered less reliable and the Evaluation confidence for those questions can be decreased.

The practicality and the feasibility of the methodology were tested by conducting a pilot study on two agencies that are different in terms of size, level of equipment, technologies used, number of staff etc. The data were collected mostly by agency staff providing answers on previously prepared questions for each of the defined sections. The data from two agencies are distinctively visualized by using brown color for The City of Boca Raton and pink color for Palm Beach County. If some of the necessary data were not available, the agency staff approximated or estimated the data, where possible. The approximated data has the ≈ symbol before the value, to acknowledge that it was only an approximation/estimation as no real data was available. On the other hand, the existing data that could not be used 'as is' but required data significant effort and time for the extraction, was labeled with an '*' symbol to annotate that a more quantitative answer is available but only if a large amount of data is processed.

A significant portion of the data entered in the spreadsheets below are collected by the FAU research team in the agencies' offices. The FAU team recognized that the methodology needs to be as simple and quick to enter the data as possible. If the procedure for data collection and/or processing is too demanding (in terms of time and/or effort), the agencies may be reluctant to adopt this annual evaluation methodology. Therefore, when the methodology was developed the FAU research team has tried to make the methodology as practical as possible.

3.1.1 Contact and General Information

The evaluation starts with Contact and General Information section (Figure 3.1-1). The information necessary for identifying and contacting the person in charge as well as the information about the agency's address are provided in this first part.

General information is important for describing the agency subject to evaluation and some parts are used in calculations afterwards. Data sources are explained in the previous Deliverable 2. These data will be used later in the calculation of grades for the five aforementioned remaining sections.

Contact information

Name	R. Awwad/T. Phelps	Giri Jeedigunta, PE, PTOE
Title	Traffic Ops Eng/Transportation Eng	Signal Systems manager
Agency	City of Boca Raton	Palm Beach County
Address	201 W. Palmeto Park Rd	2300 N. Jog Road, 3rd floor East
City/Town	Boca Raton	West Palm Beach
State/County	Florida	Florida
Zip code	33432	33411
Email address	rawwad@myboca.us	gjeedigu@pbcgov.org

General information

County population	91,332	1,422,789
Number of registered vehicles	72,600	1,135,116
Number of neighboring signal control agencies	2	5
Number of streets with shared signal jurisdiction	0	≈25
Total length of road network by the jurisdiction (in miles)	220	1,549
Estimated annual funding for signal operations and management	$150,000	NA
Estimated annual funding for signal related capital investments	$80,000	NA
Number of signalized intersections	136	1,047

Figure 3.1-1. General and contact information section

3.1.2 Management

The detailed methodology for management section, with the flowcharts explaining the evaluation process, is given in Figure 3.1-2, Figure 3.1-3 and Figure 3.1-4. Numerical and logical values are multiplied with the weight factors immediately or after previous calculations by using the derived values or item values from another sections. In this way, partial grades for all subsections are calculated and summed for the final result of the subject section. The same principle is used in the other sections of the annual evaluation methodology. In some cases, the methodology uses the data from other sections and those cases are obvious in the flowcharts because the fields are marked with the color of the section from where the data was originally taken. For example, total number of complaints is divided by number of signalized intersections (orange field) from the Contact and General Information section (see Figure 3.1-2).

The Management section contains nine subsections addressing various important issues:

1. Number, expertise and training of regular and outsourced staff
2. Monitoring
3. User satisfaction
4. Public relations
5. Cooperation with adjacent agencies
6. Safety and traffic accidents
7. Inventory
8. Service vehicles number and activation
9. Signal System Central Software (SSCS)

The first subsection is dedicated to the ***number, expertise and training of regular and outsourced staff***. The respondent needs to enter number of persons per their job types in Full time equivalents (it is possible that some of the personnel works less than full-time). Weight factors are possible to use for emphasizing the higher or lower importance for certain answers in this but in other questions, subsections and sections as well. In this example, all weight factors had the same values except for the question where it is necessary to pick one answer from several offered. Staff training is divided into several categories (Basic Signal Timing, Advanced Signal Timing, ITS courses, Hardware and communications and other), and the respondents need to insert total number of staff and hours spent on the training (the number inserted should be number of people x number of hours of training). That gives the equivalent number of training hours that is divided by total equivalent number of staff which finally represents the measure of how much the agency invests in staff training compared to the number of staff.

Next subsection addresses the ***monitoring***. Number of staff designated to monitoring is multiplied by number of hours in one week that they are designated to monitor the traffic and that is compared with the total number of engineering and technician staff (both regular and outsourced). Then, their average number of work hours per week is calculated. This value quantifies how much of human resources the agency designates for the monitoring of the network-wide traffic conditions and provide necessary responses.

The user satisfaction is measured by comparing the number of complaints to population of the county or city (agency's jurisdiction) on one hand and the number of signalized intersections on the other hand. Also, the existence of telephone number and/or web site where public can report malfunctions ask questions and make suggestions increases the willingness of the agency to meet the needs of the citizens.

How much attention an agency gives to relations with the public is tested by three indicators. The first one is the average time from receiving of memo or a call until responding to it. Shorter response time indicates better responsiveness and more points in the evaluation process. The next factor is the number of information types available for the public. Larger number of information types suggests higher level of transparency and the agency's effort to keep the citizens updated about the relevant traffic information. Finally, all means used for communication with the public have to be selected. Larger number denotes that the agency puts more effort in providing more ways for communication between the citizens and the agency officials.

The grade for subsection number 5 (cooperation with adjacent agencies) is calculated by dividing the number of neighboring agencies, with whom the data are being exchanged, with the total number of neighboring agencies. The grade also includes ratios of: 1. The number of inter-coordinated streets with traffic signals with the neighboring agencies, and 2. The total number of shared signalized streets with number of the neighboring agencies. Higher values for these ratios bring more points in the evaluation process, because such values mean that the agency strongly cooperates with the adjacent agencies.

The safety aspect is evaluated by using simple formulas for comparing number of accidents in the zones of 150 feet from the signals compared to total number of signalized intersections. The additional factor are accidents caused due to running red light compared to number of signalized intersections. The data about the number of accidents can be obtained using Signal Four Analytics that is available to any public agency or organization in Florida. Total number of accidents and accidents caused by running the red light are collected after applying some filters in Signal Four Analytics. Geographic extent was set to City, Network extent as Intersection, Intersection offset distance – 150 feet, Road circumstances to None, Other, Unknown (to eliminate impact of weather and other non-recurring events). For Road System Identifier the selected options are US, State, County and Local.

Organizational level of the agency is defined by observing presence of the inventory system for the signal equipment including the spare parts. A grade for the number and activation of the service vehicles is calculated as a ratio between the number of vehicles in operation by shift and the number of signalized intersections. The coverage of the network per vehicle is calculated by dividing the number of vehicles in operation by shift with total length of the street network under jurisdiction of the subject agency. Finally, the number of miles that every service vehicle runs during one year could also be a useful indicator. The optimal number of miles per year has to be determined in such a way that significant deviations from the optimal value bring fewer points. This factor was not used in this example for two agencies, due to lack of relevant data.

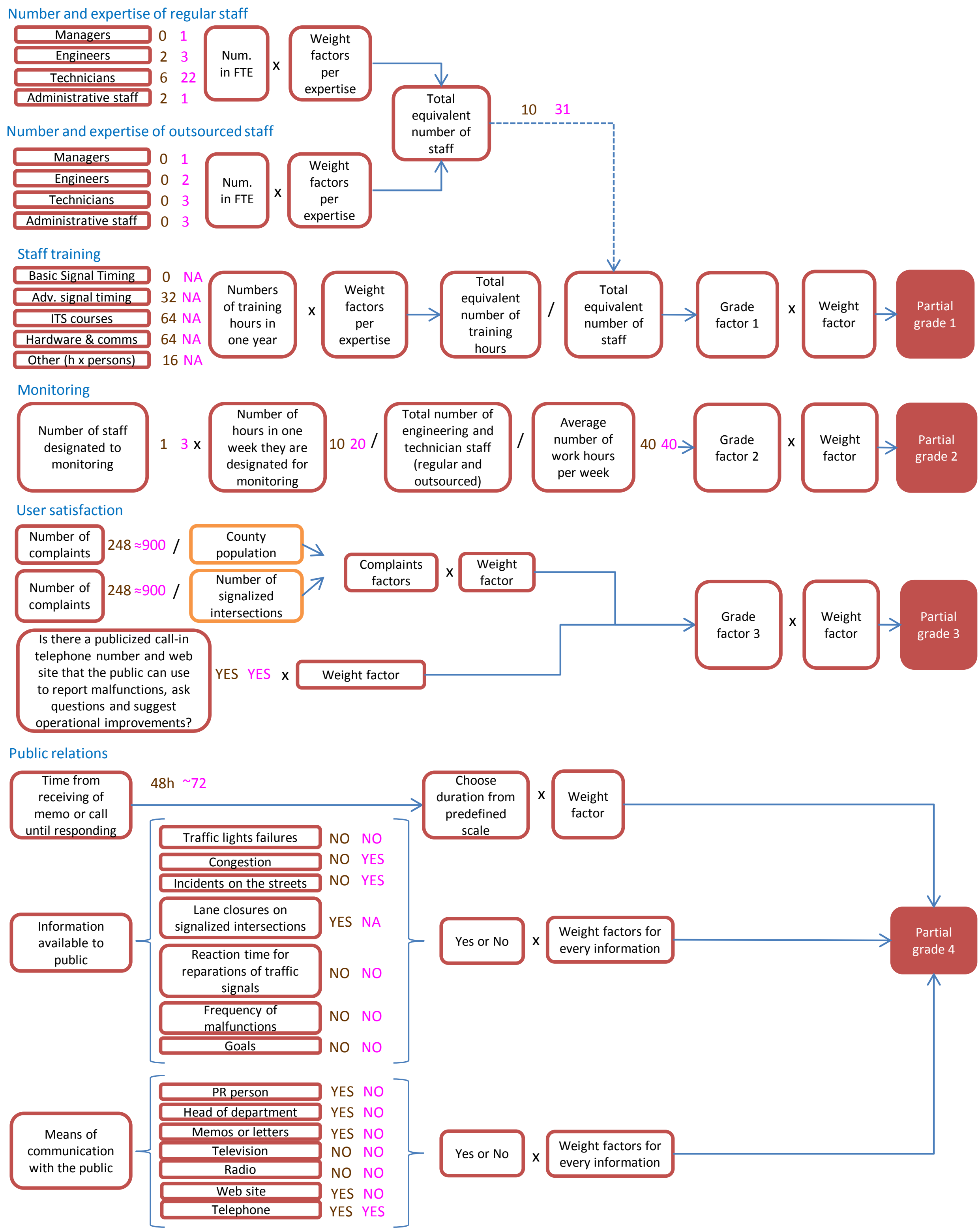


Figure 3.1-2. Flowchart for evaluation of Management (part 1)

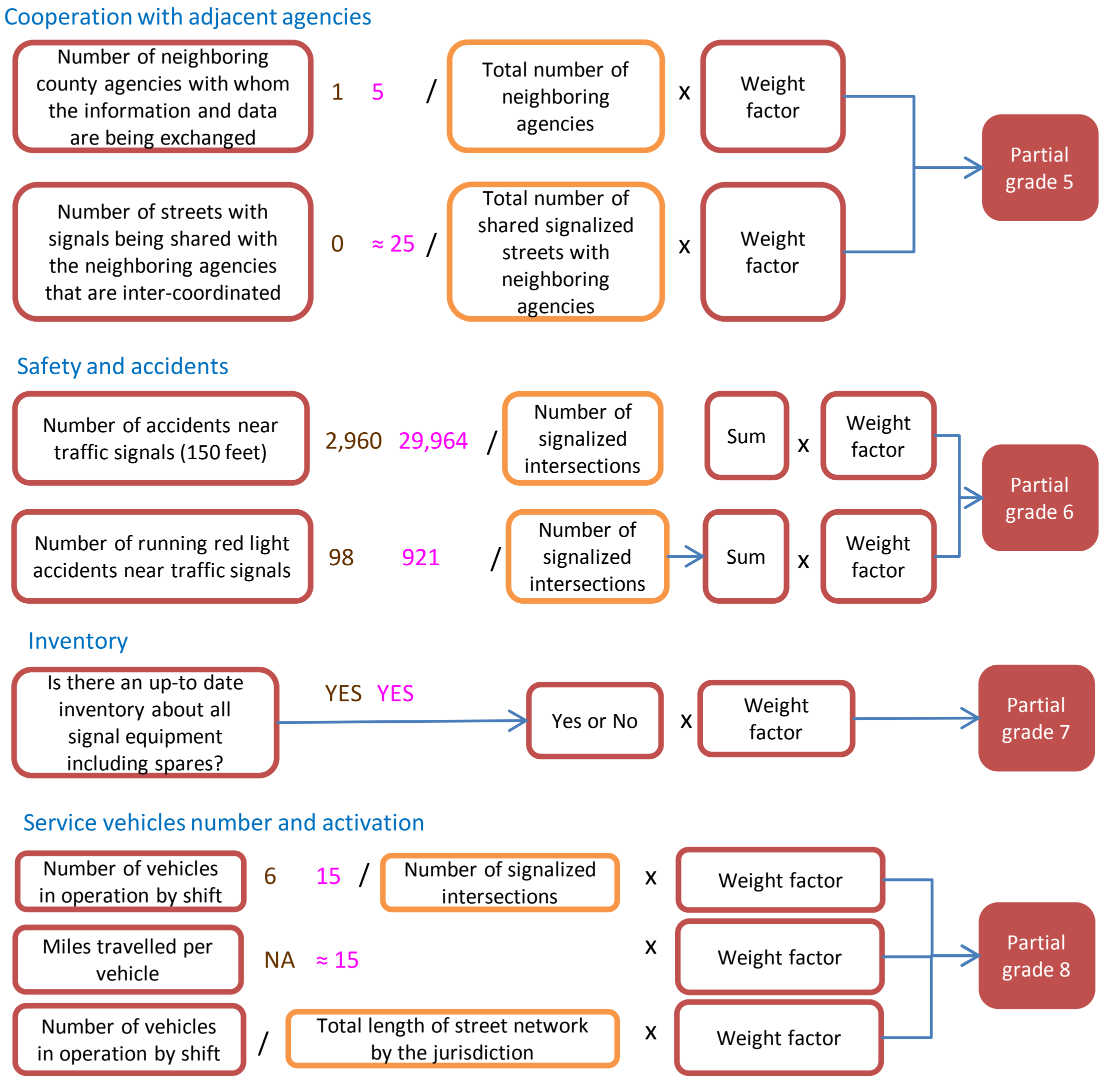


Figure 3.1-3. Flowchart for evaluation of Management (part 2)

The last subsection in four out of six sections is dedicated to signal system central software, in case that the agency uses one. After checking presence of the signal system central software (SSCS) (having such software brings more points), the respondents provide the number of signalized intersections connected to SSCS. The ratio between number of connected signals to the SSCS and the total number of signal is a measure of SSCS's coverage. The result 1 (when all signals are connected to the SSCS) gives the maximal number of points. The third question asks for a type of the SSCS. The type of SSCS significantly affects questions in the following sections because different systems will have different characteristics and capabilities. Both agencies involved in the pilot project have ATMS.now signal system central software, and the questions in this methodology are tailored considering that fact. Type of the SSCS is not per se used to calculate any grades but further questions are defined based on the capabilities of the system. So, type of SSCS is a key point to determine set of questions (developed for appropriate SSCS's) to be used further in the evaluation. This project considers only ATMS.now platform but this step can be useful if this framework is to be extended for the other SSCS.

Next question investigates the functionalities of the existing SSCS. More functionalities indicate that an agency is better equipped and brings the higher grade. Number of staff that actively use SSCS is divided by number of signalized intersections in the jurisdiction to show the coverage of the network. A lower ratio gives a lower grade because fewer number of operators may have trouble to efficiently cover a large number of signals. The last two questions check the existence of the alarms for malfunctions and the existing mediums for communicating those alarms to persons in charge. The existence of those types of alarms, and higher number of mediums for communicating those alarms, provide higher grades in the evaluation process.

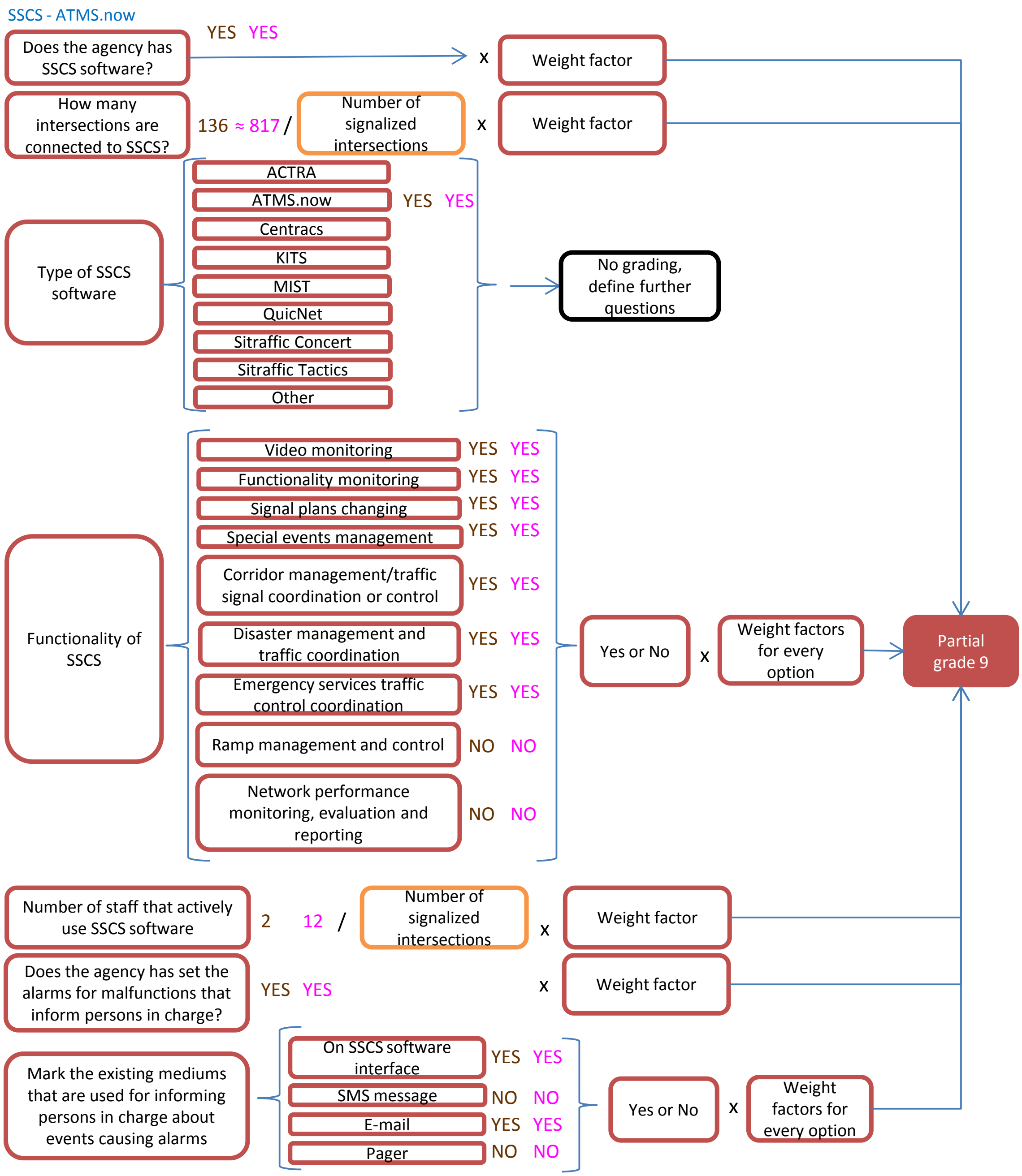


Figure 3.1-4. Flowchart for evaluation of Management (part 3)

3.1.3 Traffic Signal Operations

The Traffic Signal Operations section contains two subsections - one general and the other based on the data available from signal system central software. In the latter subsection, answers to multiple questions are labeled with *. For example, coordination failure duration is possible to calculate from ATMS.now reports but after extensive processing of relevant data, which has not been established yet.

The general subsection starts with the question if the agency uses traffic responsive or traffic adaptive control. Usage of those signal control types indicates that the agency is on a higher level of technological development, has more flexibility in operations, which provides more points in the evaluation process.

The next question checks the frequency of signal operations reviews. More frequent reviews get higher grades. If the agency adjusts traffic signals based on the legitimate requests from public, this will increase the sectional grade for an agency. Also the score can be improved if an agency performs the review the sight distances to intersections for all new signal installations. The existence of advanced warning indications (flashers) or additional signal heads, poles and other equipment where limited site distances exist shows that the agency takes care about timely communicating the signal control symbols on critical sites. That implies that the agency is taking care about the fact that their hardware components send the timely and useful information to the drivers which also has the positive effect on safety.

The number of traffic signals adjusted for visually impaired persons compared to total number of signalized intersections states how strong the agency makes effort to make operations of signals in their jurisdiction available to sensitive groups of infrastructure users, in this case, blind or visually impaired persons.

The ratio between expected and actual time to implement, evaluate and calibrate the new signal timing settings shows agency’s ability to efficiently and punctually execute signal operations projects. Frequency of retiming the signals is also very good measure of signal agency performance, operations wise. More frequently an agency retimes traffic signals the higher grade it will get for its operational section. Finally, a ratio between number of coordinated traffic signals and the total number of signalized intersections shows agency’s effort to provide better signal progression for its public. It is important to note that agencies do not need to have the ratio of 1 to be considered successful as there could be many isolated intersections which do not warrant signal coordination.

Second partial grade for this subsection mostly relies on the data from SSCS. To begin with, the ratios between the number of: special events, disasters, VIP routes and emergency signal timings and the total number of signal timings, denote the preparedness of the agency for the non-recurrent and special situations where manual changes in signal timings could be helpful but sometimes cannot be executed fast enough to deliver desired outcomes.

The next measure is the ratio between number of school zone signals and the total number of schools in the jurisdiction area of the subject agency. A higher ratio shows that an agency has more complex operations to deal with as such signals are required to improve safety of the students near the schools. The ratio between number of signalized intersections with the preemption capability and the total number of signalized intersections indicates a technological level of an agency and its ability to provide priority to special types of vehicles (trains, ambulance or firefighter vehicles…). Ratio between the number of intersections with Public transit (PT) prioritization capability and the total number of signalized intersections along PT vehicle routes shows the current coverage of network with the PT prioritization capabilities.

Percentage of time when the adaptive system is active (if the agency has one) shows the level of readiness of an agency to use that technology for signal operation. It is important to stress that agencies sometimes turn off the adaptive operations during peak (or off-peak) periods. The ratio between number of hours with congestion and total number of hours in an observed period (AM peak, PM, peak, Midday) or signal pattern can be helpful indicator for the efficiency of the traffic signals. Even well optimized traffic signals cannot remove traffic congestion but can delay or reduce duration of congested conditions.

The ATMS.now has the Real Time Congestion Data report that can provide information about congestion in the subject network, but in both interviewed agencies that type of report did not contain any data. For creating that kind of report, the data about volume, occupancy and direction from the detectors are taken into account. At the moment of data collection for two subject corridors in the two pilot agencies, the detectors were not set to collect and forward these data to ATMS.now. In the same periods, the number of cycle failures and faults can be observed as well. Cycle failure in ATMS.now is defined as the situation when a serviceable call has not been serviced in approximately two cycle times while coordination was not active. The cycle fault represents similar situation but with the difference that in this case coordination was active. Number of those events per period, when a signal timing pattern is active, divided by total number of cycles in the same period represents a good measure of traffic signal level of service. On the other hand, the phase failures can be approximately determined by observing the phase termination events (max-out and force-off versus gap-outs). That measure will be part of the weekly/monthly evaluation. For accurate measures of phase failures, the queue detection and signal indication data need to be provided by automated technology because manual observation is not feasible since it would be too time consuming. High-resolution logging about signal statuses and detectors actuations can be useful to measure the frequency and the ratio of phase failures compared to number of cycles.

If an agency has coordinated corridors or zones, the ratio between number of coordination failures and the duration of the period while the coordination is active indicates the robustness of the coordinated signal operations. Also, total time while the coordination has been in transition compared to the period while the coordination is active shows if there were too many changes between signal plans, which can cause transient effects on the traffic.

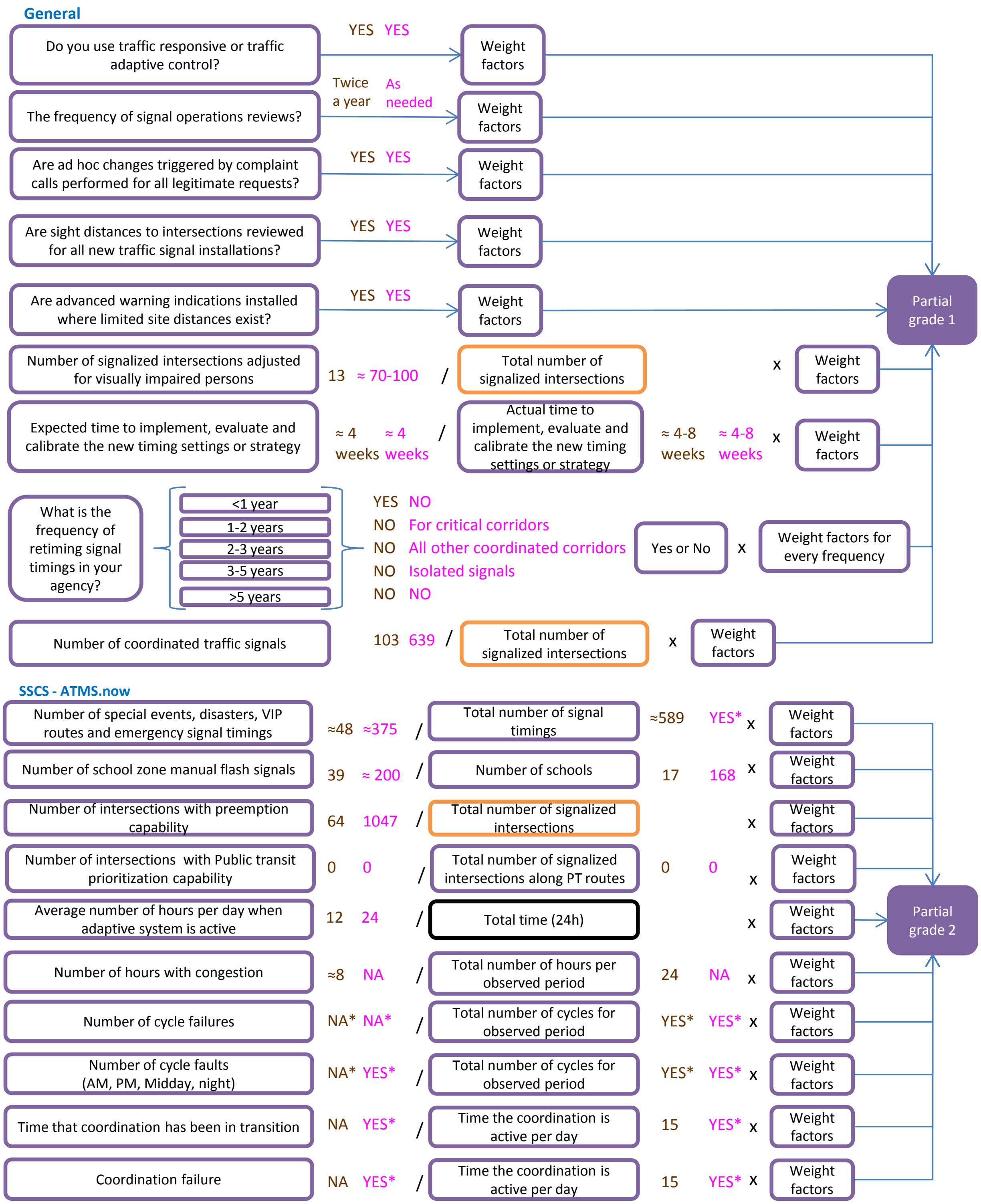


Figure 3.1-5. Flowchart for evaluation of Traffic Signal Operations

3.1.4 Signal Timing Practices

The goal of Signal Timing Practices section is to determine which performance measures, data types, and signal timing software are used by the agency's staff when creating new signal timing plans. It is assumed that if the input is better, the output will have the higher quality.

The first subsection starts with the question if records of conflict situations are used to identify signalized intersections where safety could be improved by revised signal operations. If an agency applies such a practice, it gets more points in the evaluation process. This input indicates that an agency takes into consideration available data when creating signal timings. In the next question, the number of performance measures that an agency collects, is being investigated. More performance measures an agency collects, more measures can be used to retime traffic signals. The third question examines if the agency uses some of the signal timing optimization software (Synchro, PASSER, TRANSYT…) to develop new signal timings. If software tools are used, that ensures the adequate quality of signal timings and decreases the dependence solely on engineers' experience. However, the fine tuning of the output results from those software tools is often necessary. This subsection is concluded by investigating the number of parameters that the agency staff uses to create signal timings. The quality of signal timings increases with the number of parameters that are used so better grades are assigned to those agencies that utilize more parameters.

The next subsection considers the data from SSCS, where the first indicator is the ratio between average duration of splits per period (pattern) and the programmed duration of splits. It is intended to calculate deviation of splits from programmed values. If the deviations are too large, maybe there is a need to refine signal timings in the field. Also, the number of times a phase was activated in some period (or pattern) compared to the maximal number of times that phase could be activated (total number of cycles in that period) can be a valuable indicator. If some of phases are activated too often or too rarely, this may also indicate need to refine signal timings. Such data are difficult to collect for all intersections and all periods, so an agency may want to define some sampling procedures or representative signal sections for the annual evaluation. For weekly or monthly evaluation, these two indicators can be used when and where needed.

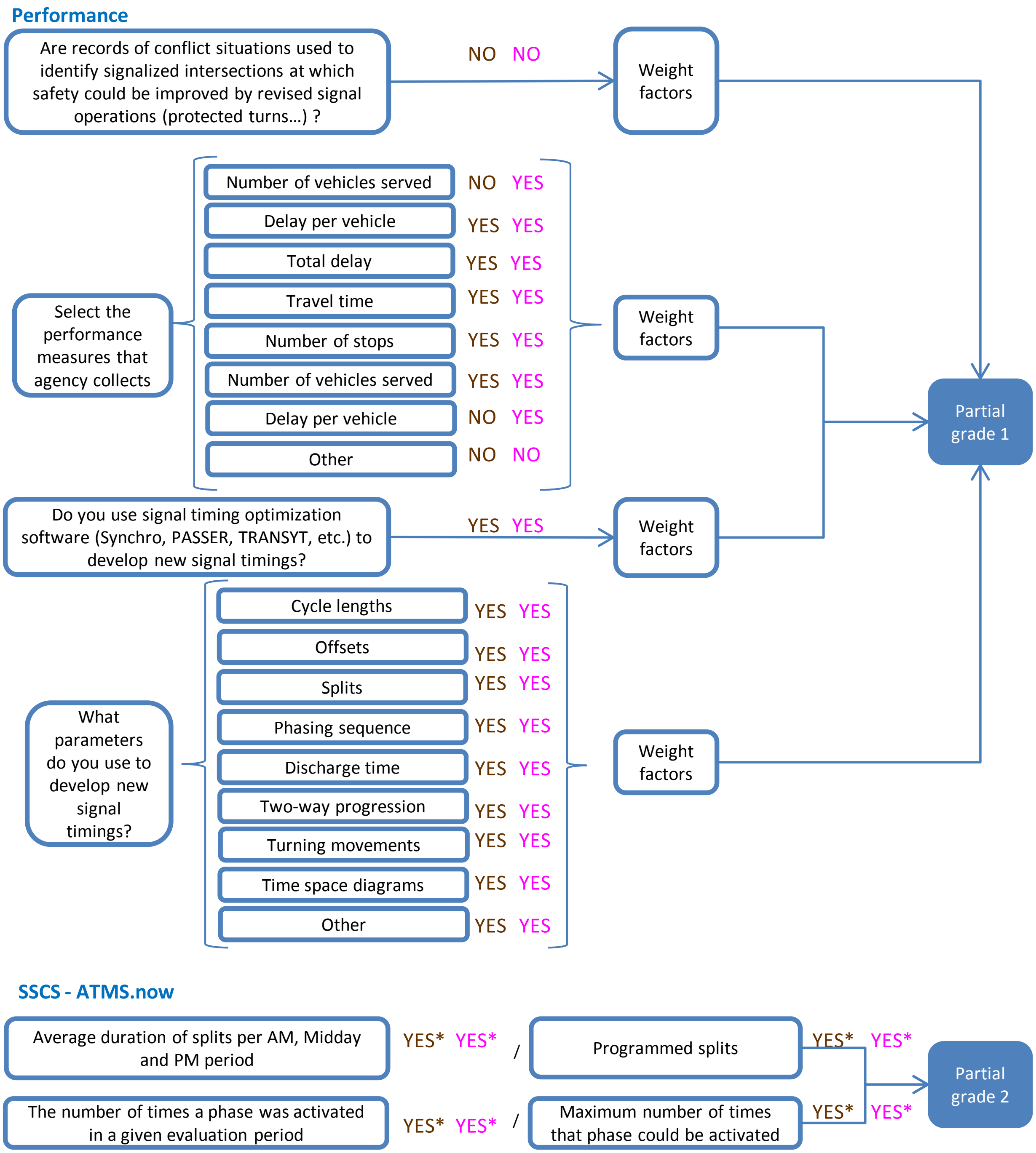


Figure 3.1-6. Flowchart for evaluation of Signal Timing Practices

3.1.5 Traffic Monitoring and Data Collection

The Traffic Monitoring and Data Collection is a very important aspect for any modern traffic signal agency in nowadays data-rich environment. Existence of detection (number, types and practices), their data collection and storage, the quality/accuracy of collected data and other relevant questions are grouped into four subsections shown in the Figure 3.1-7 and Figure 3.1-8 below.

The first subsection is dedicated to investigating general questions about available detection. It starts with the ratio between the total number of detectors and the total length of road network. The number of signalized intersections is not used for the denominator because the various intersections require different detection levels. Also, sometimes detectors can be placed far from intersections and not affect the signal operation (for example microwave vehicle detection system detectors for collecting the volume data).

The next question examines what other detector types, by position, are used far ahead of the stop-bars and near stop-bar detectors (midblock or near upstream intersection system detectors). Higher number of detectors may indicate better agency's capability to be aware of the traffic conditions. The number of data types collected by those detectors also affects the evaluation grade. The following step checks if an agency uses the advantage of queue detectors. If an agency uses video detection, the last two questions in this subsection refer to video detectors: quality and frequency of the calibration of video detectors.

In the following subsection, the data collection and storage procedures are examined. First of all, a respondent needs to provide all the data archiving methods used by the staff in the agency (paper, electronic database, GIS or no data storing). Various archiving methods, along with the availability of the collection and storage procedures, can indicate the quality and level of details of the agency's database. The willingness to share the collected data with the public and other organizations is investigated in the following question. More positive answers ensure the higher score in the evaluation. In the end of this subsection, the technologies used to collect travel times, are examined. A variety of technologies and travel time data sources brings more points because it shows that the agency has a reliable source of major congestion indicator – travel time. However, various technologies to collect travel times have different precisions, costs, etc. which warrants further answers.

Scrutiny of the collected data quality starts with the question if the collected data is checked for quality, consistency and correctness. Purpose of this question is to check if the arriving data are validated against the real-world conditions observed through other sources. The resolution of the collected travel times, delays and actual signal timings, shows how often the agency's staff can extract the data from the field sources. Higher resolution means that the data is less aggregated, more precise and therefore guarantees the better score.

Additional measures, which include: frequency of turning movement counts data collection, and ratio between number of weather stations and the total length of road network, are part of the final subsection of Traffic Monitoring and Data Collection section.

