AGENDA
COUNTY TRANSPORTATION COMMITTEE
Wednesday, May 18, 2016
4:00 p.m.
Executive Conference Room, Administration Building
Beaufort County Government Robert Smalls Complex
100 Ribaut Road, Beaufort

Committee Members:
Kraig Gordon, Chairman
Bob Arundell, Joe DeVito
J. Craig Forrest, Mark McCain
Steve Miller, James Morrall
Paul Runko, Joseph Stroman
Stephen Wilson

1. CALL TO ORDER – 4:00 P.M.
   A. APPROVAL OF MINUTES – March 16, 2016 (backup)

2. INTRODUCTIONS

3. PUBLIC COMMENT

4. STATUS OF CURRENT ROAD PROJECTS
   Mr. Robert McFee, PE, Division Director, Construction Engineering and Facilities

5. UTILITY INFRASTRUCTURE
   Chairman Kraig Gordon

6. OLD BUSINESS
   A. UPDATE ON CTC RESERVE FUND REVIEW
      Mr. Bob Arundell

   B. UPDATE ON DIRT ROAD EVALUATION PROCESS FROM SUBCOMMITTEE

7. NEW BUSINESS
   A. CHARIMAN'S UPDATE
      Chairman Kraig Gordon

   B. REVIEW BCTC MARCH 31, 2016 FINANCIAL STATEMENT
      Mr. Robert McFee, PE, Division Director, Construction Engineering and Facilities

   C. FUNDING REQUEST FOR TRAFFIC SIGNAL ENHANCEMENT/DATA COLLECTION US 21/SC 170 (backup)
      Mr. Colin Kinton, Division Director, Transporation & Traffic Engineering

8. PUBLIC COMMENT

The County Channel

9. ADJOURNMENT - Special Meeting with Senator Davis – Wednesday, June 15, 2015 at 4:00 p.m., Executive Conference Room, County Administration Building, 100 Ribaut Road, Beaufort, SC

Next Regular Meeting – July 20, 2016, at 4:00 p.m., Executive Conference, Room County Administration Building, 100 Ribaut Road, Beaufort, SC

BEAUFORT COUNTY TRANSPORTATION COMMITTEE
MINUTES OF MEETING ON MARCH 16, 2016

The first meeting of the newly appointed Beaufort County Transportation Committee (BCTC) was held on March 16, 2016 in the Executive Conference Room of the Beaufort County Administrative Complex located at 100 Ribaut Road, Beaufort, South Carolina.

MEMBERS PRESENT: Kraig Gordon, Bob Arundell, JoeDeVito, Craig Forrest, Mark McCain (via conference phone link), Joseph Stroman, Stephen Wilson

MEMBERS ABSENT: Steve Miller Vacant Districts 5,7,9

OTHERS PRESENT: Rob McFee, Beaufort County Division Director for Construction, Engineering & Facilities
Jeff Buckalew, Town of Hilton Head Engineer
Darrin Shoemaker, Town of Hilton Head Traffic Engineer
Wendell Mulligan, SCDOT Resident Maintenance Engineer
County Council Member Cynthia Bensch
County Council Member Gerald Dawson

Notification. An audio recording of this meeting is available from the Beaufort County Engineering Department. Please contact the department at 843 255-2700 and request an audio copy.

1. **Call to Order**. Meeting was called to order at approximately 4:00 p.m. by Chairman Gordon.
Motion: Motion was made and seconded to approve the minutes from the January 20, 2016 meeting. Motion passed unanimously.

2. **Members Roll Call & Introductions**. An attendance roll call was taken. Introductions by County Staff and visitors were completed.

3. **Public Comment**. Chairman Gordon reviewed the January 18, 2016 letter from Mr. Robert Williams written to the BCTC concerning the resurfacing of Pulaski Drive, an SCDOT road in the Colonial Terrace Subdivision, Burton SC. Mr. McFee stated that he is discussing with Mr. Mulligan, SCDOT Resident Maintenance Engineer about getting Pulaski Drive and several of the other SCDOT roadways in the subdivision in some future SCDOT resurfacing contract as appropriate. The subdivision roads are short roadways with vary minimal traffic. The main road that encompasses the subdivision, Colonial Terrace Drive was resurfaced about a year ago but the smaller roads in the subdivision were not resurfaced. The CTC members suggested that the Chairman send him a response letter.

4. **Old Business**

A. Election of Vice Chairman

Motion: Motion was made by Mr. Arnudell and seconded by Mr. Stroman to appoint Mr. DeVito as Vice Chairman. Motion passed unanimously.

B. US 278 Street Sweeping & Litter Control. CTC has received a 1/22/16 letter from County Administrator indicating that the County would fund the street sweeping services on US 278 between the SC 170 overpass and the Hampton Parkway. The CTC did not approve a funding request for $3,060 annual street sweeping and litter control presented by the County at the CTC meeting on January 21, 2016.

Motion: Motion was made by Mr. McCain to accept the letter as information and that there is no further action necessary. The motion was seconded by Mr. DeVito. The vote for: Mr McCain, Mr. DeVito, Mr. Arundell, Mr. Stroman Opposed: Mr. Forrest, Mr. Wilson Motion passed.

Mr. DeVito stated that at any point in time the item can be brought back for approval to fund. At the appropriate time the funding for street sweep from McGarvey's Corner to the Hampton Parkway on US 278 could be re-presented once the BCTC understands what their 25% commitment should be spent on & then the BCTC could choose to reimburse the County.

C. **Status of Current Road Projects**. Mr. McFee reviewed the current road projects. Design/Build Contract 49 for dirt road paving is the only active construction contract at this time. Per the project update worksheets, Huspah Court N & S are scheduled for paving by end of this month. For Wimbee Landing Road Phase 2, final design has been completed. Construction work should start in April. County Engineering is working on the contracts for Design/Build Contract 47.

Contract 50 should be advertised for design soon. County Engineering is presenting Contract 50 as a design-bid-build contract in order to compare design and construction costs to the design/build contracts that have been done in recent years. There have been 6 design/build contracts for dirt road improvements since 2011.

Mr. McFee also reviewed the right of way acquisition status report. Right of way acquisition for the dirt roads is a lengthy process. The Engineering Department has a written policy that a total of 3 letters will be sent to property owners requesting their grant of right of way. The Engineering Department staff evaluates the right of way efforts for each road and determines if enough property owners have granted right of way. Depending on the number of positive, negative or not returned right of way requests, the Engineering Department and Public Works Department will either submit a request to County Council for condemnation of the remaining right or way or a recommendation to remove the dirt road from the County's dirt road maintenance inventory.

The SCDOT Resurfacing Project for ±31 miles of SCDOT roadway has been advertised for bid. Bids are due to the County by April 5, 2016. The BCTC approved the SCDOT roadways for resurfacing at its September 2015 meeting.

The BCTC web page is located on the County's web site under the Engineering Department. There is an interactive map that shows past and future projects. Mr. McFee asked the members to look at the web page. He also requested that if the BCTC members have any comments, questions or additions to the web page to let him know.

5. **New Business**

Chairman Gordon conducted the review of the New Business items on the agenda. Most of these items resulted from the BCTC's workshop meeting in February.

A. **Appointment of Dirt Road Evaluation Process Subcommittee**. Mr. Forrest was appointed chairman of this subcommittee with Mr. DeVito and Mr. Stroman as members. The subcommittee will be reviewing the needs rating evaluation form and will report back on its progress at the May BCTC meeting. This examination of the evaluation process is necessary because the Engineering Department should be starting a new dirt road rating program at the end of 2016.

B. **Election of Treasurer & Reserve Fund Discussion**

Motion: Motion was made by Mr. DeVito and seconded by Mr. Stroman to appoint Mr. Arundell as BCTC Treasurer. Motion passed unanimously.

The BCTC members discussed establishing a reserve fund within the BCTC's budget. The BCTC can hold up to 300% of its revenue in reserve. Chairman Gordon would not recommend holding 300% of revenue but also does not want the BCTC to spend all funding it receives. He believes it is necessary to establish a reserve fund. Mr. Arundell will investigate to determine what reserve amount would be applicable for the BCTC budget and recommend how to adopt a plan to achieve the reserved capital revenue.

Mr. McFee reminded the BCTC that County TAG funds are also used on County dirt road projects and if there was a case were there would be insufficient C Funds to complete a BCTC dirt road project, TAG funds would be requested from County Council.

C. **Invitation to Utility Companies**. The Engineering Department will prepare an invitation letter to all the County's utilities that have infrastructure on County BCTC projects to attend the May BCTC meeting.