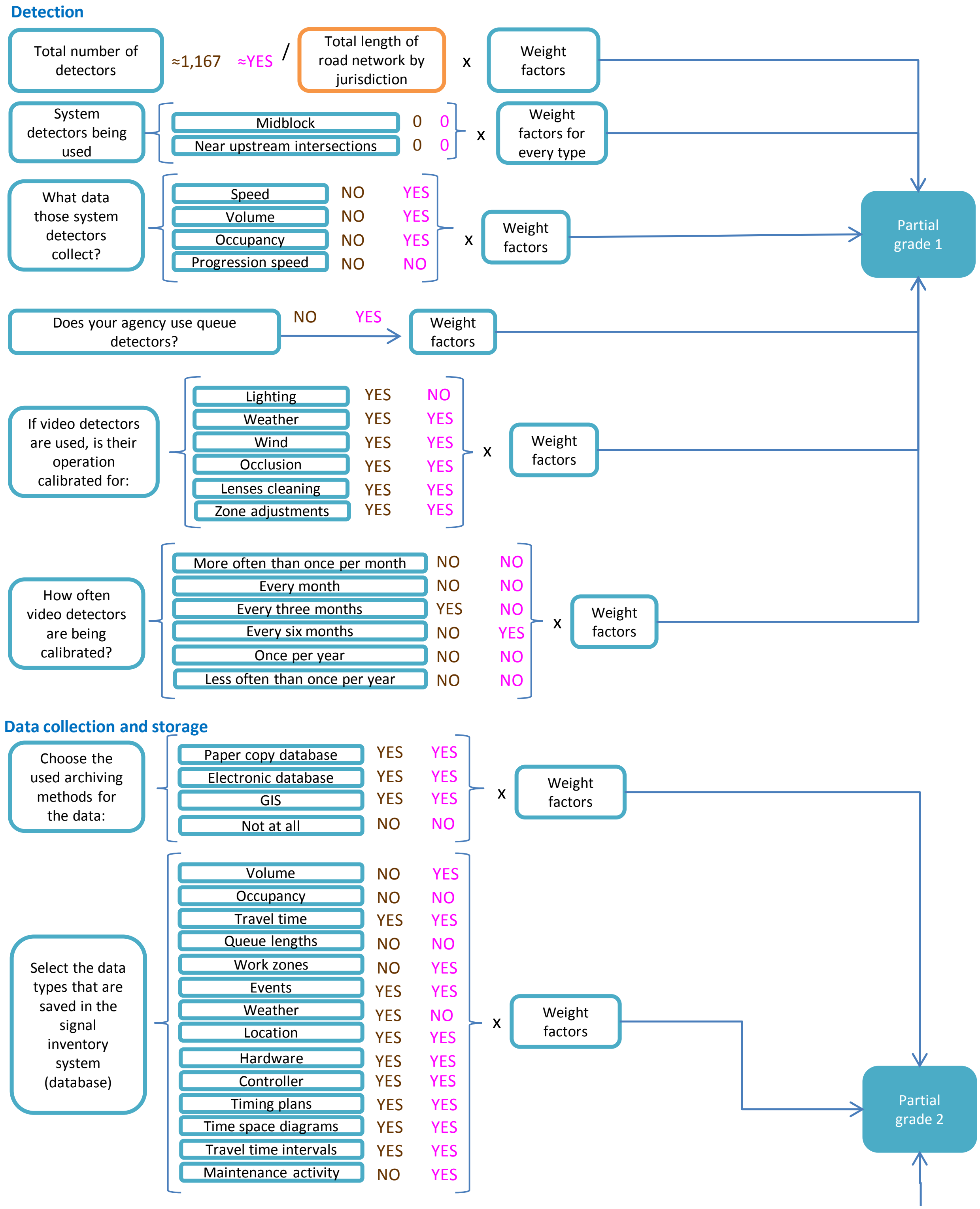


Figure 3.1-7. Flowchart for evaluation of Traffic Monitoring and Data Collection (part 1)

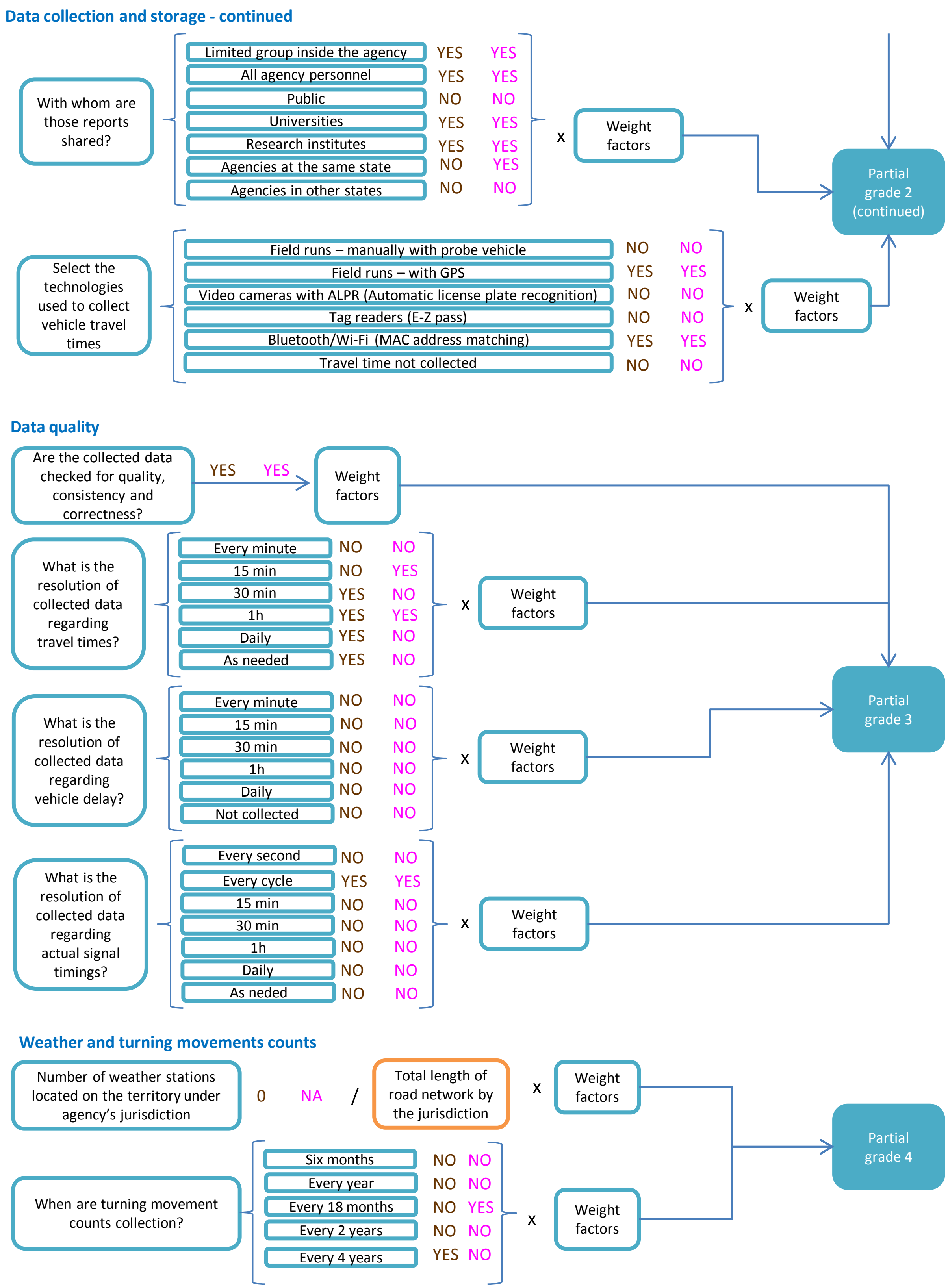


Figure 3.1-8. Flowchart for evaluation of Traffic Monitoring and Data Collection (part 2)

3.1.6 Maintenance

The Maintenance section of the proposed methodology is one of the most extensive. This section is designed in such a way that most of the questions require yes/no answers. Numerical values are required for the last two questions. In some cases numerical values are not available at all while in the others they may be very difficult to extract from an abundance of data. For example, the data about maintenance activities are kept as hard copies and although available they would be very difficult to process to provide numerical values for some of the evaluation questions. Some of the entries, like coordination failures or communication errors, are too numerous to be collected and processed for the entire agency and for the entire year, especially if the agency has a lot of traffic signals. The solution is to select the representative sections or time periods and extrapolate the value for the entire agency and the entire year.

The evaluation of maintenance starts with the strategic questions about maintenance agreement and required performance monitoring and reporting. Positive answers indicate better practices for an agency.

The following section is dedicated to maintenance of the equipment. Number of detectors out of function multiplied with the average duration of the detector failures and divided by total number of detectors can be used as a measure of reliability of the system's detection (can be separated to vehicle and pedestrian detectors if necessary). The following question checks if the agency's staff make adjustments to reflect changes due to potentially different characteristics of the new equipment. This question addresses agency's diligence to maintain the equipment and keep operations in the optimal state. The ratio of the number of changed bulbs (LED modules) to total number of bulbs (or modules) indicates number of bulb replacements. Fewer reparations means higher reliability and therefore higher score in the evaluation. Remaining questions in this subsection investigate how often the operability of different elements and parameters of the traffic signal system are being checked (alignment and position of signal heads, operability of signal controllers, communication infrastructure, SSCS, signal heads and synchronizing controllers' clocks). This group of questions investigate the frequency of equipment validity inspections for different components of the signal system. Higher frequency provides higher evaluation score.

In the subsection concerning the reaction time, all four questions examine the average time required to respond to reported failures, user complaints, etc. The respondents are supposed to choose frequency of the responses which is nearest to their agency's field practice. Shorter response times bring more points in the scoring process.

Inventory and reporting is also the important part of the maintenance procedures. The assessment starts with the question if the inventory includes a record of maintenance activity. Affirmative answer indicate good reporting and inventory practices. The next question asks the respondents to select type of failures for which the agency creates maintenance reports. More types of failures covered by the reports means better track of the performed works and a higher score.

The following question checks how frequently the maintenance reports are being generated. A greater frequency implies that the data are regularly updated and the grade will be higher. Finally, the number of specifics found in the maintenance task and work orders points out how well an agency organizes maintenance inventory and reporting processes.

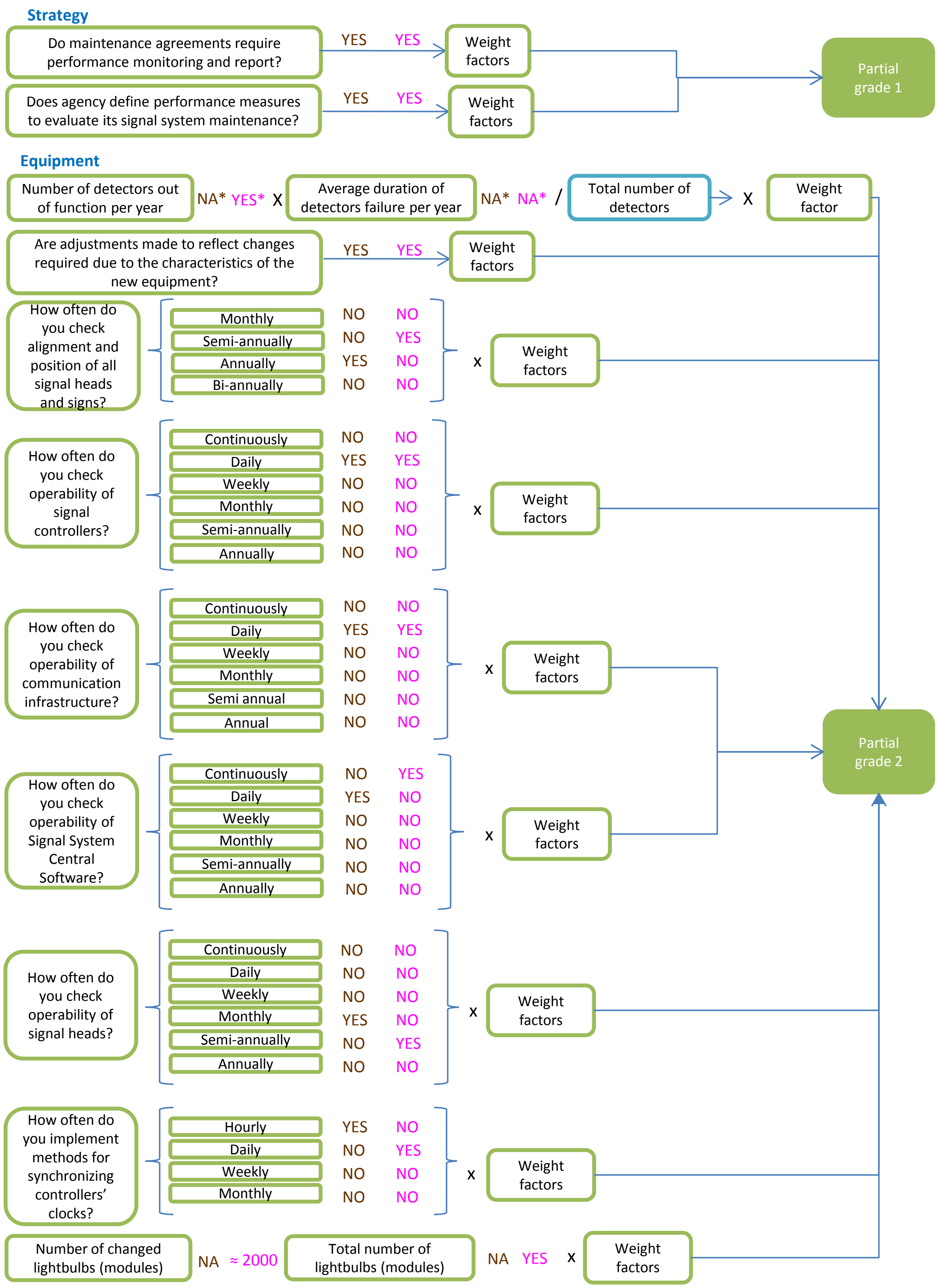


Figure 3.1-9. Flowchart for evaluation of Maintenance (part 1)

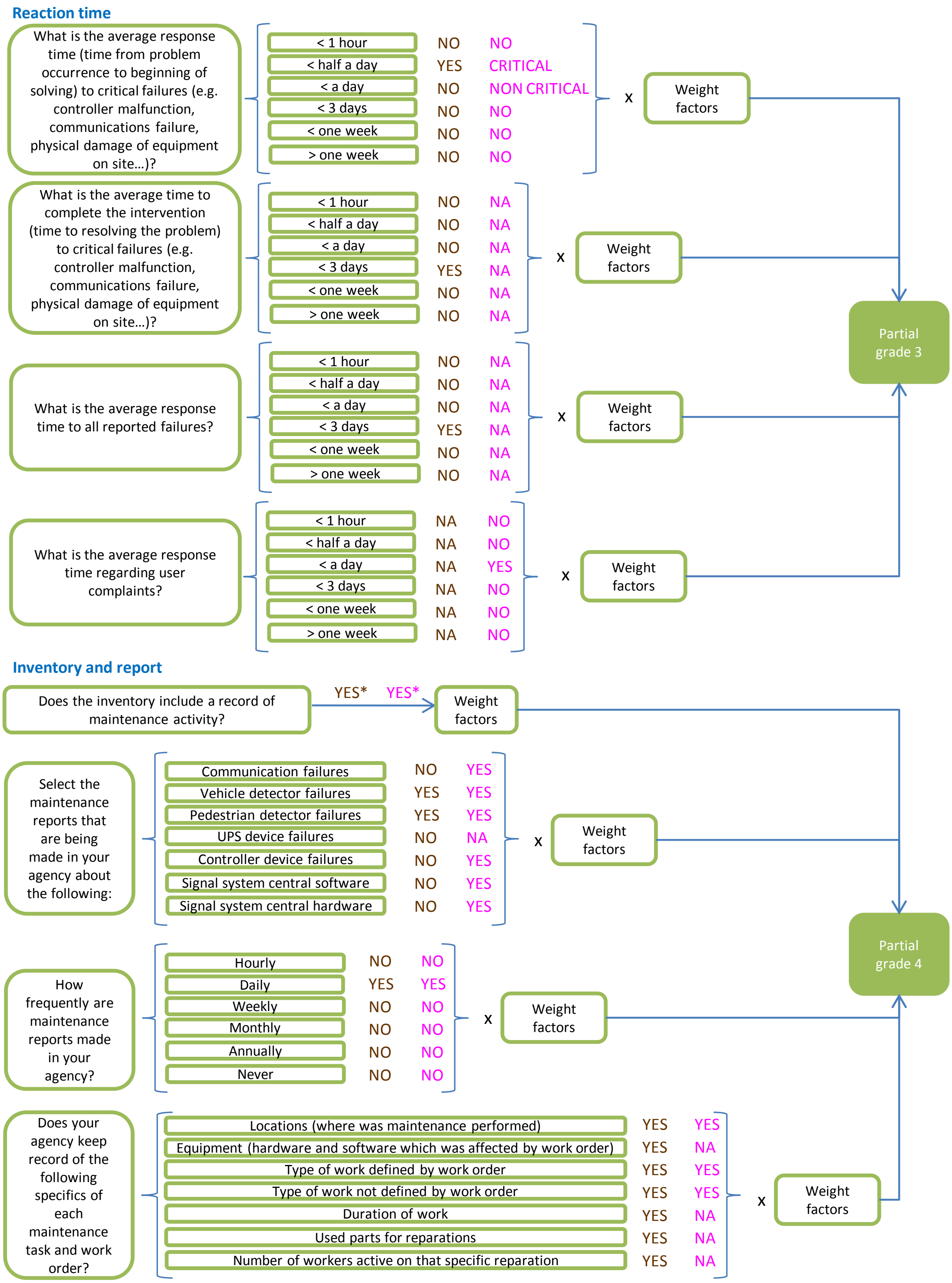


Figure 3.1-10. Flowchart for evaluation of Maintenance (part 2)

The final subsection, in the Maintenance section, refers to the data available through SSCS. The first indicator is the ratio between the duration of coordination failures and the total time when signals should be coordinated. With a longer duration of the coordination failures, the lower grade is achieved. Another indicator is a duration of the communication errors (expressed in hours per year) which is divided by total number of hours in one year. The measure for reliability of vehicle or pedestrian detectors is calculated when total number of detectors (pedestrian or vehicle) is divided by number of detector malfunctions (pedestrian or vehicle).

A ratio between duration of all reparations of an average maintenance crew team (in hours) and total number of hours in one year (2086) is subtracted from 1 to get an indicator of the effectiveness of the average reparations. In order to collect this ratio, the maintenance inventory needs to contain all maintenance actions (sorted per team) which needs to be compared to the total duration of the time when controller doors were open (per year).

The utilization of reparation staff is assessed by dividing the total duration of routine and non-routine reparations with total number of staff and the number of routine and non-routine reparations per year. The number of signalized intersections is divided by number of routine and non-routine reparations and such a measure indicates how many maintenance efforts, per intersection, agency's staff needs to perform in a year. Lower numbers indicate more maintenance needed and a less reliable system.

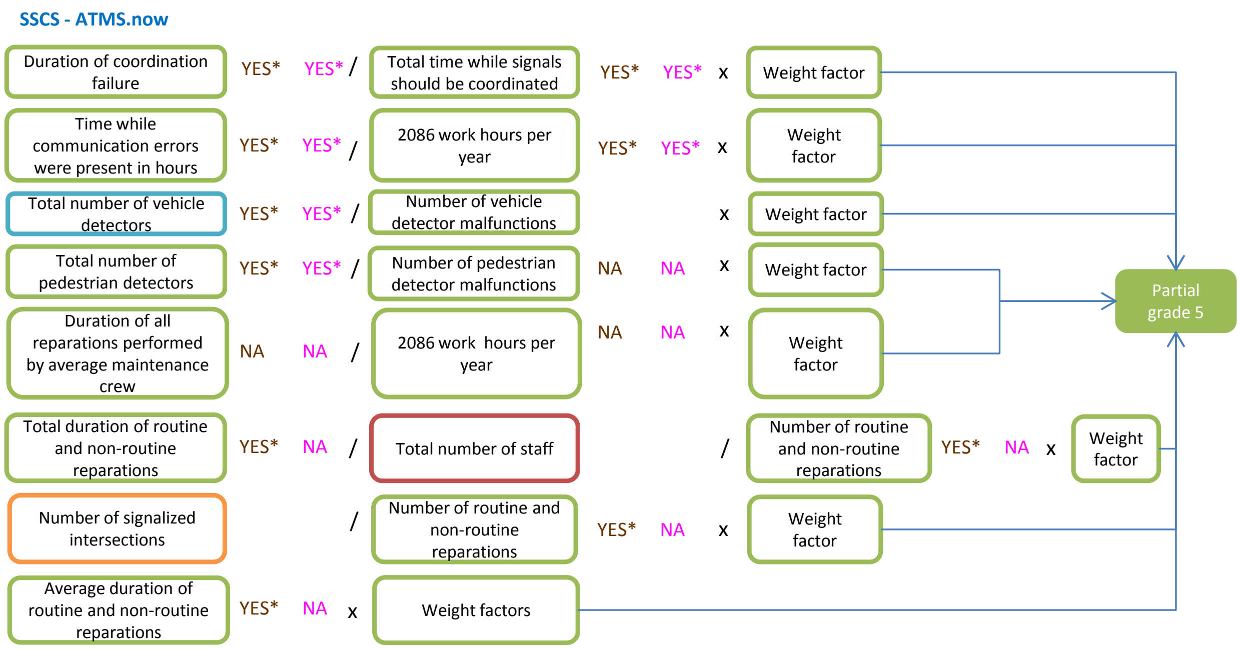


Figure 3.1-11. Flowchart for evaluation of Maintenance (part 3)

Some of the records that can be used to derive values for the maintenance section (e.g. coordination failures or communication errors), are too numerous to be collected and processed for the entire year, especially if the agency has a large number of traffic signals. A solution to this issue could be to select the representative parts of network or time periods and extrapolate the values for the entire year.

3.1.7 Grading

After all of the data have been collected, and the evaluation process is done, all of the sub-sectional grades are combined into a unique grade for the subject section. After defining a grading scale, the numerical result of the evaluation process indicates level of service letter, for each section. Further, by combining grades for the five sections, the level of service letter can be obtained for the overall assessment of signal agency. Figure 3.1-12 illustrates the grading process.

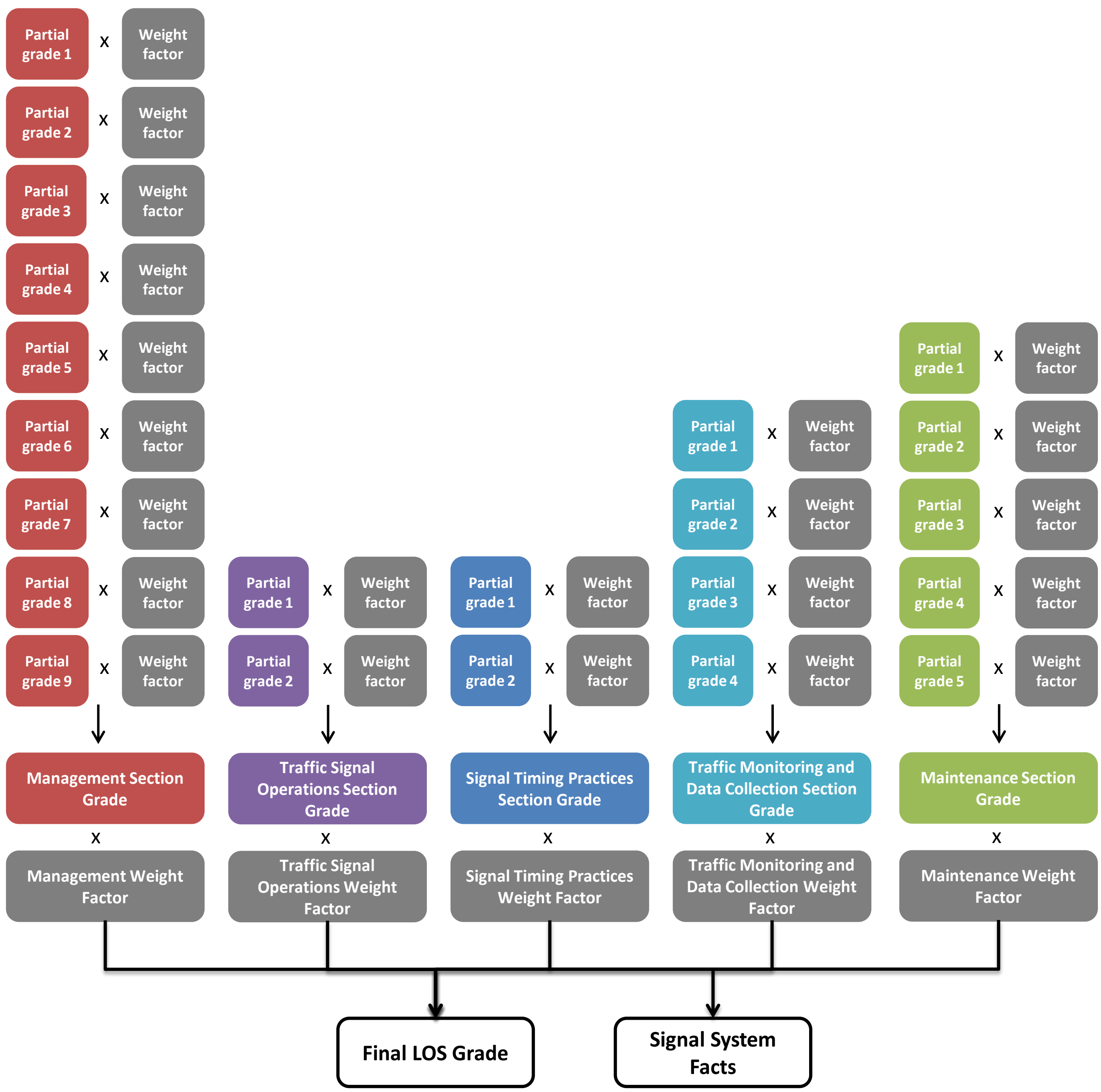


Figure 3.1-12. General flowchart for proposed evaluation methodology

After all of the data have been collected, and coded in a spreadsheet that represents a counterpart of the evaluation processes shown in Figures 3.1.11 to 3.1-11, all of the sub-sectional grades can be averaged into an overall section grade, and an Evaluation Confidence can be derived for the subject grade. By combining the grades and Evaluation Confidences for all of the five sections, one can calculate the overall Level of Service (LOS) letter and Evaluation Confidence for the entire agency, for a given year.

Summary of the grades and the evaluation processes are presented in Table 3.1-1. The numerical values, obtained through the assessment process described in Figures 3.1-1 to 3.1-11, were used to derive a LOS grade for each section. Minimal and maximal values for each question are not identical. Such ranges depend on formulas used for calculation of the relevant indicators and can vary significantly. In order to make the grading scales and procedures uniform, the results are normalized, as displayed in Table 3.1-1. Weighted grading scores are obtained when the normalized grades are multiplied with the weighting factors (all of which have been assigned a value of 1, in this study). The Evaluation confidence is a measure that represents reliability of the grades. If a subsection did not get at least 50% of the answers, it was not used in the calculation of the sectional grade.

The yellow cells in Table 3.1-1 indicate fields where formulas need to be changed if some of the missing data become available. Also, some of the fields are empty because data for evaluation is missing and therefore formulas behind those cells were adjusted not to take in account the missing data.

Table 3.1-1 and Table 3.1-2 show the evaluation calculations for traffic signal operations and maintenance for two agencies: City of Boca Raton and Palm Beach County, respectively. The overall scores and evaluation confidences for these two agencies are different. The results shown indicate current status of signal system components but they should be taken with caution. Small differences in the grade score can lead into significant difference in the overall letter grade if the evaluation score is near the threshold values (e.g. if Palm Beach County's score was just 0.1 lower it would not get the LOS letter B). Also, the Evaluation confidence needs to be high in order to fully stand behind the scores which may be calculated based on partial inputs.

Table 3.1-1. Grades and evaluation confidence factors for City of Boca Raton

Section	Partial grade num	Partial Grade subsection	Grade Value	Weight factors	Weighted Grade Value	Evaluation confidence (%)	Grade Value Per Section	Weight factors	Weighted Grade per Section	Level of Service	Evaluation confidence (%)	Final Grade	Level of Service	Evaluation confidence (%)
Management	1	Staff Training	50.0	1.0	50.0	100	54.7	1.0	54.7	C	94.4	57.5	C	77.3
	2	Monitoring	33.3	1.0	33.3	100								
	3	User satisfaction	70.5	1.0	70.5	100								
	4	Public relations	50.4	1.0	50.4	100								
	5	Cooperation with neighboring agencies	25.0	1.0	25.0	100								
	6	Safety and accidents	51.9	1.0	51.9	100								
	7	Inventory	100.0	1.0	100.0	100								
	8	Vehicles for interventions	45.4	1.0	45.4	50								
	9	SSCS	65.5	1.0	65.5	100								
Traffic Signal Operations	1	General	63.9	1.0	63.9	100	51.4	1.0	51.4	C	75.0			
	2	SSCS	38.8	1.0	38.8	50								
Signal Timing Practices	1	General	62.5	1.0	62.5	100	62.5	1.0	62.5	C	50.0			
	2	SSCS	#DIV/0!	1.0	#DIV/0!	0								
Traffic Monitoring and Data Collection	1	Detection	47.8	1.0	47.8	80	48.6	1.0	48.6	D	95.0			
	2	Data Collection and Storage	62.8	1.0	62.8	100								
	3	Data Quality	50.0	1.0	50.0	100								
	4	Weather and turning movements	33.7	1.0	33.7	100								
Maintenance	1	Strategy	100.0	1.0	100.0	100	70.4	1.0	70.4	B	72.0			
	2	Maintenance of equipment	57.9	1.0	57.9	60								
	3	Reaction time	44.4	1.0	44.4	100								
	4	Inventory and reporting	79.1	1.0	79.1	100								
	5	SSCS	#DIV/0!	1.0	#DIV/0!	0								

Table 3.1-2. Grades and evaluation confidence factors for Palm Beach County

Section	Partial grade num	Partial Grade subsection	Normalized Grade Value	Evaluation confidence (%)	Grade Value Per Section	Weight factors	Weighted Grade per Section	Level of Service	Evaluation confidence (%)	Final Grade	Level of Service	Evaluation confidence (%)
Management	1	Staff Training	#VALUE!	0	57.4	1.0	57.4	C	75.0	66.8	B	68.5
	2	Monitoring	57.1	100								
	3	User satisfaction	70.4	75								
	4	Public relations	32.5	100								
	5	Cooperation with neighboring agencies	100.0	50								
	6	Safety and accidents	26.8	100								
	7	Inventory	100.0	100								
	8	Vehicles for interventions	14.1	50								
	9	SSCS	58.2	100								
Traffic Signal Operations	1	General	49.5	94	49.5	1.0	49.5	D	47.0			
	2	SSCS	#DIV/0!	0								
Signal Timing Practices	1	General	93.8	100	93.8	1.0	93.8	A	50.0			
	2	SSCS	#VALUE!	0								
Traffic Monitoring and Data Collection	1	Detection	53.3	80	62.0	1.0	62.0	C	95.0			
	2	Data Collection and Storage	70.9	100								
	3	Data Quality	64.5	100								
	4	Weather and turning movements	59.5	100								
Maintenance	1	Strategy	100.0	100	71.5	1.0	71.5	B	75.6			
	2	Maintenance of equipment	56.8	78								
	3	Reaction time	50.0	100								
	4	Inventory and reporting	79.1	100								
	5	SSCS	#VALUE!	0								

Legend

[light green cell] The cells where weight factors for sections can be changed.

In addition to the final LOS letter grade and the sectional grades (boundaries given in Figure 3.1-13), the outputs of the evaluation process can be summarized in the form of Signal System Facts (Figure 3.1-14). This format, designed after a similar label for nutritional facts, can provide a summary of the most important information related to signal system performance of an individual agency. The authors of this report find that such a summary provides, at a glance, better information than the five-section-grade card from NTSRC, without overwhelming a reader with redundant information. Such Signal System Facts cards can be customized to include various fields and to satisfy the agency's own needs. For example, the agency might want to show the average cost of the reparation instead of one of the displayed measures.

Grade	Lower Value	Higher Value
A	83.34	100.00
B	66.67	83.33
C	50.00	66.66
D	33.33	49.99
E	16.67	33.32
F	0.00	16.66

Figure 3.1-13. Grade scale

Signal System Facts

Contact Information	
Agency	City of Boca Raton
Contact Person	Rasem Awwad/Tracy Phelps
Email Address	rawad@myboca.us
Grading	
Overall Grade	C
Overall Score	57.5
Evaluation confidence	77.3%
General Information	
Population	91,000
Annual Funding for Signal O&M	$150,000
Annual Capital Investments	$80,000
Operational Information	
FTEs	10
Signalized Intersections	136
Coordinated Signals	103
Aver. Freq. of Signal Retiming	Less than 1 year
Central Signal System	ATMS.now
Malfunctions per year	1,581
Annual Reparation Cost	$150,000
Response Time	48h

Signal System Facts

Contact Information	
Agency	Palm Beach County
Contact Person	Giri Jeedigunta, PE, PTOE
Email Address	gjeedigu@pbcgov.org
Grading	
Overall Grade	B
Overall Score	66.7
Evaluation confidence	68.5%
General Information	
Population	1,422,789
Annual Funding for Signal O&M	NA
Annual Capital Investments	NA
Operational Information	
FTEs	31
Signalized Intersections	1047
Coordinated Signals	639
Aver. Freq. of Signal Retiming	2-3 years
Central Signal System	ATMS.now
Malfunctions per year	Approx. 12,000
Annual Reparation Cost	NA
Response Time	72h

Figure 3.1-14. Signal system facts - examples

3.1.8 Conclusions

The signal system evaluation (either for the purposes of self-assessment and/or comparison with the other similar agencies) is very important process for several reasons:

- Identifying issues that an agency faces
- Understanding the efficiency of the changes made after previous evaluation
- Defining future plans and strategies
- Quantifying financial performance-based rewards

This study is a step towards the development of evaluation methodology that can fully rely on the available data and quantitative approach. Several important conclusions can be made from this research:

1. Impartial and unbiased evaluation and grading, based only on numerical and logical values, but not on personal opinion, is the way to improve current assessment practices.
2. The data that are difficult to extract, or not collected at all, can be identified and new procedures and tools for data collection and processing can be proposed.
3. The proposed methodology advocates the use of weight factors to enable assigning higher or lower importance to certain answer options, subsections or the entire sections of the methodology. Thereby, users could define which aspects of the signal system operations and maintenance are more important than others. That approach is recommended for conducting the self-evaluation. For comparison with the other agencies, the weight factors should be uniform for all agencies. Those weight factors should be defined after collecting the data and performing the evaluation of a higher number of agencies, so the grading scale and the weight factors could be defined after investigating the larger group of data and the survey results.
4. There is a need for a regularly updated inventory of assets and detailed maintenance activities. In such a way, the agencies would be better prepared for this, similar evaluation efforts and other uses.
5. Some questions, especially the ones that require numerical answers, could help in identifying the need for signal retiming or assessing the reliability of the systems components.
6. The introduction of signal controllers with high-resolution data logging capabilities would enable the usage of additional performance measures that would increase the significance and the accuracy of current methodology. If that type of controllers becomes prevalent in many agencies' inventory, that type of evaluation will be possible, moreover necessary.

The time required for conducting the annual evaluation process is very important. If that time is too long, it is possible that the agency staff will not be able or motivated to perform the entire process. It is challenging to precisely specify the time that would be necessary to complete the entire evaluation from the experience during the development of the methodology due to the fact that some time is spent for determining possible data sources in each agency. Time for completion will also depend on the fact if the questions marked with asterisk will be included in the final version of the evaluation. In the current form, the evaluation can be completely done in couple of days, including the data collection. It is important to stress that that time probably can be reduced later when agency's staff gets familiar with the methodology and know in advance from where to gather the necessary data or make preparations for that process in advance.

During execution of this research it was realized that this new annual evaluation methodology needs to interface short-term performance and monitoring of signalized intersections, which resulted in development of weekly/monthly performance and reliability evaluation dashboards. These dashboards, their use, input data and other details are explained in the following parts of this study.

The future research should consider proposed methodology with more agency subjects and create procedures and tools for processing data that are readily available but not used to assess performance of the signal-operating agencies. When the larger database of inputs from many agencies is obtained, it will be recommendable to define the proposed weight factors and the grading scale with a very high Evaluation Confidence. Also, integrating high-resolution data, and relevant performance metrics, in similar methodology is one of the future research directions for further quantification of the signal evaluation process.

3.2 Weekly/Monthly Evaluation

In order to provide more proactive monitoring of traffic signals, it is necessary to increase the resolution of the evaluation and not track signal performance only once per year. Comparing to the annual evaluation that was oriented towards assessment of the entire agency and all aspects of signal system, the weekly/monthly evaluation is oriented more to operations and reliability of the traffic signals and corresponding components in shorter intervals but with higher level of details.

The main goal of this part of the study is to determine adequate performance measures to monitor and report the performance and the reliability of traffic signal systems. Two different methods (for two agencies: City of Boca Raton and Palm Beach County) will be developed to reflect their infrastructural and technological levels. The external systems for data collection will be used to feed data into spreadsheet tools for weekly/monthly evaluation, but primary sources will be SSCS and adaptive traffic control system reports and outputs.

Considering that monthly/weekly evaluations require large amounts of data (e.g. duration of signal phases and other traffic signal parameters), and because of the need to investigate integration of the external travel time data collection systems (Wi-Fi or Bluetooth), it is not feasible to develop an evaluation tool for the spatial scope of the entire agency’s network. Therefore, a scope for weekly/monthly evaluation of signal operations needs to be focused on certain corridors or zones with signalized intersections. However, not all of the corridors or zones have the same data collecting and reporting capabilities. Such data collection capabilities will depend on the existing ITS technologies installed along the subject corridor. After defining the subject corridor for the evaluation, all available technologies on a specific corridor can be used to maximize the amount and quality of available data.

The selected corridor for the City of Boca Raton agency is consisted of 10 signalized intersections along the Military Trail from Yamato road in the north to the West Palmetto Park Road in the south. For the Palm Beach County, the selected corridor consists of 13 intersections on Northlake Boulevard from A1A on the east to the intersection with Military Trail on the west side. Both corridors are selected after careful consideration and consultation with staff from both agencies. One of the main reason for selecting these corridors is a good coverage (of both corridors) with the ITS technologies that can provide significant amount of traffic data.

3.2.1 Input Data

The data for inputs in the MS Excel tool, which is under development, will be provided as feeds from the existing infrastructure and technologies. Both City of Boca Raton and Palm beach County use ATMS.now as their SSCS, which will represent the main source of input data. Most of those data will come from two report types in ATMS.now - Split History Report and Field Alarms Report (available in .pdf and .xls formats). The .xls format will be used for manipulation into the MS excel spreadsheets. Due to large amounts of data and specific layouts of the reports it was necessary to develop MS Excel macros which would transform the original .xls reports from ATMS.now into databases that will be used later. Following sections describe development of those macros.

3.2.2 Macros for Reports Manipulation and Data Processing

Due to limitations of the ATMS.now reports in maximum number of rows per report, it is possible that more than one report needs to be made for each month. In some cases, number of events (and consequently rows containing data) can be higher or lower for the same time interval and the same number of intersections. If the selected time interval is too long the report will show a notification that there are too many rows that needs to be displayed (for the Field Alarm Report) or in case of Split History Report, only termination counts will be displayed. When such an outcome occurs the operator needs to decrease the time interval and initiate extraction of the report again. After creating all of the report files, and transforming them by using the macros mentioned in the previous section, the resulting files will serve as a database for the MS Excel dashboards. Due to the fact that manual compilation of all of the files is a very time-consuming job, the FAU research team has developed a set of macros for automatic compiling of all the report files. These macros include:

1. “FAU Split history Report Analyzer.xlsm” - Macro for transforming the Split History Reports into database for Traffic Signal System Performance Dashboard,
2. “FAU Phase Termination Analyzer.xlsm” - Macro for transforming the Split History Reports into Terminations database
3. “FAU Field Alarms Report Analyzer.xlsm” - Macro for transforming Field Alarm Reports

All of the macros above are provided in the Appendices of this report.

FAU Split history Report Analyzer.xlsm introduces an additional column in the records. The column is named “Period” and it indicates actual period of the records by checking the current time. The boundaries for the time periods are given in Table 3.2-1 below.

Table 3.2-1. Periods for traffic signal operation

Period	Start time	End time
AM Peak	07:00 AM	08:59 AM
Midday	09:00 AM	03:59 PM
PM Peak	04:00 PM	06:59 PM
Evening	07:00 PM	09:59 PM
Night	10:00 PM	06:59 AM

Also, all columns for 16 splits are duplicated in the same file with the difference that all of the zero values are excluded. This part of the spreadsheet will be used to count number of activations of splits over time because the Excel considers zero values provided by Split history report as a legitimate events even though they indicate that the subject split was not activated in that cycle. There is a possibility to later introduce an additional column that will enable filtering the data by the day.

In addition to split durations, cycle lengths, active patterns and the time when the subject cycle has started, the Split History Report also provides the data about termination counts. Therefore, the termination types for all phases, in all of the cycles are being collected, classified and summed. These records enable tracking of the number of Force-off, Gap-out and Max-out phase terminations in the evaluation period.

The termination counts tables at the end of the Split History Reports can be copied into a file to summarize termination types per phase. The FAU research team has developed a macro to automatize this task and reduce amount of manual labor required. The name of that macro is FAU Phase Termination Analyzer.xlsm.

The revised scope defines that weekly/monthly evaluation process needs to focus on assessing performance and reliability of the traffic signals on the selected corridors. The following sections describe the major performance and reliability indicators and measures that will be used in the Excel dashboard for weekly/monthly monitoring. Some of these measures can be also used in annual evaluation methodology if the examined corridor is considered an adequate representative of the entire system. Having in mind that ATMS.now is very powerful SSCS, majority of the measures are provided from the reports created by this SSCS.

3.2.3 Performance Indicators

Multiple measures can be used for representing the performance of the traffic signal system on the selected corridor. Based on the available technology and data, the following indicators were selected for describing the performance of signal systems.

Cycle Length

Shows the cycle length changes in the selected time interval. Depending on the selected interval, the user can track the planned and unplanned changes in the cycle lengths, deviations and make adequate inferences.

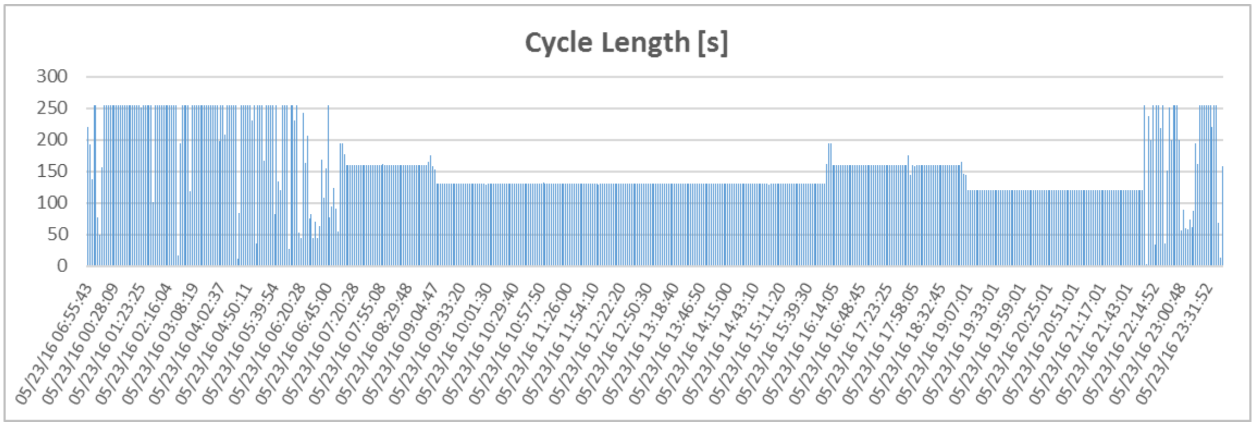


Figure 3.2-1. Cycle length diagram

Average, minimal and maximal duration of splits

Average, minimal and maximal duration of splits per signal timing pattern can be extracted and compared with the programmed splits. This can be a useful indicator to determine if signal timing needs to be refined.

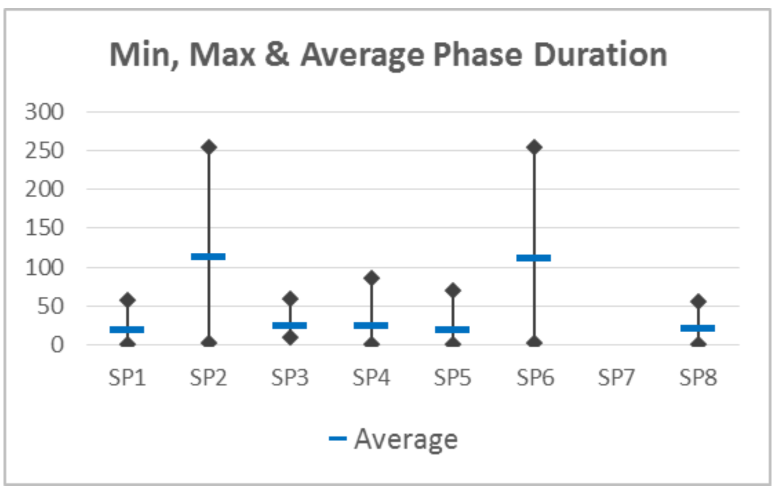


Figure 3.2-2. Minimal, maximal and average duration of phases

Number of phase activations

The number of phase activations per pattern can be compared to the maximal number of times that phase could be activated (number of cycles). If the result shows that some phases are omitted many times this could help operators to review existing phasing/timing arrangements and make some necessary changes. Such data can be filtered for date, intersection, and period.

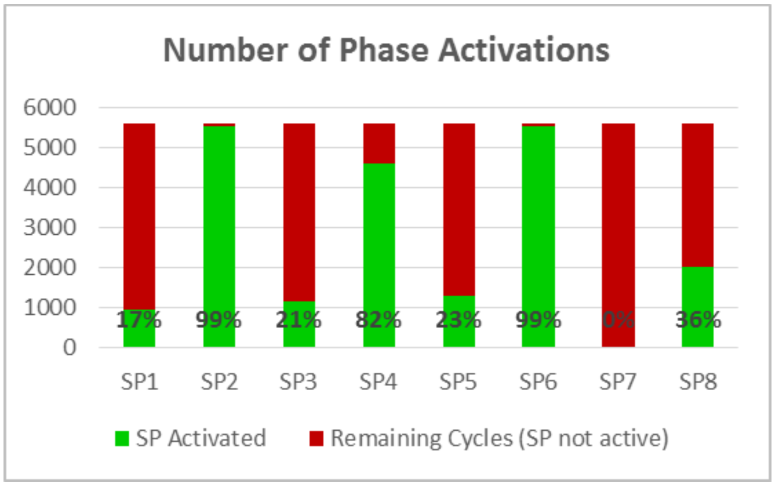


Figure 3.2-3. Number of phase activations

Phase duration distribution

This performance measure can show the most and the least frequent durations of phases. This information can be used to decide if the minimal or maximal duration of each phase need to be revised. The durations have to be compared only within a single period, because durations in different periods (and for different signal timing patterns) can vary significantly.

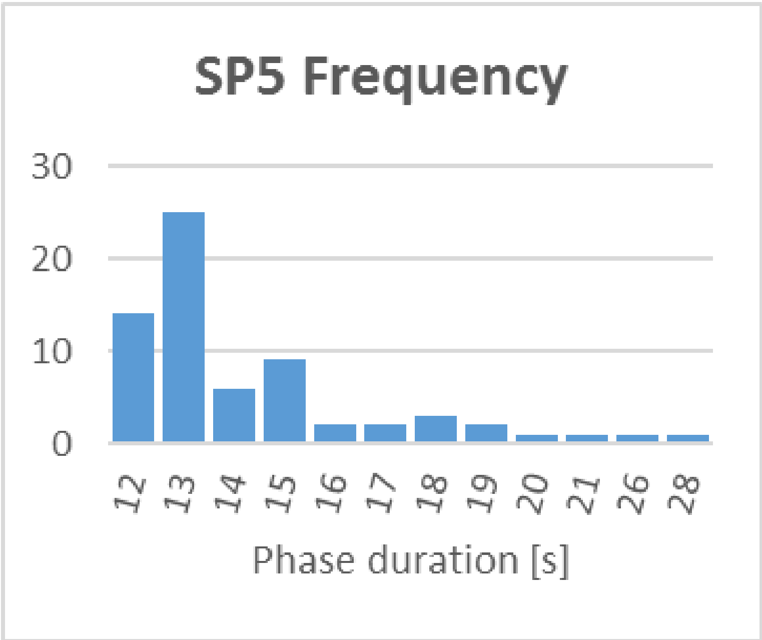


Figure 3.2-4. Phase duration distribution

Green to cycle ratio (phase splits)

This measure indicates the percentage of time that a certain movement utilized for green time of the entire cycle length. This value can imply what level of priority certain movements have, and help to decide if there is a need for making changes.

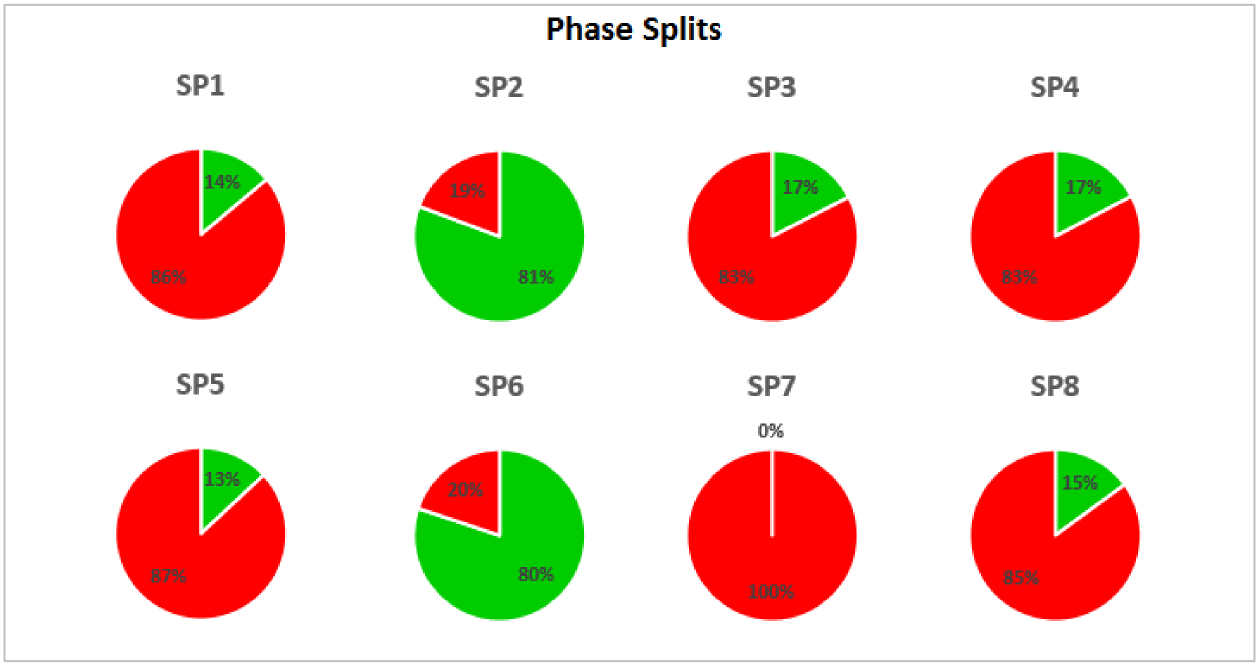


Figure 3.2-5. Phase splits diagram

Phase Duration Over Time

The set of graphs shows the changes in minimal, average and maximal durations of signal phases over time. Besides the fact that a user can observe how durations of the phases change over time, one can also keep track of variability of phases over time (the difference between minimal and maximal duration, with the current position of the average duration between those two values).

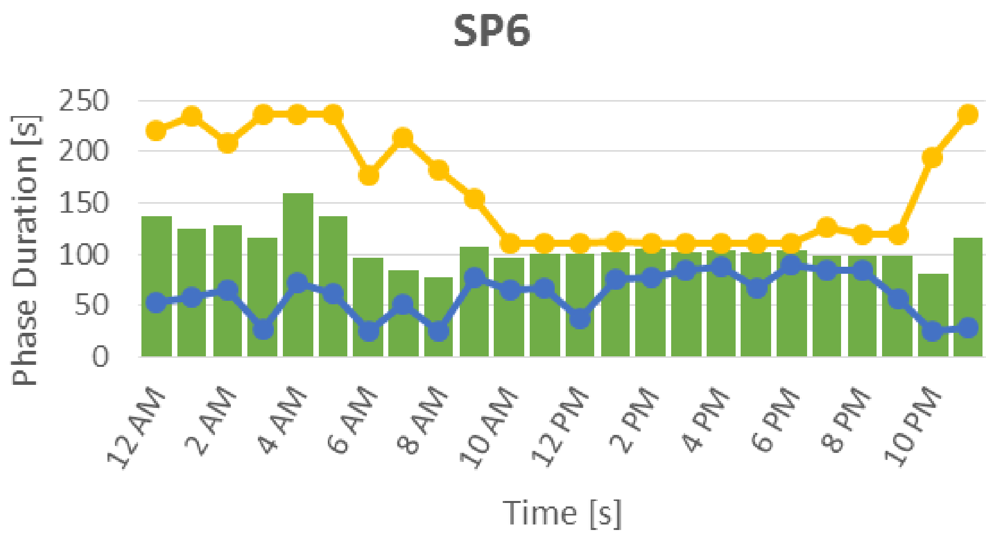


Figure 3.2-6. Phase duration over time

Phase terminations per type

Number and percentage of each phase termination type (Force-offs, Max-outs and Gap-outs) can be a powerful measure for understanding actions which can be taken to improve the traffic signal operations. For example, if Max-out is predominant type of phase terminations this may indicate that the observed phase deserves the increase of the maximal green time. Also it can indicate that the signal operation cannot serve all the traffic demand etc.

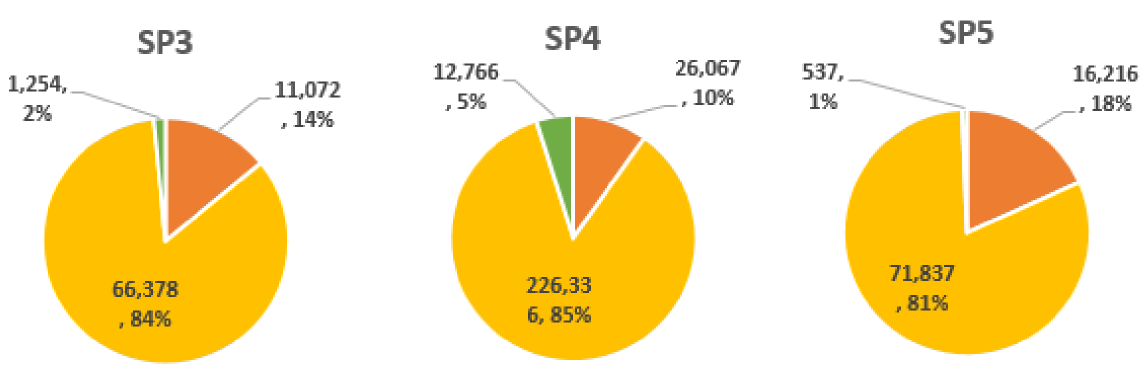


Figure 3.2-7. Phase terminations per type

3.2.4 Reliability Indicators

The second group of indicators for signal system monitoring are the reliability indicators. Unlike the performance indicators where the majority of the data comes from the Split History Report, the reliability indicators mostly rely on Field Alarm Reports from ATMS.now SSCS. In this type of report, information about the intersection (date, time, event code, status (on or off) and the description of the event) is available. Those data need to be preprocessed and used for deriving the following indicators.

Analysis of Field Alarm Reports can be performed on a weekly, monthly or an annual basis, on various levels from the single intersection, a corridor, or the entire agency. Investigating all of the agency's signals, annually, is possible but this would require that multiple reports are created. On the other hand, analysis of the Split History Reports cannot be used for annual evaluation of the entire agency because each report would be too large due to high frequency of data collection (each report shows data for only one intersection and the information is collected per cycle for 24 hours every day).

Cabinet door opened - duration

The total amount of time when the cabinet doors are open, during the observation period, can be useful indicator of maintenance efforts taken for intervening on specific signal controllers. Unless the maintenance is preventive, this is also a measure that shows the reliability of system. Longer periods when the cabinet doors are open indicates frequent interventions and lower reliability of the signal system.

Number of communication failures

This reliability measure can show how many times the communications were not functional. If the number is smaller, the reliability of the system is better. It should be noted that sometimes the fake alarms are recorded. In some cases, Field Alarm Reports show that communications have failed, or have been restored, multiple times in a row. Those cases need to be filtered out.

Number of controller faults

The number of the controller faults can show the reliability of that component of traffic signal system. More faults mean less reliable operations and more time spent on troubleshooting.

Number and the distribution of cycle failures and cycle faults

The higher number of cycle failures indicates more problems with the traffic signals. The distribution of these events can help in identifying the signals which need most of the attention from the operators.

Detector failures (vehicle and pedestrian)

Detector failures are supposed to be collected by investigating the Ped failure alarms, detector diagnostic failures, detector failures from SDLC and the detector SDLC failures alarms, their frequency, spatial distribution. That enables the operator to identify the problematic detectors in the network and plan maintenance activities that can increase the reliability of the system.

Number of situation when manual control was enabled and its duration

This measure shows how often and how long the traffic signal was switched to manual control (Police Push Button). This indicator shows how often the system was overridden and when stopped being in that state.

Number of times when the controller lost the power and/or was rebooted

These indicators can display the reliability of power supply system by number of times when the controller have lost the power and could not be functional. If the frequency of these events gets higher, the reliability of the system deteriorates.

Number and spatial distribution of the preemptions (per type)

These measures can show frequency of the preemption events and thus level of disruptions of the regular operation of the traffic signals. Their average duration, and duration distribution can help to understand predominant time periods when signals work differently than defined by designated signal plan for that period of the day. Spatial distribution can be useful to check parts of the subject network are mostly affected by various preemptions. For all aforementioned indicators, the type of the preemption is known so the prevalent cause for disruptions can be identified.

The number of the congestion incidents

ATMS.now generates a report that can indicate level of congestion in the network. Congestion status is defined by set of thresholds defined in the ATMS.now platform.

3.2.5 Attachments

With this report, four Excel files are submitted as tool for the annual evaluation methodology and part of the Deliverable 3. Those files are:

1. Annual Evaluation Spreadsheet filled with hypothetical data of the Best Agency (defines the maximal scores and results that an agency can get by using this methodology)
2. Annual Evaluation Spreadsheet filled with hypothetical data of the Worst Agency (defines the minimal scores and results that an agency can get by using this methodology)
3. Boca Raton Annual Evaluation Spreadsheet – current (the annual evaluation performed for City of Boca Raton agency using recently collected data)
4. PBC Annual Evaluation Spreadsheet – current (the annual evaluation performed for Palm Beach County agency using recently collected data)
5. FAU Traffic Signal System Annual Evaluation Spreadsheet Ver 2 – the universal spreadsheet tool that should be created for performing the evaluation of traffic agencies in the future.

4 Annual Evaluation Spreadsheet Tool – User Manual

The investments in traffic signal assets and relevant staff can bring improvements to agencies who operate traffic signals, but without quantifying operations and maintenance, the true effects of the improvements remain unknown. Even in cases where the budgets, number of signals and staff sizes are similar, the resulting operational and maintenance performances can vary significantly. In order to assess the main strengths, weaknesses and efficiency of an agency, a comprehensive evaluation is needed. This is especially important if operations and maintenance of the traffic signals are assigned to private companies or contractors, in which case, evaluation or grading is contractually mandatory between the public agencies and private vendors/consultants. Thus, the satisfactory evaluation results of the contractors' performance may be a necessary prerequisite for receiving the financial reimbursement for the provided services to operate and maintain traffic signals.

A difficult part of the evaluation process is to define the performance measures that should be observed, can be collected, and provide a comprehensive overview of the agency's operations and maintenance performance. Until now, several attempts have been made to develop a methodology for such a comprehensive evaluation. The best known is certainly the effort of National Transportation Operations Coalition with the creation and issue of the National Traffic Signal Report Card (NTSRC). That type of evaluation had been performed in 2005, 2007 and 2012. It provided a good insight into the current status of traffic signal systems in several different categories. However, there is a feeling that the NTSRCs rely too much on qualitative (and thus subjective) information from the surveyed agencies. The goal of this research is to address this shortcoming and propose a methodology which evaluates traffic signal agency performance in a more quantitative way, with inputs and factors which are based on data-driven outputs from the signal-operating agencies. It should be noted that the proposed methodology is not fully quantitative and without subjective assessments. However, a significant effort has been made to limit subjective assessments wherever possible.

The evaluation framework presented in this study is inspired on the inputs from multiple sources, mainly research reports, papers presented in the literature review section. Due to the significant differences of various agencies, it is challenging to create a single methodology that can be applicable to all agencies while remaining comprehensive enough to evaluate the adequate level of details of traffic signal operations and management. The annual evaluation can be used by an agency to determine the status of the traffic signal system in various aspects. The agency can use the proposed methodology to perform a self-assessment, or to compare its results with other agencies. Both way, strengths, weaknesses and the efficiency of the agency's signal systems components are investigated. This methodology is intended for being used once per year, and all it options cannot be used in case of shorter intervals of examination.

The spreadsheet tool for annual evaluation of traffic signal system performance and maintenance is accompanied by a Manual that will help the respondents to answer questions and fill proper fields in the spreadsheet. The Manual explains the evaluation procedure question by question, for all of the sections of the evaluation methodology. The potential data sources, the logic behind the selected methodology and the challenges faced during the completion of the pilot project are all addressed in this manual. After reading the Manual, agency staff should be able to complete the evaluation procedure and perform the assessment for the agency's traffic signal system.

The aforementioned pilot project is actually process of defining the available sources, questions developing the methodology and implementing that proposed methodology on two selected traffic agencies in Florida. Two selected agencies are the City of Boca Raton and Palm Beach County.

In the annual evaluation methodology importance factor represents a weight which can be given to certain choices throughout the entire assessment to emphasize their significance in overall assessment methodology. For example, one could argue that it is more important, in the overall framework of maintaining traffic signals to maintain a healthy detection system than to pay attention to signal retiming procedures. Such Importance Factors are given to provide agencies with flexibility to assess their operations and maintenance of signals in a customized way. However, in this study, all of these factors were kept the same, in order to normalize the results and avoid any potential bias towards certain agency's policies, strategy and priorities. It should be noted that specifying importance factors should be used for agencies' self-assessment efforts whereas when the performances are compared between various agencies, all of the factors should be kept at the same values, unless there is a strong justification for the opposite.

To increase or decrease the influence of one subsection's grade on the overall section's grade, the subsection grade can be multiplied by a higher or lower weight factor (between 0 and 1). In this research project, all the weight factors have the same value of one (1). Similar to the case of Importance Factors, if an agency wants to compare its results with those from the other agencies, it needs to set its weight factors to be equivalent with those from the other agency. Although an agency can change the weight factors in a custom way (e.g. for the purpose a self-evaluation), such an action is not recommended without a strong justification (e.g. to reflect handling traffic during special events or around special areas (e.g. schools, hospitals).

Overall, the methodology has three levels of factors that influence the results:

1. Importance factors for certain answer choices for all questions
2. Weight factors for Subsections
3. Weight factors for Sections

By changing the weight and importance factors, the user can accentuate certain parts of the methodology, or on the other hand, decrease the importance and the impact of that part. For example, the user can change the default value of a subsection weight factor from 1 to 1.20 and thereby increase the impact of the subject subsection for the 20% on the sectional grade and consequently on the final grade. The opposite effect will be created if the weight factor is changed to a smaller number (between 0 and 1).

For omitting the subsection from the calculation process (in case when data are not available, the Evaluation confidence is lower than 50% or if that is the desire of the user), one just needs to set the weight factor value to 0. Then the subject subsection will be disregarded in the calculation of the grade for the entire section and the general grade. That means the value of zero will not be used in the calculation of the average score.

4.1 Contact and General Information

In the first part of the evaluation methodology, it is needed to collect general and contact information of the responding agency. The contact information is used to identify and potentially contact the person in charge at the interviewed agency.

In the general information subsection, several relevant data are collected to describe the subject agency and the signalized network under its jurisdiction. The population of the city or county, number of registered vehicles in the zone under jurisdiction, etc. are data used in the various calculations later in the spreadsheet/evaluation. Table 4.1-1 provides explanation for each entry in this section.

Table 4.1-1. Contact and general information user manual

Contact Information	
0.1	Name
	Enter the name of person responsible of conducting the evaluation process.
0.2	Title
	Enter the Title of the person from above.
0.3	Agency
	Name of agency (usually the name of a city or county).
0.4	Address
	The physical address of the agency.
0.5	City/Town
	Enter the city in which the agency is located.
0.6	State/County
	Enter names of the State and the County.
0.7	Zip code
	Enter the Zip code.
0.8	Telephone contact
	Enter the telephone number of the person responsible from above.
0.9	Email address
	Enter the email address of the person responsible from above.
Note: Information provided above is not used in the grading process but only to document basics about the agency and person responsible for filling the survey and performing the evaluation process.	
General Information	
0.10	County/City population
	Enter the approximate population of the city or the county under agency's jurisdiction. If not available from other sources please use the United States Census Bureau (www.census.gov).
0.11	Number of registered vehicles
	Enter the number of vehicles registered in the city or county under agency's jurisdiction. If such information is not readily available, it can be obtained from Florida Department of Highway Safety and Motor Vehicles (FLHSMV) (www.flhsmv.gov). The FLHSMV provides data per county. If an agency is smaller than a county, it is necessary to approximate the number of registered vehicles (e.g. use a proportional number based on population of the area under agency's jurisdiction).

0.12	Number of neighboring signal control agencies
	Enter a number of agencies whose areas of jurisdiction are bordering with the agency's area of jurisdiction.
0.13	Number of streets with shared signal jurisdiction
	Enter a number of streets with traffic signals that extend from the area under control of the agency to the area under control of another (bordering) agency.
0.14	Total length of road network by the jurisdiction (miles)
	Enter the total length of the road network under agency's jurisdiction. If the information is not readily available, it can be obtained through Florida Department of Transportation's web-site with GIS files (http://www.dot.state.fl.us/planning/statistics/gis/road.shtm). It is possible to select all public streets with traffic signals (freeways are excluded).
0.15	Estimated annual funding for signal operations and management
	Enter the approved funding for traffic signal operations and management for the current or last year. This information is very illustrative of the efforts done to operate and maintain signals and is used for a number of calculations. Thus it is very important to enter a value even if it is only the best approximation.
0.16	Estimated annual funding for signal related capital investments
	Enter the approved funding for capital investments in traffic signal system for current or last year. Importance of the entry is similar as above.
0.17	Number of signalized intersections
	Insert the total number of signalized intersections (with full signals).
Note: This subsection contains no calculations, but the data presented here are used in many other sections for the evaluation and grading processes.	

In the following chapters, all five sections similar to those from the National Traffic Signal Report Card, are addressed in such a way to avoid any ambiguity when responding to the questions.

4.2 Management

The Management section contains nine subsections addressing various important issues:

- Number, expertise and training of regular and outsourced staff
- Monitoring
- User satisfaction
- Public relations
- Cooperation with adjacent agencies
- Safety and traffic accidents
- Inventory
- Service vehicles number and activation
- Signal System Central Software (SSCS)

All questions relevant for this section are addressed in Table 4.3-1.

Table 4.2-1. Management section evaluation user manual

Number, expertise and training of regular and outsourced staff	
1.1	Number and expertise of in-house staff
	Please enter number of employees, per qualification type, expressed in Full Time Equivalents (FTEs). This number does not have to be an integer because a person can be engaged part-time (40 hours per week if considered a full-time workload). If a person is engaged 40 hours per week this should be entered as "1" in the corresponding field.
1.2	Number and expertise of outsourced staff
	The number of FTEs for outsourced staff is required, if the agency employs outside staff members. The inputs should follow the same rules as in the previous entry, where the staff is divided in several groups (Managers, Engineers, Technicians, Admin staff and others).
1.3	Staff training
	Represents types and quantities of staff training efforts each year. Respondents need to enter the total number of training hours per training type (Basic signal timing, advanced signal timing, ITS courses, hardware and communications and other). The number of training hours is a product of number of staff who received training and number of training hours that each staff member has taken. For example, if two persons had, each, 8 hours of advanced signal timing training, the correct number should be 16 hours.
Note: The subsection grade is calculated by adding all of the training hours and dividing them with the total equivalent number of staff and 100.	

Monitoring	
1.4.1	Number of staff designated to monitoring signal/traffic operations
	The number of people that are designated to monitor traffic flows using CCTV cameras, various software platforms and other TMC tools.
1.4.2	Number of hours (per week) designated for monitoring signal/traffic operations
	Considering that staff from 1.4.2 may have other responsibilities, it is necessary to approximate and enter a number of hours per week that are specifically used to monitor signal/traffic operations.
1.4.3	Total number of engineering and technician staff (regular and outsourced)
	This number is calculated automatically from entries 1.1 and 1.2 and it represents the sum of all engineers and technicians engaged both within the agency and out-sourced.
1.4.4	Average number of work hours per week (for the staff from entries 1.4.1/1.4.2)
	If the staff is engaged full-time than enter 40 hours, otherwise enter the exact number of hours per week.
Note: Product of 1.4.1 and 1.4.2 is divided by product of 1.4.3 and 1.4.4	
User Satisfaction	
1.5.1	Number of complaints per year
	Number of complaints on traffic signals per year over the telephone, mail, web site or any other mean of communication.
1.5.2	Is there a publicized call-in telephone number and web site that the public can use to report malfunctions, ask questions and suggest operational improvements?
	The requested answer is 1 (Yes) or 0 (No).
Note: The User satisfaction partial grade represents a sum of values from entries 1.5.1 & 1.5.2.	
Public Relations	
1.6	Average time from receiving complaint until responding to it
	Enter an average response time that an agency needs to address a reported issue. Select one of the provided answers and enter "1" next to it.
1.7	Information available to public
	Select all of the types of information that the agency shares with public by entering "1" in the corresponding fields.
1.8	Means of communication with the public
	Select all of the means of sharing information with the public by entering "1" in the corresponding fields.
Note: Sums for answer groups are divided by maximum number of points (100) to calculate grade for this section.	

Cooperation With the Neighboring Agencies	
1.9.1	Number of neighboring agencies for information and data exchange
	Enter number of neighboring agencies with which information and data are shared
1.9.2	Number of inter-coordinated signalized streets shared with the neighboring agencies
	Enter number of signalized corridors which are coordinated in agreement/ communication with the other neighboring agencies
Note: Entries used to relate with the data from entries 2.3 and 2.4 from General Information.	
Safety and Accidents	
1.10.1	Number of accidents on streets close to traffic signals
	If an agency does not have its own database with traffic accidents, or cannot provide these data from any other source, such data can be obtained from Signal Four Analytics (https://s4.geoplan.ufl.edu/). To get the appropriate results, the respondent needs to set appropriate filters in Signal Four Analytics: • Geographic extent should be set to City or County jurisdictional boundaries • Network extent should be set to Intersection. • Intersection offset distance can be set to 150 feet. • For road circumstances None, Other and Unknown should be selected to exclude any special situations that can cause traffic accidents. • For Road System Identifier filter, select U.S., State, County and Local roads and streets. In such a way, the probability that the recorded accidents are related to all of the traffic signals is maximized.
1.10.2	Number of accidents involving red-light running
	For accidents caused by running the red lights, the Common Violations filter in Signal Four Analytics needs to be set to Run red lights, while the other settings should remain the same as explained under entry 1.10.1.
Inventory	
1.11.1	Is there an up-to date inventory of all of the signal equipment including spare parts?
	If the answer is Yes insert 1; if No, insert 0.
Service Vehicles number and Activation	
1.12.1	Number of vehicles in operation by shift
	Type in the number of vehicles used for interventions on traffic signals per work shift. Include cars, pick-up trucks, vans, trucks and bucket-trucks.

1.12.2	Miles travelled per vehicle (in thousands)
	Enter (an approximate) average number of miles that a vehicle used by the agency travels per year (on signal operations and maintenance activities).
1.12.3	The vehicle coverage ratio
	Value in this filed is automatically calculated by dividing the number of utilized vehicles (1.12.1) and the total length of road network (2.5).
Note:	
Signal System Central Software (SSCS)	
1.13.1	Does the agency has SSCS software?
	If Yes insert 1, if No insert 0.
1.13.2	How many intersections are connected to SSCS?
	Enter number of signals that can be accessed through the SSCS. This number is later related to the total number of signals.
1.14	Type of SSCS software
	Select the type of SSCS software by entering “1” in the appropriate field. This answer is not used to judge quality of operations but only to define some of further questions, as various SSCSs may have different options and functionalities.
1.15	Functionality of SSCS
	Select all options that the subject SSCS contains by entering “1” in the appropriate fields.
1.16	Number of staff that actively use SSCS software
	Enter number of agency personal who regularly and actively use the SSCS software.
1.17	Has the agency set alarms to inform persons in charge about system malfunctions?
	For Yes insert 1, for No insert 0.
1.18	Select means used to inform persons in charge about events that trigger alarms
	For all of the communication means that the agency use, enter “1” in corresponding fields.
Note:	

4.3 Traffic Signal Operations

The Traffic Signal Operations section addresses the questions related to the traffic signal’s performance. By answering the carefully selected questions, the respondents provide the input data for the evaluation process.

Table 4.3-1 Traffic signal operations section evaluation user manual

General	
2.1	Does agency utilize any traffic responsive or traffic adaptive control?
	If yes, enter 1. Otherwise, enter 0.
2.2	Are field reviews of signal operations performed at least once a year?
	If the reviews are performed at least once per year, enter 1. Otherwise, enter 0.
2.3	Are ad-hoc changes of signal timings performed for all legitimate complaint calls?
	If yes, enter 1. Otherwise, enter 0.
2.4	Are sights distances to intersections reviewed for all new traffic signal installations?
	If the sights distances to intersections are reviewed before determining the positions and the number of signals, then enter 1. Otherwise enter 0.
2.5	Are advanced warning indications installed where limited site distances exist?
	If flashers or additional signal heads are installed where limited site distances exist, then enter 1. Otherwise, enter 0.
2.6	Number of signalized intersections adjusted for visually impaired persons.
	Enter the exact number of intersections adjusted for visually impaired persons. This number is later related to the total number of signalized intersections.
2.7	Actual time to implement, evaluate and fine-tune new signal timings (in weeks).
	Enter average actual time (in weeks) necessary for the agency to implement, evaluate and fine-tune new signal timings.
2.8	Expected time to implement, evaluate and fine-tune new signal timings (in weeks).
	Enter average expected time (in weeks) necessary for the agency to implement, evaluate and fine-tune new signal timings.
2.9	Frequency of signal retiming
	Select one of the offered options, which best represents frequency of the signal retiming of the subject. Enter “1” in the corresponding field.
2.10	Number of coordinated traffic signals
	Enter number of coordinated signals under jurisdiction of the subject agency.
Note: Grade for this subsection represents the sum of all of the scores for entries above.	

Signal System Central Software - SSCS	
2.11	Number of special events, disasters, VIP routes and emergency signal timings
	Enter number of signal timings created for special events, natural disasters, emergency and VIP routes for all signals.
2.12	Total number of signal timing plans
	Enter the total number of signal timing plans for all of the signals.
2.13	Number of school zone manual flash signals
	Enter the total number of manual flash signals in school zones inside the area of the agency's jurisdiction.
2.14	Number of schools
	Enter number of schools in the jurisdiction area of the subject agency.
2.15	Number of intersections with preemption capability
	Enter number of signals with capability to activate preemption.
2.16	Number of intersections with Public Transit prioritization capability
	Enter number of signals that have capability to provide priority to Public Transit vehicles.
2.17	Total number of signalized intersections along PT routes.
	Enter total number of signals along all of the Public Transportation routes.
2.18	Average number of hours per day when adaptive system is active
	Enter an average number of hours when adaptive system is active (in case that agency uses one).
2.19	Number of hours with congestion (per day, week, month)
	Enter approximate number of hours with congestion on the most important corridors (or zones) in the network (it can be per day, week or month depending of the available data).
2.20	Total number of hours per observed period (in day, in week, in month…)
	Enter the total number of hours during the period selected under 2.19 (e.g. number of hours in a day, in a week, or in a month).
2.21	Number of cycle failures
	Enter number of cycle failures, as reported by the ATMS.now (for all signals). Additional data processing needs to be performed to derive this information for the entire network. Macros and Dashboard tools developed by the FAU research team can be used to obtain this information. A value entered here needs to correspond to the period selected in the entry 2.22.

2.22	Total number of cycles per observed period
	Enter number of cycles for all signals (or a selected representative zone) as reported by the ATMS.now Split History Report. Additional preprocessing needs to be done to derive this information from the ATMS.now data. The FAU research has developed macros and Dashboard tools to retrieve this information. It is possible to use the data for a period shorter than a year.
2.23	Number of cycle faults
	Enter number of cycle faults for all signals as reported by the ATMS.now. Additional preprocessing needs to be done to derive this information from the ATMS.now data. The FAU research has developed macros and Dashboard tools to retrieve this information. A value entered here needs to correspond to the period selected in the entry 2.22.
2.24	Time that coordination has been in transition
	Enter duration of events (in hours) when the coordination has been in the transition for the period of your choice (the entire year, 6 months…)
2.25	Time the coordination is active
	Enter the entire time (in hours) when the coordination was active for the same period used under entry 2.24 above.
2.26	Coordination failure
	Enter the number of coordination failures for the previously selected period (entries 2.24 and 2.25).

4.4 Signal Timing Practices

In Signal Timing Practices section, the goal is to determine which performance measures, data types, and signal timing software are used by the agency's staff when creating new signal timing plans. It is assumed that if the input in the signal retiming process is better, the output will have a higher quality. A guidance to correctly complete this part of the evaluation is provided in the Table 4.4-1.

Table 4.4-1. Signal timing practices evaluation user manual

General	
3.1	Records of conflict situations used to identify signalized intersections at which safety could be improved by revising signal operations (e.g. protected turns…)
	Does the subject agency use the data about conflicts at signalized intersections in the process of creating new signal timings or signal strategies? If the answer is Yes enter 1, otherwise enter 0.
3.2	Performance measures that agency collects
	From the provided list of performance measures, select those that are used by the subject agency to create new signal timings. Enter "1" in the corresponding fields next to the performance measure name.
3.3	Signal timing optimization software (Synchro, PASSER, TRANSYT, etc.) to develop new signal timings?

	If staff from the subject agency uses signal timing optimization software in the process of developing new signal timings enter 1, otherwise enter 0.
3.4	Parameters used to develop new signal timings
	Select the parameters which are used for development of new signal timings. In the provided list enter "1" for all of the parameters which are used. The other fields should have zeros.
Note: The answers are summed into one subsection grade.	
Signal System Central Software - SSCS	
3.5	Average duration of splits per AM, Midday and PM period
	Enter average durations of phase green times per AM peak, Midday and PM peak periods. Dashboard for weekly/monthly evaluation of signals, developed by the FAU Research team, can be used for this task.
3.6	Duration of programmed splits
	Enter programmed durations of phase green times per AM peak, Midday and PM peak periods from signal timing sheets.
3.7	The number of times a phase was activated in a given evaluation period
	Enter number of times a certain phase was activated (green) in an evaluation period. Dashboard for weekly/monthly evaluation of signals, developed by the FAU Research team, can be used to retrieve this information.
3.8	Maximum number of times that phase could be activated
	Enter the maximum number of times when a phase could be activated (equivalent to a number of cycles for such period).
Note: The methodology in this subsection is suitable for investigation of one signal phase	

4.5 Traffic Monitoring and Data Collection

The Traffic Monitoring and Data Collection is a very important aspect for any modern traffic signal agency in nowadays data-rich environment. The detection (number, types and practices), data collection and storage, checking the quality of collected data and other relevant data are grouped into four subsections shown in Table 4.5-1.

Table 4.5-1. Traffic monitoring and data collection evaluation user manual

Detection	
4.1	Total number of detectors
	Enter number of all vehicle detectors that the subject agency has.
4.2	Detection distribution by type
	Enter, in the corresponding cells, number of detectors of each type that the subject agency has. This information is not used to derive grades but is used in the summary section (Signal System Facts).
4.3	System detectors

	Specify if the subject agency uses system detectors and their locations. Enter “1” in the corresponding fields, or enter “0” if no system detectors are used.
4.4	Data collected by the system detectors
	Select the data types that the subject agency collects by entering “1” next to the corresponding fields. Types which are not supported should be given “0”.
4.5	Use of queue detectors
	Enter “1” if queue detectors are used, otherwise enter “0”.
4.6	Calibration of video detectors
	Select the factors for which the video detectors are calibrated by entering “1”, or “0” for those which are not supported.
4.7	Frequency of calibration of video detectors
	Specify frequency of video detection calibration by entering “1” (or “0”) in corresponding fields.
Data Collection and Storage	
4.8	Data archiving methods.
	Specify archiving methods of the subject agency practices by entering “1” in the corresponding fields, or “0” if such methods are not used.
4.9	Data types stored in the signal system database.
	Specify which of the data are stored in the signal system database by entering “1” in the corresponding fields, otherwise enter “0”.
4.10	Sharing data reports
	For every institution type with which the agency shares the data, either on regular or ‘per request’ basis, enter “1”. For those which are not applicable enter “0”.
4.11	Select the technologies used to collect vehicle travel times.
	Enter “1” for each technology that the subject agency uses to collect vehicle travel times. For the technologies that are not used enter “0”.
Data Quality	
4.12	Data quality, consistency and correctness
	If the data collected by the subject agency are checked for quality, consistency and correctness enter “1” in the corresponding fields. Otherwise, enter “0”.
4.13	Frequency of collected travel times

	Specify which of the offered options best describes how often the subject agency collects the travel time data, by entering "1" in the appropriate field. Other options should be "0".
4.14	Frequency of collected vehicle delays
	Specify which of the offered options best describes how often the subject agency collects the vehicle delay data, by entering "1" in the appropriate field. Other options should be "0".
4.15	Frequency of collected signal timings
	Specify which of the offered options best describes how often the subject agency collects the signal timing data, by entering "1" in the appropriate field. Other options should be "0".
Weather and Turning Movements	
4.16	Number of weather stations located on the territory under agency's jurisdiction
	Enter the number of weather stations located on the territory under agency's jurisdiction.
4.17	Locations of turning movement counts
	Enter number of locations at which the turning movement counts are collected in period of one year.
4.18	Frequency of turning movement count data collection
	From the provided options select one which best describes practice of the subject agency by entering "1" in the corresponding field. The other cells should be filled with "0".