D. **Alternate Dirt Road Paving Study**. Mr. McFee will research a series of alternatives to dirt road paving and will report back to the BCTC at the July meeting. Mr. McCain also requested that an investigation be completed on the collection of data for determining which roads to resurface so a more scientific format can be used. He would like to do away with the subjective rating of the SCDOT roads for resurfacing.

Mr. McFee indicated that he has already been in contact with SCDOT about using there pavement evaluation van.

E. **Transportation Plan**. Mr. McCain will be working on re-writing the BCTC's current transportation plan. Mr. McCain will have this task completed and a draft ready for presentation at the September. Mr. DeVito will assist Mr. McCain.

F. **Other Items**. Chairman Gordon has been discussing with County Council members the possibility of a County resolution for the BCTC to coordinate the use of the County's TAG funds. He will report back to the BCTC on any developments. The Chairman has also been reviewing the County's MPO and its processes.

Meeting Adjourned. Next regular meeting is scheduled for on Wednesday, May 18, 2016 at 4:00 pm in the Executive Conference Room, County Administration Building, Robert Smalls Complex, Beaufort, SC.

COUNTY COUNCIL OF BEAUFORT COUNTY
BEAUFORT COUNTY TRAFFIC & TRANSPORTATION
ENGINEERING DEPARTMENT
113 Industrial Village Road, 29906
PO Drawer 1228, Beaufort, SC 29901-1228
Phone: (843) 255-2940 Fax: (843) 255-9443

TO: Beaufort County Transportation Committee

FROM: Colin Kinton, Division Director, Transportation and Traffic Engineering

SUBJ: **Funding Request for Traffic Signal Enhancement/Data Collection US21/SC170**

DATE: May 18, 2016

BACKGROUND. As traffic signals age and are in need of re-construction, approximately every 15 years, Beaufort County frequently partners with The South Carolina Department of Transportation (SCDOT) and local municipalities to provide decorative and storm resistant mast arm poles, street lighting, and improved vehicle and pedestrian detection. SCDOT is in the process of upgrading the US 21/SC 170 (Paris Island Gateway at Robert Smalls Pkwy) signalized intersection. SCDOT plans include replacement of wood poles with steel poles and replacement of cabinet, signal heads, and wiring. The Traffic Engineering Department recommends partnering with SCDOT to enhance the upgrades at this intersection because of the high volumes experienced daily on all four approaches to the intersection, safety concerns, and the overall critical importance of this intersection to network traffic flow in northern Beaufort County. Recommended enhancements would improve storm resilience, appearance, data collection and analysis, and safety.

The intersection of US 21/SC 170 was studied for mast arm and street-lighting upgrades. Because of the intersection angle, standard mast arm design would not be functional and difficult to provide required minimum setbacks. An alternative was developed, which would be the first in the State of South Carolina, for a mono-tube mast arm design (a single arm pole connected at both ends and traversing the shortest distance between two intersection corners).

Beaufort County has been participating in an experimental test location to collect high-resolution (HR) real-time and archived traffic data for the last two years. The intersection chosen for the study, Ribaut Road at Lady's Island Drive, was selected based on frequent congestion, high volumes from the side street approach, and variability of traffic flows (both predictable and unpredictable). The attached white paper has been written as an initial report on the findings of the study. Because of the volume and importance of this intersection, US 21/SC 170 would be an ideal location for HR data collection.

Recommended traffic signal upgrades are as follows:

1. Monotube Mast arm traffic signal upgrade:	$125,000
2. High-resolution traffic data collection system deployment:	$ 45,000
3. Contingency of 10%:	$ 17,000
Total upgrade request:	$187,000

Attached are draft intersection plans, correspondence with pole and foundation design estimate, and HR vehicle detection system quote. The equipment quoted is compatible with our existing vehicle data collection system deployed county-wide.

RECOMMENDATION. That the Beaufort County Transportation Committee approve the funding for mono-tube mast arm and high-resolution data collection system upgrades for the intersection of US 21/SC 170 in the amount of $187,000 funded by C Funds.

Attachments: 1) Automatic Generation of Timing Plans with High-Resolution Data white paper
2) Correspondence with Atlantic Technical Sales on Mono-tube mast arm design
3) Quote dated 5/16/16
4) Draft signal design
5) Site location map

Cc: Wendell Mulligan, SCDOT Resident Maintenance Engineer

CK/ae

Automatic Generation of Timing Plans with High-Resolution Data

Samuel Coogan, Department of Electrical Engineering,
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March 4, 2016

Abstract

A high-resolution (HR) data system for an intersection collects the location (lane), speed, and turn movement of every vehicle as it enters an intersection, together with the signal phase. The system operates 24×7. The data are available in real time and archived. The archived data are used in a three-step automated procedure to optimize timing plans. In the first step, the data are clustered by day-of-week. In the second step an intra-day segmentation is derived for each cluster. In the third step the optimum green split is determined for each intra-day segment to minimize the delay or to equalize VC ratios. Various intersection performance measures may also be derived. The procedure is illustrated for an intersection in Beaufort, SC. HR systems can also be used to evaluate safety, e.g. red-light and right-turn-on-red violations.

Keywords. High-resolution data, arterial data, timing plans, vehicle counts, turn ratios, red light violations

1 Introduction

Poor management of intersections causes excessive delay and more frequent crashes. Conditions are worse in cities experiencing rapid growth in automobile ownership, but mature cities also face challenges as road capacity is taken away from vehicles to accommodate increasing bicycle and pedestrian traffic. Management today is handicapped by insufficient data. It can be more effective if it is based on high-resolution (HR) real-time and archived data about the movement of vehicles, bicycles, and pedestrians. "If you don't know what's happening on your roads, don't expect to manage them well" is a truism.

A basic HR system measures the location (lane) and speed of every vehicle as it approaches and enters the intersection, together with the signal phase. The system operates 24×7 and the measurements are archived in a database. The database generates reports providing continuous monitoring of the intersection performance in terms of delay, VC ratios and LOS, cycle failures, etc. This paper presents a three-step automated procedure that uses the database to generate optimal timing plans whenever needed. The agency can thus determine when the performance has degraded sufficiently to change the existing timing plans.

Continuous performance monitoring combined with automatic re-timing represents a paradigm shift in intersection management. Urban traffic in the U.S. today is regulated by 300,000 signalized intersections, whose performance is determined by their signal control algorithms. The performance is poor: the 2012 National Transportation Operations Coalition (NTOC) assessment of traffic signal control gives an overall grade of D+ (National Traffic Operations Coalition (2012)). Ninety percent of the signalized intersections use fixed time of day (TOD) plans, which are re-timed once in five years, based on three days of manual data collection. These traffic snapshots and the timing plans based on them completely miss the variability in the traffic to which the plans should adapt. Moreover, the infrequent snapshots do not permit the operating agencies or the public to determine whether the road network is performing well or poorly.

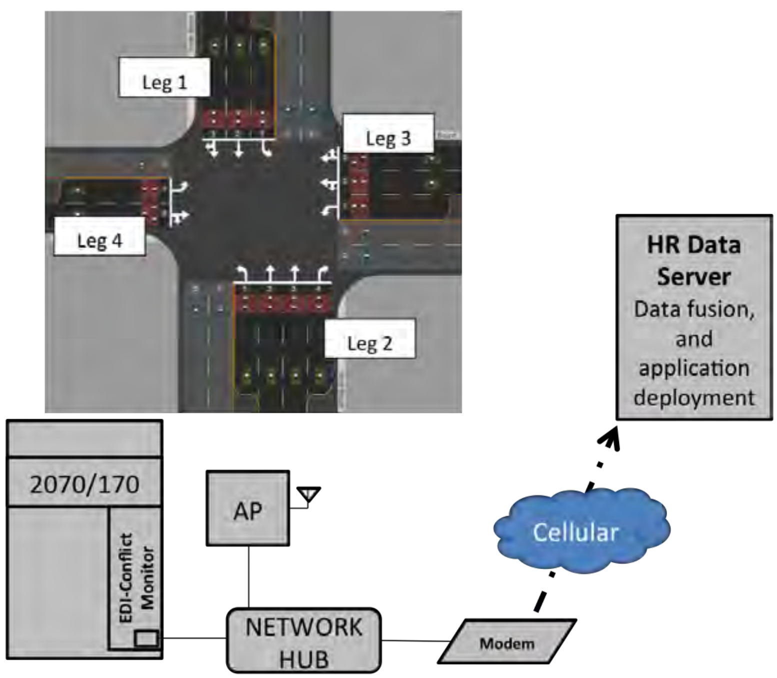

Figure 1: Schematic for HR system at intersection in Beaufort, SC: each small white dot is vehicle detector.