4.6 Maintenance

Detailed instructions for answering each question in this section are provided in Table 4.6-1.

Table 4.6-1. Maintenance section evaluation user manual

Strategy	
5.1	Do maintenance agreements require performance monitoring and report?
	If Yes enter 1, if No enter 0.
5.2	Does agency use performance measures to evaluate its signal system maintenance?
	If Yes enter 1, if No enter 0.
Equipment	
5.3	Number of detectors out of function per year
	Enter the number of detectors that experience malfunctions in a year.
5.4	Duration of detectors failure per year
	Enter the total duration (in hours) of detector failures per year.
5.5	Adjustments made to reflect deployment of new equipment
	When new equipment is installed, does the staff of the subject agency make necessary adjustments based on the characteristics of that equipment? If yes then enter 1, otherwise 0.
5.6	Checking alignment and position of all signal heads and signs
	Select an interval that most closely describes the frequency of checking the alignment and position of the signal heads in the subject agency by entering 1 in the corresponding field. Other answers should be filled with 0.
5.7	Checking operability of signal controllers
	Select the interval that most closely describes the frequency of checking the operability of the signal controllers under the subject agency by entering 1 in the corresponding field. Other answers should be filled with 0.
5.8	Checking operability of communication infrastructure
	Select the interval that most closely describes the frequency of checking the operability of the communication infrastructure (router hubs, fiber optics, internet connection, wireless connection...) under agency's jurisdiction by entering 1 in the corresponding fields. Other answers should be filled with 0.
5.9	Checking operability of Signal System Central Software

	Select the interval that most closely describes the frequency of checking the Signal System Central Software under agency's jurisdiction by entering 1 in the corresponding fields. Other answers should be filled with 0.
5.10	Checking operability of signal heads
	Select the interval that most closely describes the frequency of checking the operability of the signal heads under agency's jurisdiction by entering 1 in the corresponding fields. Other answers should be filled with 0.
5.11	Frequency of synchronizing controllers' clocks
	Select the interval that most closely describes the frequency of synchronizing the clocks of controllers under your agency's jurisdiction? Select the closest answer by entering 1. Other options should have 0.
5.12	Total cost of all reparations per year
	Enter the total amount of money spent for all reparations in a year.
5.13	Number of all malfunctions per year
	Enter the number of all malfunctions recorded in a year.
5.14	Number of changed lightbulbs
	Enter the total number of changed lightbulbs or LED modules in a year, all of the signal heads under agency's jurisdiction.
5.15	Total number of lightbulbs
	Enter the total number of lightbulbs or LED modules that the subject agency has in all of the installed signal heads.
Notes: The entries 5.12 and 5.13 are not included in the grading method but they can be used for calculating the average cost per one maintenance intervention and/or can be presented in Signal System Facts sheet.	
Reaction time	
5.16	Average response time for critical failures (e.g. controller malfunction, communications failure, physical damage of equipment on site…)
	Select an average response time that most closely describes the average time the subject agency needs to start addressing the critical failures, by entering 1 in the appropriate field. Other responses should have 0.
5.17	Average time to complete an intervention (resolve a problem) of critical failures (e.g. controller malfunction, communications failure, physical damage or equipment on site…)
	Select the answer that best describes an average time the subject agency needs to complete the intervention for critical failures, by entering 1 in the appropriate field. Other responses should have 0.
5.18	Average response time to all reported failures

	Select the answer that best describes an average time the subject agency needs to complete the intervention for all failures, by entering 1 in the appropriate field. Other responses should have 0.
5.19	Average response time regarding user complaints?
	Select the answer that most closely describes average time the subject agency needs to respond to user complaints, by entering 1 in the appropriate field. Other responses should have 0.
Inventory and Reporting	
5.20	Record of maintenance activity
	Enter 1 if the inventory kept by agency contains the records of maintenance activities. Otherwise enter 0.
5.21	Maintenance reports
	Select the failure types that are being reported by the subject agency. Enter 1 for all of the options that apply. The other fields should have 0.
5.22	Frequency of the maintenance reports
	Select the frequency of creating the maintenance reports by the subject agency. Enter 1 for the best option; enter 0 for all others.
5.23	Keeping records of the specifics of maintenance tasks and work orders
	For the offered options enter 1 for any information type, about maintenance tasks and work orders, that apply; otherwise enter 0.
Signal System Central Software - SSCS	
5.24	Duration of coordination failure
	Enter the total duration (in hours) of the coordination failures in a year.
5.25	Total time when signals should be coordinated
	Enter the total time (in hours) when signals should be coordinated. For example, if coordination is supposed to be 16 hours per day, multiply this number with number of days per year.
5.26	Time while communications errors were present in hours (per year)
	Enter the total duration (in hours) of the communication errors, for all intersections, in a year.
5.27	Number of vehicle detector malfunctions

	Enter the total number of vehicle detector malfunctions in a year.
5.28	Number of pedestrian detector malfunctions
	Enter the total number of pedestrian detector malfunctions in a year.
5.29	Total number of pedestrian detectors
	Enter the total number of pedestrian detectors (pushbuttons) installed at all of the intersections under agency's jurisdiction.
5.30	Duration of all repairs made by an average maintenance crew per year
	Enter duration (in hours) for all reparations that an average maintenance crew performed in a year (excludes preventive maintenance).
5.31	Total duration of routine and non-routine reparations
	Enter duration (in hours) for all routine and non-routine reparations that the maintenance staff performed in a period of one year.
5.32	Number of routine and non-routine reparations
	Enter the total number of all routine and non-routine reparations that the maintenance staff performed in a period of one year.
5.33	Average duration of routine and non-routine reparations
	This value will is calculated automatically based on the answers to previous entries.

4.7 Grading Procedure

After all of the entries are addressed all of the partial grades (for each subsection) are combined into a single grade for the subject section. In each of the provided sheets a respondent can select weight factors for each subsection. In this way a respondent (representative from the subject agency) can alter individual impacts of the subject subsection on the total sectional grade. Such modification of sub-sectional weights are recommended only in the case when the agency wants to perform a self-evaluation. For inter-agency comparisons, all weight factors should be kept the same, to have consistent results. Once the weighting of the partial grades is finished, they are normalized and translated into values on a scale from 0 to 100. Figure 4.7-1 explains graphically the grading process.

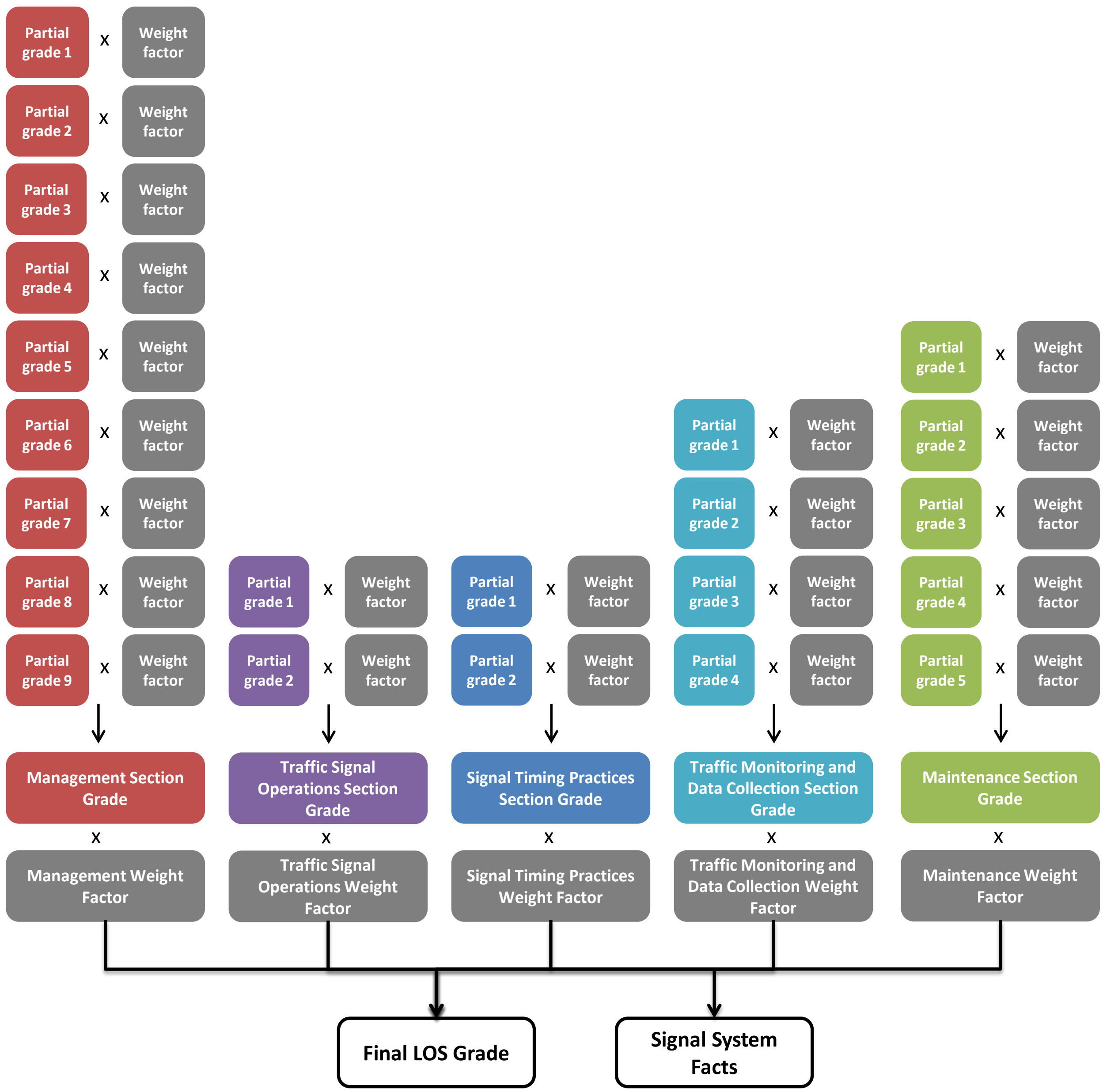


Figure 4.7-1. General flowchart for proposed evaluation methodology

After all data have been entered in the evaluation spreadsheet, all sub-sectional grades can be averaged into an overall sectional grade, and the Evaluation Confidence can be derived for the subject grade. The Evaluation Confidence is a parameter calculated by dividing number of addressed entries (answered questions) and the total number of entries. It is recommended that the subsections with Evaluation Confidence lower than 50% are not used in further calculation of the sectional grades. Evaluation Confidence for the entire section (or final grade) is calculated as an average value of sub-sectional Evaluation confidences (or sectional for the final grade). By combining the grades and Evaluation Confidences for all of the five sections, one can calculate the final Level of Service (LOS) grade and Evaluation Confidence for the entire evaluation process.

Considering that all of the subsection grades are normalized, the grading overall scale is set with a range between 0 and 100. This range is further divided in six equal parts where the highest score of 100 equals to the grade A, and the lowest (from 0 to 16.66) equals grade F. The other grades are assigned based on the appropriate values in between. Numerical results for each section indicate which LOS grade the agency gets for a specific section. By combining the grades for the five sections, the LOS grade for the evaluation is obtained.

Table 4.7-1. The grade scale

Lower Value	Higher Value	Grade
0.00	16.66	**F**
16.67	33.32	**E**
33.33	49.99	**D**
50.00	66.66	**C**
66.67	83.33	**B**
83.34	100.00	**A**

Green cells in Table 4.7-2 indicate fields where a user can modify the value of weight to increase or decrease the importance of that particular section when calculating the overall evaluation grade.

Table 4.7-2. The overview of calculation and grading process

Section	Partial grade num	Partial Grade subsection	Normalized Grade Value	Evaluation confidence (%)	Grade Value Per Section	Weight factors	Weighted Grade per Section	Level of Service	Evaluation confidence (%)	Final Grade	Level of Service	Evaluation confidence (%)
Management	1	Staff Training	#VALUE!	0	57.4	1.0	57.4	C	75.0	66.8	B	68.5
	2	Monitoring	57.1	100								
	3	User satisfaction	70.4	75								
	4	Public relations	32.5	100								
	5	Cooperation with neighboring agencies	100.0	50								
	6	Safety and accidents	26.8	100								
	7	Inventory	100.0	100								
	8	Vehicles for interventions	14.1	50								
	9	SSCS	58.2	100								
Traffic Signal Operations	1	General	49.5	94	49.5	1.0	49.5	D	47.0			
	2	SSCS	#DIV/0!	0								
Signal Timing Practices	1	General	93.8	100	93.8	1.0	93.8	A	50.0			
	2	SSCS	#VALUE!	0								
Traffic Monitoring and Data Collection	1	Detection	53.3	80	62.0	1.0	62.0	C	95.0			
	2	Data Collection and Storage	70.9	100								
	3	Data Quality	64.5	100								
	4	Weather and turning movements	59.5	100								
Maintenance	1	Strategy	100.0	100	71.5	1.0	71.5	B	75.6			
	2	Maintenance of equipment	56.8	78								
	3	Reaction time	50.0	100								
	4	Inventory and reporting	79.1	100								
	5	SSCS	#VALUE!	0								

Legend

The cells where weight factors for sections can be changed.

4.8 Evaluation Outputs

The evaluation methodology presented in the previous sections produces two major outputs:

- Summarized table with grades (overall and sectional)
- The Signal System Facts Card (SSFC)

The Summarized table (Table 4.8-1) with grades provides the scores and the grades for all five sections and the final score and grade. Therefore, by this table a user is given an overview of the evaluation results: sectional scores and weighting factors assigned to that section, weighted scores, Evaluation Confidence and the Level of Service.

Table 4.8-1. Summarized grades

NTSRC Grades						
Num.	**Section**	**Sectional Score**	**Weight factor**	**Result**	**Evaluation Confidence (%)**	**Grade of Service**
1	**Management**	54.6	1	54.6	94.4	C
2	**Traffic Signal Operation**	51.4	1	51.4	75.0	C
3	**Signal Timing Practices**	62.5	1	62.5	50.0	C
4	**Traffic Monitoring and Data Collection**	48.6	1	48.6	95.0	D
5	**Maintenance**	70.4	1	70.4	72.0	B
			Total:	**57.5**	**77.3**	**C**

The SSFC, designed after a similar label for nutritional facts, can provide a summary of the most important information related to signal system performance of an individual agency. Such a summary provides, at a glance, the most useful information without overwhelming a reader with redundant information. Such Signal System Facts Cards can be customized to include various fields of agency's particular interest. An example of such information is provided below in Figure 4.8-1. In another case, for example, an agency may want to show the average cost of the reparation instead of one of the currently displayed measures.

Signal System Facts

Contact Information	
Agency	City of Boca Raton
Contact Person	Rasem Awwad/Tracy Phelps
Email Address	rawwad@myboca.us
Grading	
Overall Grade	C
Overall Score	57.5
Evaluation confidence	64.1%
General Information	
Population	91,000
Annual Funding for Signal O&M	$150,000
Annual Capital Investments	$80,000
Operational Information	
FTEs	10
Signalized Intersections	136
Coordinated Signals	103
Frequency of Signal Retiming	Less than 1 year
Central Signal System	ATMS.now
Malfunctions per year	1,581
Annual Reparation Cost	$150,000
Response Time	48h

Signal System Facts

Contact Information	
Agency	Palm Beach County
Contact Person	Giri Jeedigunta, PE, PTOE
Email Address	gjeedigu@pbcgov.org
Grading	
Overall Grade	B
Overall Score	66.8
Evaluation confidence	67.4%
General Information	
Population	1,422,789
Annual Funding for Signal O&M	NA
Annual Capital Investments	NA
Operational Information	
FTEs	31
Signalized Intersections	1047
Coordinated Signals	639
Frequency of Signal Retiming	Less than 1 year
Central Signal System	ATMS.now
Malfunctions per year	12,000
Annual Reparation Cost	NA
Response Time	72h

Figure 4.8-1. Signal system facts card examples

The Table 4.8-2 below, provides the explanations about how to interpret the results of the evaluation. The positive and the negative outcomes are elaborated, so the users can interpret correctly the scores and grades created after conducting the evaluation process. By investigating the scores for the specific section or subsection, the user can identify the existing issues and timely address them.

Table 4.8-2. The positive and the negative outcomes from the evaluation process

No.	Section	Description of Positive Outcomes	Description of Negative Outcomes
1	**Management**	The agency invests in the staff training, enough staff members are involved in active monitoring, the agency is opened for communication with the public and the users are satisfied with the service provided by the agency. The agency is well equipped in terms of central software, hardware related to traffic signals but also for support and maintenance activities (e.g., vehicles)	The Signal System Central Software or some of its existing functionalities are not used. The agency's level of equipment is not adequate, the inventory about the equipment and the spare parts does not exist. The agency could cooperate better with other neighboring agencies or public and the agency could put more effort in staff training and monitoring. Large number of user complaints.
2	**Traffic Signal Operations**	The agency uses advanced strategies for traffic control (traffic responsive or traffic adaptive), the frequency of the signals retiming is high, the percentage of the intersections that are coordinated is high, the field reviews are performed regularly. The percentage of intersections with the capability for preemption and giving priority to PT vehicles is a plus.	Congestion appears often on parts of the network, not enough flash signals in the vicinity of schools, lack of signal timings for special events, disasters , VIP routes or other emergency situations. The agency does not use traffic adaptive or traffic responsive control, the field reports are not performed regularly and the percentage of the signals that are coordinated is low.
3	**Signal Timing Practices**	The agency uses signal timing optimization software and multiple performance measures and parameters for creating new signal timings. The difference between average duration of actual splits and programmed splits for different periods is minimal.	The difference between average duration of actual splits and programmed splits for different periods is significant. The agency's staff does not use signal timing optimization softwares for developing new signal timings. Very few performance measures or parameters is used in the process of developing new performance measures.
4	**Traffic Monitoring and Data Collection**	The agency is equipped with large number of detection devices, the functionality of those devices is regularly checked and the devices are calibrated. The agency stores large number of data types , and checks the quality of the collected data. Data about turning movement counts is being collected on many locations and on a regular basis.	The agency has small number of detectors and the detectors are not calibrated regularly. The agency does not have data from the weather stations. The data collected from the detectors is not checked for quality, consistency and correctness. Also, the resolution of data collection is not frequent enough. The turning movement counts are not collected or ther are collected rarely.
5	**Maintenance**	The agency frequently checks the operability of all equipment, uses the performance measures to evaluate the signal system maintenance. Time for reaction and resolving the problem is not too long. The agency keeps thorough and comprehensive inventory about the maintenance activities. Percentage of faulty equipment is not too high.	Coordination, communication, detector and other malfunctions happen too frequent. The agency does not keep the inventory about maintenance activities, or does not update that inventory frequently. Average time for reacting and finally resolving the problem is not short, and the equipment is not checked for operability frequent enough.

5 Weekly/Monthly Dashboard Tools

Due to the need for a frequent assessment of traffic signal system's performance and reliability, two weekly/monthly assessment dashboards were created. The first one addresses the performance (Traffic Signal System Performance Dashboard - TSSPD), and the second deals with the reliability measures of a traffic signal system (Traffic Signal System Reliability Dashboard - TSSRD). The dashboards are developed with the intention to minimize the effort that signal-controlling agencies need to put into data collection, processing and presentation of the results.

The TSSPD dashboard is related to the efficiency aspects of traffic signal system, and it reflects operational traffic impacts of traffic signals. The input data (cycle lengths, active patterns, duration of each phase per each cycle and phase terminations) are processed in order to derive several measures that are presented graphically. In this way signal timing engineers, or other users, can interpret signal performance without a need to spend a lot of time on data processing and calculations. All of the signal parameter changes are being stored by Split History reports in ATMS.now and the dashboard performance measures are processed from these records.

The TSSRD dashboard is created to help engineers and other users to analyze reliability of the traffic signal systems. Such an analysis is aided by observations of the graphical and numerical outputs that TSSRD dashboard creates after processing the alarm data from the ATMS.now Field Alarm reports.

In order to keep track about the performance and the reliability of the traffic signal system in a timely manner, more frequent checks are necessary. The agency's staff should have the ready methods and tools that can be used to assess the operations of the traffic signals. In such a way, trends, issues, or possibilities for improvement can be identified and appropriate actions can be taken.

Previously, the evaluations have been performed by conducting field studies or by using the signal system central software and its existing capabilities. Field studies are time consuming and costly, while the usage of signal system central software is much easier and faster, but has limitations depending on the type of a system that is used. Users get notifications in real about changes that happen in the traffic signal system of an agency, or they can create various reports with relevant historical data. The data provided in real time about the events in the traffic signal system are useful for immediate reacting to certain events, but not so much when the evaluation is concerned. For that use, historical data provides the user with much better possibilities for assessment.

If the historical data is concerned, the reports that can be created from signal system central software contain large number of important data, but interpreting them in that format is challenging and tedious process. Visual representation of the data and the measures derived from it provides the condensed view of relevant parameters and activities. That is the reason why two dashboard tools (performance and the reliability dashboard) are created with an emphasis on visual presentation of the data that can be easier to interpret and can show at a glance large number of different types of data concentrated in several measures. The purpose of the dashboards is to help the operators and the decision makers in identifying problems, isolating the causes and addressing them, and at the same tame provides very useful tool for self-evaluation.

For developing the dashboards, it was necessary to acquire the knowledge about what capabilities (hardware, software, data types, etc.) do traffic agencies possess and how they can be used for creating the tools for weekly or monthly evaluation of traffic signal operations. During the visits, the agency's current hardware, software current practices for monitoring and evaluation, signal system central software, available technologies for data collection were investigated and the corridors of interest were selected, which will be used as a testbed for the evaluation methodology. That is the reason why two agencies were selected as part of a pilot project.

During the investigation of the possibilities for the data collection in both City of Boca Raton and Palm Beach County agency, the Signal System Central Software (in both cases ATMS.now) was shown to be a good source of information for necessary signal performance measures. The ATMS.now is able to collect and store large number of various data types, and those data can be accessed through various types of reports available in the software. In order to simplify the process of collecting the ATMS.now data, the FAU researchers used only one report type per each dashboard. More specifically, the Split History Reports is needed for TSSPD whereas the reliability dashboard uses the data from Field Alarms Reports. In such a way, the user does not need to deal with the multiple report types to collect the data from ATMS.now.

Because of the large number of intersections per agency and abundance of the data for each intersection (especially the Split History Reports who represent the data per each cycle), it is decided to develop a tool for assessing two corridors, one per each agency, for evaluating the performance of traffic signal system. In this document, as an example, the Military Trail in City of Boca Raton is selected as a corridor of interest and 9 intersections were selected for further investigation. The streets that intersect with Military Trail and belong to the subject corridor, are provided below:

1. Spanish River Boulevard
2. Lynn University
3. Potomac Road
4. Banyan Boulevard
5. Butts Road
6. 19th Street
7. Town Center Drive
8. Lennox Drive
9. South Verde Trail

The dashboards are created using the data collected from ATMS.now in City of Boca Raton Traffic Management Center, and all examples in this document are created by using that data.

The aforementioned corridor is used for performance assessment while in case of reliability dashboard, due to the smaller amount of data that Field Alarms Reports creates compared to the Split History Reports, not only the subject corridor but the entire network of 136 signalized intersections in jurisdiction of City of Boca Raton was used.

In the following chapters, the entire procedure how to use both dashboards is explained, step-by-step.

5.1 Traffic Signal System Performance Dashboard (TSSPD)

TSSPD is a tool in form of a dashboard that displays the vital information about the operation of traffic signals. With the help of appropriate macros, the TSSPD processes the information retrieved from ATMS.now signal system central software and from them derives the various measures of traffic signal performance. By defining the spatial and temporal selection, the user can investigate the aforementioned measures.

In order to enable the operators to use the dashboard, the clear and complete instructions of how to use the TSSPD are provided in the following part of this document. In general, the major steps for using the Dashboards are provided below, while their details are given in the following subchapters.

Steps for using the Traffic Signal System Performance Dashboard:

1. **Data collection -** Create the Split History Reports for all intersections of a corridor and put them in one folder. Copy that folder twice and add suffixes Copy 1 and Copy 2 to their names.
2. **Reports transformation -** Execute "*FAU Split History Report Analyzer.xslm*" file that will transform the data and compile all report files into one spreadsheet. Select the folder with the Copy 1 suffix that contains the Split history reports from step 1. After executing, the macro will show the data to be copied to the Traffic Signal System Performance Dashboard.
3. **Copy the data to Database** –Open the Traffic Signal System Performance Dashboard, go to the sheet *Database,* delete all data that already exist there, go back to the *"FAU Split History Report Analyzer.xslm"* copy the data created by the macro in the previous step, and paste the data that you have copied in the *Database* sheet of the Traffic Signal System Performance Dashboard.
4. **Refresh the data** – Go to *Dashboard Pg1* sheet, click on Refresh button.
5. **Reports transformation (Phase terminations) -** Execute "FAU Phase Termination Analyzer.xslm" file that will transform the data and compile all report files into one spreadsheet with Phase termination data. Select the copied folder with the Copy 2 suffix that also contains Split history reports from step 1. After executing, the macro will show the data to be copied to the Traffic Signal System Performance Dashboard.
6. **Copy the data to Termination Database** –Open the Traffic Signal System Performance Dashboard, go to the sheet *Termination Database*, delete all data that already exist there, go back to the *"FAU Phase Termination Analyzer.xslm,"* copy all data created by the macro in the previous step, and paste the data you have copied in the *Termination Database* sheet of the Traffic Signal System Performance Dashboard.
7. **Refresh the data** – Go to *Dashboard Pg1* sheet, click on Refresh button.
8. **Use the Dashboard -** Save the file under appropriate name (as macro-enabled worksheet) and the Traffic Signal System Performance Dashboard is ready for use. Change your selections in time and spatial data slicers/filters to select what will be displayed. Please ensure that the selected date, or range of dates, is inside the range defined by Begin and End dates displayed above the slicers on the Dashboard Pg1 worksheet. If the selected date(s) are outside of such range, all of the graphs will be empty.

All the steps listed above will be explained in detail in the following sub-chapters.

5.1.1 Data Collection

The first step in the assessment process is data collection. As previously mentioned, all data is collected from ATMS.now signal system central software. For this dashboard, the user first needs to create the Split History Reports for all intersections of the selected corridor and all days in the evaluation period. The maximal recommended period for the evaluation (size of the spreadsheet file) for the 9-intersection subject corridor is one month because of the quantity of the data produced by Split History Report. Longer periods are possible to be accommodated in the TSSPD, however increasing of the evaluation period causes slower operations of the TSSPD. All Reports should be created as **.xls files** from ATMS.now, and not as .pdf files or others.

It is recommended to set up a scheduler in ATMS.now to generate Split History Reports automatically at 12:00 AM for the previous 24 hours, so the users do not have to spend time on creating the reports on a daily basis. *(Termination of the phases are summed at the end of every Split History Report, so limiting the Split History Report to a full day will enable users to report phase terminations on daily basis, which is a useful feature. If the Split History Reports are created for a period longer than a day then the terminations of the phases will be aggregated for the entire period (e.g. of few days) which will prevent agency staff to filter those terminations on daily basis, For the Pilot Dashboard, the Split History Reports were collected for intervals of several days, so filtering per day is not possible (only filtering per intersections and for the entire assessment period is possible)*

In Figure 5.1-1 the Termination counts for all phases are provided on the right side, with three types of the phase terminations framed with the red ellipse. On the left side, framed with the red rectangle, one can observe search and navigation bar where type of the report, intersection, begin and end date and time can be selected as parts of the filtering process to create the Split History Reports.

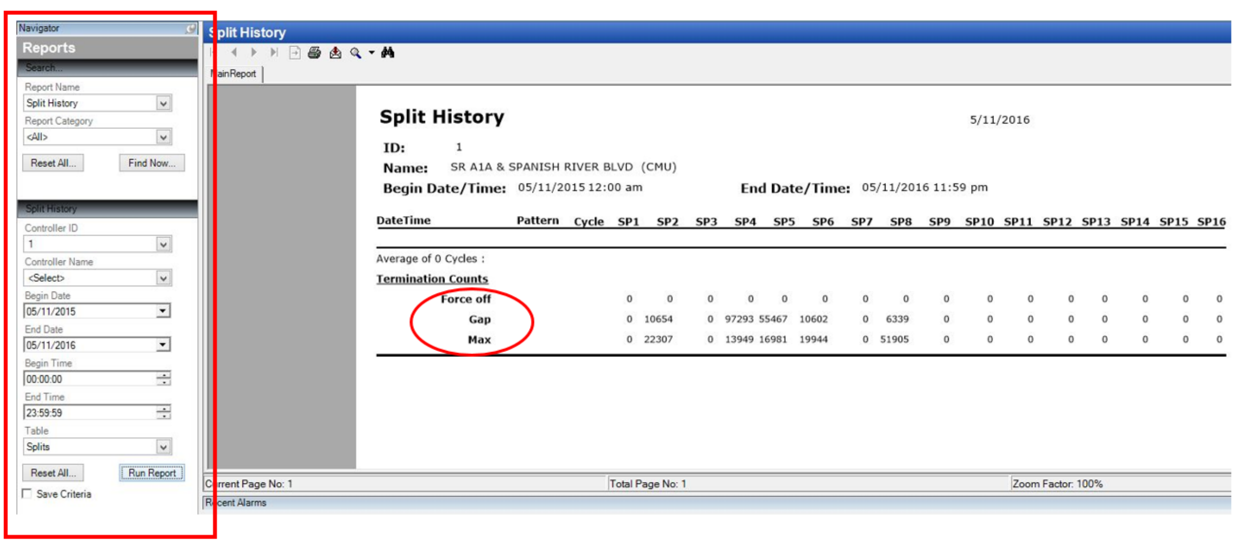
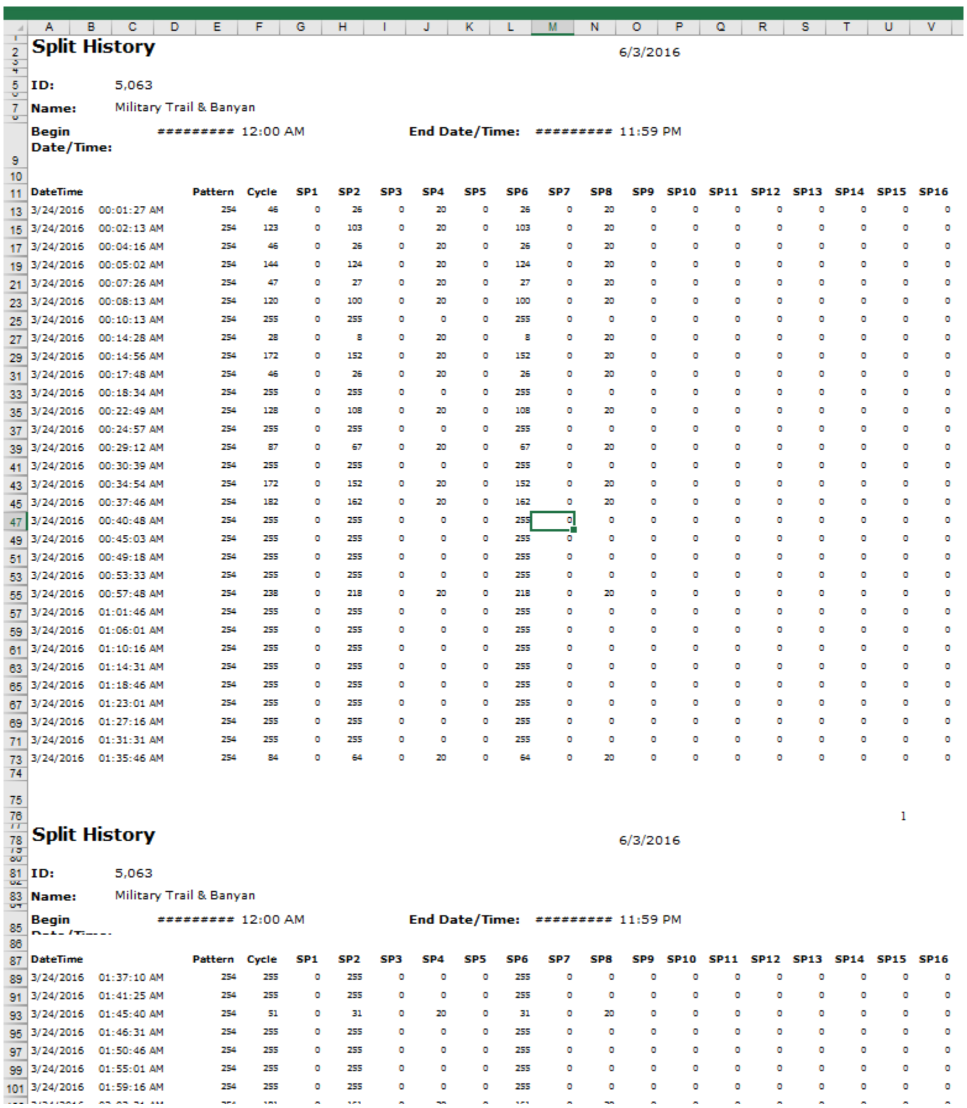


Figure 5.1-1. ATMS.now report setup with the example of phase termination counts

After Split History Reports (for all intersections and all days) are created, and stored in one folder, a user should copy that folder twice and add a suffix, e.g. Copy 1 and Copy 2, in its name. Both folders need to have only Split History reports for the period that will be investigated and other files are not allowed in those folders (for example, "*April 2016 Split History Reports Copy 1*" folder and "*April 2016 Split History Report – Copy 2*" folder). The reason for making two copies beside the original folder where all Split History Reports are placed is that after running the macro, the files become irreversibly changed. If user wants to go back to original reports they will be lost and should be created again from ATMS.now.

5.1.2 Reports Transformation

The data from the reports need to be reformatted in order to be processed further. One can see from Figure 5.1-2 below, that the Split History Report is created in a specific format in Excel. After every 75 rows, the header is placed again where it is considered to be the next page. Also, the data are given per each cycle, but every second row is empty (one row has the data, and the next one is empty), which creates difficulties in further data processing.



Split History 6/3/2016

ID: 5,063

Name: Military Trail & Banyan

Begin Date/Time: ######### 12:00 AM **End Date/Time:** ######### 11:59 PM

Row	DateTime		Pattern	Cycle	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10	SP11	SP12	SP13	SP14	SP15	SP16
13	3/24/2016	00:01:27 AM	254	46	0	26	0	20	0	26	0	20	0	0	0	0	0	0	0	0
15	3/24/2016	00:02:13 AM	254	123	0	103	0	20	0	103	0	20	0	0	0	0	0	0	0	0
17	3/24/2016	00:04:16 AM	254	46	0	26	0	20	0	26	0	20	0	0	0	0	0	0	0	0
19	3/24/2016	00:05:02 AM	254	144	0	124	0	20	0	124	0	20	0	0	0	0	0	0	0	0
21	3/24/2016	00:07:26 AM	254	47	0	27	0	20	0	27	0	20	0	0	0	0	0	0	0	0
23	3/24/2016	00:08:13 AM	254	120	0	100	0	20	0	100	0	20	0	0	0	0	0	0	0	0
25	3/24/2016	00:10:13 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
27	3/24/2016	00:14:28 AM	254	28	0	8	0	20	0	8	0	20	0	0	0	0	0	0	0	0
29	3/24/2016	00:14:56 AM	254	172	0	152	0	20	0	152	0	20	0	0	0	0	0	0	0	0
31	3/24/2016	00:17:48 AM	254	46	0	26	0	20	0	26	0	20	0	0	0	0	0	0	0	0
33	3/24/2016	00:18:34 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
35	3/24/2016	00:22:49 AM	254	128	0	108	0	20	0	108	0	20	0	0	0	0	0	0	0	0
37	3/24/2016	00:24:57 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
39	3/24/2016	00:29:12 AM	254	87	0	67	0	20	0	67	0	20	0	0	0	0	0	0	0	0
41	3/24/2016	00:30:39 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
43	3/24/2016	00:34:54 AM	254	172	0	152	0	20	0	152	0	20	0	0	0	0	0	0	0	0
45	3/24/2016	00:37:46 AM	254	182	0	162	0	20	0	162	0	20	0	0	0	0	0	0	0	0
47	3/24/2016	00:40:48 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
49	3/24/2016	00:45:03 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
51	3/24/2016	00:49:18 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
53	3/24/2016	00:53:33 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
55	3/24/2016	00:57:48 AM	254	238	0	218	0	20	0	218	0	20	0	0	0	0	0	0	0	0
57	3/24/2016	01:01:46 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
59	3/24/2016	01:06:01 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
61	3/24/2016	01:10:16 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
63	3/24/2016	01:14:31 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
65	3/24/2016	01:18:46 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
67	3/24/2016	01:23:01 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
69	3/24/2016	01:27:16 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
71	3/24/2016	01:31:31 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
73	3/24/2016	01:35:46 AM	254	84	0	64	0	20	0	64	0	20	0	0	0	0	0	0	0	0

1

Split History 6/3/2016

ID: 5,063

Name: Military Trail & Banyan

Begin ######### 12:00 AM **End Date/Time:** ######### 11:59 PM

Row	DateTime		Pattern	Cycle	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10	SP11	SP12	SP13	SP14	SP15	SP16
89	3/24/2016	01:37:10 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
91	3/24/2016	01:41:25 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
93	3/24/2016	01:45:40 AM	254	51	0	31	0	20	0	31	0	20	0	0	0	0	0	0	0	0
95	3/24/2016	01:46:31 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
97	3/24/2016	01:50:46 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
99	3/24/2016	01:55:01 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0
101	3/24/2016	01:59:16 AM	254	255	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0

Figure 5.1-2. Split history report in Excel

Therefore, in order to transform the Split History Reports into a new format and compile multiple reports into a single spreadsheet (that will be used as a **Database** in TSSPD) the FAU research team created a macro in the *"FAU Split History Report Analyzer.xslm"*. Steps which illustrate how to use such a macro are provided below:

1. Open the *"FAU Split History Report Analyzer.xslm"*, click Enable content (or Enable Macro depending of the Excel version) to enable the macro executions.
2. In the top left corner (in Quick Access Toolbar) click the circular icon (when you put a mouse cursor over it, "FAU_Split_History_Report_Analyzer" will appear) to run a macro.

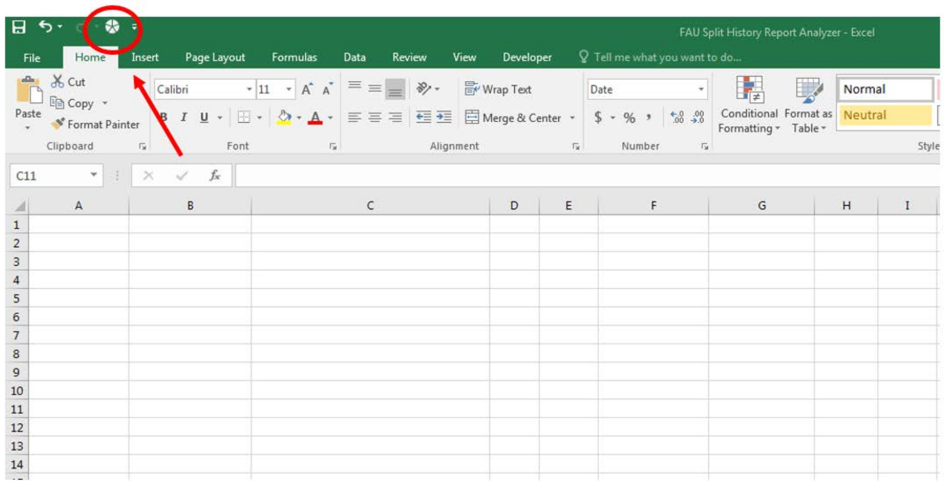


Figure 5.1-3. FAU Split history report analyzer activation

3. In the dialog window that will appear, find and select the folder and select it with one click (do not double click) where you have saved Split History Reports (for example "*April 2016 Split History Reports Copy 1*"). Press OK.

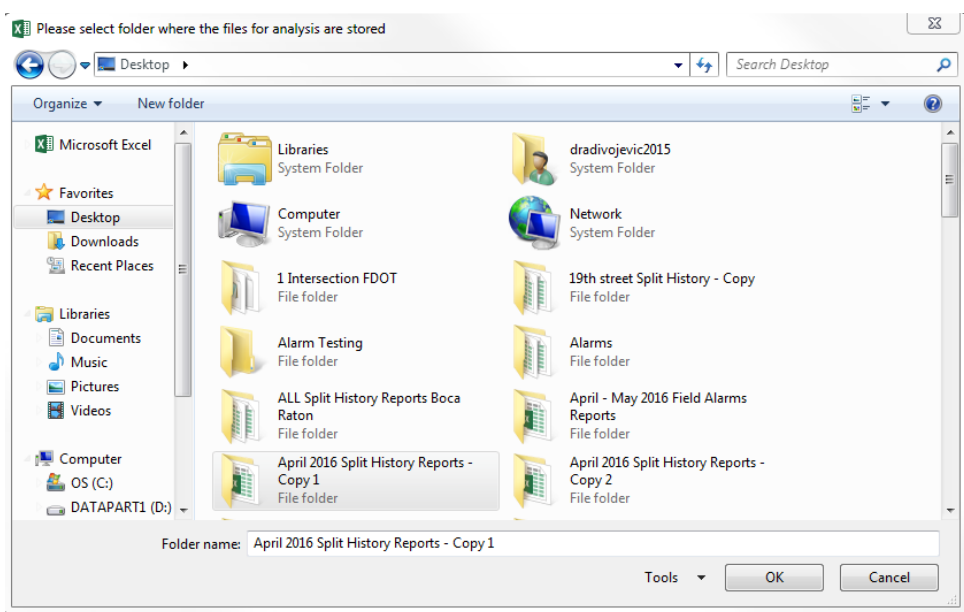


Figure 5.1-4. Selection of folder with split history reports

4. A message will appear with the address of the folder you have selected. Press OK.

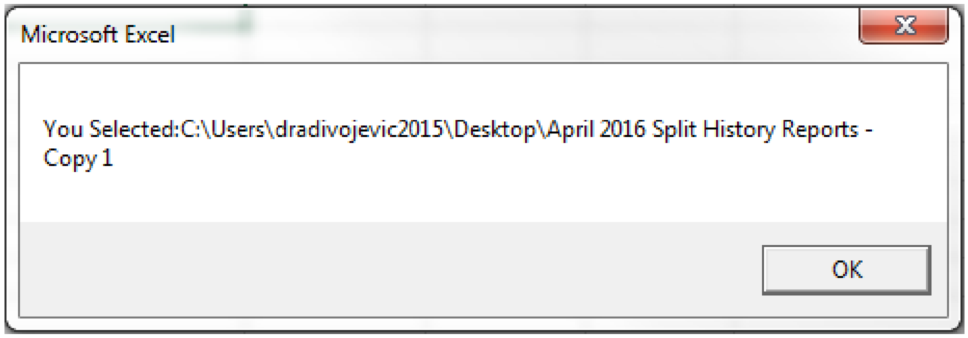


Figure 5.1-5. Selection confirmation screen in FAU Split history reports analyzer

5. Wait until the macro is executed and the data appears. This process can last up to 25-30 minutes depending on the speed of the computer which is used, as well as number and size of the files - reports that are being processed. If the Excel freezes and acts non-responsive for more than 30 minute time interval, do not turn off the program, because such an outcome is quite normal.

In certain cases, Split History Reports from ATMS.now can contain erroneous data which do not represent anything meaningful. An example of such case is when a certain phase duration has negative value. The FAU Split History Reports Analyzer automatically searches for such data/events and deletes all of the data associated with that cycle. In such a way, the tool eliminates the illogical values caused by system errors. For the pilot corridor in the City of Boca Raton and period of one month, 192 cycles contained negative values for at least one of the phases (compared to total number of 333,982 cycles of collected data). The number of erroneous cycles is small, and their elimination does not impact significantly the total amount of collected data, but instead it increases the precision and the fidelity of the procedures.

5.1.3 Copy the new data to the Database Sheet of TSSPD

1. When the transformed data show up, open the Traffic Signal System Performance Dashboard (TSSPD),), select the ***Database*** sheet and delete all the existing data (this can be done by pressing Ctrl + A and then Delete key).
2. Copy the data that the *FAU Split History Analyzer* macro has previously created.

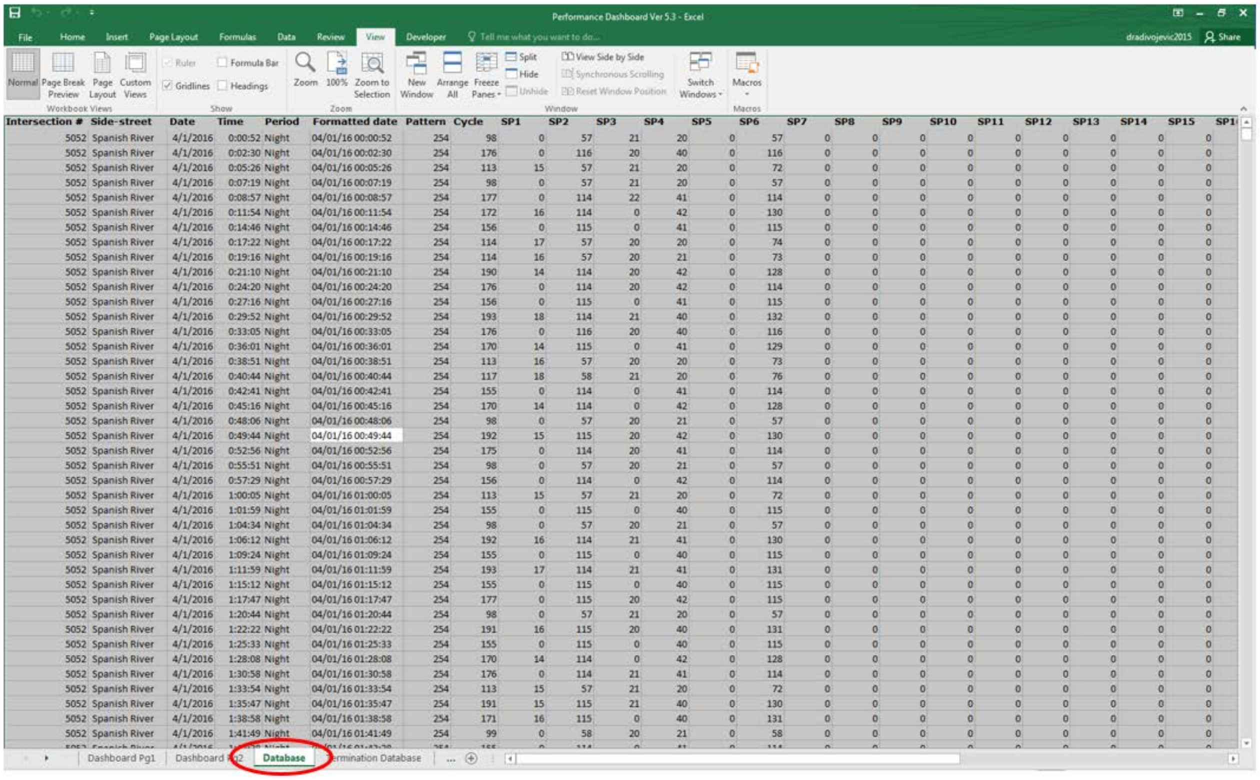


Figure 5.1-6. Replacing the database in the TSSPD tool

3. Open the TSSPD again, open the Database sheet, select the cell A1 and paste the data copied in the step 2.

If the macro cannot finish the execution after a long time (over 1 hour) or creates the database with the disrupted columns (for example, date and time ends up in the Pattern column), it means that one of the original reports from ATMS.now is corrupted. In that case, the user should open the folder where all the original ATMS.now reports are stored (not Copy 1 or Copy 2) and try to open each report file in the folder. If, after opening the file, a notification that the file is protected appear, the user should remove protection by clicking on the message bar on the top, click “Edit anyway” and click Save. In case that some file cannot be opened, that file needs to be deleted because the macros cannot read the data and consequently that causes disruption in other files as well. Alternatively, user can try to again manually create in ATMS.now the report file that cannot be opened, and put it in the folder. Finally, in that case one more time two copies of subject folder need to be created (old folders Copy1 and Copy 2 should be deleted). This procedure should be followed in case problems appear for each of the macro files (*FAU Field Alarms Report Analyzer, FAU Phase Termination Analyzer and FAU Split History Analyzer*).

5.1.4 Refresh the Data

1. Go to the *Dashboard Pg1* sheet, click on Refresh button. Every time the Refresh button is activated, the subroutine will check the Corridor name, Begin and End dates for the data inserted in the Database and update all the charts and values.

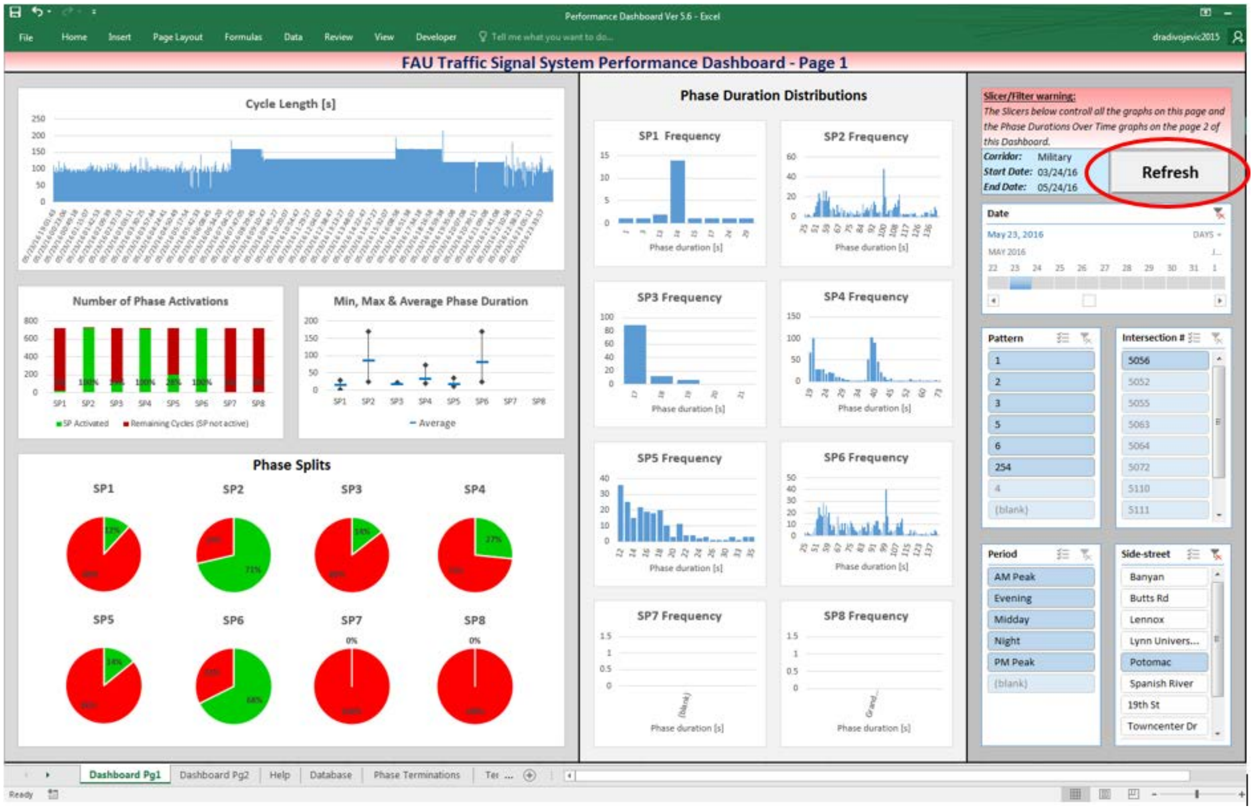


Figure 5.1-7. Refreshing the data

The procedure is repeated one more time, however this time the Phase termination data will be inserted into the TSSPD Dashboard.

5.1.5 Reports Transformation – Phase Terminations

The data from the reports need to be truncated and changed into a different format which will make the data more useful. For transforming the Split History Reports into a new format and compiling them into one spreadsheet (which is used as a Terminations Database in TSSPD), the FAU research team created a macro in the "*FAU Phase Termination Analyzer.xslm*" file. The steps to use such a macro are provided below:

1. Open the "*FAU Phase Termination Analyzer.xslm*", click Enable content (or Enable Macro depending of the Excel version) to enable the macro executions.
2. In the top left corner (in Quick Access Toolbar) click the icon in the shape of three triangular flags (when you put a mouse cursor over it "*FAU_Phase_Termination_Analyzer*" will appear) to run a macro.

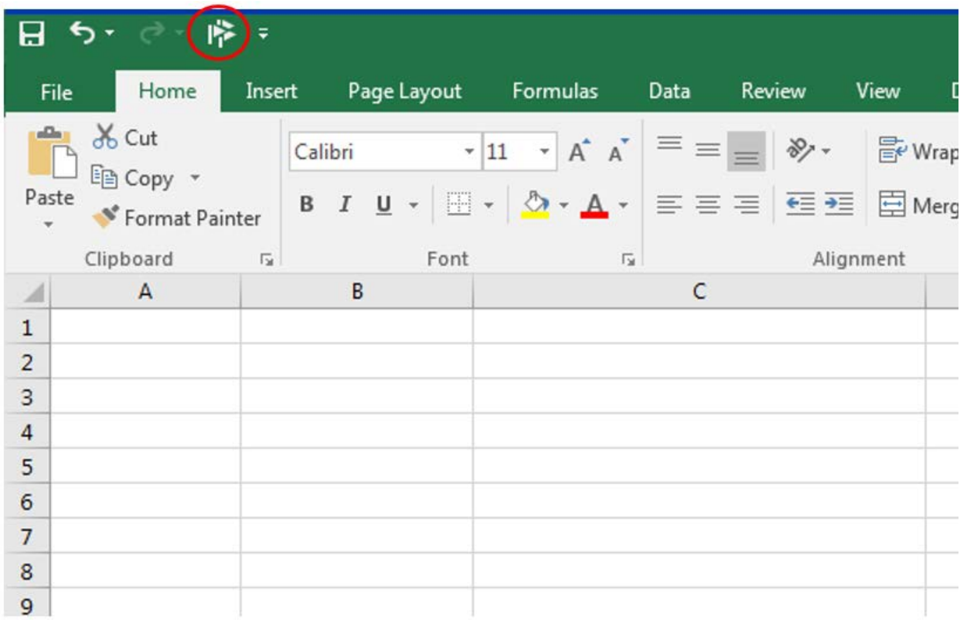


Figure 5.1-8. FAU Phase termination analyzer macro activation

3. In the dialog window that will appear, find and select the folder you have copied with the Split History Reports ("*April 2016 Split History Reports – Copy 2*") by clicking once (do not double-click). Press OK.

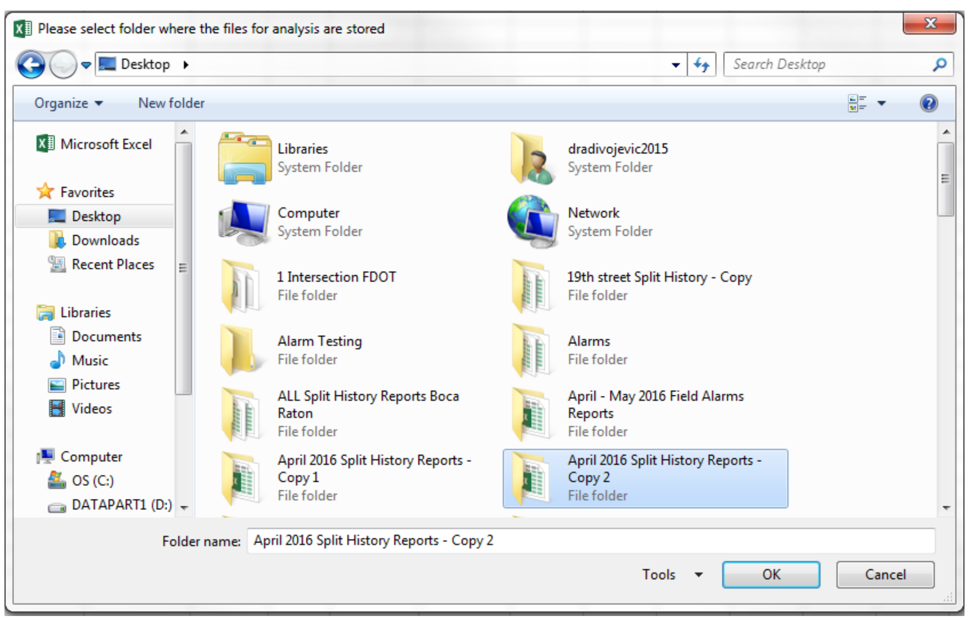


Figure 5.1-9. Selection of folder with split history reports for phase terminations

4. A message will appear with the address of the folder you have selected. Press OK.

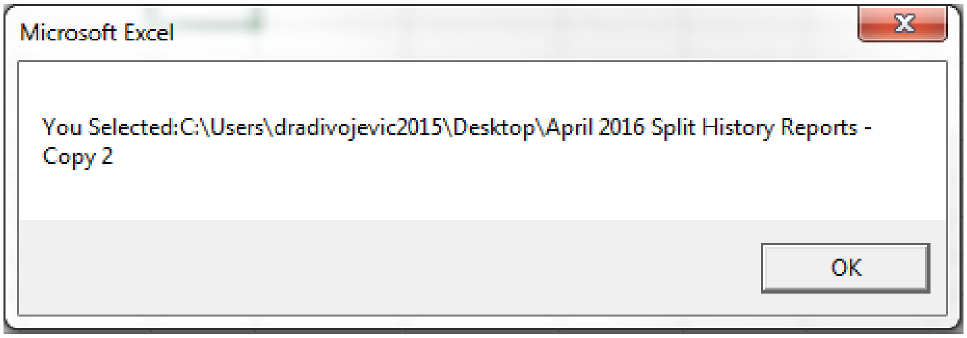
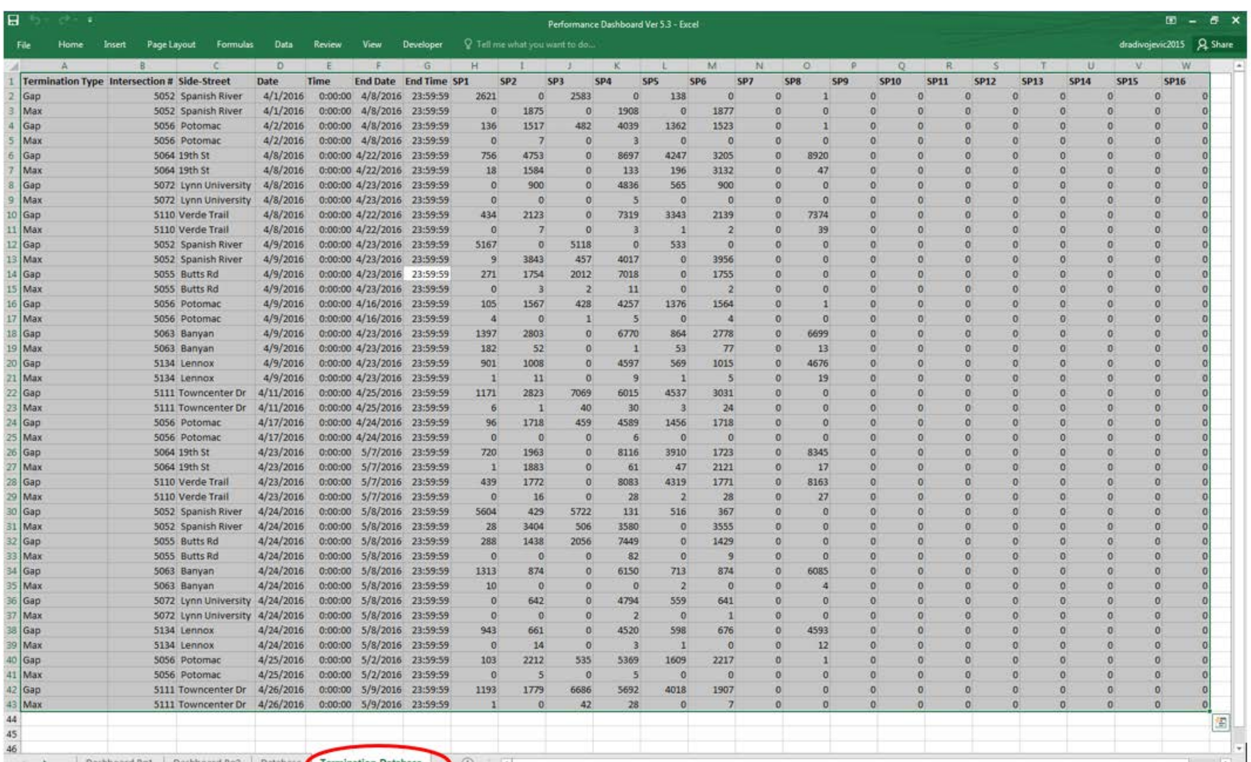


Figure 5.1-10. Selection confirmation screen in FAU Split history reports analyzer

5. Wait until the macro is executed and the data appears. This process can last up to 25-30 minutes depending on the speed of the computer which is used, as well as number and size of the files - reports that are being processed. If the Excel freezes and acts non-responsive within this 25-30 minute time interval, do not turn off the program, because such an outcome is quite normal.

5.1.6 Copy the new data to Termination Database Sheet of TSSPD

1. When the transformed data appear, open the Performance Dashboard (TSSPD), select the Termination Database sheet and delete all the existing data (this can be done by pressing Ctrl + A and Delete).
2. Copy the data that *FAU Phase Terminations Analyzer* macro has previously created.



Termination Type	Intersection #	Side-Street	Date	Time	End Date	End Time	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10	SP11	SP12	SP13	SP14	SP15	SP16
Gap	5052	Spanish River	4/1/2016	0:00:00	4/8/2016	23:59:59	2621	0	2583	0	138	0	0	1	0	0	0	0	0	0	0	0
Max	5052	Spanish River	4/1/2016	0:00:00	4/8/2016	23:59:59	0	1875	0	1908	0	1877	0	0	0	0	0	0	0	0	0	0
Gap	5056	Potomac	4/2/2016	0:00:00	4/8/2016	23:59:59	136	1517	482	4039	1362	1523	0	1	0	0	0	0	0	0	0	0
Max	5056	Potomac	4/2/2016	0:00:00	4/8/2016	23:59:59	0	7	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Gap	5064	19th St	4/8/2016	0:00:00	4/22/2016	23:59:59	756	4753	0	8697	4247	3205	0	8920	0	0	0	0	0	0	0	0
Max	5064	19th St	4/8/2016	0:00:00	4/22/2016	23:59:59	18	1584	0	133	196	3132	0	47	0	0	0	0	0	0	0	0
Gap	5072	Lynn University	4/8/2016	0:00:00	4/23/2016	23:59:59	0	900	0	4836	565	900	0	0	0	0	0	0	0	0	0	0
Max	5072	Lynn University	4/8/2016	0:00:00	4/23/2016	23:59:59	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Gap	5110	Verde Trail	4/8/2016	0:00:00	4/22/2016	23:59:59	434	2123	0	7319	3343	2139	0	7374	0	0	0	0	0	0	0	0
Max	5110	Verde Trail	4/8/2016	0:00:00	4/22/2016	23:59:59	0	7	0	3	1	2	0	39	0	0	0	0	0	0	0	0
Gap	5052	Spanish River	4/9/2016	0:00:00	4/23/2016	23:59:59	5167	0	5118	0	533	0	0	0	0	0	0	0	0	0	0	0
Max	5052	Spanish River	4/9/2016	0:00:00	4/23/2016	23:59:59	9	3843	457	4017	0	3956	0	0	0	0	0	0	0	0	0	0
Gap	5055	Butts Rd	4/9/2016	0:00:00	4/23/2016	23:59:59	271	1754	2012	7018	0	1755	0	0	0	0	0	0	0	0	0	0
Max	5055	Butts Rd	4/9/2016	0:00:00	4/23/2016	23:59:59	0	3	2	11	0	2	0	0	0	0	0	0	0	0	0	0
Gap	5056	Potomac	4/9/2016	0:00:00	4/16/2016	23:59:59	105	1567	428	4257	1376	1564	0	1	0	0	0	0	0	0	0	0
Max	5056	Potomac	4/9/2016	0:00:00	4/16/2016	23:59:59	4	0	1	5	0	4	0	0	0	0	0	0	0	0	0	0
Gap	5063	Banyan	4/9/2016	0:00:00	4/23/2016	23:59:59	1397	2803	0	6770	864	2778	0	6699	0	0	0	0	0	0	0	0
Max	5063	Banyan	4/9/2016	0:00:00	4/23/2016	23:59:59	182	52	0	1	53	77	0	13	0	0	0	0	0	0	0	0
Gap	5134	Lennox	4/9/2016	0:00:00	4/23/2016	23:59:59	901	1008	0	4597	569	1015	0	4676	0	0	0	0	0	0	0	0
Max	5134	Lennox	4/9/2016	0:00:00	4/23/2016	23:59:59	1	11	0	9	1	5	0	19	0	0	0	0	0	0	0	0
Gap	5111	Towncenter Dr	4/11/2016	0:00:00	4/25/2016	23:59:59	1171	2823	7069	6015	4537	3031	0	0	0	0	0	0	0	0	0	0
Max	5111	Towncenter Dr	4/11/2016	0:00:00	4/25/2016	23:59:59	6	1	40	30	3	24	0	0	0	0	0	0	0	0	0	0
Gap	5056	Potomac	4/17/2016	0:00:00	4/24/2016	23:59:59	96	1718	459	4589	1456	1718	0	0	0	0	0	0	0	0	0	0
Max	5056	Potomac	4/17/2016	0:00:00	4/24/2016	23:59:59	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
Gap	5064	19th St	4/23/2016	0:00:00	5/7/2016	23:59:59	720	1963	0	8116	3910	1723	0	8345	0	0	0	0	0	0	0	0
Max	5064	19th St	4/23/2016	0:00:00	5/7/2016	23:59:59	1	1883	0	61	47	2121	0	17	0	0	0	0	0	0	0	0
Gap	5110	Verde Trail	4/23/2016	0:00:00	5/7/2016	23:59:59	439	1772	0	8083	4319	1771	0	8163	0	0	0	0	0	0	0	0
Max	5110	Verde Trail	4/23/2016	0:00:00	5/7/2016	23:59:59	0	16	0	28	2	28	0	27	0	0	0	0	0	0	0	0
Gap	5052	Spanish River	4/24/2016	0:00:00	5/8/2016	23:59:59	5604	429	5722	131	516	367	0	0	0	0	0	0	0	0	0	0
Max	5052	Spanish River	4/24/2016	0:00:00	5/8/2016	23:59:59	28	3404	506	3580	0	3555	0	0	0	0	0	0	0	0	0	0
Gap	5055	Butts Rd	4/24/2016	0:00:00	5/8/2016	23:59:59	288	1438	2056	7449	0	1429	0	0	0	0	0	0	0	0	0	0
Max	5055	Butts Rd	4/24/2016	0:00:00	5/8/2016	23:59:59	0	0	0	82	0	9	0	0	0	0	0	0	0	0	0	0
Gap	5063	Banyan	4/24/2016	0:00:00	5/8/2016	23:59:59	1313	874	0	6150	713	874	0	6085	0	0	0	0	0	0	0	0
Max	5063	Banyan	4/24/2016	0:00:00	5/8/2016	23:59:59	10	0	0	0	2	0	0	4	0	0	0	0	0	0	0	0
Gap	5072	Lynn University	4/24/2016	0:00:00	5/8/2016	23:59:59	0	642	0	4794	559	641	0	0	0	0	0	0	0	0	0	0
Max	5072	Lynn University	4/24/2016	0:00:00	5/8/2016	23:59:59	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0
Gap	5134	Lennox	4/24/2016	0:00:00	5/8/2016	23:59:59	943	661	0	4520	598	676	0	4593	0	0	0	0	0	0	0	0
Max	5134	Lennox	4/24/2016	0:00:00	5/8/2016	23:59:59	0	14	0	3	1	0	0	12	0	0	0	0	0	0	0	0
Gap	5056	Potomac	4/25/2016	0:00:00	5/2/2016	23:59:59	103	2212	535	5369	1609	2217	0	1	0	0	0	0	0	0	0	0
Max	5056	Potomac	4/25/2016	0:00:00	5/2/2016	23:59:59	0	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Gap	5111	Towncenter Dr	4/26/2016	0:00:00	5/9/2016	23:59:59	1193	1779	6686	5692	4018	1907	0	0	0	0	0	0	0	0	0	0
Max	5111	Towncenter Dr	4/26/2016	0:00:00	5/9/2016	23:59:59	1	0	42	28	0	7	0	0	0	0	0	0	0	0	0	0

Figure 5.1-11. Replacing the termination database in the TSSPD tool

3. Open the TSSPD again, select Termination Database worksheet, select cell A1 and paste the data copied in the step 2.

5.1.7 Refresh the Data

1. Go to *Dashboard Pg1* sheet, click on Refresh button. Every time the Refresh button is activated, the subroutine will check the Corridor name, Begin and End dates for the data inserted in the Database and update all the charts and values.

2. After inserting the new data in Database, the user can delete the folder with copies of the original Field Alarm Reports (in this example they had names *April – May 2016 Split History Reports – Copy 1 and Copy 2*).

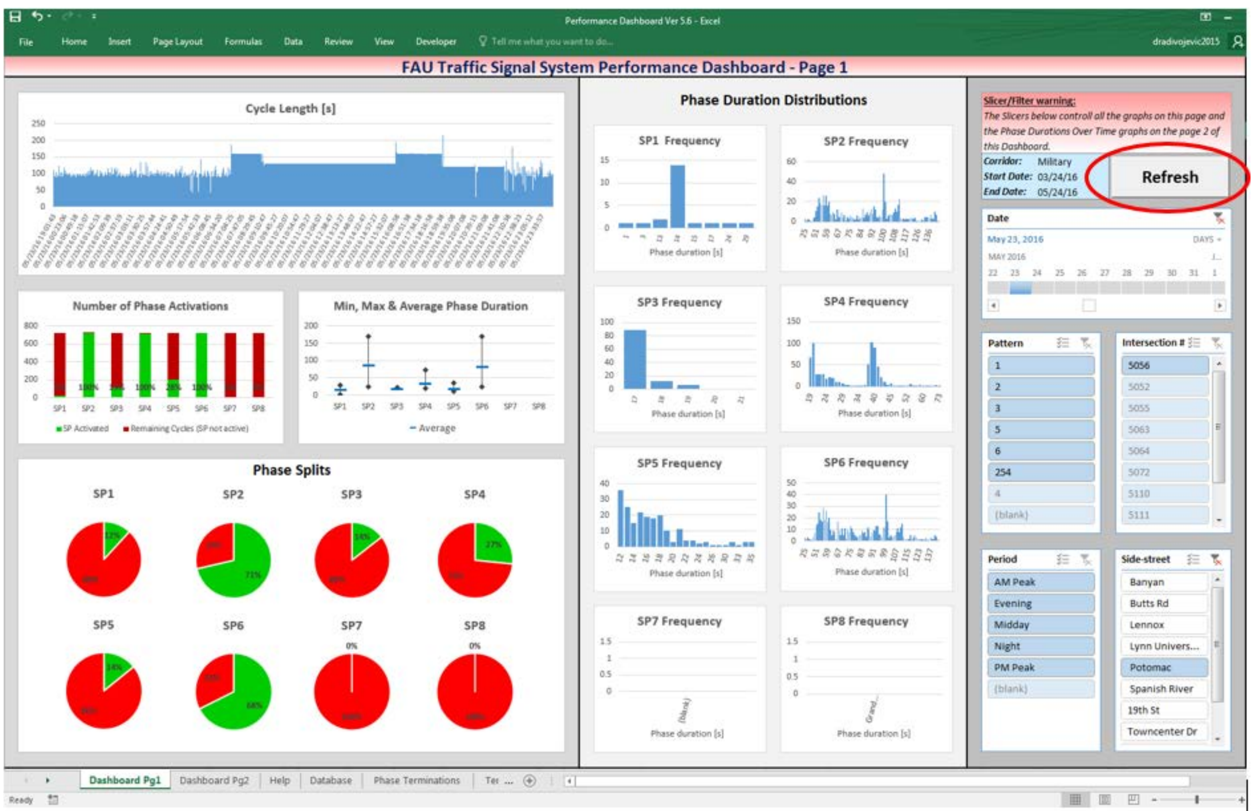


Figure 5.1-12. Refreshing the data for phase terminations

3. You are ready to start using the Traffic Signal System Performance Dashboard

5.1.8 Using the TSSPD Tool

Once the necessary data inputs are made in the TSSPD tool, the tool is ready for use. First, it is needed to read the Slicer/Filter warning in the upper right box where it is explained that all slicers on the Dashboard Pg1 affect all the charts on the same page (sheet), and also the Phase Durations Over Time charts on the Dashboard Pg2 sheet. The Phase Terminations chart is not affected by these slicers, but it is affected by the two slicers on the Dashboard Pg2 that are integrated in the chart itself. The reason for this arrangement is that Phase Terminations are calculated from different database than the rest of the charts.

By changing the selections on the Date, Intersection #, Side-Street, Pattern and Period slicers a user can make numerous combinations of spatial and temporal selections. The Date slicer enables the user to select any interval from a single day to all days in one month. For one day the user just needs to click on the rectangle assigned to the desired date, and for longer intervals a user needs to click and drag the left and right edge of the rectangle while it dynamically selects the desired range of dates. Even intervals larger than a month can be selected, but it is recommended that the data copied in the Database do not exceed a period of one month due to potential computation problems with larger data sets.

The spatial extent of the analysis is defined with two slicers, Intersection # and Side-street. Those slicers actually have the same role, to select one intersection, multiple intersections or all intersections. In the Intersection # slicer, the intersections can be selected by their assigned IDs (by the agency). The Side-Street slicer enables selection of the intersection by the side-street that intersects the main street of subject corridor. Those two slicers are connected and a selection made in one automatically affects the selection of the other. The selection of one field is done by clicking on it, while the selection of multiple fields can be performed by holding the Ctrl key and clicking on multiple choices. Resetting of the selections and inclusion of all of the possible choices is done by clicking on the Clear Filter button in the top right corner of all the slicers.

The remaining slicers enable a user to further specify conditions under which the data are investigated. Therefore, for example, by making a selection in Period slicer, a user can set if the Dashboard will show information about AM Peak period, Midday, PM Peak, Evening, Night period or their combinations. The periods are defined in the Table 5.1-1 below:

Table 5.1-1. The definition of periods in one day

Period	**Activity interval**
AM Peak	7:00 AM – 8:59 AM
Midday	9:00 AM – 3:59 PM
PM Peak	4:00 PM – 6:59 PM
Evening	7:00 PM – 9:59 PM
Night	10:00 PM – 6:59 AM

The Patterns numeration represent the different signal timings that are in use during one day. Each pattern represents the separate signal timing plan and they are used to accommodate the prevalent traffic flows in certain time periods.

5.1.9 Dashboard Outputs

The TSSPD Dashboard shows 7 different chart types that display the most relevant data about traffic signal activities. All the charts are explained in the paragraphs below.

Cycle Length

This chart shows the cycle length changes in the selected time interval. Depending on the selected interval, the user can track the planned and unplanned changes in the cycle lengths, deviations and make adequate inferences.

Number of Phase Activations

This graph shows graphically and numerically (in percent) how many times each phase was activated out of total number of times it could be activated (number of cycles) for the defined selection. The numerical presentation is given on the bottom part of every bar that represents the phase and the green color displays graphically the ratio of how many times each of the phases was activated, while the red indicates the situations when the phase was not activated. The tool currently examines up to 8 phases.

Min, Max & Average Phase duration

This chart calculates the minimal, maximal and the average value of each phase for the defined selection. By observing the relation between those values for carefully selected locations, pattern or specific time interval, a user can make inferences about the traffic signals operations.

Phase Splits

The average splits for each phase are presented in the Phase Splits charts. Duration of the green versus the red is presented in percentages and graphically in the pie charts for each phase (up to 8 phases).

Phase Duration Distributions

The number of times the different durations of phases occurred are shown in this group of charts. By observing these charts a user can keep track about how many times a phase of certain duration is repeated, for the selection made in slicers, or how many times certain durations of phases are repeated compared to some other durations of the same phase.

Phase Duration Over Time

The set of graphs shows the changes in minimal, average and maximal durations of signal phases over time. Besides the fact that a user can observe how durations of the phases change over time, one can also keep track of variability of phases over time (the difference between minimal and maximal duration, with the current position of the average duration between those two values).

Phase Terminations

The Phase Terminations charts show which type of phase termination were executed, accompanied with their frequency and the overall percentage in the total number of phase terminations. The three observed termination types are Force-off, Gap-out and Max-out. The proportions of each of these termination types can help operators to determine if certain phases (at certain locations and daily peaks) have appropriate minimal time, maximal time or passage time. If the data collected in Split History Reports cover several days (per one report), the only criteria for filtering is location (intersection). If the Split History Reports are collected for every day separately, then a Date filter/slicer can be introduced. The data in the charts represent the number of phase terminations per type, for selected intersection and for the entire period of evaluation inserted in the Database.

5.2 Traffic Signal System Reliability Dashboard

In order to help the users to use this type of dashboard, the clear and complete instructions of how to use the Traffic Signal System Reliability Dashboard (TSSRD) are provided in the following part of this document. In general, the major steps for using the TSSRD are provided below, while their details are explained in the following subchapters.

Steps for using the Traffic Signal System Reliability Dashboard:

1. **Data collection -** Create the Field Alarm reports for all intersections in an agency's jurisdiction and put them in a folder. Copy that folder, add the suffix Copy, and this will create a folder ready to be used by a macro in the next step. The pilot dashboard uses the data for 136 intersections in period of two months, but larger quantities of data can be used as well.
2. **Reports transformation -** Execute "*FAU Field Alarms Report Analyzer.xslm*" file that will transform the data and compile all report files into one spreadsheet. Select the folder with the suffix Copy that contains the Field Alarm reports from step 1. After executing, the macro will show the data to be copied to the Traffic Signal System Reliability Dashboard.
3. **Copy the data to Database** –Open the Traffic Signal System Reliability Dashboard, go to the sheet *Database*, delete all data that already exist there, go back to the *"FAU Field Alarms Report Analyzer.xslm"*, and copy all the data created by the macro in previous step. Go back to the *Database* sheet of TSSRD and paste the data you have copied in cell A1.
4. **Refresh the data** – Go to *Dashboard* sheet, click on Refresh button.
5. **Use the Dashboard** – Save the file under appropriate name (as macro-enabled worksheet), and the Traffic Signal System Reliability Dashboard is ready for use. A user should change selections in filters/slicers to select the data that will be displayed. One should ensure that the selected date is within the range defined by Begin and End dates which are displayed above the slicers on the Dashboard worksheet. If the selected date(s) are outside of the range, all of the graphs will be empty.

5.2.1 Data Collection

The first step in the assessment process is the data collection. As already mentioned, all data is collected from ATMS.now signal system central software. For this dashboard, the user first needs to create the Field Alarms Reports for all intersections of the agency, and all days in the evaluation period (the pilot database contains the data for 136 intersections for a period of two months). The TSSRD can accommodate longer periods, however excessive increasing of the evaluation period may cause slower computing operations. All Reports should be created as **.xls files**, and not as .pdf or other files.