The applications discussed below use data from an HR system at an intersection in Beaufort, SC, where it has been operating for two years. We briefly describe the hardware architecture of the HR system. The system components are from Sensys Networks, Inc. The Beaufort intersection of Figure 1 is a standard fully actuated four-way intersection with stop bar and advanced detectors. The system has in addition one detector in each departure lane to permit accurate evaluation of turn movements. Each detector senses the time when a vehicle crosses it. All detectors are wireless and communicate with the Access Point (AP) located near the 2070/170 controller. Signal phase is obtained from the controller conflict monitoring card. All measurements are time-stamped and synchronous to within 100ms or 0.1s. The data are sent to the HR data server via a cellular modem. The data are organized in a database called APSAMS in Figure 2.

The rest of the paper is organized as follows. §2 discusses the flow chart of the three-step procedure. §3 describes the clustering by day-of-week. §4 describes how the intra-day segmentation and optimal timing plans are calculated. §5 collects some conclusions.

2 Flowchart

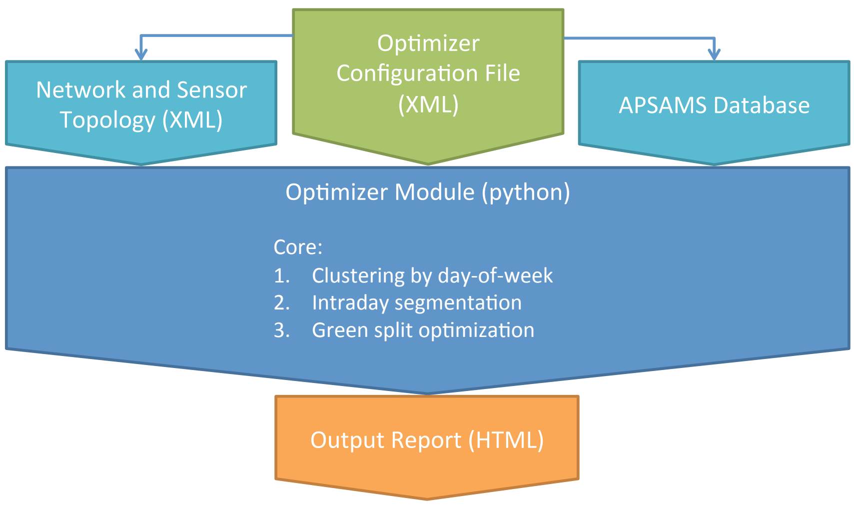

Figure 2: Flowchart for timing plan optimization.

Figure 2 summarizes the steps in the design of the timing plan. The optimization module collects information about the sensor placement in the network. In this illustration the network is a single intersection defined by lanes and turn movements, but more generally there would be a network of intersections. From Figure 1 we see that there are 12 movements in all: left, through and right turn from each of the four legs.

The APSAMS database is part of the HR data server of Figure 1. The optimizer configuration file specifies the range of days for which data is extracted from APSAMS and the parameters used in the optimization algorithms. The raw data consists of detection events for each vehicle. The database aggregates the raw data into 5-minute, 15-minute and hourly intervals.

The optimizer module carries out the three-step procedure: clustering, intra-day segmentation and green split optimization. Each step is described below.

3 Day of week clustering

The standard approach to designing TOD plans begins with manual measurement of counts over three days, selecting days of the week that will have different plans (e.g. weekday and weekend) and, for each day, selecting time intervals with different plans (e.g. AM and PM peak and off-peak periods). The selection of the days and time intervals is based on judgment based on familiarity with the traffic patterns. However, if we have continuous measurements for one year (say), we could cluster the daily data to reveal the days of the week with significantly different traffic patterns, and then cluster the intra-day data to divide the day into periods with significantly different traffic.

We illustrate the procedure using hourly data for the Beaufort intersection in Beaufort, S.C. for counts of the 12 movements for 164 days, Dec 2014 to May 2015. The data represents each day's traffic by a 24×12 vector of hourly counts, giving 164 (24×12)-dimensional vectors. Before describing the clusters, we indicate the variability of traffic in Figure 3, which displays the measured percentile flows for each movement.

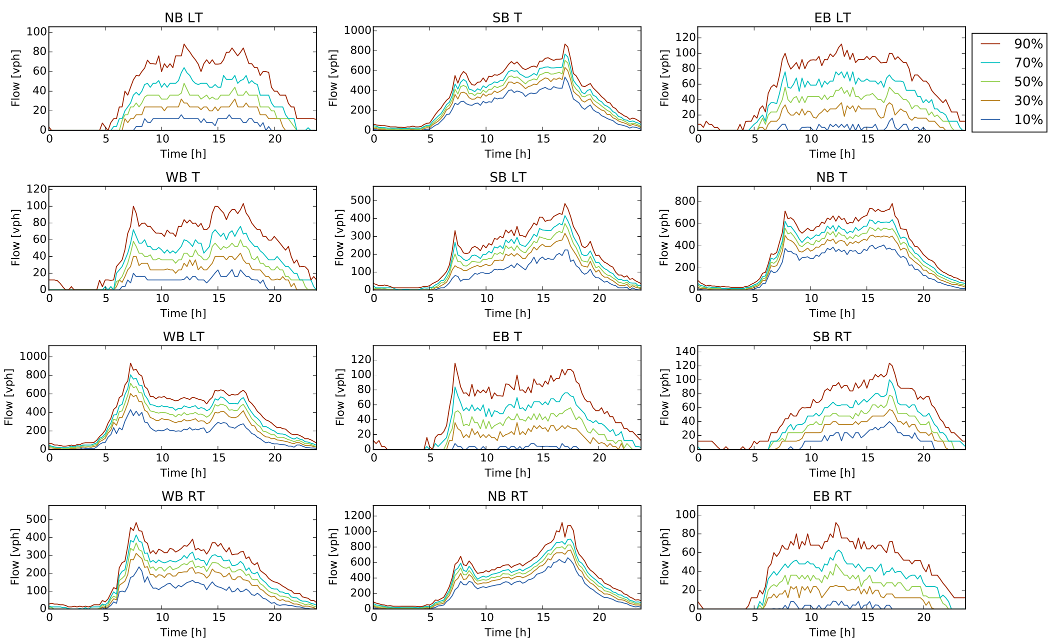

Figure 3: Empirically measured percentile flow for all 12 movements during 164 days.

The large variability suggests that there is a day-of-week structure that may be revealed by cluster analysis. We take the 164 vectors of hourly counts and group them into clusters using a standard k-means clustering of the 164 vectors. The result for $k = 4$ is displayed in Figure 4. The procedure divides the 164 vectors into four groups, G_1, G_2, G_3, G_4. The four plots display the average of these groups. Each average is a 24×12 vector, displayed as 12 separate movements over 24 hours. There is a pronounced day-of-week effect: the four clusters correspond to Mon-Th, Fri, Sat and Sun. The actual traffic plan in the intersection also groups the days of the week into these four classes. So the automatic clustering procedure agrees with experience-based judgment.

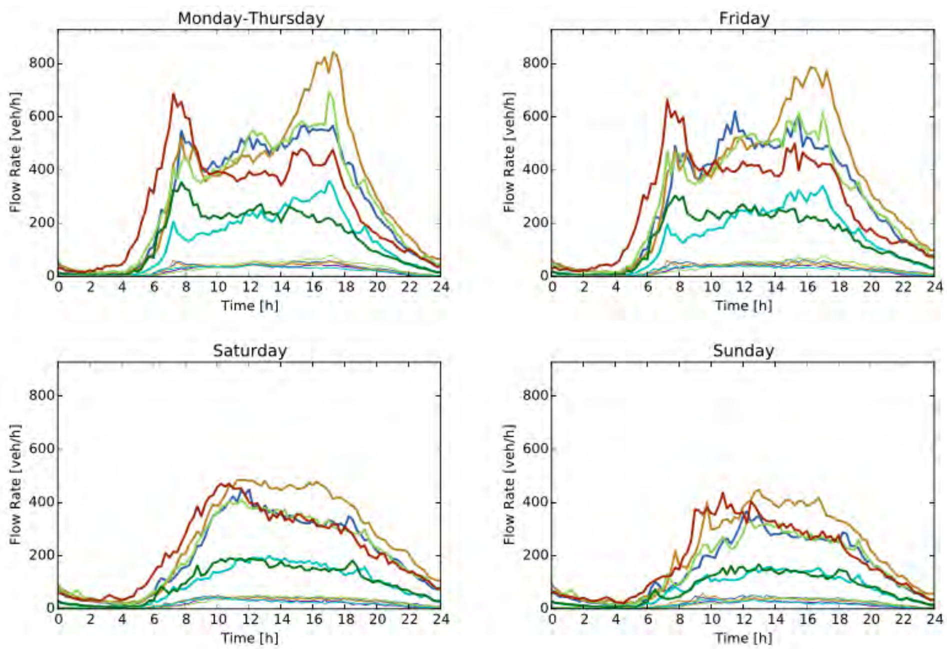

Figure 4: The 4-means cluster for all 12 movements during 164 days.