Field Alarms

6/3/2016

100-NW 13 ST & NW 9 CT (MMU)

ID	Date/Time Occurred	#	State	Data	Description
100	5/25/2016-WED-17:12:07	257	ON	0	Communications Restored
100	5/27/2016-FRI-05:14:50	257	ON	0	Communications Restored
100	5/27/2016-FRI-08:19:38	257	ON	0	Communications Restored
100	5/28/2016-SAT-18:24:23	1	ON	1	Power Up Alarm
100	5/28/2016-SAT-18:24:24	2	ON	0	Stop Timing
100	5/28/2016-SAT-18:24:24	15	ON	0	MMU Flash Input
100	5/28/2016-SAT-18:24:29	1	ON	1	Power Up Alarm
100	5/28/2016-SAT-18:24:30	2	ON	0	Stop Timing
100	5/28/2016-SAT-18:24:30	15	ON	0	MMU Flash Input
100	5/28/2016-SAT-18:24:32	2	OFF	0	Stop Timing
100	5/28/2016-SAT-18:24:33	15	OFF	0	MMU Flash Input
100	5/28/2016-SAT-18:57:49	1	OFF	1	Power Up Alarm
100	5/28/2016-SAT-18:59:33	1	ON	1	Power Up Alarm
100	5/28/2016-SAT-18:59:33	2	ON	0	Stop Timing
100	5/28/2016-SAT-18:59:34	15	ON	0	MMU Flash Input
100	5/28/2016-SAT-18:59:36	2	OFF	0	Stop Timing
100	5/28/2016-SAT-18:59:37	15	OFF	0	MMU Flash Input
100	5/29/2016-SUN-19:47:57	257	ON	0	Communications Restored

101-PALMETTO PARK ROAD & NW 9 AVE

ID	Date/Time Occurred	#	State	Data	Description
101	5/25/2016-WED-09:05:56	49	ON	0	Preempt 1
101	5/25/2016-WED-09:06:45	49	OFF	0	Preempt 1
101	5/25/2016-WED-12:30:09	257	ON	0	Communications Restored
101	5/25/2016-WED-13:01:34	49	ON	0	Preempt 1
101	5/25/2016-WED-13:02:21	49	OFF	0	Preempt 1
101	5/25/2016-WED-17:46:05	49	ON	0	Preempt 1
101	5/25/2016-WED-17:46:49	49	OFF	0	Preempt 1
101	5/25/2016-WED-18:18:02	49	ON	0	Preempt 1
101	5/25/2016-WED-18:18:48	49	OFF	0	Preempt 1
101	5/25/2016-WED-19:43:02	49	ON	0	Preempt 1
101	5/25/2016-WED-19:43:49	49	OFF	0	Preempt 1

Sheet1

Figure 5.2-1. Field alarms report in Excel

Contrary to Split History Reports, this type of report does not need to be created every day, but still there is a limit of maximal number of rows that can be displayed in the report exist. This means that an agency with a smaller number of alarm activation can create reports less frequently compared to the agency with a higher number of alarm activations. It is possible to set up a scheduler in ATMS.now to generate the Field Alarm Reports automatically (e.g. at 12:00 AM for the previous 24 hours. However, this type of report can be created for multiple days as this will, most likely, not negatively affect the operation of the TSSRD dashboard.

A user should put Field Alarms Reports, for all intersections of a subject agency and all days of the evaluation, in one folder. The folder should have only Field Alarms Reports for the period that will be investigated and should contain no other files. That folder needs to be copied and named for example, "*April - May 2016 Field Alarms Reports - Copy*".

5.2.2 Reports Transformation

The data from the reports need to be transferred into a different format for easy post-processing in the TSSRD. From the Figure 5.2-1 above, it is possible to observe that the Field Alarms Reports are created in a specific format of Excel files.

For transforming the Field Alarms Reports into a new format and compiling them into a single spreadsheet (that will be used as a Database in TSSRD) the FAU research team has developed a macro within the “FAU Field Alarms Report Analyzer.xslm”. Steps to use such a macro are provided below:

1. Open the “FAU Field Alarms Report Analyzer.xslm”, click Enable content (or Enable Macro depending of the Excel version) to enable the macro execution.
2. In the top left corner (Quick Access Toolbar) click the bell icon (when you put a mouse cursor over it “FAU_Field_Alarms_Report_Analyzer” will appear) to run a macro.

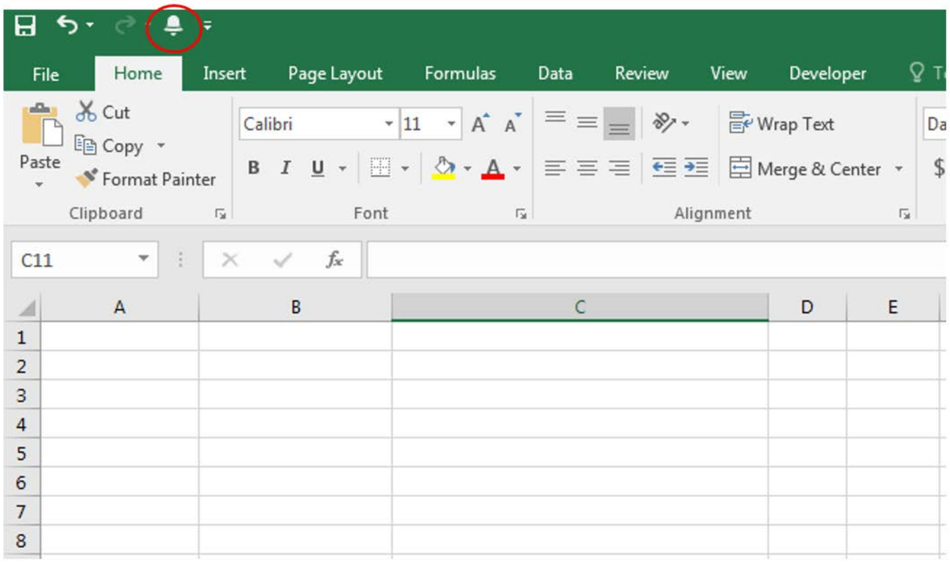


Figure 5.2-2. FAU Field alarms report analyzer macro activation

3. In the dialog window that will appear, find and select the folder where you have saved Field Alarms Reports (“*April - May 2016 Field Alarm Reports*”) by clicking once (do not double click). Press OK.

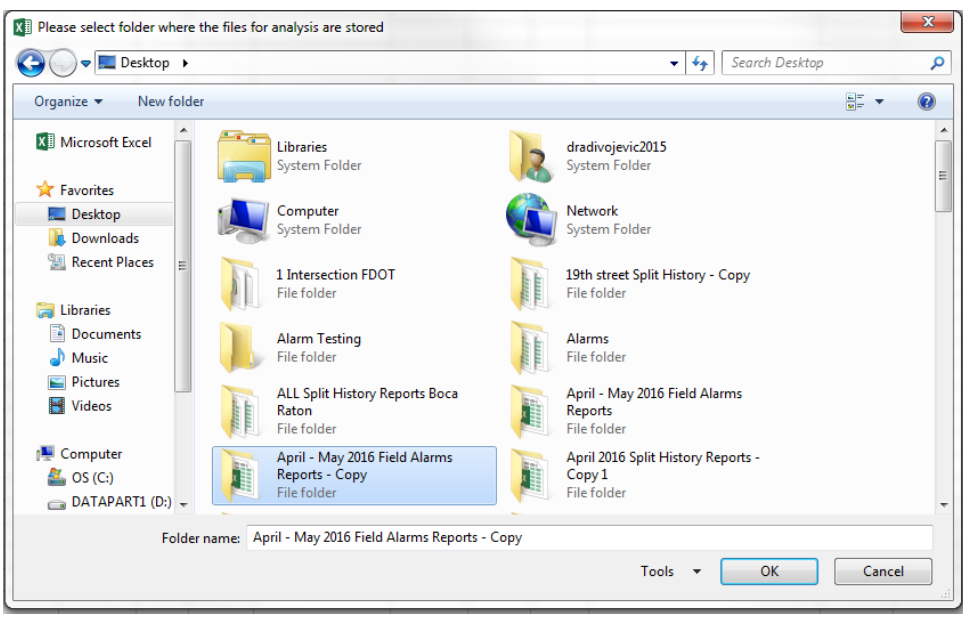


Figure 5.2-3. Selection of folder with Field alarms reports

4. A message will appear with the address of the folder you have selected. Press OK.

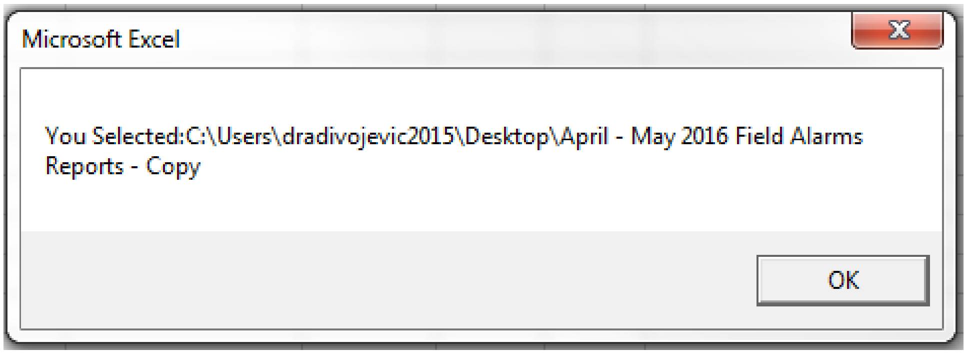
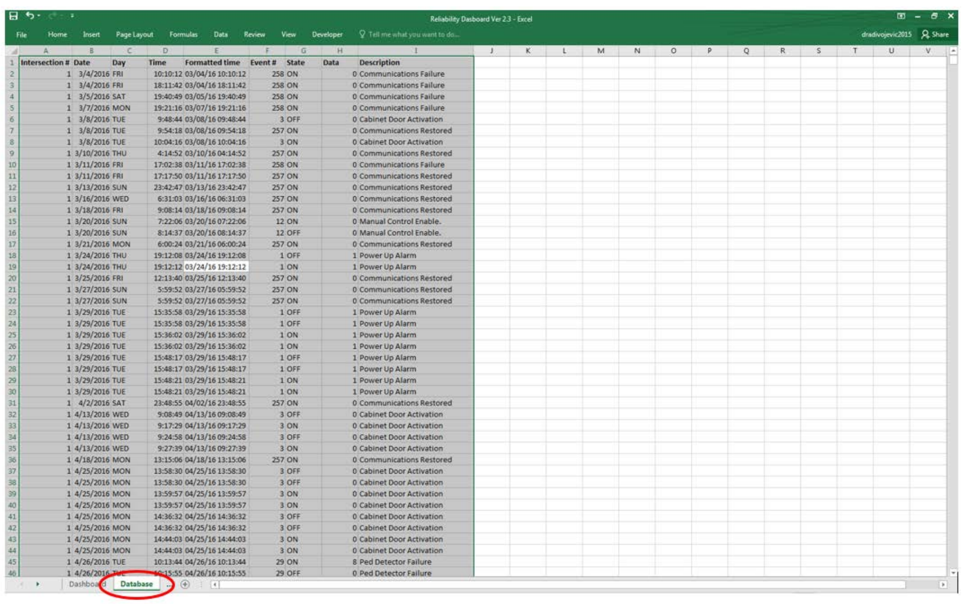


Figure 5.2-4. Selection confirmation screen in FAU Field alarms reports analyzer

5. Wait until the macro is executed and the data appears. This process can last up to 25-30 minutes depending on the speed of the computer which is used, as well as number and size of the files - reports that are being processed. If the Excel freezes and acts non-responsive within this 25-30 minute time interval, do not turn off the program, because such an outcome is quite normal.

5.2.3 Copy the new data to the Database Sheet of TSSPD

1. When the transformed data show up, go to Files, open the Traffic Signal System Reliability Dashboard, select the Database sheet and delete all the existing data (you can do that by pressing Ctrl + A and Delete).
2. Copy the data that *FAU Field Alarms Report Analyzer* macro has previously created.



	A	B	C	D	E	F	G	H	I
1	Intersection #	Date	Day	Time	Formatted time	Event #	State	Data	Description
2	1	3/4/2016	FRI	10:10:12	03/04/16 10:10:12	258	ON	0	Communications Failure
3	1	3/4/2016	FRI	18:11:42	03/04/16 18:11:42	258	ON	0	Communications Failure
4	1	3/5/2016	SAT	19:40:49	03/05/16 19:40:49	258	ON	0	Communications Failure
5	1	3/7/2016	MON	19:21:16	03/07/16 19:21:16	258	ON	0	Communications Failure
6	1	3/8/2016	TUE	9:48:44	03/08/16 09:48:44	3	OFF	0	Cabinet Door Activation
7	1	3/8/2016	TUE	9:54:18	03/08/16 09:54:18	257	ON	0	Communications Restored
8	1	3/8/2016	TUE	10:04:16	03/08/16 10:04:16	3	ON	0	Cabinet Door Activation
9	1	3/10/2016	THU	4:14:52	03/10/16 04:14:52	257	ON	0	Communications Restored
10	1	3/11/2016	FRI	17:02:38	03/11/16 17:02:38	258	ON	0	Communications Failure
11	1	3/11/2016	FRI	17:17:50	03/11/16 17:17:50	257	ON	0	Communications Restored
12	1	3/13/2016	SUN	23:42:47	03/13/16 23:42:47	257	ON	0	Communications Restored
13	1	3/16/2016	WED	6:31:03	03/16/16 06:31:03	257	ON	0	Communications Restored
14	1	3/18/2016	FRI	9:08:14	03/18/16 09:08:14	257	ON	0	Communications Restored
15	1	3/20/2016	SUN	7:22:06	03/20/16 07:22:06	12	ON	0	Manual Control Enable.
16	1	3/20/2016	SUN	8:14:37	03/20/16 08:14:37	12	OFF	0	Manual Control Enable.
17	1	3/21/2016	MON	6:00:24	03/21/16 06:00:24	257	ON	0	Communications Restored
18	1	3/24/2016	THU	19:12:08	03/24/16 19:12:08	1	OFF	1	Power Up Alarm
19	1	3/24/2016	THU	19:12:12	03/24/16 19:12:12	1	ON	1	Power Up Alarm
20	1	3/25/2016	FRI	12:13:40	03/25/16 12:13:40	257	ON	0	Communications Restored
21	1	3/27/2016	SUN	5:59:52	03/27/16 05:59:52	257	ON	0	Communications Restored
22	1	3/27/2016	SUN	5:59:52	03/27/16 05:59:52	257	ON	0	Communications Restored
23	1	3/29/2016	TUE	15:35:58	03/29/16 15:35:58	1	OFF	1	Power Up Alarm
24	1	3/29/2016	TUE	15:35:58	03/29/16 15:35:58	1	OFF	1	Power Up Alarm
25	1	3/29/2016	TUE	15:36:02	03/29/16 15:36:02	1	ON	1	Power Up Alarm
26	1	3/29/2016	TUE	15:36:02	03/29/16 15:36:02	1	ON	1	Power Up Alarm
27	1	3/29/2016	TUE	15:48:17	03/29/16 15:48:17	1	OFF	1	Power Up Alarm
28	1	3/29/2016	TUE	15:48:17	03/29/16 15:48:17	1	OFF	1	Power Up Alarm
29	1	3/29/2016	TUE	15:48:21	03/29/16 15:48:21	1	ON	1	Power Up Alarm
30	1	3/29/2016	TUE	15:48:21	03/29/16 15:48:21	1	ON	1	Power Up Alarm
31	1	4/2/2016	SAT	23:48:55	04/02/16 23:48:55	257	ON	0	Communications Restored
32	1	4/13/2016	WED	9:08:49	04/13/16 09:08:49	3	OFF	0	Cabinet Door Activation
33	1	4/13/2016	WED	9:17:29	04/13/16 09:17:29	3	ON	0	Cabinet Door Activation
34	1	4/13/2016	WED	9:24:58	04/13/16 09:24:58	3	OFF	0	Cabinet Door Activation
35	1	4/13/2016	WED	9:27:39	04/13/16 09:27:39	3	ON	0	Cabinet Door Activation
36	1	4/18/2016	MON	13:15:06	04/18/16 13:15:06	257	ON	0	Communications Restored
37	1	4/25/2016	MON	13:58:30	04/25/16 13:58:30	3	OFF	0	Cabinet Door Activation
38	1	4/25/2016	MON	13:58:30	04/25/16 13:58:30	3	OFF	0	Cabinet Door Activation
39	1	4/25/2016	MON	13:59:57	04/25/16 13:59:57	3	ON	0	Cabinet Door Activation
40	1	4/25/2016	MON	13:59:57	04/25/16 13:59:57	3	ON	0	Cabinet Door Activation
41	1	4/25/2016	MON	14:36:32	04/25/16 14:36:32	3	OFF	0	Cabinet Door Activation
42	1	4/25/2016	MON	14:36:32	04/25/16 14:36:32	3	OFF	0	Cabinet Door Activation
43	1	4/25/2016	MON	14:44:03	04/25/16 14:44:03	3	ON	0	Cabinet Door Activation
44	1	4/25/2016	MON	14:44:03	04/25/16 14:44:03	3	ON	0	Cabinet Door Activation
45	1	4/26/2016	TUE	10:13:44	04/26/16 10:13:44	29	ON	8	Ped Detector Failure
46	1	4/26/2016	[illegible]	[illegible]	04/26/16 10:15:55	29	OFF	0	Ped Detector Failure

Figure 5.2-5. Replacing the database in the TSSRD tool

3. Open the TSSRD again, and in cell A1 of Database worksheet paste the data copied in the step 2.

5.2.4 Refresh the Data

1. Go to *Dashboard* sheet, click on Refresh button. Every time the Refresh button is activated, the subroutine will check the Begin and End dates for the data inserted in the Database and update all the charts and values.
2. Save the file as macro-enabled workbook, under an appropriate name (for example, *TSSRD – April - May 2016*) and you are ready to start using the Traffic Signal System Reliability Dashboard.
3. After inserting the new data in Database, the user can delete the folder with copies of the original Field Alarm Reports (in this example they had names *April – May 2016 Field Alarms Reports – Copy*).

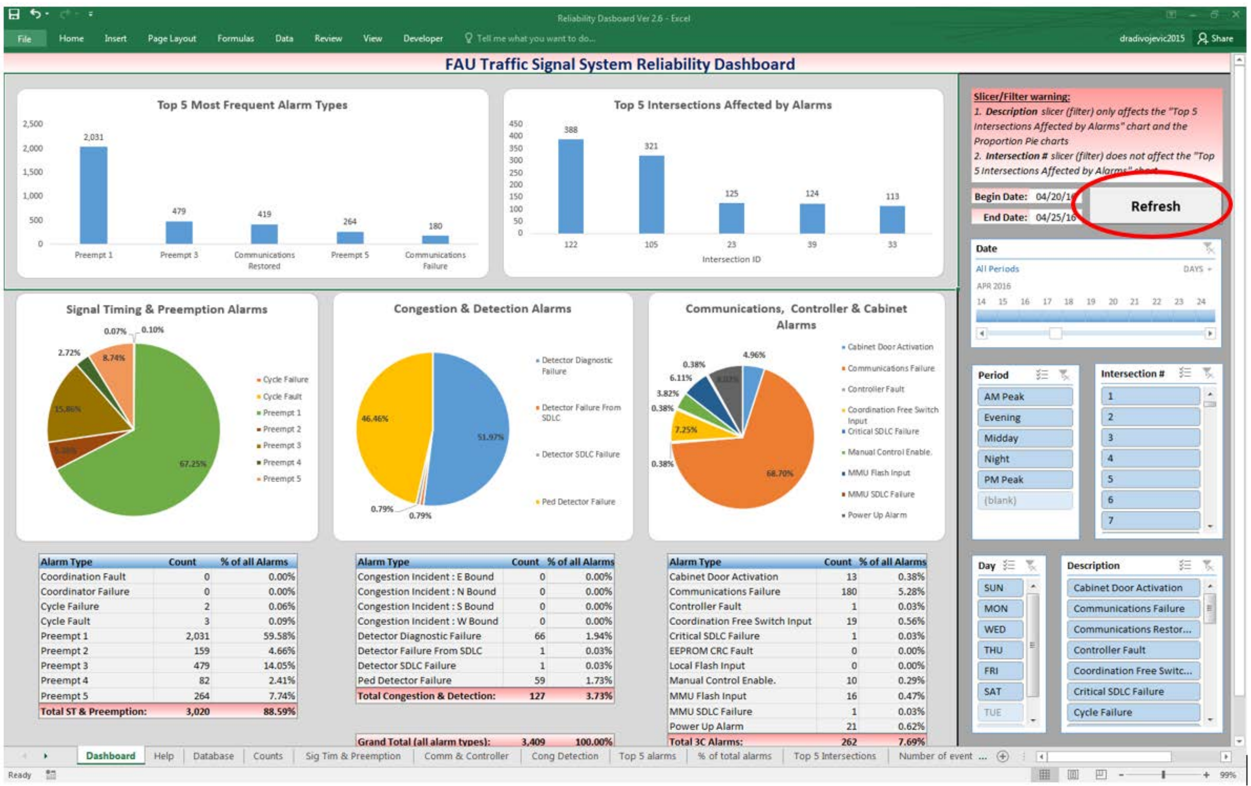


Figure 5.2-6. Refreshing the data before using the TSSRD

5.2.5 Using the TSSRD Tool

Once the data are inserted into the TSSRD tool, one can start using it. The first thing is to read the Slicer/Filter warning in the upper right box where it is explained which graphs are not affected by which slicers. The Description Slicer only affects the graph "Top 5 Intersections Affected by Alarms", while the Intersection # slicer is the only one that does not affect that graph.

By changing the selections on the Date, Intersection #, Day, Period and Description slicers, a user can make numerous combinations of spatial and temporal selections to be displayed. The

Date slicer enables the user to select any interval from a single day to all days of the investigation period. For one day, a user just needs to click on the rectangle assigned to the desired date, whereas for longer date ranges it is necessary to click and/or drag the left and right edge of the rectangle and dynamically select the desired interval.

The Day slicer can filter the database and isolate only days of interest. In such a way, a user can check, for example, how many of the alarms occurred during the weekend (e.g. Saturday and Sunday need to be selected). The Period slicer enables the user to select the certain period or periods of one day. The available periods are: AM peak, Midday, PM peak, Evening and Night.

The spatial extent of the analysis is defined with Intersection # slicer. That slicer can be used to select an intersection, multiple intersections or all intersections. The intersections can be selected by their assigned ID numbers. The selection of one field can be done by clicking on it, whereas selection of multiple fields can be performed by holding the Ctrl key and clicking on multiple fields. Resetting of the selections and inclusion of all possible choices is done by clicking the Clear Filter in the top right corner of all the slicers.

The Description slicer enables the user to select the alarm types that will be shown on the "Top 5 Intersection Affected by Alarms". In such a way, a user can select the alarms of interest and the information about the top 5 signals where those alarms have occurred will be provided.

5.2.6 Dashboard Outputs

The TSSRD Dashboard shows 7 different chart types that display the most relevant data about traffic signal activities. All the charts are explained in the paragraphs below.

Top 5 Most Frequent Alarm Types

This chart displays which 5 alarms are the most frequent in the data bounded by the selections a user have made by using the slicers. By changing the selections in Date, Day and Intersection # slicers, the graph will be automatically updated to show the relevant information.

Top 5 Intersections Affected by Alarms

After examining the data defined by the selection made in slicers, the graph shows top 5 intersections with the highest number of alarms that comply with such a selection. The Intersection # slicer does not affect this graph so the selection must be made by using other slicers (Date, Day and alarm type in the Description slicer).

All alarms are divided into three groups:

1. Signal timing and preemption alarms
2. Congestion and detection alarms
3. Communication, controller and cabinet alarms (3C alarms)

Signal timing & Preemption alarms

This group of alarms is presented on the first pie chart on the left side. It shows the following alarms:

1. Coordination fault
2. Coordination failure
3. Cycle failure
4. Cycle fault
5. Preemption 1
6. Preemption 2
7. Preemption 3
8. Preemption 4
9. Preemption 5

The presence of those alarms is shown on a pie chart with a percentage that a specific alarm partakes within that group (for example Signal timing & Preemption group of alarms). The pie charts are automatically updated when the selections are changed in slicers.

Congestion and Detection alarms

The middle pie chart is reserved for the second group of alarms. This group contains the congestion and detection alarms which are listed below:

1. Congestion incident: Northbound
2. Congestion incident: Eastbound
3. Congestion incident: Southbound
4. Congestion incident: Westbound
5. Detector Diagnostics failure
6. Detector failure from SDLC (Synchronous Data Link Control)
7. Detector SDLC Failure
8. Pedestrian detector failure

All the alarms are represented by different colors in the chart and the percentage of each alarm in total number of alarms that belong to this group are shown on the chart itself.

Communication, Controller & Cabinet (3C) alarms

The remaining pie chart addresses the communication, controller and cabinet alarms. The list of those alarms is provided below:

1. Cabinet door activation
2. Communications failure
3. Controller fault
4. Coordination free switch input
5. Critical SDLC failure
6. EEPROM CRC fault
7. Local flash input
8. Manual control enable
9. MMU (Malfunction Monitoring Unit) Flash input
10. MMU SDLC failure

All alarms are represented numerically (percent from the total number of alarms that belong to this group of alarms) and graphically using different colors. The layout is set so that the first alarm gets the position of 12 o'clock if the analogy with the watch is used, and the other alarms are placed one after another in the direction of the movement of clock's hands.

Alarm Counts and Percentage of Total Number of Alarms

The three tables, given below each of the pie charts, show the alarm types displayed on the chart above. The differences compared to the charts are reflected in the facts that the tables contain exact count of the alarm activations. All counts are summed into total number of alarm activations per group, and all three groups are summed into Grand Total that holds the total number of all alarm activations for the defined selection.

Other measure that is provided is the percentage that a specific alarm has in the total number of all alarm activations (Grand Total) (this is different from percentages provided in the pie charts, where group totals are used instead of the Grand Total).

The FAU research team will further investigate the possibility of including the calculation of the duration for each alarm type, for the selected time period. Such calculations could be somewhat complex, and will be considered together with other recommendations for improvements from FDOT.

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Appendix A: Palm Beach County Annual Evaluation Spreadsheet

Contact and general information			
Contact information			
0.1	Name	Giri Jeedigunta, PE, PTOE	
0.2	Title	Signal Systems Manager	
0.3	Agency	Palm Beach County	
0.4	Address	2300 N. Jog Road, 3rd floor	
0.5	City/Town	West Palm Beach	
0.6	State/County	Florida	
0.7	Zip code	33411	
0.8	Telephone contact		
0.9	Email address	gjeedigu@pbcgov.org	
General information			
0.10	County/City population	1,422,789	www.census.gov
0.11	Number of registered vehicles	1,135,116	www.flhsmv.gov
0.12	Number of neighboring signal control agencies	5	
0.13	Number of streets with shared signal jurisdiction	25	
0.14	Total length of road network by the jurisdiction (miles)	1,549	http://www.dot.state.fl.us/planning/statistics/gis/road.shtm
0.15	Estimated annual funding for signal operations and management	NA	
0.16	Estimated annual funding for signal related capital investments	NA	
Signal System Central Software			
0.17	Number of signalized intersections	1047	

Figure A-1 Contact and general information section (Palm Beach County)

MAN	Management				
1.1	**Number and expertise of in-house staff**	**Numbers of FTEs**	**Importance**	**Importance factor**	**Total equivalent weighted number of regular staff**
1.1.1	Managers	1.0	Important	100	100
1.1.2	Engineers	3.0	Important	100	300
1.1.3	Technicians	22.0	Important	100	2200
1.1.4	Administrative staff	1.0	Important	100	100
1.1.5	Other	0.0	Important	100	0
1.2	**Number and expertise of outsourced staff**	**Numbers of FTEs**	**Importance**	**Importance factor**	**Total equivalent weighted number of outsourced staff**
1.2.1	Managers	1.0	Important	100	100
1.2.2	Engineers	2.0	Important	100	200
1.2.3	Technicians	1.0	Important	100	100
1.2.4	Administrative staff	0.0	Important	100	0
1.2.5	Other	0.0	Important	100	0
		Total equivalent number of staff:			**31.00**

1.3	Staff training	Numbers of training hours in one year (hours x persons)	Importance	Importance factor	
1.3.1	Basic signal timing	NA	Important	100	#VALUE!
1.3.2	Advanced signal timing	NA	Important	100	#VALUE!
1.3.3	ITS courses	NA	Important	100	#VALUE!
1.3.4	Hardware and communications	NA	Important	100	#VALUE!
1.3.5	Other	NA	Important	100	#VALUE!
		Partial grade 1:			**#VALUE!**
		Staff training weight factor:			**1.00**
		Weightred Partial grade MAN 1:			**#VALUE!**
		Normalized Partial grade MAN 1:			**#VALUE!**

New min	New max
0	100
Old min	**Old max**
0	3.52
Old value	**New value**
#VALUE!	#VALUE!

1.4	Monitoring	
1.4.1	Number of staff designated to monitoring	3
1.4.2	Number of hours in one week they are designated for monitoring	20
1.4.3	Total number of engineering and technician staff (regular and outsourced)	28
1.4.4	Average number of work hours per week (for the persons from questions 1.4.1 and 1.4.2)	40
	Partial grade 2:	**0.54**
	Monitoring weight factor:	**1.00**
	Weighted Partial grade MAN 2:	**0.54**
	Normalized Partial grade MAN 2:	**57.14**

New min	New max
0	100
Old min	**Old max**
0	0.9375
Old value	**New value**
0.54	57.142857

Figure A-2 Management section (Palm Beach County) - Part 1

1.5	User satisfaction	Value	Importance	Importance factor	
1.5.1	Number of complaints per year	900	Important	100	0.0001
1.5.2	Is there a publicized call-in telephone number and web site that the public can use to report malfunctions, ask questions and suggest operational improvements?	1	Important	100	1
				Partial grade3:	**1.00**
				User satisfaction weight factor:	**1.00**
				Weighted Partial grade MAN 3:	**1.00**
				Normalized Partial grade MAN 3:	**70.43**

New min	New max
0	100
Old min	**Old max**
0	1.42
Old value	**New value**
1.00	70.426547

1.6	Average time from receiving of memo or call until answering	Choose Value	Importance	Importance factor	
1.6.1	24h	0	Important	100	0
1.6.2	48h	0	Important	80	0
1.6.3	72h	1	Important	60	60
1.6.4	7 days	0	Important	40	0
1.6.5	10 days	0	Important	20	0
1.6.6	More than 10 days	0	Important	0	0
1.7	**Information available to public**	**0 or 1**	**Importance**	**Importance factor**	
1.7.1	Traffic lights failures	0	Important	100	0
1.7.2	Congestion	1	Important	100	100
1.7.3	Incidents on signalized intersections	1	Important	100	100
1.7.4	Lane closures at signalized intersections	1	Important	100	100
1.7.5	Reaction time for reparations of traffic signals	0	Important	100	0
1.7.6	Frequency of malfunctions	0	Important	100	0
1.7.7	Goals	0	Important	100	0
1.8	**Means of communication with the public**	**0 or 1**	**Importance**	**Importance factor**	
1.8.1	PR person	0	Important	100	0
1.8.2	Head of department	0	Important	100	0
1.8.3	Memos or letters	0	Important	100	0
1.8.4	Television	0	Important	100	0
1.8.5	Radio	0	Important	100	0
1.8.6	Web site	0	Important	100	0
1.8.7	Telephone	1	Important	100	100
				Partial grade 4:	**1.17**
				Public relations weight factor:	**1.00**
				Weighted Partial grade MAN 4:	**1.17**
				Normalized Partial grade MAN 4:	**32.53**

New min	New max
0	100
Old min	**Old max**
0.29	3
Old value	**New value**
1.17	32.52504

Figure A-3 Management section (Palm Beach County) - Part 2

1.9	Cooperation with neighboring signal control agencies	Value	Importance	Importance factor	
1.9.1	Number of neighboring county agencies with whom the information and data are being exchanged	5	Important	100	100
1.9.2	Number of streets with signals being shared with the neighboring agencies that are inter-coordinated	NA	Important	100	#VALUE!
				Partial grade 5:	**100.00**
				Cooperation weight factor:	**1.00**
				Weighted Partial grade MAN 5:	**100.00**
				Normalized Partial grade MAN 5:	**100.00**

New min	New max
0	100
Old min	**Old max**
0	100
Old value	**New value**
100.00	100

1.10	Safety and accidents	Value	Importance	Importance factor	
1.10.1	Number of accidents on streets close to traffic signals	29964	Important	100	80.56
1.10.1	Number of accidents involving the running of red lights	921	Important	100	9.59
				Partial grade 6:	90.15
				Safety and accidents weight factor	1.00
				Weighted Partial grade MAN 6:	**90.15**
				Normalized Partial grade MAN 6:	**26.82**

New min	New max
0	100
Old min	**Old max**
72.9	137.22
Old value	**New value**
90.15	26.815617

1.11	Inventory - up to date inventory about all signal equipment including spares	0 or 1	Importance	Importance factor	
1.11.1	Is there an up-to date inventory about all signal equipment including spares?	1	Important	100	
				Weighted Partial grade MAN 7:	**100.00**
				Normalized Partial Grade 7:	**100.00**

New min	New max
0	100
Old min	**Old max**
0	100
Old value	**New value**
100.00	100

1.12	Service vehicles number and activation	Value	Importance	Importance factor	
1.12.1	Number of vehicles in operation by shift	15	Important	100	1.43
1.12.2	Miles travelled per vehicle (in thousands)	15	Important	100	2.50
1.12.3	The vehicle coverage ratio		Important	100	0.97
				Partial grade 8:	**1.63**
				Service vehicles number weight factor:	**1.00**
				Weighted Partial grade MAN 8:	**1.63**
				Normalized Partial grade MAN 8:	**14.14**

New min	New max
0	100
Old min	**Old max**
0.57	8.09
Old value	**New value**
1.63	14.144643

Figure A-4 Management section (Palm Beach County) - Part 3

1.13	Signal System Central Software (SSCS) - ATMS.now	0 or 1/Value	Importance	Importance factor	
1.13.1	Does the agency has Signal System Central Software software	1	Important	100	100
1.13.2	How many intersections are connected to SSCS?	817	Important	100	78
1.14	**Type of Signal System Central Software**	**0 or 1**			
1.14.1	ACTRA	0			
1.14.2	ATMS.now	1			
1.14.3	Centracs	0			
1.14.4	KITS	0			
1.14.5	MIST	0			
1.14.6	QuicNet	0			
1.14.7	Sitraffic Concert	0			
1.14.8	Sitraffic Tactics	0			
1.14.9	Other	0			
1.15	**Functionality of Signal System Central Software**	**0 or 1/Value**	**Importance**	**Importance factor**	
1.15.1	Video monitoring	1	Important	100	100
1.15.2	Functionality monitoring	1	Important	100	100
1.15.3	Signal plans changing	1	Important	100	100
1.15.4	Special events management	1	Important	100	100
1.15.5	Corridor management/traffic signal coordination or control	1	Important	100	100
1.15.6	Disaster management and traffic coordination	1	Important	100	100
1.15.7	Emergency services traffic control coordination	1	Important	100	100
1.15.8	Ramp management and control	0	Important	100	0
1.15.9	Network performance monitoring, evaluation and reporting	1	Important	100	100
1.16	Number of staff that actively use SSCS	12	Important	100	115
1.17	Does the agency has set the alarms for malfunctions that inform persons in charge?	1	Important	100	100
1.18	**Select the existing mediums that are used for informing persons in charge about events causing alarms**	**0 or 1**	**Importance**	**Importance factor**	
1.18.1	On Signal System Central Software interface	1	Important	100	100
1.18.2	SMS message	0	Important	100	0
1.18.3	E-mail	1	Important	100	100
1.18.4	Pager	0	Important	100	0
				Partial grade 9:	**1994.94**
				SSCS weight factor:	**1.00**
				Weighted Partial grade MAN 9:	**1994.94**
				Normalized Partial grade MAN 9:	**58.17**

New min	New max
0	100
Old min	**Old max**
0	3429.41
Old value	**New value**
1994.94	58.171462

Figure A-5 Management section (Palm Beach County) - Part 4

TSO	Traffic Signal Operations

2	General	0 or 1/Value	Importance	Importance factor	
2.1	Do you use traffic responsive or traffic adaptive control?	1	Important	100	100
2.2	Are field reviews of signal operations performed annually?	0	Important	100	0
2.3	Are ad hoc changes triggered by complaint calls performed for all requests?	1	Important	100	100
2.4	Are sights distances to intersections reviewed for all new traffic signal installations?	1	Important	100	100
2.5	Are advanced warning indications installed where limited site distances exist?	1	Important	100	100
2.6	Number of signalized intersections adjusted for visually impaired persons.	85	Important	100	8.11843362
2.7	Actual time to implements, evaluate and calibrate the new timing settings or strategy (in weeks)	4	Important	100	
2.8	Expected time to implement, evaluate and calibrate the new timing settings or strategy (in weeks)	4	Important	100	100
2.9	What is the frequency of signal retiming in your agency?				
2.9.1	Less than 1 year	0	Important	100	0
2.9.2	1-2 years	0	Important	75	0
2.9.3	2-3 years	1	Important	50	50
2.9.4	3-5 years	0	Important	25	0
2.9.5	More than 5 years	0	Important	0	0
2.10	Number of coordinated traffic signals	639	Important	100	61.03151862
		Partial grade 1:			**619.15**
		General subsection weight factor:			**1.00**
		Weighted Partial grade TSO 1:			**619.15**
		Normalized Partial grade TSO 1:			**49.49**

New min	New max
0	100
Old min	**Old max**
50	1200
Old value	**New value**
619.15	49.4913

Figure A-6 Traffic Signal Operations section (Palm Beach County) - Part 1

	Signal System Central Software - ATMS.now	Value	Importance	Importance factor	
2.11	Number of special events, disasters, VIP routes and emergency signal timings	375			
2.12	Total number of signal timings	3755	Important	100	90.01331558
2.13	Number of school zone manual flash signals	200			
2.14	Number of schools	168	Important	100	119.047619
2.15	Number of intersections with preemption capability	1047	Important	100	100
2.16	Number of intersections with Public transit prioritization capability	0			
2.17	Total number of signalized intersections along PT routes.	0	Important	100	#DIV/0!
2.18	Average number of hours per day when adaptive system is active	24	Important	100	100
2.19	Number of hours with congestion (per day, week, month)	NA			
2.20	Total number of hours per observed period (in day, in week, in month...)	24	Important	100	#VALUE!
2.21	Number of cycle failures	NA			
2.22	Total number of cycles per observed period	NA	Important	100	#VALUE!
2.23	Number of cycle faults (AM, PM, Midday, Night)	NA	Important	100	#VALUE!
2.24	Time that coordination has been in transition	NA			
2.25	Time the coordination is active	NA	Important	100	#VALUE!
2.26	Coordination failure	NA	Important	100	#VALUE!
				Partial grade 2:	**#DIV/0!**
				SSCS subsection weight factor:	**1.00**
				Weighted Partial grade TSO 2:	**#DIV/0!**
				Normalized Partial grade TSO 2:	**#DIV/0!**

New min	New max
0	100
Old min	**Old max**
41.67	777.67
Old value	**New value**
#DIV/0!	#DIV/0!