4 Intra-day segmentation and optimum splits

The next step is to take each of the four 'day' clusters $G_1, \cdots, G_4$ and divide each 24-hour day into a number of disjoint time intervals, $T_1, \cdots, T_m$. The parameter m is the number of intra-day timing plans we want to consider. Since we want a finer time resolution, we now take 15-minute rather than hourly count data. For each m we select the intervals to minimize the sum of squares,

$$\sum_{i=1}^{m} \sum_{t \in T_i} |\mu_i(t) - \bar{\mu}_i|^2.$$

Here $\mu_i(t)$ is the mean of a day cluster G_k for the 15-min period t and $\bar{\mu}_i$ is its average in the interval T_i. Figure 5 shows the result of this procedure for the Mon-Th cluster. A good design is to select 7 TOD (time of day) plans for M-Th (beginning at 0:00, 5:15, 6:45, 8:45, 14:30, 18:00 and 20:15). The figure shows the corresponding time intervals, for each of which we must design an individual timing plan (splits and cycle time). Applied to the other clusters this procedure suggests 8 plans for Fri, 4 plans for Sa, and 3 for Su. These are not shown here.

We design the timing plan for interval T_i taking $\bar{\mu}_i$ to be the 12-dimensional vector of average volumes of the 12 movements. We calculate the 'optimum' splits and cycle time. Two options are available in the optimization.

In the first option the splits and cycle time are determined by solving a quadratic programming problem that seeks to equalize the VC ratio for all 12 movements, constrained by a specified maximum VC ratio and min and max green.

In the second option the splits and cycle time are determined by solving a convex programming problem that minimizes the delay expressed by the HCM formula. We give the results of this minimization. In order to obtain a robust design we take for the demand the 90th percentile (instead of the average) of all 12 flows (see

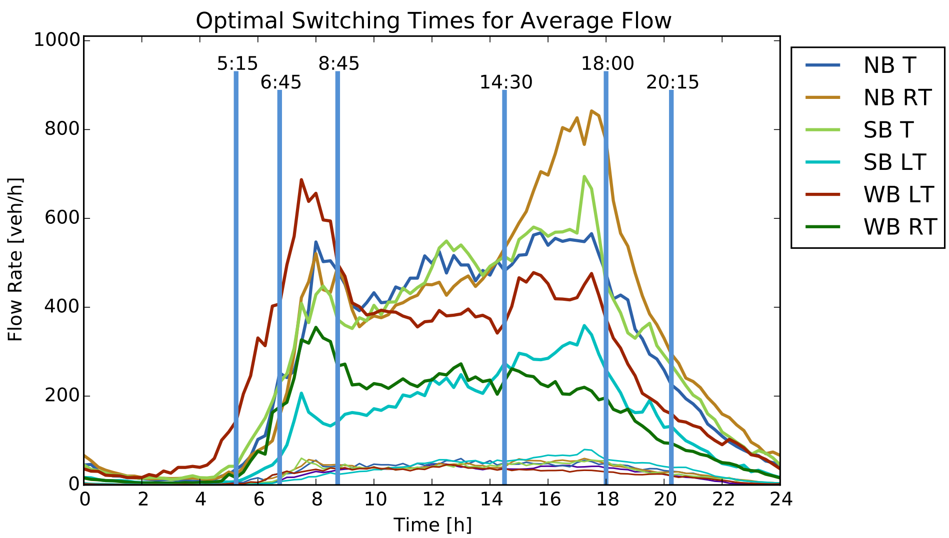

Figure 5: Optimum intra-day segments for the Mon-Th cluster.

Figure 3). Figure 6 shows the minimum delay splits and its predicted performance for the 90th percentile traffic. The predicted performance uses HCM formulas.

	Phase 1	Phase 2	Phase 4	Phase 5	Phase 6	Phase 8	Intersection
Splits (incl. Y and R)	13.7s	58.6s	39.8s	36.6s	35.6s	17.7s	129.8s
Splits (Green only)	7.7s	52.6s	33.8s	30.6s	29.6s	11.7s	105.8s
Splits (%)	6.0%	40.5%	26.0%	23.6%	22.8%	9.0%	81.5%
VC Ratios	65.6%	57.5%	92.1%	95.3%	92.8%	92.9%	93.3%
Avg. Queue Length	1.2veh	5.9veh	15.1veh	5.7veh	12.0veh	4.0veh	43.8veh
Avg. Delay	57.1s	26.7s	36.9s	51.4s	38.9s	57.1s	38.5s

Figure 6: Minimum delay splits with 90th percentile traffic and predicted performance.

Figure 7 compares the existing timing plans with those produced by Synchro and the delay-minimizing plan of Figure 6.

The existing cycle time of 130s is virtually the same as the delay-minimizing cycle time of 128.8s. Synchro gives a cycle time of 60s which is too short. In the plans of Figure 7, Synchro is forced to use a cycle time of 130s. The main difference between the three plans is the green time devoted to phase 4 which carries the west bound left turn traffic (WBLT) which is by far the largest, as seen in Figure 3. The existing plan gives the least green time to phase 4, Synchro gives the most, and the delay-minimizing plan has an intermediate value.

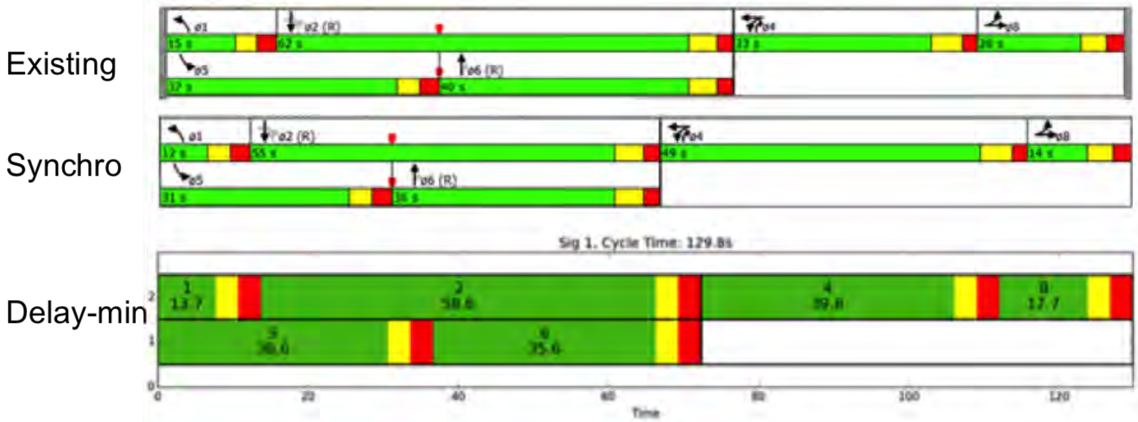

Figure 7: Splits from existing timing plans, Synchro and delay-minimizing plans.

We offer an educated guess as to why Synchro gives the most green time to phase 4. Synchro calculates the 90th percentile traffic for WBLT by by inflating the average rate λ vph to the 90th percentile, assuming the arrivals are Poisson. By making a Gaussian approximation to the Poisson distribution, the 90th percentile is $\lambda + 1.6\sqrt{\lambda}$. Because we have event-by-event data we can actually obtain the inter-arrival distribution. Figure 8 shows histograms of inter-arrival times for 11 out of 12 movements (the missing movement from leg 3, lane 1 does not have an advanced detector and is not considered). Superimposed on each histogram is the exponential distribution in red. The numbers below the *x*-axis is the average inter-arrival time λ^{-1} in seconds. The histogram is close to the exponential for small values of λ, which is not surprising. However, for the right-turn movement from lane 4 of leg 2 , which has the largest rate, the exponential is a poor fit and suggests a much larger variance than what the data indicate. Hence for this movement the empirical 90th percentile is much smaller than Synchro's estimate of $\lambda + 1.6\sqrt{\lambda}$. This is the reason we believe that Synchro assigns a larger split to this movement (as well as a larger cycle length) than what the actual data indicate is required.