Figure A-7 Traffic Signal Operations section (Palm Beach County) - Part 2

STP	Signal Timing Practices

3	General	0 or 1/Value	Importance	Importance factor	
3.1	Are records of conflict situations used to identify signalized intersections at which safety could be improved by revised signal operations (protected turns...)	0	Important	100	0
3.2	Select the performance measures that agency collects				
3.2.1	Number of vehicles served	1	Important	100	100
3.2.2	Delay per vehicle	1	Important	100	100
3.2.3	Total delay	1	Important	100	100
3.2.4	v/c	1	Important	100	100
3.2.5	Travel time	1	Important	100	100
3.2.6	Number of stops	1	Important	100	100
3.2.7	Other	0	Important	100	0
3.3	Do you use signal timing optimization software (Synchro, PASSER, TRANSYT, etc) to develop new signal timings?	1	Important	100	100
3.4	What parameters do you use to develop new signal timings?				
3.4.1	Cycle lenghts	1	Important	100	100
3.4.2	Offsets	1	Important	100	100
3.4.3	Splits	1	Important	100	100
3.4.4	Phasing sequence	1	Important	100	100
3.4.5	Discharge time	1	Important	100	100
3.4.6	Two-way progression	1	Important	100	100
3.4.7	Turning movements	1	Important	100	100
3.4.8	Time space diagrams	1	Important	100	100
3.4.9	Other	0	Important	100	0
				Partial grade 1:	**1500.00**
				General subsection weight factor:	**1.00**
				Weighted Partial grade STP 1:	**1500.00**
				Normalized Partial grade STP 1:	**93.75**

New min	New max
0	100
Old min	**Old max**
0	1600
Old value	**New value**
1500.00	93.75

Figure A-8 Signal Timing Practices (Palm Beach County) - Part 1

	ATMS.now	0 or 1/Value	Importance	Importance factor	
3.5	Average duration of splits per AM, Midday and PM period				
	AM	YES*			
	Midday	YES*			#VALUE!
	PM	YES*			
3.6	Duration of programmed splits				#VALUE!
	AM	YES*			
	Midday	YES*			
	PM	YES*	Important	100	#VALUE!
3.7	The number of times a phase was activated in a given evaluation period	YES*			
3.8	Maximum number of times that phase could be activated	YES*	Important	100	#VALUE!
				Partial grade 2:	**#VALUE!**
				SSCS subsection weight factor:	
				Weighted Partial grade STP 2:	**#VALUE!**
				Normalized Partial grade STP 2:	**#VALUE!**

New min	New max
0	100
Old min	**Old max**
Old value	**New value**
#VALUE!	#VALUE!

Figure A-9 Traffic Signal Operations section (Palm Beach County) - Part 2

TMDC	Traffic Monitoring and Data Collection				
4	**Detection**	**0 or 1/Value**	**Importance**	**Importance factor**	
4.1	Total number of detectors	7545	Important	100	487.09
4.2	Detection distribution by type:				
4.2.1	Inductive loop	6700	Important	100	
4.2.2	Video	838	Important	100	
4.2.3	Microwave	7	Important	100	
4.2.4	Infrared	0	Important	100	
4.3	Choose system detectors that are being used in your agency:				
4.3.1	Midblock	0	Important	100	0
4.3.2	Near upstream intersections	0	Important	100	0
4.4	What data do those system detectors collect?				
4.4.1	Speed	1	Important	100	100
4.4.2	Volume	1	Important	100	100
4.4.3	Occupancy	1	Important	100	100
4.4.4	Progression speed	0	Important	100	0
4.5	Does your agency use queue detectors?	0	Important	100	0
4.6	If video detectors are used, is their operation calibrated for:				
4.6.1	Lighting	0	Important	100	0
4.6.2	Weather	1	Important	100	100
4.6.3	Wind	1	Important	100	100
4.6.4	Occlusion	1	Important	100	100
4.6.5	Lense cleaning	1	Important	100	100
4.6.6	Zone adjustments	1	Important	100	100
4.7	How often video detectors are being calibrated?				
4.7.1	More often than once per month	0	Important	100	0
4.7.2	Every month	0	Important	80	0
4.7.3	Every three months	0	Important	60	0
4.7.4	Every six months	1	Important	40	40
4.7.5	Once per year	0	Important	20	0
4.7.6	Less often than once per year	0	Important	5	0
				Partial grade 1:	**1327.09**
				Detection subsection weight factor:	**1.00**
				Weighted Partial grade TMDC 1:	**1327.09**
				Normalized Partial grade TMDC 1:	**53.34**

New min	New max
0	100
Old min	**Old max**
6.82	2481.82
Old value	**New value**
1327.09	53.34418

Figure A-10 Traffic Monitoring and Data Collection section (Palm Beach County) - Part 1

	Data collection and storage	0 or 1	Importance	Importance factor	
4.8	Choose the used archiving methods for the data:				
4.8.1	Paper copy database	1	Important	10	10
4.8.2	Electronic database	1	Important	60	60
4.8.3	GIS	1	Important	30	30
4.8.5	Not at all	0	Important	0	0
4.9	Select the data types that are saved in the signal inventory system (database):				
4.9.1	Volume	1	Important	100	100
4.9.2	Occupancy	0	Important	100	0
4.9.3	Travel time	1	Important	100	100
4.9.4	Queue lengths	0	Important	100	0
4.9.5	Work zones	1	Important	100	100
4.9.6	Events	1	Important	100	100
4.9.7	Weather	0	Important	100	0
4.9.8	Location	1	Important	100	100
4.9.9	Hardware	1	Important	100	100
4.9.10	Controller	1	Important	100	100
4.9.11	Timing plans	1	Important	100	100
4.9.12	Time space diagrams	1	Important	100	100
4.9.13	Maintenance activity	1	Important	100	100
4.9.14	Other	0	Important	100	0
4.10	With who are those reports shared?				
4.10.1	Limited group inside the agency	1	Important	50	50
4.10.2	All agency personnel	1	Important	100	100
4.10.3	Public	0	Important	100	0
4.10.4	Universities	1	Important	100	100
4.10.5	Research institutes	1	Important	100	100
4.10.6	Agencies at the same state	1	Important	100	100
4.10.7	Agencies in other states	0	Important	100	0
4.10.8	Other	0	Important	100	0
4.11	Select the technologies used to collect vehicle travel times:				
4.11.1	Field runs - manually with probe vehicle	0		20	0
4.11.2	Field runs - with GPS	1	Important	100	100
4.11.3	Video cameras with ALPR (Automatic license plate recognition)	0	Important	100	0
4.11.4	Tag readers (E-Z Pass)	0	Important	100	0
4.11.5	Bluetooth/Wi-Fi (MAC address matching)	1	Important	100	100
4.11.6	Other	0	Important	100	0
4.11.7	Travel time not collected	0	Important	0	0
				Partial grade 2:	**1750.00**
				Data collection and storage subsection weight factor:	**1.00**
				Weighted Partial grade TMDC 2:	**1750.00**
				Normalized Partial grade TMDC 2:	**70.85**

New min	New max
0	100
Old min	**Old max**
0	2470
Old value	**New value**
1750.00	70.850202

Figure A-11 Traffic Monitoring and Data Collection section (Palm Beach County) - Part 2

	Data quality	0 or 1/Value	Importance	Importance factor	
4.12	Are the collected data checked for quality, consistency and correctness?	1	Important	100	100
4.13	What is the resolution of collected data regarding travel times?				
4.13.1	Every minute	0	Important	100	0
4.13.2	15 min	1	Important	80	80
4.13.3	30 min	0	Important	60	0
4.13.4	1h	0	Important	40	0
4.13.5	Daily	0	Important	20	0
4.13.6	As needed	0	Important	10	0
4.14	What is the resolution of collected data regarding vehicle delay?				
4.14.1	Every minute	0	Important	100	0
4.14.2	15 min	0	Important	80	0
4.14.3	30 min	0	Important	60	0
4.14.4	1h	0	Important	40	0
4.14.5	Daily	0	Important	20	0
4.14.6	Not collecting	1	Important	0	0
4.15	What is the resolution of collected data regarding actual signal timings?				
4.15.1	Every second	0	Important	100	0
4.15.2	Every minute	1	Important	85	85
4.15.3	15 min	0	Important	70	0
4.15.4	30 min	0	Important	55	0
4.15.5	1h	0	Important	40	0
4.15.6	Daily	0	Important	25	0
4.15.7	As needed	0	Important	10	0
		Partial grade 3:			**265.00**
		Data quality subsection weight factor:			**1.00**
		Weighted Partial grade TMDC 3:			**265.00**
		Normalized Partial grade TMDC 3:			**64.47**

New min	New max
0	100
Old min	**Old max**
20	400
Old value	**New value**
265.00	64.473684

	Weather and turning movements	0 or 1/Value	Importance	Importance factor	
4.16	Number of weather stations located on the territory under agency's jurisdiction	0	Important	100	0
4.17	On how many locations, turning movement counts are being collected?	1047	Important	100	100
4.18	When are turning movement counts collected?				
4.18.1	Each year	1	Important	100	100
4.18.2	When signals are retimed	0		20	0
		Partial grade 4:			**200.00**
		Weather and turning movements subsection weight factor:			**1.00**
		Weighted Partial grade TMDC 4:			**200.00**
		Normalized Partial grade TMDC 4:			**59.46**

New min	New max
0	100
Old min	**Old max**
0	336.36
Old value	**New value**
200.00	59.460102

Figure A-12 Traffic Monitoring and Data Collection section (Palm Beach County) - Part 3

MAI	Maintenance

	Strategy	0 or 1	Importance	Importance factor	
5.1	Do maintenance agreements require performance monitoring and report?	1	Important	100	100
5.2	Does agency use performance measures to evaluate its signal system maintenance?	1	Important	100	100
				Partial grade 1:	**200.00**
				Strategy subsection weight factor:	**1.00**
				Weighted Partial grade MAI 1:	**200.00**
				Normalized Partial grade MAI 1:	**100.00**

New min	New max
0	100
Old min	**Old max**
0	200
Old value	**New value**
200.00	100

Figure A-13 Maintenance section (Palm Beach County) - Part 1

	Equipment	0 or 1/Value	Importance	Importance factor	
5.3	Number of detectors out of function per year	600	Important		
5.4	Duration of detectors failure per year	YES*		100	#VALUE!
5.5	Are adjustment made to reflect changes required due to the characteristics of the new equipment?	1	Important	100	100
5.6	How often do you check alignment and position of all signal heads and signs?				
5.6.1	Monthly	0	Important	100	0
5.6.2	Semi annual	1	Important	70	70
5.6.3	Annual	0	Important	40	0
5.6.4	Bi annual	0	Important	10	0
5.7	How often do you check operability of signal controllers?				
5.7.1	Continuously	0	Important	100	0
5.7.2	Daily	1	Important	90	90
5.7.3	Weekly	0	Important	70	0
5.7.4	Monthly	0	Important	50	0
5.7.5	Semi annual	0	Important	30	0
5.7.6	Annual	0	Important	10	0
5.8	How often do you check operability of communication infrastructure?				
5.8.1	Continuously	0	Important	100	0
5.8.2	Daily	1	Important	90	90
5.8.3	Weekly	0	Important	70	0
5.8.4	Monthly	0	Important	50	0
5.8.5	Semi annual	0	Important	30	0
5.8.6	Annual	0	Important	10	0

Figure A-14 Maintenance section (Palm Beach County) - Part 2

5.9	How often do you check operability of Signal System Central Software				
5.9.1	Continuously	1	Important	100	100
5.9.2	Daily	0	Important	90	0
5.9.3	Weekly	0	Important	70	0
5.9.4	Monthly	0	Important	50	0
5.9.5	Semi annual	0	Important	30	0
5.9.6	Annual	0	Important	10	0
5.10	How often do you check operability of signal heads?				
5.10.1	Continuously	0	Important	100	0
5.10.2	Daily	0	Important	90	0
5.10.3	Weekly	0	Important	70	0
5.10.4	Monthly	0	Important	50	0
5.10.5	Semi annual	1	Important	30	30
5.10.6	Annual	0	Important	10	0
5.11	How often do you implement methods for synchronizing controllers' clocks?				
5.11.1	Hourly	0	Important	100	0
5.11.2	Daily	1	Important	70	70
5.11.3	Weekly	0	Important	40	0
5.11.4	Monthly	0	Important	10	0
5.12	Total cost of all reparations per year	NA	Important	100	#VALUE!
5.13	Number of all malfunctions per year	12000			
5.14	Number of changed lightbulbs	2000	Important	100	#VALUE!
5.15	Total number of lightbulbs	NA			
				Partial grade 2:	550.00
				Equipment subsection weight factor:	1.00
				Weighted Partial grade MAI 2:	550.00
				Normalized Partial grade MAI 2:	56.80

New min	New max
0	100
Old min	**Old max**
50.04	930.31
Old value	**New value**
550.00	56.79621025

Figure A-15 Maintenance section (Palm Beach County) - Part 2

	Reaction time	0 or 1/Value	Importance	Importance factor	
5.16	What is the average response time (time from problem occurrence to beginning of solving) to critical failures (e.g. controller malfunction, communications failure, physical damage of equipment on site…)				
5.16.1	< 1 hour	0	Important	100	0
5.16.2	< half a day	1	Important	90	90
5.16.3	< a day	0	Important	70	0
5.16.4	< 3 day	0	Important	50	0
5.16.5	< one week	0	Important	30	0
5.16.6	> one week	0	Important	10	0
5.17	What is the average time to complete the intervention (time to resolving the problem) to critical failures (e.g. controller malfunction, communications failure, physical damage or equipment on site…)				
5.17.1	< 1 hour	0	Important	100	0
5.17.2	< half a day	0	Important	90	0
5.17.3	< a day	0	Important	70	0
5.17.4	< 3 day	1	Important	50	50
5.17.5	< one week	0	Important	30	0
5.17.6	> one week	0	Important	10	0
5.18	What is the average response time to all reported failures?				
5.18.1	< 1 hour	0	Important	100	0
5.18.2	< half a day	0	Important	90	0
5.18.3	< a day	0	Important	70	0
5.18.4	< 3 day	0	Important	50	0
5.18.5	< one week	0	Important	30	0
5.18.6	> one week	1	Important	10	10
5.19	What is average response time regarding user complaints?				
5.19.1	< 1 hour	0	Important	100	0
5.19.2	< half a day	0	Important	90	0
5.19.3	< a day	1	Important	70	70
5.19.4	< 3 day	0	Important	50	0
5.19.5	< one week	0	Important	30	0
5.19.6	> one week	0	Important	10	0
				Partial grade 3:	**220.00**
				Reaction time subsection weight factor:	**1.00**
				Weighted Partial grade MAI 3:	**220.00**
				Normalized Partial grade MAI 3:	**50.00**

New min	New max
0	100
Old min	**Old max**
40	400
Old value	**New value**
220.00	50

Figure A-16 Maintenance section (Palm Beach County) - Part 3

	Inventory and reporting	0 or 1/Value	Importance	Importance factor	
5.20	Does the inventory include a record of maintenance activity?	1	Important	100	100
5.21	Select the maintenance reports that are being made in your agency about the following:				
5.21.1	Communication failures	1	Important	100	100
5.21.2	Vehicle detector failures	1	Important	100	100
5.21.3	Pedestrian detector failures	1	Important	100	100
5.21.4	UPS device failures	0	Important	100	0
5.21.5	Controller device failures	1	Important	100	100
5.21.6	Signal system central software	1	Important	100	100
5.21.7	Signal system central hardware	1	Important	100	100
5.22	How frequent the maintenance reports are being made in your agency?				
5.22.1	Hourly	0	Important	100	0
5.22.2	Daily	1	Important	90	90
5.22.3	Weekly	0	Important	70	0
5.22.4	Monthly	0	Important	50	0
5.22.5	Annually	0	Important	30	0
5.22.6	Never	0	Important	10	0
5.23	Does your agency keep record of the following specifics of each maintenance taks and work order about:				
5.23.1	Locations (where was maintenance performed)	1	Important	100	100
5.23.2	Equipment (hardware and software which was affected by work order)	0	Important	100	0
5.23.3	Type of work defined by work order	1	Important	100	100
5.23.4	Type of work not defined by work order	1	Important	100	100
5.23.5	Duration of work	0	Important	100	0
5.23.6	Used parts for reparations	0	Important	100	0
5.23.7	Number of workers active on that specific reparation	0	Important	100	0
				Partial grade 4:	**318.57**
				Inventory and reporting weight factor:	**1.00**
				Weighted Partial grade MAI 4:	**318.57**
				Normalized Partial grade MAI 4:	**79.12**

New min	New max
0	100
Old min	**Old max**
10	400
Old value	**New value**
318.57	79.12087912

Figure A-17 Maintenance section (Palm Beach County) - Part 4

	Signal System Central Software	0 or 1/Value	Importance	Importance factor	
5.24	Duration of coordination failure	YES*	Important	100	#VALUE!
5.25	Total time while signals should be coordinated	YES*			
5.26	Time while communications errors were present (per year)	YES*	Important	100	#VALUE!
5.27	Number of vehicle detector malfunctions	YES*	Important	100	#VALUE!
5.28	Number of pedestrian detector malfunctions	YES*	Important	100	#VALUE!
5.29	Total number of pedestrian detectors	NA			
5.30	Duration of all reparations made by average maintenance crew per year	NA	Important	100	#VALUE!
5.31	Total duration of routine and non-routine reparations	NA	Important	100	#VALUE!
5.32	Number of routine and non-routine reparations	NA	Important	100	#VALUE!
5.33	Average duration of routine and non-routine reparations	#VALUE!	Important	100	#VALUE!
				Partial grade 5:	**#VALUE!**
				SSCS subsection weight factor:	**1.00**
				Weighted Partial grade MAI 5:	**#VALUE!**
				Normalized Partial grade MAI 5:	**#VALUE!**

New min	New max
0	100
Old min	**Old max**
na	na
Old value	**New value**
#VALUE!	#VALUE!

Figure A-18 Maintenance section (Palm Beach County) – Part 5

Section	Partial grade num	Partial Grade subsection	Normalized Grade Value	Evaluation confidence (%)	Grade Value Per Section	Weight factors	Weighted Grade per Section	Level of Service	Evaluation confidence (%)	Final Grade	Level of Service	Evaluation confidence (%)
Management	1	Staff Training	0.0	0	57.4	1.0	57.4	C	91.7	66.8	B	67.4
	2	Monitoring	57.1	100								
	3	User satisfaction	70.4	100								
	4	Public relations	32.5	100								
	5	Cooperation with neighboring agencies	100.0	50								
	6	Safety and accidents	26.8	100								
	7	Inventory	100.0	100								
	8	Vehicles for interventions	14.1	100								
	9	SSCS	58.2	100								
Traffic Signal Operations	1	General	49.5	100	49.5	1.0	49.5	D	50.0			
	2	SSCS	0.0	0								
Signal Timing Practices	1	General	93.8	67	93.8	1.0	93.8	A	33.3			
	2	SSCS	0.0	0								
Traffic Monitoring and Data Collection	1	Detection	53.3	80	62.0	1.0	62.0	C	86.7			
	2	Data Collection and Storage	70.9	100								
	3	Data Quality	64.5	100								
	4	Weather and turning movements	59.5	67								
Maintenance	1	Strategy	100.0	100	71.5	1.0	71.5	B	75.6			
	2	Maintenance of equipment	56.8	78								
	3	Reaction time	50.0	100								
	4	Inventory and reporting	79.1	100								
	5	SSCS	0.0	0								

Legend

(green cell) The cells where weight factors for sections can be changed.

Figure A-19 Grading (Palm Beach County)

NTSRC Grades						
Num.	Section	Sectional Score	Weighting factor	Result	Evaluation Confidence (%)	Grade of Service
1	Management	57.4	1	57.4	91.7	C
2	Traffic Signal Operation	49.5	1	49.5	50.0	D
3	Signal Timing Practices	93.8	1	93.8	33.3	A
4	Traffic Monitoring and Data Collection	62.0	1	62.0	86.7	C
5	Maintenance	71.5	1	71.5	75.6	B
			Total:	**66.8**	**67.4**	**B**

Figure A-20 Summarized grades (Palm Beach County)

Signal System Facts

Contact Information

Agency	Palm Beach County
Contact Person	Giri Jeediginta, PE, PTOE
Email Address	gjeedigu@pbcgov.org

Grading

Overall Grade	B
Overall Score	66.8
Evaluation confidence	67.4%

General Information

Population	1,422,789
Annual Funding for Signal O&M	NA
Annual Capital Investments	NA

Operational Information

FTEs	31
Signalized Intersections	1047
Coordinated Signals	639
Frequency of Signal Retiming	Less than 1 year
Central Signal System	ATMS.now
Malfunctions per year	12,000
Annual Reparation Cost	NA
Response Time	72h

Figure A-21 Signal System Facts Card (Palm Beach County)

Appendix B: The City of Boca Raton Annual Evaluation Spreadsheet

Contact and General Information			
Contact Information			
0.1	Name	Rasem Awwad/Tracy Phelps	
0.2	Title	Traffic Ops Eng/Transportation Eng	
0.3	Agency	City of Boca Raton	
0.4	Address	201 W. Palmetto Park Rd	
0.5	City/Town	Boca Raton	
0.6	State/County	Palm Beach County , Florida	
0.7	Zip code	33432	
0.8	Telephone contact	561-416-3387	
0.9	Email address	rawwad@myboca.us	
General Information			
0.10	County/City population	91,000	www.census.gov
0.11	Number of registered vehicles	72,600	www.flhsmv.gov
0.12	Number of neighboring signal control agencies	2	
0.13	Number of streets with shared signal jurisdiction	2	
0.14	Total length of road network by the jurisdiction (miles)	220	http://www.dot.state.fl.us/planning/statistics/gis/road.shtm
0.15	Estimated annual funding for signal operations and management	150,000	
0.16	Estimated annual funding for signal related capital investments	80,000	
Signal System Central Software			
0.17	Number of signalized intersections	136	

Figure B-1 Contact and General Information section (Boca Raton)

MAN	Management

1.1	Number and expertise of in-house staff	Numbers of FTEs	Importance	Importance factor	Total equivalent weighted number of regular staff
1.1.1	Managers	0.0	Important	100	0
1.1.2	Engineers	2.0	Important	100	200
1.1.3	Technicians	6.0	Important	100	600
1.1.4	Administrative staff	2.0	Important	100	200
1.1.5	Other	0.0	Important	100	0
1.2	**Number and expertise of outsourced staff**	**Numbers of FTEs**	**Importance**	**Importance factor**	**Total equivalent weighted number of outsourced staff**
1.2.1	Managers	0.0	Important	100	0
1.2.2	Engineers	0.0	Important	100	0
1.2.3	Technicians	0.0	Important	100	0
1.2.4	Administrative staff	0.0	Important	100	0
1.2.5	Other	0.0	Important	100	0
				Total equivalent number of staff:	**10.00**

1.3	Staff training	Numbers of training hours in one year (hours x persons)	Importance	Importance factor	
1.3.1	Basic signal timing	0	Important	100	0
1.3.2	Advanced signal timing	32	Important	100	320
1.3.3	ITS courses	64	Important	100	640
1.3.4	Hardware and communications	64	Important	100	640
1.3.5	Other	16	Important	100	160
				Partial grade 1:	**1.76**
				Staff training weight factor:	**1.00**
				Weighted Partial grade MAN 1:	**1.76**
				Normalized Partial grade MAN 1:	**50.00**

New min	New max
0	100
Old min	**Old max**
0	3.52
Old value	**New value**
1.76	50

1.4	Monitoring	
1.4.1	Number of staff designated to monitoring	1
1.4.2	Number of hours in one week they are designated for monitoring	10
1.4.3	Total number of engineering and technician staff (regular and outsourced)	8
1.4.4	Average number of work hours per week (for the persons from questions 1.4.1 and 1.4.2)	40
	Partial grade 2:	**0.31**
	Monitoring weight factor:	**1.00**
	Weighted Partial grade MAN 2:	**0.31**
	Normalized Partial grade MAN 2:	**33.33**

New min	New max
0	100
Old min	**Old max**
0	0.9375
Old value	**New value**
0.31	33.333333

Figure B-2 Management section (Boca Raton) - Part 1

1.5	User satisfaction	Value	Importance	Importance factor	
1.5.1	Number of complaints per year	248	Important	100	0.0017
1.5.2	Is there a publicized call-in telephone number and web site that the public can use to report malfunctions, ask questions and suggest operational improvements?	1	Important	100	1
				Partial grade 3:	1.00
				User satisfaction weight factor:	1.00
				Weighted Partial grade MAN 3:	1.00
				Normalized Partial grade MAN 3:	70.54

New min	New max
0	100
Old min	**Old max**
0	1.42
Old value	**New value**
1.00	70.542535

1.6	Average time from receiving of memo or call until answering	Choose Value	Importance	Importance factor	
1.6.1	24h	0	Important	100	0
1.6.2	48h	1	Important	80	80
1.6.3	72h	0	Important	60	0
1.6.4	7 days	0	Important	40	0
1.6.5	10 days	0	Important	20	0
1.6.6	More than 10 days	0	Important	0	0
1.7	**Information available to public**	**0 or 1**	**Importance**	**Importance factor**	
1.7.1	Traffic lights failures	0	Important	100	0
1.7.2	Congestion	0	Important	100	0
1.7.3	Incidents on signalized intersections	0	Important	100	0
1.7.4	Lane closures at signalized intersections	1	Important	100	100
1.7.5	Reaction time for reparations of traffic signals	0	Important	100	0
1.7.6	Frequency of malfunctions	0	Important	100	0
1.7.7	Goals	0	Important	100	0
1.8	**Means of communication with the public**	**0 or 1**	**Importance**	**Importance factor**	
1.8.1	PR person	1	Important	100	100
1.8.2	Head of department	1	Important	100	100
1.8.3	Memos or letters	1	Important	100	100
1.8.4	Television	0	Important	100	0
1.8.5	Radio	0	Important	100	0
1.8.6	Web site	1	Important	100	100
1.8.7	Telephone	1	Important	100	100
				Partial grade 4:	1.66
				Public relations weight factor:	1.00
				Weighted Partial grade MAN 4:	1.66
				Normalized Partial grade MAN 4:	50.45

New min	New max
0	100
Old min	**Old max**
0.29	3
Old value	**New value**
1.66	50.448076

Figure B-3 Management section (Boca Raton) - Part 2

1.9	Cooperation with neighboring signal control agencies	Value	Importance	Importance factor	
1.9.1	Number of neighboring county agencies with whom the information and data are being exchanged	1	Important	100	50
1.9.2	Number of streets with signals being shared with the neighboring agencies that are inter-coordinated	0	Important	100	0
				Partial grade 5:	**25.00**
				Cooperation weight factor:	**1.00**
				Weighted Partial grade MAN 5:	**25.00**
				Normalized Partial grade MAN 5:	**25.00**

New min	New max
0	100
Old min	**Old max**
0	100
Old value	**New value**
25.00	25

1.10	Safety and accidents	Value	Importance	Importance factor	
1.10.1	Number of accidents on streets close to traffic signals	2960	Important	100	104.94
1.10.1	Number of accidents involving the running of red lights	91	Important	100	1.35
				Partial grade 6:	106.29
				Safety and accidents weight factor	1.00
				Weighted Partial grade MAN 6:	**106.29**
				Normalized Partial grade MAN 6:	**51.91**

New min	New max
0	100
Old min	**Old max**
72.9	137.22
Old value	**New value**
106.29	51.906106

1.11	Inventory - up to date inventory about all signal equipment including spares	0 or 1	Importance	Importance factor	
1.11.1	Is there an up-to date inventory about all signal equipment including spares?	1	Important	100	
				Weighted Partial grade MAN 7:	**100.00**
				Normalized Partial Grade MAN 7:	**100.00**

New min	New max
0	100
Old min	**Old max**
0	100
Old value	**New value**
100.00	100

1.12	Service vehicles number and activation	Value	Importance	Importance factor	
1.12.1	Number of vehicles in operation by shift	6	Important	100	4.41
1.12.2	Miles travelled per vehicle (in thousands)		Important	100	0.77
1.12.3	The vehicle coverage ratio	[redacted]	Important	100	2.73
				Partial grade 8:	**3.95**
				Service vehicles number weight factor:	**1.00**
				Weighted Partial grade MAN 8:	**3.95**
				Normalized Partial grade MAN 8:	**45.00**

New min	New max
0	100
Old min	**Old max**
0.57	8.09
Old value	**New value**
3.95	45.001783

Figure B-4 Management section (Boca Raton) - Part 3

1.13	Signal System Central Software (SSCS) - ATMS.now	0 or 1/Value	Importance	Importance factor	
1.13.1	Does the agency has Signa lSystem Central Software	1	Important	100	100
1.13.2	How many intersections are connected to SSCS?	136	Important	100	100
1.14	**Type of Signal System Central Software**	**0 or 1**			
1.14.1	ACTRA	0			
1.14.2	ATMS.now	1			
1.14.3	Centracs	0			
1.14.4	KITS	0			
1.14.5	MIST	0			
1.14.6	QuicNet	0			
1.14.7	Sitraffic Concert	0			
1.14.8	Sitraffic Tactics	0			
1.14.9	Other	0			
1.15	**Functionality of Signal System Central Software**	**0 or 1/Value**	**Importance**	**Importance factor**	
1.15.1	Video monitoring	1	Important	100	100
1.15.2	Functionality monitoring	1	Important	100	100
1.15.3	Signal plans changing	1	Important	100	100
1.15.4	Special events management	1	Important	100	100
1.15.5	Corridor management/traffic signal coordination or control	1	Important	100	100
1.15.6	Disaster management and traffic coordination	1	Important	100	100
1.15.7	Emergency services traffic control coordination	1	Important	100	100
1.15.8	Ramp management and control	0	Important	100	0
1.15.9	Network performance monitoring, evaluation and reporting	1	Important	100	100
1.16	Number of staff that actively use SSCS software	2	Important	100	147
1.17	Does the agency has set the alarms for malfunctions that inform persons in charge?	1	Important	100	100
1.18	**Select the existing mediums that are used for informing persons in charge about events causing alarms**	**0 or 1**	**Importance**	**Importance factor**	
1.18.1	On Signal System Central Software interface	1	Important	100	100
1.18.2	SMS message	0	Important	100	0
1.18.3	E-mail	1	Important	100	100
1.18.4	Pager	0	Important	100	0
				Partial grade 9:	**2247.06**
				SSCS weight factor:	**1.00**
				Weighted Partial grade MAN 9:	**2247.06**
				Normalized Partial grade MAN 9:	**65.52**

New min	New max
0	100
Old min	**Old max**
0	3429.41
Old value	**New value**
2247.06	65.52319

Figure B-5 Management section (Boca Raton) - Part 4

TSO	Traffic Signal Operations

2	General	0 or 1/Value	Importance	Importance factor	
2.1	Do you use traffic responsive or traffic adaptive control?	1	Important	100	100
2.2	Are field reviews of signal operations performed annually?	1	Important	100	100
2.3	Are ad hoc changes triggered by complaint calls performed for all legitimate requests?	1	Important	100	100
2.4	Are sights distances to intersections reviewed for all new traffic signal installations?	1	Important	100	100
2.5	Are advanced warning indications installed where limited site distances exist?	1	Important	100	100
2.6	Number of signalized intersections adjusted for visually impaired persons.	13	Important	100	9.558823529
2.7	Actual time to implements, evaluate and calibrate the new timing settings or strategy (in weeks)	4	Important	100	
2.8	Expected time to implement, evaluate and calibrate the new timing settings or strategy (in weeks)	4	Important	100	100
2.9	What is the frequency of signal retiming in your agency?				
2.9.1	Less than 1 year	1	Important	100	100
2.9.2	1-2 years	0	Important	75	0
2.9.3	2-3 years	0	Important	50	0
2.9.4	3-5 years	0	Important	25	0
2.9.5	More than 5 years	0	Important	0	0
2.10	Number of coordinated traffic signals	103	Important	100	75.73529412
		Partial grade 1:			**785.29**
		General subsection weight factor:			**1.00**
		Weighted Partial grade TSO 1:			**785.29**
		Normalized Partial grade TSO 1:			**63.94**

New min	New max
0	100
Old min	**Old max**
50	1200
Old value	**New value**
785.29	63.938619

Figure B-6 Traffic signal operations section (Boca Raton) - Part 1

	Signal System Central Software - ATMS.now	Value	Importance	Importance factor	
2.11	Number of special events, disasters, VIP routes and emergency signal timings	48			
2.12	Total number of signal timings	589	Important	100	8.149405772
2.13	Number of school zone manual flash signals	39			
2.14	Number of schools	17	Important	100	229.4117647
2.15	Number of intersections with preemption capability	64	Important	100	47.05882353
2.16	Number of intersections with Public transit prioritization capability	0			
2.17	Total number of signalized intersections along PT routes.	1	Important	100	0
2.18	Average number of hours per day when adaptive system is active	12	Important	100	50
2.19	Number of hours with congestion (per day, week, month)	8			
2.20	Total number of hours per observed period (in day, in week, in month...)	24	Important	100	0.520833333
2.21	Number of cycle failures	NA			
2.22	Total number of cycles per observed period	NA	Important	100	#VALUE!
2.23	Number of cycle faults (AM, PM, Midday, Night)	NA	Important	100	#VALUE!
2.24	Time that coordination has been in transition	NA			
2.25	Time the coordination is active	15	Important	100	#VALUE!
2.26	Coordination failure	NA	Important	100	#VALUE!
				Partial grade 2:	**326.99**
				SSCS subsection weight factor:	**1.00**
				Weighted Partial grade TSO 2:	**326.99**
				Normalized Partial grade TSO 2:	**38.77**

New min	New max
0	100
Old min	**Old max**
41.67	777.67
Old value	**New value**
326.99	38.766497

Figure B-7 Traffic signal operations section (Boca Raton) - Part 2

STP	Signal Timing Practices				
3	General	0 or 1/Value	Importance	Importance factor	
3.1	Are records of conflict situations used to identify signalized intersections at which safety could be improved by revised signal operations (protected turns...)	0	Important	100	0
3.2	Select the performance measures that agency collects				
3.2.1	Number of vehicles served	0	Important	100	0
3.2.2	Delay per vehicle	1	Important	100	100
3.2.3	Total delay	1	Important	100	100
3.2.4	v/c	0	Important	100	0
3.2.5	Travel time	1	Important	100	100
3.2.6	Number of stops	1	Important	100	100
3.2.7	Other	0	Important	100	0
3.3	Do you use signal timing optimization software (Synchro, PASSER, TRANSYT, etc) to develop new signal timings?	1	Important	100	100
3.4	What parameters do you use to develop new signal timings?				
3.4.1	Cycle lenghts	1	Important	100	100
3.4.2	Offsets	1	Important	100	100
3.4.3	Splits	1	Important	100	100
3.4.4	Phasing sequence	1	Important	100	100
3.4.5	Discharge time	0	Important	100	0
3.4.6	Two-way progression	0	Important	100	0
3.4.7	Turning movements	0	Important	100	0
3.4.8	Time space diagrams	1	Important	100	100
3.4.9	Other	0	Important	100	0
				Partial grade 1:	**1000.00**
				General subsection weight factor:	**1.00**
				Weighted Partial grade STP 1:	**1000.00**
				Normalized Partial grade STP 1:	**62.50**

New min	New max
0	100
Old min	**Old max**
0	1600
Old value	**New value**
1000.00	62.5

Figure B-8 Signal timing practices section (Boca Raton) - Part 1

	ATMS.now	0 or 1/Value	Importance	Importance factor	
3.5	Average duration of splits per AM, Midday and PM period				
	AM				
	Midday				#DIV/0!
	PM				
3.6	Duration of programmed splits				#DIV/0!
	AM				
	Midday				
	PM		Important	100	#DIV/0!
3.7	The number of times a phase was activated in a given evaluation period				
3.8	Maximum number of times that phase could be activated		Important	100	#DIV/0!
				Partial grade 2:	**#DIV/0!**
				SSCS subsection weight factor:	
				Weighted Partial grade STP 2:	**#DIV/0!**
				Normalized Partial grade STP 2:	**#DIV/0!**

New min	New max
0	100
Old min	**Old max**
Old value	**New value**
#DIV/0!	#DIV/0!