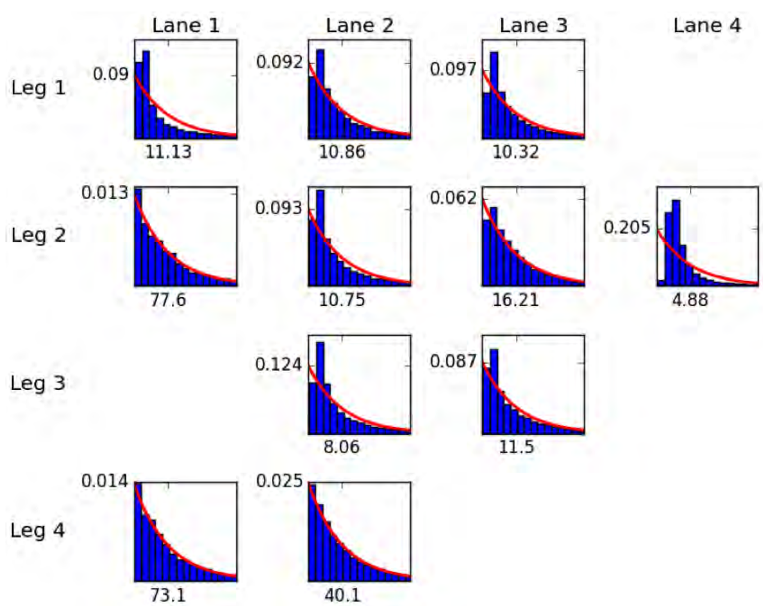

Figure 8: Histogram of inter-arrival times.

5 Discussion

The paper presented a procedure for automatically generating optimal TOD plans based on high-resolution (HR) data. The procedure requires several months of 24×7 detector data to cluster days of week, to select optimum intra-day intervals and to determine delay-minimizing splits. This way of automatic TOD plan generation is a paradigm shift from the current practice of designing plans based on manual traffic counts for three days once every few years. Using HR data to automatically produce timing plans is just one instance of the dramatic impact that an HR system will have on intersection management. We briefly describe other applications, grouping them into mobility and multi-modal traffic.

Mobility From individual event data we can determine such performance measures as cycle and split failures, wasted green, queue estimation and waiting times, and progression quality (Muralidharan et al. (2016)). The procedure described above to design the splits for time interval T_i uses only the average counts $\bar{\mu}_i$ in that interval. But the HR system provides *real time* counts, which one could use to *predict* future volume. These predictions could be used to adapt the splits to take the predicted traffic into account. This leads to proactive timing plans that anticipate changes in traffic (Coogan (2015)). Queue estimation permits implementation of sophisticated adaptive traffic control that maximize throughput in a network (Varaiya (2013)). Data for a network of intersections can be used to optimize offsets (Coogan et al. (2015)).

Knowledge of the time and lane location when a vehicle enters the intersection can be combined with the phase information to determine whether the vehicle is running a red light or whether it is making a right turn on red. The HR system can automatically detect such hazardous events and one can analyze the frequency of these event by phase movements and time periods to determine if corrective measures are needed to reduce these hazards.

Multi-modal traffic In addition to vehicle detectors an HR system may have sensors that detect pedestrians and bicycles and parked vehicles (Muralidharan et al. (2016)). As vehicles, bicycles and pedestrians compete for the same roadway surface, conflicts are inevitable since these different modes of traffic move with different speeds and occupy space with different shapes. The conflicts will be most severe in intersections and so managing the movement of this multi-modal traffic will be of growing importance. We can see an evolution in the way space is shared. Fixed time controllers provide "walk/don't walk signals" for pedestrians at marked crosswalks; but if crosswalk utilization is low, it may be more efficient to use push-buttons. If the occupancy of parking spaces is sensed, the price for on-street parking may be adapted to keep occupancy at a desired level, e.g. 80 percent (Pierce and Shoup (2013)). Similar to congestion pricing in HOT lanes, such a pricing policy will reduce double-parking and the number of cars looking for an empty spot.

HR systems as described here collect microscopic data on individual vehicles at particular locations. This data is naturally complemented by sensors that collect a sample of vehicle trajectories, e.g. using Bluetooth or WiFi receivers or GPS traces. The trajectory data can be analyzed to reveal O-D patterns and preferred paths. In case of incidents this patterns may be used to suggest alternative paths to drivers. It may be used design incentives for travelers to change their trip times and other behavior in ways that improve traffic (Pluntke and Prabhakar (2013)). The only practical way to accommodate the growing demands on the urban road system is to change behavior, and motivating the appropriate change will require fine-grained and extensive data.

References

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Kinton, Colin

From: semhar <semhar@ats-sales.com>
Sent: Friday, May 13, 2016 10:11 AM
To: Kinton, Colin
Subject: RE: New intersection design with monotube

Colin,

I got an answer back from Valmont that the poles with luminaire arms are possible.
Let us know if you have any other question please.
Thanks,

Semhar Russom

Staff Engineer
ATS-Sales, LLC
Email: semhar@ats-sales.com
Phone: 703-631-6661
Fax: 703-631-6694

From: Kinton, Colin [mailto:ckinton@bcgov.net]
Sent: Wednesday, May 11, 2016 5:16 PM
To: semhar <semhar@ats-sales.com>
Subject: RE: New intersection design with monotube

Semhar,
Thanks for this information.
While I like the mitered connection, I would like to see us go with a flange plate type connection and a 30.5' tall pole if possible (similar to our mast arms we use now) as we would like to be able to add street lights on the two ends on 4' arms mounted at 30.0 ft. is this possible? I've attached a quick sketch as what I was thinking.

Colin Kinton, P.E.
Beaufort County Transportation Engineering ckinton@bcgov.net
Phone: (843) 255-2940
Beaufort County, SC

From: semhar [mailto:semhar@ats-sales.com]
Sent: Wednesday, May 11, 2016 1:08 PM
To: Kinton, Colin
Subject: FW: New intersection design with monotube

Colin,

We have been working on your request concerning monotube structures for Beaufort County , SC. Valmont does in fact design and fabricate these types of structures. I've attached a prior example for you. The attached structure is much larger (i.e. 188' Center-To- Center) and costed approximately $200K. Smaller structures in the 110' range are approximately $125K. The attached drawing was selected for you, in that the shaft to horizontal arm is a mitered connection which may appeal visually. Typical connections are more flange plate based and reduce some fabrication costs.

Let us know if we can help with preliminary calculations or designs as you explore this approach.

Semhar Russom

Staff Engineer
ATS-Sales, LLC
Email: semhar@ats-sales.com
Phone: 703-631-6661
Fax: 703-631-6694

From: Louise Engebretson [mailto:louise@ats-sales.com]
Sent: Wednesday, May 11, 2016 11:22 AM
To: semhar@ats-sales.com
Subject: FW: New intersection design with monotube

From: Kinton, Colin [mailto:ckinton@bcgov.net]
Sent: Wednesday, March 16, 2016 8:27 AM
To: armand@ats-sales.com
Cc: Louise Engebretson <louise@ats-sales.com>
Subject: RE: New intersection design with monotube

Louise and Armand,
Attached is a more complete draft signal design.
We are requesting that the arm span attach at 23 ft elevation on the vertical poles
Can you please provide a quote for the design/fabrication of a monotube system for this intersection?
thanks

Colin Kinton, P.E.
Beaufort County Transportation Engineering ckinton@bcgov.net
Phone: (843) 255-2940
Beaufort County, SC

From: Kinton, Colin
Sent: Wednesday, March 02, 2016 11:22 AM
To: 'armand@ats-sales.com'
Cc: 'Louise Engebretson'
Subject: New intersection design with monotube

Armand,
We are working with SCDOT on the possibility of the state's first monotube traffic signal.
Attached is a draft sketch of the intersection illustrating the proposed 110 ft span monotube along with FDOT design standards.
Is this something that Valmont and ATS can design/fabricate?