Figure B-9 Signal timing practices section (Boca Raton) - Part 2

TMDC	Traffic Monitoring and Data Collection				
4	**Detection**	**0 or 1/Value**	**Importance**	**Importance factor**	
4.1	Total number of detectors	1167	Important	100	530.45
4.2	Detection distribution by type:				
4.2.1	Inductive loop	928	Important	100	
4.2.2	Video	239	Important	100	
4.2.3	Microwave	0	Important	100	
4.2.4	Infrared	0	Important	100	
4.3	Choose system detectors that are being used in your agency:				
4.3.1	Midblock	0	Important	100	0
4.3.2	Near upstream intersections	0	Important	100	0
4.4	What data do those system detectors collect?				
4.4.1	Speed	0	Important	100	0
4.4.2	Volume	0	Important	100	0
4.4.3	Occupancy	0	Important	100	0
4.4.4	Progression speed	0	Important	100	0
4.5	Does your agency use queue detectors?	0	Important	100	0
4.6	If video detectors are used, is their operation calibrated for:				
4.6.1	Lighting	1	Important	100	100
4.6.2	Weather	1	Important	100	100
4.6.3	Wind	1	Important	100	100
4.6.4	Occlusion	1	Important	100	100
4.6.5	Lense cleaning	1	Important	100	100
4.6.6	Zone adjustments	1	Important	100	100
4.7	How often video detectors are being calibrated?				
4.7.1	More often than once per month	0	Important	100	0
4.7.2	Every month	0	Important	80	0
4.7.3	Every three months	1	Important	60	60
4.7.4	Every six months	0	Important	40	0
4.7.5	Once per year	0	Important	20	0
4.7.6	Less often than once per year	0	Important	5	0
				Partial grade 1:	**1190.45**
				Detection subsection weight factor:	**1.00**
				Weighted Partial grade TMDC 1:	**1190.45**
				Normalized Partial grade TMDC 1:	**47.82**

New min	New max
0	100
Old min	**Old max**
6.82	2481.82
Old value	**New value**
1190.45	47.823618

Figure B-10 Traffic monitoring and data collection section (Boca Raton) - Part 1

	Data collection and storage	0 or 1	Importance	Importance factor	
4.8	Choose the used archiving methods for the data:				
4.8.1	Paper copy database	1	Important	10	10
4.8.2	Electronic database	1	Important	60	60
4.8.3	GIS	1	Important	30	30
4.8.5	Not at all	0	Important	0	0
4.9	Select the data types that are saved in the signal inventory system (database):				
4.9.1	Volume	0	Important	100	0
4.9.2	Occupancy	0	Important	100	0
4.9.3	Travel time	1	Important	100	100
4.9.4	Queue lengths	0	Important	100	0
4.9.5	Work zones	0	Important	100	0
4.9.6	Events	1	Important	100	100
4.9.7	Weather	1	Important	100	100
4.9.8	Location	1	Important	100	100
4.9.9	Hardware	1	Important	100	100
4.9.10	Controller	1	Important	100	100
4.9.11	Timing plans	1	Important	100	100
4.9.12	Time space diagrams	1	Important	100	100
4.9.13	Maintenance activity	1	Important	100	100
4.9.14	Other	0	Important	100	0
4.10	With who are those reports shared?				
4.10.1	Limited group inside the agency	1	Important	50	50
4.10.2	All agency personnel	1	Important	100	100
4.10.3	Public	0	Important	100	0
4.10.4	Universities	1	Important	100	100
4.10.5	Research institutes	1	Important	100	100
4.10.6	Agencies at the same state	0	Important	100	0
4.10.7	Agencies in other states	0	Important	100	0
4.10.8	Other	0	Important	100	0
4.11	Select the technologies used to collect vehicle travel times:				
4.11.1	Field runs - manually with probe vehicle	0		20	0
4.11.2	Field runs - with GPS	1	Important	100	100
4.11.3	Video cameras with ALPR (Automatic license plate recognition)	0	Important	100	0
4.11.4	Tag readers (E-Z Pass)	0	Important	100	0
4.11.5	Bluetooth/Wi-Fi (MAC address matching)	1	Important	100	100
4.11.6	Other	0	Important	100	0
4.11.7	Travel time not collected	0	Important	0	0
				Partial grade 2:	**1550.00**
				Data collection and storage subsection weight factor:	**1.00**
				Weighted Partial grade TMDC 2:	**1550.00**
				Normalized Partial grade TMDC 2:	**62.75**

New min	New max
0	100
Old min	**Old max**
0	2470
Old value	**New value**
1550.00	62.753036

Figure B-11 Traffic monitoring and data collection section (Boca Raton) - Part 2

	Data quality	0 or 1/Value	Importance	Importance factor	
4.12	Are the collected data checked for quality, consistency and correctness?	1	Important	100	100
4.13	What is the resolution of collected data regarding travel times?				
4.13.1	Every minute	0	Important	100	0
4.13.2	15 min	0	Important	80	0
4.13.3	30 min	0	Important	60	0
4.13.4	1h	0	Important	40	0
4.13.5	Daily	0	Important	20	0
4.13.6	As needed	1	Important	10	10
4.14	What is the resolution of collected data regarding vehicle delay?				
4.14.1	Every minute	0	Important	100	0
4.14.2	15 min	0	Important	80	0
4.14.3	30 min	0	Important	60	0
4.14.4	1h	0	Important	40	0
4.14.5	Daily	0	Important	20	0
4.14.6	Not collecting	0	Important	0	0
4.15	What is the resolution of collected data regarding actual signal timings?				
4.15.1	Every second	1	Important	100	100
4.15.2	Every minute	0	Important	85	0
4.15.3	15 min	0	Important	70	0
4.15.4	30 min	0	Important	55	0
4.15.5	1h	0	Important	40	0
4.15.6	Daily	0	Important	25	0
4.15.7	As needed	0	Important	10	0
				Partial grade 3:	**210.00**
				Data quality subsection weight factor:	**1.00**
				Weighted Partial grade TMDC 3:	**210.00**
				Normalized Partial grade TMDC 3:	**50.00**

New min	New max
0	100
Old min	**Old max**
20	400
Old value	**New value**
210.00	50

Figure B-12 Traffic monitoring and data collection section (Boca Raton) - Part 3

	Weather and turning movements	0 or 1/Value	Importance	Importance factor	
4.16	Number of weather stations located on the territory under agency's jurisdiction	0	Important	100	0
4.17	On how many locations, turning movement counts are being collected?	127	Important	100	93.38235294
4.18	When are turning movement counts collected?				
4.18.1	Each year	0	Important	100	0
4.18.2	When signals are retimed	1		20	20
				Partial grade 4:	**113.38**
				Weather and Turning movements subsection weight factor:	**1.00**
				Weighted Partial grade TMDC 4:	**113.38**
				Normalized Partial grade TMDC 4:	**33.71**

New min	New max
0	100
Old min	**Old max**
0	336.36
Old value	**New value**
113.38	33.708632

Figure B-13 Traffic monitoring and data collection section (Boca Raton) - Part 4

MAI	Maintenance				
	Strategy	0 or 1	Importance	Importance factor	
5.1	Do maintenance agreements require performance monitoring and report?	1	Important	100	100
5.2	Does agency use performance measures to evaluate its signal system maintenance?	1	Important	100	100
				Partial grade 1:	**200.00**
				Strategy subsection weight factor:	**1.00**
				Weighted Partial grade MAI 1:	**200.00**
				Normalized Partial grade MAI 1:	**100.00**

New min	New max
0	100
Old min	**Old max**
0	200
Old value	**New value**
200.00	100

Figure B-14 Maintenance section (Boca Raton) - Part 1

	Equipment	0 or 1/Value	Importance	Importance factor	
5.3	Number of detectors out of function per year		Important		
5.4	Duration of detectors failure per year			100	#DIV/0!
5.5	Are adjustment made to reflect changes required due to the characteristics of the new equipment?	1	Important	100	100
5.6	How often do you check alignment and position of all signal heads and signs?				
5.6.1	Monthly	0	Important	100	0
5.6.2	Semi annual	0	Important	70	0
5.6.3	Annual	1	Important	40	40
5.6.4	Bi annual	0	Important	10	0
5.7	How often do you check operability of signal controllers?				
5.7.1	Continuously	0	Important	100	0
5.7.2	Daily	1	Important	90	90
5.7.3	Weekly	0	Important	70	0
5.7.4	Monthly	0	Important	50	0
5.7.5	Semi annual	0	Important	30	0
5.7.6	Annual	0	Important	10	0
5.8	How often do you check operability of communication infrastructure?				
5.8.1	Continuously	0	Important	100	0
5.8.2	Daily	1	Important	90	90
5.8.3	Weekly	0	Important	70	0
5.8.4	Monthly	0	Important	50	0
5.8.5	Semi annual	0	Important	30	0
5.8.6	Annual	0	Important	10	0

Figure B-15 Maintenance section (Boca Raton) - Part 2

5.9	How often do you check operability of Signal System Central Software				
5.9.1	Continuously	0	Important	100	0
5.9.2	Daily	1	Important	90	90
5.9.3	Weekly	0	Important	70	0
5.9.4	Monthly	0	Important	50	0
5.9.5	Semi annual	0	Important	30	0
5.9.6	Annual	0	Important	10	0
5.10	How often do you check operability of signal heads?				
5.10.1	Continuously	0	Important	100	0
5.10.2	Daily	0	Important	90	0
5.10.3	Weekly	0	Important	70	0
5.10.4	Monthly	1	Important	50	50
5.10.5	Semi annual	0	Important	30	0
5.10.6	Annual	0	Important	10	0
5.11	How often do you implement methods for synchronizing controllers' clocks?				
5.11.1	Hourly	1	Important	100	100
5.11.2	Daily	0	Important	70	0
5.11.3	Weekly	0	Important	40	0
5.11.4	Monthly	0	Important	10	0
5.12	Total cost of all reparations per year	150000	Important		
5.13	Number of all malfunctions per year	1581		100	94.88
5.14	Number of changed lightbulbs		Important		
5.15	Total number of lightbulbs			100	#DIV/0!
				Partial grade 2:	**560.00**
				Equipment subsection weight factor:	**1.00**
				Weighted Partial grade MAI 2:	**560.00**
				Normalized Partial grade MAI 2:	**57.93**

New min	New max
0	100
Old min	**Old max**
50.04	930.31
Old value	**New value**
560.00	57.93222534

Figure B-16 Maintenance section (Boca Raton) - Part 3

	Reaction time	0 or 1/Value	Importance	Importance factor	
5.16	What is the average response time (time from problem occurrence to beginning of solving) to critical failures (e.g. controller malfunction, communications failure, physical damage of equipment on site…)				
5.16.1	< 1 hour	0	Important	100	0
5.16.2	< half a day	1	Important	90	90
5.16.3	< a day	0	Important	70	0
5.16.4	< 3 day	0	Important	50	0
5.16.5	< one week	0	Important	30	0
5.16.6	> one week	0	Important	10	0
5.17	What is the average time to complete the intervention (time to resolving the problem) to critical failures (e.g. controller malfunction, communications failure, physical damage or equipment on site…)				
5.17.1	< 1 hour	0	Important	100	0
5.17.2	< half a day	0	Important	90	0
5.17.3	< a day	0	Important	70	0
5.17.4	< 3 day	1	Important	50	50
5.17.5	< one week	0	Important	30	0
5.17.6	> one week	0	Important	10	0
5.18	What is the average response time to all reported failures?				
5.18.1	< 1 hour	0	Important	100	0
5.18.2	< half a day	0	Important	90	0
5.18.3	< a day	0	Important	70	0
5.18.4	< 3 day	1	Important	50	50
5.18.5	< one week	0	Important	30	0
5.18.6	> one week	0	Important	10	0
5.19	What is average response time regarding user complaints?				
5.19.1	< 1 hour	0	Important	100	0
5.19.2	< half a day	0	Important	90	0
5.19.3	< a day	0	Important	70	0
5.19.4	< 3 day	0	Important	50	0
5.19.5	< one week	0	Important	30	0
5.19.6	> one week	1	Important	10	10
				Partial grade 3:	**200.00**
				Reaction time subsection weight factor:	**1.00**
				Weighted Partial grade MAI 3:	**200.00**
				Normalized Partial grade MAI 3:	**44.44**

New min	New max
0	100
Old min	**Old max**
40	400
Old value	**New value**
200.00	44.44444444

Figure B-17 Maintenance section (Boca Raton) - Part 4

	Inventory and reporting	0 or 1/Value	Importance	Importance factor	
5.20	Does the inventory include a record of maintenance activity?	1	Important	100	100
5.21	Select the maintenance reports that are being made in your agency about the following:				
5.21.1	Communication failures	0	Important	100	0
5.21.2	Vehicle detector failures	1	Important	100	100
5.21.3	Pedestrian detector failures	1	Important	100	100
5.21.4	UPS device failures	0	Important	100	0
5.21.5	Controller device failures	0	Important	100	0
5.21.6	Signal system central software	0	Important	100	0
5.21.7	Signal system central hardware	0	Important	100	0
5.22	How frequent the maintenance reports are being made in your agency?				
5.22.1	Hourly	0	Important	100	0
5.22.2	Daily	1	Important	90	90
5.22.3	Weekly	0	Important	70	0
5.22.4	Monthly	0	Important	50	0
5.22.5	Annually	0	Important	30	0
5.22.6	Never	0	Important	10	0
5.23	Does your agency keep record of the following specifics of each maintenance taks and work order about:				
5.23.1	Locations (where was maintenance performed)	1	Important	100	100
5.23.2	Equipment (hardware and software which was affected by work order)	1	Important	100	100
5.23.3	Type of work defined by work order	1	Important	100	100
5.23.4	Type of work not defined by work order	1	Important	100	100
5.23.5	Duration of work	1	Important	100	100
5.23.6	Used parts for reparations	1	Important	100	100
5.23.7	Number of workers active on that specific reparation	1	Important	100	100
		Partial grade 4:			**318.57**
		Inventory and reporting weight factor:			**1.00**
		Weighted Partial grade MAI 4:			**318.57**
		Normalized Partial grade MAI 4:			**79.12**

New min	New max
0	100
Old min	**Old max**
10	400
Old value	**New value**
318.57	79.12087912

Figure B-18 Maintenance section (Boca Raton) - Part 5

	Signal System Central Software	0 or 1/Value	Importance	Importance factor	
5.24	Duration of coordination failure		Important	100	#DIV/0!
5.25	Total time while signals should be coordinated				
5.26	Time while communications errors were present (per year)		Important	100	100
5.27	Number of vehicle detector malfunctions		Important	100	#DIV/0!
5.28	Number of pedestrian detector malfunctions		Important	100	#DIV/0!
5.29	Total number of pedestrian detectors				
5.30	Duration of all reparations made by average maintenance crew per year		Important	100	100
5.31	Total duration of routine and non-routine reparations		Important	100	#DIV/0!
5.32	Number of routine and non-routine reparations		Important	100	#DIV/0!
5.33	Average duration of routine and non-routine reparations		Important	100	#DIV/0!
				Partial grade 5:	**#DIV/0!**
				SSCS subsection weight factor:	**1.00**
				Weighted Partial grade MAI 5:	**#DIV/0!**
				Normalized Partial grade MAI 5:	**#DIV/0!**

New min	New max
0	100
Old min	**Old max**
na	na
Old value	**New value**
#DIV/0!	#DIV/0!

Figure B-19 Maintenance section (Boca Raton) - Part 6

Section	Partial grade num	Partial Grade subsection	Weighted Grade Value	Evaluation confidence (%)	Grade Value Per Section	Weight factors	Weighted Grade per Section	Level of Service	Evaluation confidence (%)	Final Grade	Level of Service	Evaluation confidence (%)
Management	1	Staff Training	50.0	100	54.6	1.0	54.6	C	86.1	57.5	C	64.1
	2	Monitoring	33.3	100								
	3	User satisfaction	70.5	100								
	4	Public relations	50.4	100								
	5	Cooperation with neighboring agencies	25.0	50								
	6	Safety and accidents	51.9	100								
	7	Inventory	100.0	100								
	8	Vehicles for interventions	45.0	67								
	9	SSCS	65.5	100								
Traffic Signal Operations	1	General	63.9	100	51.4	1.0	51.4	C	50.0			
	2	SSCS	38.8	0								
Signal Timing Practices	1	General	62.5	67	62.5	1.0	62.5	C	33.3			
	2	SSCS	0.0	0								
Traffic Monitoring and Data Collection	1	Detection	47.8	60	48.6	1.0	48.6	D	75.4			
	2	Data Collection and Storage	62.8	100								
	3	Data Quality	50.0	75								
	4	Weather and turning movements	33.7	67								
Maintenance	1	Strategy	100.0	100	70.4	1.0	70.4	B	75.6			
	2	Maintenance of equipment	57.9	78								
	3	Reaction time	44.4	100								
	4	Inventory and reporting	79.1	100								
	5	SSCS	0.0	0								

Legend

(light green cell)	The cells where weight factors for sections can be changed.

Figure B-20 Grading (Boca Raton)

NTSRC Grades						
Num.	**Section**	**Sectional Score**	**Weighting factor**	**Result**	**Evaluation Confidence (%)**	**Grade of Service**
1	**Management**	54.6	1	54.6	86.1	C
2	**Traffic Signal Operation**	51.4	1	51.4	50.0	C
3	**Signal Timing Practices**	62.5	1	62.5	33.3	C
4	**Traffic Monitoring and Data Collection**	48.6	1	48.6	75.4	D
5	**Maintenance**	70.4	1	70.4	75.6	B
			Total:	**57.5**	**64.1**	**C**

Figure B-21 Summarized grades (Boca Raton)

Signal System Facts

Contact Information	
Agency	City of Boca Raton
Contact Person	Rasem Awwad/Tracy Phelps
Email Address	rawwad@myboca.us
Grading	
Overall Grade	C
Overall Score	57.5
Evaluation confidence	64.1%
General Information	
Population	91,000
Annual Funding for Signal O&M	$150,000
Annual Capital Investments	$80,000
Operational Information	
FTEs	10
Signalized Intersections	136
Coordinated Signals	103
Frequency of Signal Retiming	Less than 1 year
Central Signal System	ATMS.now
Malfunctions per year	1,581
Annual Reparation Cost	$150,000
Response Time	48h

Figure B-22 Signal system facts card (Boca Raton)

Appendix C: FAU Split History Report Analyzer Macro

FAU Split History Report Analyzer

```
Option Explicit

Sub FAU_Split_History_Report_Analyzer()

Dim wbk As Workbook
Dim Filename As String
Dim Path As String
Dim sItem As String
Dim FolderSelected As String
Dim myFolder As FileDialog
Dim iRow As Double
Dim iColumn As Double
Dim LastRow As Double

Application.ScreenUpdating = False
Application.Calculation = xlAutomatic



    Set myFolder = Application.FileDialog(msoFileDialogFolderPicker)
    With myFolder
    .Title = "Please select folder where the files for analysis are stored"
    .AllowMultiSelect = False
    If .Show <> -1 Then

   End If
    FolderSelected = .SelectedItems(1)
    End With

    MsgBox "You Selected:" & FolderSelected
```

```
Path = FolderSelected & "\"
Filename = Dir(Path & "*.xls")
'--------------------------------------------
'OPEN EXCEL FILES
 Do While Len(Filename) > 0  'IF NEXT FILE EXISTS THEN
    Set wbk = Workbooks.Open(Path & Filename)

        Columns("A:E").UnMerge

        Range("A4").EntireColumn.Insert
        Range("A4").EntireColumn.Insert
        Range("E5").Copy
        Range("A13").PasteSpecial
        Range("E7").Copy
        Range("B13").PasteSpecial

        LastRow = Range("C" & Rows.Count).End(xlUp).Row
        For iRow = LastRow To 1 Step -1
            If WorksheetFunction.Trim(Cells(iRow, 3).Value) = "DateTime" Then Cells(iRow,
3).EntireRow.Delete

        Next iRow

        On Error Resume Next
        Columns("X").SpecialCells(xlCellTypeBlanks).EntireRow.Delete

        Application.DisplayAlerts = False

        Range("E1").EntireColumn.Insert
        Range("E1").EntireColumn.Insert
        Range("E1").EntireColumn.Insert
```

```
Columns("C:C").TextToColumns Destination:=Range("C1"), DataType:=xlDelimited, _
TextQualifier:=xlDoubleQuote, ConsecutiveDelimiter:=True, Tab:=True, _
Semicolon:=False, Comma:=False, Space:=True, Other:=True, OtherChar:= _
"-", FieldInfo:=Array(Array(1, 1), Array(2, 1), Array(3, 1)), _
TrailingMinusNumbers:=True



Range("F1").FormulaR1C1 = _
"=TEXT(RC[-3],""mm/dd/yy "")&TEXT(RC[-2],""hh:mm:ss"")"

Range("F1").AutoFill Range("F1").Resize(Range("C2").End(xlDown).Row)
Range("F:F").NumberFormat = "[h]:mm:ss"

On Error Resume Next
Rows(1).SpecialCells(xlCellTypeBlanks).EntireColumn.Delete

LastRow = Range("C" & Rows.Count).End(xlUp).Row
For iRow = LastRow To 1 Step -1
    If WorksheetFunction.Trim(Cells(iRow, 3).Value) = "Average" Then Cells(iRow,
3).EntireRow.Delete

Next iRow

For iRow = LastRow To 2 Step -1
    If Cells(iRow, 7) <> 0 Then Cells(iRow, 1).Value = Cells(1, 1)
    If Cells(iRow, 7) <> 0 Then Cells(iRow, 2).Value = Cells(1, 2)
Next iRow



Range("A1").EntireRow.Insert
```

```
Range("A1").Value = "Intersection #"
Range("B1").Value = "Side-Street"
Range("C1").Value = "Date"
Range("D1").Value = "Time"
Range("E1").Value = "AM-PM"
Range("F1").Value = "Formatted date"
Range("G1").Value = "Pattern"
Range("H1").Value = "Cycle"
Range("I1").Value = "SP1"
Range("J1").Value = "SP2"
Range("K1").Value = "SP3"
Range("L1").Value = "SP4"
Range("M1").Value = "SP5"
Range("N1").Value = "SP6"
Range("O1").Value = "SP7"
Range("P1").Value = "SP8"
Range("Q1").Value = "SP9"
Range("R1").Value = "SP10"
Range("S1").Value = "SP11"
Range("T1").Value = "SP12"
Range("U1").Value = "SP13"
Range("V1").Value = "SP14"
Range("W1").Value = "SP15"
Range("X1").Value = "SP16"

If Not ActiveSheet.AutoFilterMode Then
   ActiveSheet.Range("A1").AutoFilter
End If

Range("A1:X1").Font.Bold = True
Columns("A:X").Font.Name = "Verdana"
```

```
        Columns("A:X").EntireColumn.AutoFit
        Range("A2").NumberFormat = "0"
        Range("A2").HorizontalAlignment = xlRight


        Range("A2").Select
        Range(Selection, Selection.End(xlDown)).Select
        Range(Selection, Selection.End(xlToRight)).Select
        Selection.Copy
        Windows("FAU Split History Report Analyzer.xlsm").Activate
        Range("A" & Rows.Count).End(xlUp).Select
        ActiveCell.Offset(1, 0).Select
        Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
            :=False, Transpose:=False
        Application.CutCopyMode = False
        ActiveWorkbook.Save



    wbk.Close True
    Filename = Dir
Loop


    ActiveWorkbook.Worksheets("Sheet1").Sort.SortFields.Clear
    ActiveWorkbook.Worksheets("Sheet1").Sort.SortFields.Add Key:=Range( _
        "A:A"), SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:= _
        xlSortNormal
    ActiveWorkbook.Worksheets("Sheet1").Sort.SortFields.Add Key:=Range( _
        "C:C"), SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:= _
        xlSortNormal
```

```
   ActiveWorkbook.Worksheets("Sheet1").Sort.SortFields.Add Key:=Range( _
      "D:D"), SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:= _
      xlSortNormal
   With ActiveWorkbook.Worksheets("Sheet1").Sort
      .SetRange Range(Cells.Address)
      .Header = xlYes
      .MatchCase = False
      .Orientation = xlTopToBottom
      .SortMethod = xlPinYin
      .Apply
   End With


LastRow = Range("A" & Rows.Count).End(xlUp).Row

For iRow = LastRow To 1 Step -1
   If Cells(iRow, 4).Value >= #12:00:00 AM# And Cells(iRow, 4).Value < #7:00:00 AM# Then
Cells(iRow, 5).Value = "Night"
   If Cells(iRow, 4).Value >= #10:00:00 PM# Then Cells(iRow, 5).Value = "Night"
   If Cells(iRow, 4).Value >= #7:00:00 AM# And Cells(iRow, 4).Value < #9:00:00 AM# Then
Cells(iRow, 5).Value = "AM Peak"
   If Cells(iRow, 4).Value >= #9:00:00 AM# And Cells(iRow, 4).Value < #4:00:00 PM# Then
Cells(iRow, 5).Value = "Midday"
   If Cells(iRow, 4).Value >= #4:00:00 PM# And Cells(iRow, 4).Value < #7:00:00 PM# Then
Cells(iRow, 5).Value = "PM Peak"
   If Cells(iRow, 4).Value >= #7:00:00 PM# And Cells(iRow, 4).Value < #10:00:00 PM# Then
Cells(iRow, 5).Value = "Evening"

   If Cells(iRow, 9).Value > 0 Then Cells(iRow, 25).Value = Cells(iRow, 9).Value
   If Cells(iRow, 10).Value > 0 Then Cells(iRow, 26).Value = Cells(iRow, 10).Value
   If Cells(iRow, 11).Value > 0 Then Cells(iRow, 27).Value = Cells(iRow, 11).Value
   If Cells(iRow, 12).Value > 0 Then Cells(iRow, 28).Value = Cells(iRow, 12).Value
   If Cells(iRow, 13).Value > 0 Then Cells(iRow, 29).Value = Cells(iRow, 13).Value
```

```
If Cells(iRow, 14).Value > 0 Then Cells(iRow, 30).Value = Cells(iRow, 14).Value
If Cells(iRow, 15).Value > 0 Then Cells(iRow, 31).Value = Cells(iRow, 15).Value
If Cells(iRow, 16).Value > 0 Then Cells(iRow, 32).Value = Cells(iRow, 16).Value
If Cells(iRow, 17).Value > 0 Then Cells(iRow, 33).Value = Cells(iRow, 17).Value
If Cells(iRow, 18).Value > 0 Then Cells(iRow, 34).Value = Cells(iRow, 18).Value
If Cells(iRow, 19).Value > 0 Then Cells(iRow, 35).Value = Cells(iRow, 19).Value
If Cells(iRow, 20).Value > 0 Then Cells(iRow, 36).Value = Cells(iRow, 20).Value
If Cells(iRow, 21).Value > 0 Then Cells(iRow, 37).Value = Cells(iRow, 21).Value
If Cells(iRow, 22).Value > 0 Then Cells(iRow, 38).Value = Cells(iRow, 22).Value
If Cells(iRow, 23).Value > 0 Then Cells(iRow, 39).Value = Cells(iRow, 23).Value
If Cells(iRow, 24).Value > 0 Then Cells(iRow, 40).Value = Cells(iRow, 24).Value

If Cells(iRow, 9).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 10).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 11).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 12).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 13).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 14).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 15).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 16).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 17).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 18).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 19).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 20).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 21).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 22).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 23).Value < 0 Then Cells(iRow, 1).EntireRow.Delete
If Cells(iRow, 24).Value < 0 Then Cells(iRow, 1).EntireRow.Delete

If Cells(iRow, 2).Value <> 0 Then Cells(iRow, 41).Value = Cells(iRow, 2).Value
```

```
  Next iRow



  Range("C1").EntireColumn.Insert

  For iRow = LastRow To 2 Step -1
   If Cells(iRow, 2).Value <> 0 Then Cells(iRow, 3).FormulaR1C1 = "=RIGHT(RC[-1],LEN(RC[-1])-16)"
    If Cells(iRow, 2).Value <> 0 Then Cells(iRow, 2).Value = Cells(iRow, 3).Value

   Next iRow



   Range("C1").EntireColumn.Delete

Range("A:A").NumberFormat = "0"
Range("C:C").NumberFormat = "m/d/yyyy"
Range("D:D").NumberFormat = "h:mm:ss"
Range("F:F").NumberFormat = "[h]:mm:ss"
Range("G:G").NumberFormat = "0"

Range("A1").Value = "Intersection #"
Range("B1").Value = "Side-street"
Range("C1").Value = "Date"
Range("D1").Value = "Time"
Range("E1").Value = "Period"
Range("F1").Value = "Formatted date"
Range("G1").Value = "Pattern"
Range("H1").Value = "Cycle"
Range("I1").Value = "SP1"
Range("J1").Value = "SP2"
Range("K1").Value = "SP3"
```

```
Range("L1").Value = "SP4"
Range("M1").Value = "SP5"
Range("N1").Value = "SP6"
Range("O1").Value = "SP7"
Range("P1").Value = "SP8"
Range("Q1").Value = "SP9"
Range("R1").Value = "SP10"
Range("S1").Value = "SP11"
Range("T1").Value = "SP12"
Range("U1").Value = "SP13"
Range("V1").Value = "SP14"
Range("W1").Value = "SP15"
Range("X1").Value = "SP16"
Range("Y1").Value = "SPC1"
Range("Z1").Value = "SPC2"
Range("AA1").Value = "SPC3"
Range("AB1").Value = "SPC4"
Range("AC1").Value = "SPC5"
Range("AD1").Value = "SPC6"
Range("AE1").Value = "SPC7"
Range("AF1").Value = "SPC8"
Range("AG1").Value = "SPC9"
Range("AH1").Value = "SPC10"
Range("AI1").Value = "SPC11"
Range("AJ1").Value = "SPC12"
Range("AK1").Value = "SPC13"
Range("AL1").Value = "SPC14"
Range("AM1").Value = "SPC15"
Range("AN1").Value = "SPC16"
Range("AO1").Value = "Corridor Name"
Range("A1:AP1").Font.Bold = True
```

```
        Columns("AO:AO").TextToColumns Destination:=Range("AP1"), DataType:=xlDelimited, _
        TextQualifier:=xlDoubleQuote, ConsecutiveDelimiter:=True, Tab:=True, _
        Semicolon:=False, Comma:=False, Space:=True, Other:=True, OtherChar:= _
        "-", FieldInfo:=Array(Array(1, 1), Array(2, 1), Array(3, 1)), _
        TrailingMinusNumbers:=True

 Range("AO1").EntireColumn.Delete
 Range("AP1").EntireColumn.Delete
 Range("AP1").EntireColumn.Delete
 Range("AP1").EntireColumn.Delete
 Range("AP1").EntireColumn.Delete

    If Not ActiveSheet.AutoFilterMode Then
   ActiveSheet.Range("A1:AO1").AutoFilter
 End If

   Columns("A:AO").Font.Name = "Calibri"
   Columns("A:AO").Font.Size = 11
   Columns("A:AO").AutoFit

Application.Calculation = xlAutomatic
Application.ScreenUpdating = True

End Sub
```

Appendix D: FAU Phase Termination Analyzer Macro

FAU Phase Termination Analyzer Macro

```
Option Explicit

Sub Phase_Termination_Analyzer()

Dim wbk As Workbook
Dim Filename As String
Dim Path As String
Dim sItem As String
Dim FolderSelected As String
Dim myFolder As FileDialog
Dim iRow As Double
Dim LastRow As Double


Application.ScreenUpdating = False
Application.Calculation = xlManual


    Set myFolder = Application.FileDialog(msoFileDialogFolderPicker)
    With myFolder
    .Title = "Please select folder where the files for analysis are stored"
    .AllowMultiSelect = False
    If .Show <> -1 Then

   End If
    FolderSelected = .SelectedItems(1)
    End With

    MsgBox "You Selected:" & FolderSelected

Path = FolderSelected & "\"
Filename = Dir(Path & "*.xls")
'--------------------------------------------
'OPEN EXCEL FILES
 Do While Len(Filename) > 0  'IF NEXT FILE EXISTS THEN
    Set wbk = Workbooks.Open(Path & Filename)

        Columns("A:X").UnMerge
```

```
        Range("D1").EntireColumn.Insert
        Range("D1").EntireColumn.Insert
        Range("D1").EntireColumn.Insert
        Range("D1").EntireColumn.Insert

        On Error Resume Next
        Columns("A").SpecialCells(xlCellTypeBlanks).EntireRow.Delete

        LastRow = Range("A" & Rows.Count).End(xlUp).Row
    For iRow = LastRow To 1 Step -1
        If Cells(iRow, 1).Value = "Gap" Or Cells(iRow, 1).Value = "Max" Or Cells(iRow, 1).Value =
"Force off" Then Cells(iRow, 2).Value = Cells(2, 3).Value
        If Cells(iRow, 1).Value = "Gap" Or Cells(iRow, 1).Value = "Max" Or Cells(iRow, 1).Value =
"Force off" Then Cells(iRow, 3).Value = Cells(3, 3).Value
        If Cells(iRow, 1).Value = "Gap" Or Cells(iRow, 1).Value = "Max" Or Cells(iRow, 1).Value =
"Force off" Then Cells(iRow, 4).Value = Cells(4, 8).Value
        If Cells(iRow, 1).Value = "Gap" Or Cells(iRow, 1).Value = "Max" Or Cells(iRow, 1).Value =
"Force off" Then Cells(iRow, 5).Value = Cells(4, 10).Value
        If Cells(iRow, 1).Value = "Gap" Or Cells(iRow, 1).Value = "Max" Or Cells(iRow, 1).Value =
"Force off" Then Cells(iRow, 6).Value = Cells(4, 17).Value
        If Cells(iRow, 1).Value = "Gap" Or Cells(iRow, 1).Value = "Max" Or Cells(iRow, 1).Value =
"Force off" Then Cells(iRow, 7).Value = Cells(4, 19).Value

   Next iRow



        For iRow = LastRow To 1 Step -1
            If Cells(iRow, 1).Value = "Gap" Or (Cells(iRow, 1).Value) = "Max" Or (Cells(iRow, 1).Value) =
"Force off" Then

            Else: Cells(iRow, 1).EntireRow.Delete

            End If

        Next iRow

        Range("H1").EntireColumn.Delete
        Range("H1").EntireColumn.Delete
```

```
        Range("A2").Select
        Range(Selection, Selection.End(xlDown)).Select
        Range(Selection, Selection.End(xlToRight)).Select
        Selection.Copy
        Windows("FAU Phase Termination Analyzer.xlsm").Activate
        Range("A" & Rows.Count).End(xlUp).Select
        ActiveCell.Offset(1, 0).Select
        Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
            :=False, Transpose:=False
        Application.CutCopyMode = False
        ActiveWorkbook.Save




    wbk.Close True
    Filename = Dir
Loop

Range("H:W").Select
    With Selection
        Selection.NumberFormat = "General"
        .Value = .Value
    End With

Range("B:B").NumberFormat = "0"
Range("D:D").NumberFormat = "m/d/yyyy"
Range("E:E").NumberFormat = "h:mm:ss"
Range("F:F").NumberFormat = "m/d/yyyy"
Range("G:G").NumberFormat = "h:mm:ss"
Range("H:W").NumberFormat = "0"


    ActiveWorkbook.Worksheets("Sheet1").Sort.SortFields.Clear
    ActiveWorkbook.Worksheets("Sheet1").Sort.SortFields.Add Key:=Range("B:B"), _
        SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:=xlSortNormal

    ActiveWorkbook.Worksheets("Sheet1").Sort.SortFields.Add Key:=Range("D:D"), _
```

```
        SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:=xlSortNormal

    With ActiveWorkbook.Worksheets("Sheet1").Sort
        .SetRange Range(Cells.Address)
        .Header = xlGuess
        .MatchCase = False
        .Orientation = xlTopToBottom
        .SortMethod = xlPinYin
        .Apply
    End With

LastRow = Range("A" & Rows.Count).End(xlUp).Row

 Range("D1").EntireColumn.Insert

   For iRow = LastRow To 1 Step -1
    If Cells(iRow, 2).Value <> 0 Then Cells(iRow, 4).FormulaR1C1 = "=RIGHT(RC[-1],LEN(RC[-1])-
16)"

    Next iRow

    For iRow = LastRow To 1 Step -1
    If Cells(iRow, 2).Value <> 0 Then Cells(iRow, 3).Value = Cells(iRow, 4).Value

    Next iRow

    Range("D1").EntireColumn.Delete

Range("A1").EntireRow.Insert
Range("A1").Value = "Termination Type"
Range("B1").Value = "Intersection #"
Range("C1").Value = "Side-Street"
Range("D1").Value = "Date"
Range("E1").Value = "Time"
Range("F1").Value = "End Date"
Range("G1").Value = "End Time"
Range("H1").Value = "SP1"
Range("I1").Value = "SP2"
Range("J1").Value = "SP3"
```

```
Range("K1").Value = "SP4"
Range("L1").Value = "SP5"
Range("M1").Value = "SP6"
Range("N1").Value = "SP7"
Range("O1").Value = "SP8"
Range("P1").Value = "SP9"
Range("Q1").Value = "SP10"
Range("R1").Value = "SP11"
Range("S1").Value = "SP12"
Range("T1").Value = "SP13"
Range("U1").Value = "SP14"
Range("V1").Value = "SP15"
Range("W1").Value = "SP16"

Range("A1:W1").Font.Bold = True


    If Not ActiveSheet.AutoFilterMode Then
    ActiveSheet.Range("A1:X1").AutoFilter
  End If

    Columns("A:G").AutoFit

Application.Calculation = xlAutomatic
Application.ScreenUpdating = True

End Sub
```

Appendix E: FAU Field Alarms Report Analyzer Macro

FAU Field Alarms Report Analyzer

```
Option Explicit
Sub Field_Alarm_Report_Analyzer()

Dim wbk As Workbook
Dim Filename As String
Dim Path As String
Dim sItem As String
Dim FolderSelected As String
Dim myFolder As FileDialog
Dim iRow As Double
Dim LastRow As Double

Application.DisplayAlerts = False
Application.ScreenUpdating = False
Application.Calculation = xlAutomatic


    Set myFolder = Application.FileDialog(msoFileDialogFolderPicker)
    With myFolder
    .Title = "Please select folder where the files for analysis are stored"
    .AllowMultiSelect = False
    If .Show <> -1 Then

   End If
    FolderSelected = .SelectedItems(1)
    End With

    MsgBox "You Selected:" & FolderSelected

Path = FolderSelected & "\"
Filename = Dir(Path & "*.xls")
'-------------------------------------------
'OPEN EXCEL FILES
 Do While Len(Filename) > 0  'IF NEXT FILE EXISTS THEN
    Set wbk = Workbooks.Open(Path & Filename)

        On Error Resume Next
```

```
    Columns("I").SpecialCells(xlCellTypeBlanks).EntireRow.Delete

    Columns("A:A").UnMerge
    Columns("C:C").UnMerge
    Columns("L:L").UnMerge
    Columns("C:C").TextToColumns Destination:=Range("C1"), DataType:=xlDelimited, _
    TextQualifier:=xlDoubleQuote, ConsecutiveDelimiter:=True, Tab:=True, _
    Semicolon:=False, Comma:=False, Space:=True, Other:=True, OtherChar:= _
    "-", FieldInfo:=Array(Array(1, 1), Array(2, 1), Array(3, 1)), _
    TrailingMinusNumbers:=True

Columns("B").EntireColumn.Delete
Columns("E").EntireColumn.Delete
Columns("E").EntireColumn.Delete
Columns("G").EntireColumn.Delete


    Range("A1").EntireRow.Insert

    Range("A1").Value = "ID"
    Range("B1").Value = "Date"
    Range("C1").Value = "Day"
    Range("D1").Value = "Time"
    Range("E1").Value = "#"
    Range("F1").Value = "State"
    Range("G1").Value = "Data"
    Range("H1").Value = "Description"

    If Not ActiveSheet.AutoFilterMode Then
       ActiveSheet.Range("A1").AutoFilter
    End If

    Columns("E:E").Insert Shift:=xlToRight, CopyOrigin:=xlFormatFromLeftOrAbove
    Range("E1").Value = "Formatted date"
    Range("E2").FormulaR1C1 = _
    "=TEXT(RC[-3],""mm/dd/yy "")&TEXT(RC[-1],""hh:mm:ss"")"
    Columns("E:E").EntireColumn.AutoFit

    Range("E2").AutoFill Range("E2").Resize(Range("A2").End(xlDown).Row - 1)
```

```
        Range("E:E").NumberFormat = "[h]:mm:ss"



        Columns("A:I").EntireColumn.AutoFit
        Range("A1:I1").Font.Bold = True

        Range("A2").Select
        Range(Selection, Selection.End(xlDown)).Select
        Range(Selection, Selection.End(xlToRight)).Select
        Selection.Copy
        Windows("FAU Field Alarms Report Analyzer.xlsm").Activate
        Range("A" & Rows.Count).End(xlUp).Select
        ActiveCell.Offset(1, 0).Select
        Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
            :=False, Transpose:=False
        Application.CutCopyMode = False
        ActiveWorkbook.Save

    wbk.Close True
    Filename = Dir
Loop

Range("B:B").NumberFormat = "m/d/yyyy"
Range("D:D").NumberFormat = "h:mm:ss"
Range("E:E").NumberFormat = "[h]:mm:ss"

LastRow = Range("A" & Rows.Count).End(xlUp).Row
For iRow = LastRow To 2 Step -1
    If Cells(iRow, 4).Value >= #12:00:00 AM# And Cells(iRow, 4).Value < #7:00:00 AM# Then
Cells(iRow, 10).Value = "Night"
    If Cells(iRow, 4).Value >= #10:00:00 PM# Then Cells(iRow, 10).Value = "Night"
    If Cells(iRow, 4).Value >= #7:00:00 AM# And Cells(iRow, 4).Value < #9:00:00 AM# Then
Cells(iRow, 10).Value = "AM Peak"
    If Cells(iRow, 4).Value >= #9:00:00 AM# And Cells(iRow, 4).Value < #4:00:00 PM# Then
Cells(iRow, 10).Value = "Midday"
    If Cells(iRow, 4).Value >= #4:00:00 PM# And Cells(iRow, 4).Value < #7:00:00 PM# Then
Cells(iRow, 10).Value = "PM Peak"
```

```
    If Cells(iRow, 4).Value >= #7:00:00 PM# And Cells(iRow, 4).Value < #10:00:00 PM# Then
Cells(iRow, 10).Value = "Evening"

Next iRow


    ActiveWorkbook.Worksheets("Sheet1").Sort.SortFields.Clear
    ActiveWorkbook.Worksheets("Sheet1").Sort.SortFields.Add Key:=Range("A:A"), _
        SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:=xlSortNormal

    ActiveWorkbook.Worksheets("Sheet1").Sort.SortFields.Add Key:=Range("E:E"), _
        SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:=xlSortNormal

    With ActiveWorkbook.Worksheets("Sheet1").Sort
        .SetRange Range(Cells.Address)
        .Header = xlGuess
        .MatchCase = False
        .Orientation = xlTopToBottom
        .SortMethod = xlPinYin
        .Apply
    End With

Range("A1").EntireRow.Insert
Range("A1").Value = "Intersection #"
Range("B1").Value = "Date"
Range("C1").Value = "Day"
Range("D1").Value = "Time"
Range("E1").Value = "Formatted date"
Range("F1").Value = "Event #"
Range("G1").Value = "State"
Range("H1").Value = "Data"
Range("I1").Value = "Description"
Range("J1").Value = "Period"

Range("A1:J1").Font.Bold = True


     If Not ActiveSheet.AutoFilterMode Then
    ActiveSheet.Range("A1:X1").AutoFilter
```

```
  End If

    Columns("A:I").AutoFit

Application.Calculation = xlAutomatic
Application.ScreenUpdating = True

Application.DisplayAlerts = True

End Sub
```