Can you give me a ballpark cost estimate for design and fabrication of the monotube assuming Valmont can fabricate this?
Because of the intersection skew, we don't have many alternatives for rebuilding the existing signal.
thanks

Colin Kinton, P.E.
Beaufort County Transportation Engineering ckinton@bcgov.net
Phone: (843) 255-2940
Beaufort County, SC

Please consider the environment before printing this email

Temple, Inc.
P.O. Box 2066
Decatur, Alabama 35602-2066
Phone 1-800-633-3221
Fax (256) 353-4578

Temple

Serving the South Since 1954!

DATE
May 16, 2016
NET 30
DELIVERY
4 to 6 Weeks, A.R.O.
SALESMAN
Byron Hood

Beaufort County
Colin Kinton

SC 170 @ US 21
Sensys Equipment

CONDITIONS: The prices and terms on this quotation are not subject to verbal changes or other agreements unless approved in writing by **Temple, Inc.** All quotations and agreements are contingent upon strikes, accidents, fires, availability of materials and all other causes beyond our control. Prices are based on costs and conditions existing on date of quotation and are subject to change by **Temple, Inc.** before final acceptance. Freight will be prepaid and allowed unless otherwise noted on this quotation.

Quantity	Description	Price	Amount
1	FLEX-CTRL-M-E: FlexControl Module Enhanced		
1	FLEX-CONN-M: FlexConnect Module with Mounting Bracket		
1	FLEX-ISOL-M: FlexIsolator Module (2 port)		
1	FLEX-CTRL-ACC-3: FlexControl Power Supply with Power Cords		
1	FLEX-CONN-ACC-3: FlexConnect Power Supply with Power Cords		
2	APCC Serial Port Protocol (Digital Radio): APCC-SPP		
7	Repeater: RP240-BH-LL-2		
1	FLEX RP-B-LL: FLEX Long-Life Repeater		
1	FLEX ANT-1: Standard External Antenna		
50	VSN240-F-2: FlexMag Flush Wireless Sensor		
4	VSN240-CS-2: Clear Shell for Flush Mount Wireless Sensor		
54	Epoxy tube		
11	KIT-MTG: Universal Mounting Bracket		
1	Tech Assistance (2 travel days, 2 on site days)		
		TOTAL $	**44,498.00**

Notes:
Taxes are not include in the price.
CAT5 cable is not included in the price.
Service poles not included in the price.
Installation is not included in the price.

Quote Valid For 30 Days.

SALESPERSON

FED. ROAD DIV. NO.	STATE	COUNTY	FILE NO.	PROJECT NO.	ROUTE NO.	SHEET NO.	TOTAL SHEETS
	SC	BEAUFORT			US 21		

SIGNAL EQUIPMENT

ONE (1) 8 PHASE FULLY ACTUATED STANDARD 2070 CONTROLLER WITH FLASHER, SIGNAL MONITOR UNIT, AND BASE - MOUNTED 332A CABINET. EXT. PROP.

9 MODEL 222, (2)-CHANNEL VEHICLE DETECTOR UNITS

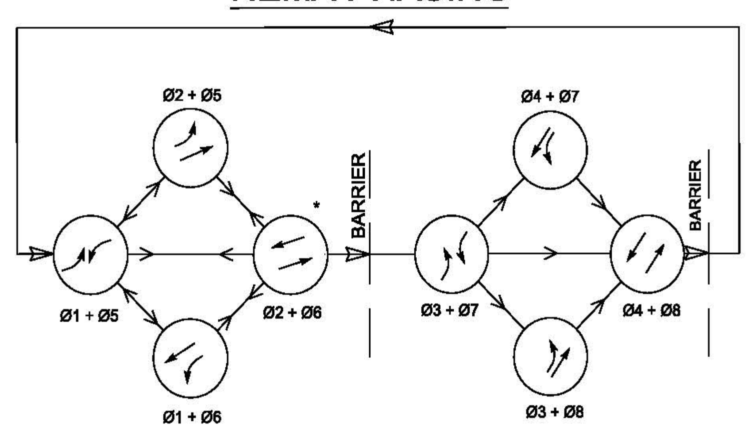
EXT. P PROP. P W/ACT. & SIGN

VEHICLE SIGNALS: EXT. PROP.

HEAD NUMBER	1,2F	2	3,4F	4	5,6F	6	7,8F	8		
LENS	←R ←Y ←FY ←G	R Y G	←R ←Y ←FY ←G	R Y G	←R ←Y ←FY ←G	R Y G	←R ←Y ←FY ←G	R Y G		
PHASE	1, OLA	2	3,OLB	4	5,OLC	6	7,OLD	8		
SIZE	12"	12"	12"	12"	12"	12"	12"	12"		
QUANTITY	1	2	1	2	1	2	1	2		

OLA= Ø1+Ø2 (FYA) OLC= Ø5+Ø6 (FYA)
OLB= Ø3+Ø4 (FYA) OLD= Ø7+Ø8 (FYA)

NEMA PHASING



NOTE: ACTUATED PHASES HAVING NO CALL, SHALL BE SKIPPED

* STREET COORDINATED

FLASHING OPERATION

SIGNING

SIGN "A"

R10-12A-36

SIGN "B1"

Robert Smalls Pkwy

D3-1

SIGN "B2"

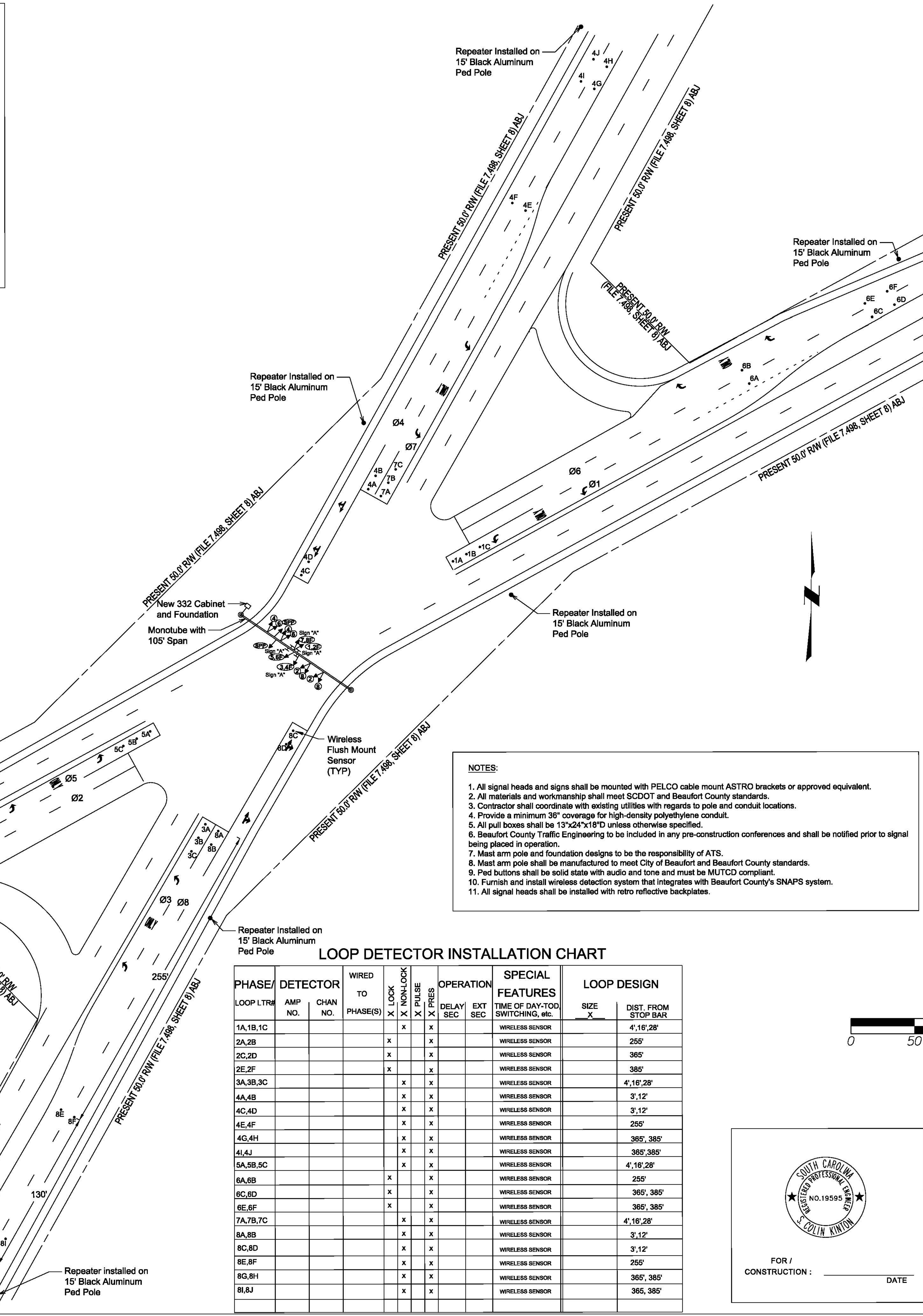
Parris Island Gtwy

D3-1

NOTE:
Signal is part of a coordinated system. Below signal timings are for free operation. Contact Beaufort County Traffic Engineering for Time of Day plan details.

SIGNAL TIMINGS

INTERVAL	PHASE 1	2	3	4	5	6	7	8
WALK								
DON'T WALK								
MIN INITIAL	6	15	6	10	6	15	6	10
MAX INITIAL								
ADD/VEH								
VEH EXT	2.5	3.0	2.5	3.0	2.5	3.0	2.5	3.0
TIM BFR REDUC								
TIME TO REDUC								
MIN GAP								
MAX LIMIT	20	45	20	20	20	45	20	20
MAXIMUM 2								
YELLOW	4.4	4.4	4.7	4.7	4.4	4.4	4.7	4.7
RED CLEAR	5.4	5.4	4.5	4.5	5.4	5.4	4.5	4.5



SIGNAL DISPLAY SEQUENCE CHART

R-RED
←R-RED ARROW
Y-YELLOW
←Y-STEADY YELLOW ARROW
←Y- FLASHING YELLOW ARROW
G-GREEN
←G-GREEN ARROW
W-WALK
DW-DON'T WALK

PHASE ON (A)	NON-CONFLICTION PHASE (B)	CONFLICTING PHASE *
1	5,6,	2, 3,4,7,8,
2	5,6,	1,3,4, 7, 8,
3	8,	12,4, 5,6, 7,
4	7,8,	1, 2,3, 5, 6,
5	1,2,	3, 4, 6,7,8,
6	1,2,	3,4, 5,7,8,
7	4,	1, 2,3,5,6,8,
8	3,4,	1, 2, 5,6, 7,

'C' = COORDINATE Ø2 ; Ø6

NOTE A: ANY ACTUATED PHASE FOR WHICH THERE IS NO CALL SHALL BE OMITTED.
NOTE B: WHEN ONE PHASE IS ON ALONE, ANY/NON-CONFLICTING PHASE MAY START TIMING CONCURRENTLY WITHOUT A CLEARANCE INTERVAL (SEE CHART).
* CONFLICTING PHASES REQUIRE A CLEARANCE INTERVAL.

** WHEN CALLED, DISPLAY SOLID 'WALKING PERSON' AND TIMES OUT WALK TIMING; THEN DISPLAYS FLASHING 'UPRAISED HAND' AND TIMES WALK CLEARANCE (DON'T WALK TIMING), THEN DISPLAYS A SOLID 'UPRAISED HAND'.

SIGNAL DISPLAY SEQUENCE (PREFERENTIAL PHASING)

Ø1 — Ø5

FLASH	SIGNAL HEAD NUMBER	R/W	CLEAR TO Ø1-Ø6		Ø2-Ø5		Ø2-Ø6		BARR.	
←Y	1,2F	←G	←G	←G	←Y	←R	←Y	←R	←Y	←R
Y	2	R	R	R	R	R	R	R	R	R
←R	3,4F	←R	←R	←R	←R	←R	←R	←R	←R	←R
R	4	R	R	R	R	R	R	R	R	R
←Y	5,6F	←G	←Y	←R	←G	←G	←Y	←R	←Y	←R
Y	6	R	R	R	R	R	R	R	R	R
←R	7,8F	←R	←R	←R	←R	←R	←R	←R	←R	←R
R	8	R	R	R	R	R	R	R	R	R
–										
–										
–										
–										

Ø2 — Ø6

SIGNAL HEAD NUMBER	R/W	CLEAR TO Ø1-Ø5		Ø1-Ø6		Ø2-Ø5		BARR.	
1,2F	←FY	←FY	←FY	←FY	←FY	←FY	←FY	←Y	←R
2	G	Y	R	Y	R	G	G	Y	R
3,4F	←R	←R	←R	←R	←R	←R	←R	←R	←R
4	R	R	R	R	R	R	R	R	R
5,6F	←FY	←FY	←FY	←FY	←FY	←FY	←FY	←Y	←R
6	G	Y	R	G	G	Y	R	Y	R
7,8F	←R	←R	←R	←R	←R	←R	←R	←R	←R
8	R	R	R	R	R	R	R	R	R

BARRIER

Ø3 — Ø7

SIGNAL HEAD NUMBER	R/W	CLEAR TO Ø3-Ø8		Ø4-Ø7		Ø4-Ø8		BARR.	
1,2F	←R	←R	←R	←R	←R	←R	←R	←R	←R
2	R	R	R	R	R	R	R	R	R
3,4F	←G	←G	←G	←Y	←R	←Y	←R	←Y	←R
4	R	R	R	R	R	R	R	R	R
5,6F	←R	←R	←R	←R	←R	←R	←R	←R	←R
6	R	R	R	R	R	R	R	R	R
7,8F	←G	←Y	←R	←G	←G	←Y	←R	←Y	←R
8	R	R	R	R	R	R	R	R	R

Ø4 — Ø8

SIGNAL HEAD NUMBER	R/W	CLEAR TO Ø3-Ø7		Ø3-Ø8		Ø4-Ø7		BARR.	
1,2F	←R	←R	←R	←R	←R	←R	←R	←R	←R
2	R	R	R	R	R	R	R	R	R
3,4F	←FY	←FY	←FY	←FY	←FY	←FY	←FY	←Y	←R
4	G	Y	R	Y	R	G	G	Y	R
5,6F	←R	←R	←R	←R	←R	←R	←R	←R	←R
6	R	R	R	R	R	R	R	R	R
7,8F	←FY	←FY	←FY	←FY	←FY	←FY	←FY	←Y	←R
8	G	Y	R	G	G	Y	R	Y	R

ALTERNATE PHASES

Ø1 — Ø6

SIGNAL HEAD NUMBER	R/W	CLEAR TO Ø1-Ø5		Ø2-Ø6				BARR.	
1,2F	←G	←G	←G	←Y	←R			←Y	←R
2	R	R	R	R	R			R	R
3,4F	←R	←R	←R	←R	←R			←R	←R
4	R	R	R	R	R			R	R
5,6F	←FY	←FY	←FY	←FY	←FY			←Y	←R
6	G	Y	R	G	G			Y	R
7,8F	←R	←R	←R	←R	←R			←R	←R
8	R	R	R	R	R			R	R

Ø2 — Ø5

SIGNAL HEAD NUMBER	R/W	CLEAR TO Ø1-Ø5		Ø2-Ø6				BARR.	
1,2F	←FY	←FY	←FY	←FY	←FY			←Y	←R
2	G	Y	R	G	G			Y	R
3,4F	←R	←R	←R	←R	←R			←R	←R
4	R	R	R	R	R			R	R
5,6F	←G	←G	←G	←Y	←R			←Y	←R
6	R	R	R	R	R			R	R
7,8F	←R	←R	←R	←R	←R			←R	←R
8	R	R	R	R	R			R	R

BARRIER

ALTERNATE PHASES

Ø3 — Ø8

SIGNAL HEAD NUMBER	R/W	CLEAR TO Ø3-Ø7		Ø4-Ø8				BARR.	
1,2F	←R	←R	←R	←R	←R			←R	←R
2	R	R	R	R	R			R	R
3,4F	←G	←G	←G	←Y	←R			←Y	←R
4	R	R	R	R	R			R	R
5,6F	←R	←R	←R	←R	←R			←R	←R
6	R	R	R	R	R			R	R
7,8F	←FY	←FY	←FY	←FY	←FY			←Y	←R
8	G	Y	R	G	G			Y	R

Ø4 — Ø7

SIGNAL HEAD NUMBER	R/W	CLEAR TO Ø3-Ø7		Ø4-Ø8				BARR.	
1,2F	←R	←R	←R	←R	←R			←R	←R
2	R	R	R	R	R			R	R
3,4F	←FY	←FY	←FY	←FY	←FY			←Y	←R
4	G	Y	R	G	G			Y	R
5,6F	←R	←R	←R	←R	←R			←R	←R
6	R	R	R	R	R			R	R
7,8F	←G	←G	←G	←Y	←R			←Y	←R
8	R	R	R	R	R			R	R

NOTES:

1. All signal heads and signs shall be mounted with PELCO cable mount ASTRO brackets or approved equivalent.
2. All materials and workmanship shall meet SCDOT and Beaufort County standards.
3. Contractor shall coordinate with existing utilities with regards to pole and conduit locations.
4. Provide a minimum 36" coverage for high-density polyethylene conduit.
5. All pull boxes shall be 13"x24"x18"D unless otherwise specified.
6. Beaufort County Traffic Engineering to be included in any pre-construction conferences and shall be notified prior to signal being placed in operation.
7. Mast arm pole and foundation designs to be the responsibility of ATS.
8. Mast arm pole shall be manufactured to meet City of Beaufort and Beaufort County standards.
9. Ped buttons shall be solid state with audio and tone and must be MUTCD compliant.
10. Furnish and install wireless detection system that integrates with Beaufort County's SNAPS system.
11. All signal heads shall be installed with retro reflective backplates.

LOOP DETECTOR INSTALLATION CHART

PHASE/ LOOP LTR#	DETECTOR AMP NO.	DETECTOR CHAN NO.	WIRED TO PHASE(S)	X LOCK	X NON-LOCK	X PULSE	X PRES	OPERATION DELAY SEC	OPERATION EXT SEC	SPECIAL FEATURES TIME OF DAY-TOD, SWITCHING, etc.	LOOP DESIGN SIZE X	LOOP DESIGN DIST. FROM STOP BAR
1A,1B,1C					x		x			WIRELESS SENSOR		4',16',28'
2A,2B				x			x			WIRELESS SENSOR		255'
2C,2D				x			x			WIRELESS SENSOR		365'
2E,2F				x			x			WIRELESS SENSOR		385'
3A,3B,3C					x		x			WIRELESS SENSOR		4',16',28'
4A,4B					x		x			WIRELESS SENSOR		3',12'
4C,4D					x		x			WIRELESS SENSOR		3',12'
4E,4F					x		x			WIRELESS SENSOR		255'
4G,4H					x		x			WIRELESS SENSOR		365', 385'
4I,4J					x		x			WIRELESS SENSOR		365',385'
5A,5B,5C					x		x			WIRELESS SENSOR		4',16',28'
6A,6B				x			x			WIRELESS SENSOR		255'
6C,6D				x			x			WIRELESS SENSOR		365', 385'
6E,6F				x			x			WIRELESS SENSOR		365', 385'
7A,7B,7C					x		x			WIRELESS SENSOR		4',16',28'
8A,8B					x		x			WIRELESS SENSOR		3',12'
8C,8D					x		x			WIRELESS SENSOR		3',12'
8E,8F					x		x			WIRELESS SENSOR		255'
8G,8H					x		x			WIRELESS SENSOR		365', 385'
8I,8J					x		x			WIRELESS SENSOR		365, 385'

SCALE IN FEET

0 50 100 200

ROUTE NUMBER	SC-170		US-21	
APPROACH DIRECTION	WB	EB	SB	NB
SIGNAL DESIGN SPEED	45	45	45	45
GRADE (%)	0*	0*	0*	-3*

* ESTIMATED

SOUTH CAROLINA REGISTERED PROFESSIONAL ENGINEER NO.19595 S. COLIN KINTON

FOR / CONSTRUCTION : DATE

DATE	REVISIONS

BEAUFORT COUNTY
TRAFFIC ENGINEERING DEPARTMENT
P.O. DRAWER 1228
BEAUFORT, SOUTH CAROLINA 29901
(843) 255 – 2940

SUBJECT TITLE: TRAFFIC SIGNAL PLAN

SPECIFIC LOCATION: US-21 (Parris Island Gateway) & SC-170 (Robert Smalls Parkway)

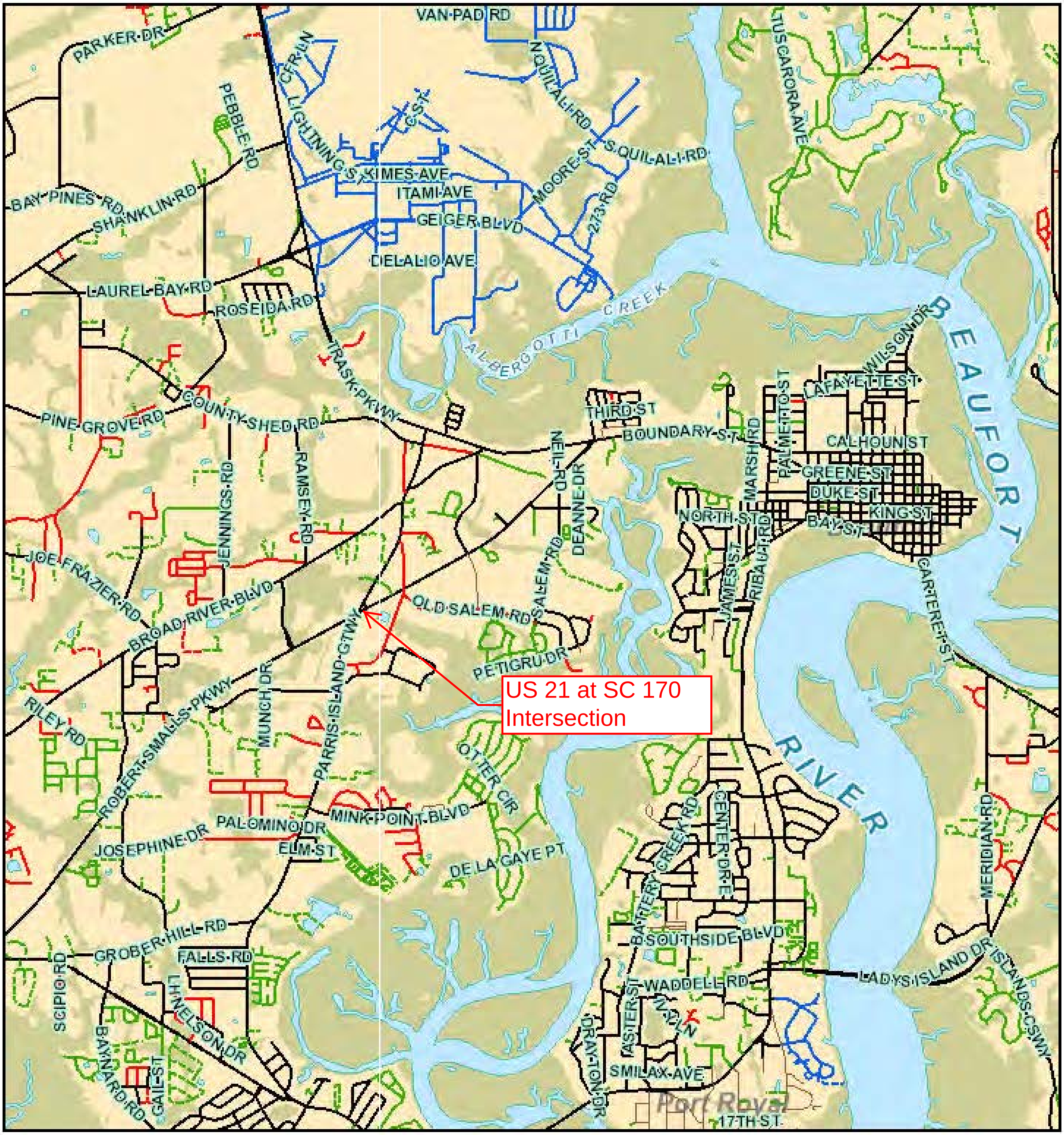
CITY: BEAUFORT COUNTY: BEAUFORT

DESIGNED: MPF
DRAWN: ———
CHECKED:
REVIEWED:
RECOMMENDED: ———

APPROVED BY
DISTRICT #6 TRAFFIC ENGINEER ENGINEER

SCALE	DATE	SHEET NO.	INDEX NO.
1"= 50'	4/23/2014	1 OF 1	

US 21 at SC 170 Intersection Upgrades



May 16, 2016

1:63,983

0 0.5 1 2 mi

0 0.75 1.5 3 km

Road Classifications

- <all other values>
- STATE, PAVED
- STATE, UNPAVED
- COUNTY, PAVED
- COUNTY, UNPAVED
- PRIVATE, PAVED
- PRIVATE, UNPAVED
- PRIVATE, UNDETERMINED
- TOWN, PAVED
- TOWN, UNPAVED
- MILITARY / PAVED
- MILITARY / UNPAVED