Texas Transportation Institute
The Texas A&M University System
701 North Post Oak, Suite 430
Houston, TX 77024-3827

713-686-2971
Fax: 713-686-5396
http://tti.tamu.edu

May 25, 2016

MEMORANDUM

TO: Mr. Mike Pietrzyk, P.E.

FROM: Roma Stevens, P.E., PTOE
Anthony Voigt, P.E., PTOE

SUBJECT: Benefit Cost Analysis of Queue Warning System (QWS) on I-610 (West Loop)

INTRODUCTION

This technical memorandum presents findings of the benefit cost analysis of QWS deployed along I-610 between Bellaire Blvd and US 59 Interchange. In 2006, the Texas Department of Transportation, Houston District deployed a queue warning system to warn motorists of traffic queues and slow traffic ahead. The QWS was installed at two locations – 1) I-610 West Loop Northbound approach to US 59 direct connectors and 2) US 59 (Southwest) Eastbound approach to I-610 West Loop direct connectors. The original plans (provided by TxDOT) showing system components and locations of warning signs are included in the Appendix. This evaluation focuses on the West Loop location only, as there were issues (detailed below) in gaining accurate crash data for the Southwest Freeway location.

The original system was deployed approximately 10 years ago and has since been upgraded with different communications and detection equipment. Based on correspondence with TxDOT staff currently involved with the maintenance of queue warning system, researchers obtained the following information about system:

- The two systems were deployed and activated in September 2006 at an approximate cost of $100k per system.
- The original system used Raven modems for communications which were replaced with spread spectrum radios in 2008.
- In 2010, a complete system maintenance was completed when processors and batteries were replaced.
- In 2011, communication equipment was changed to Digi modems.
- During 2012-2013, the QWS was integrated with TranStar using fiber network via point-to-point Ethernet at an approximate cost of $20,000.
- In January 2015, detection equipment was upgraded to Wavetronix smart sensors on the US 59 location at an approximate cost of $20,000.

Typically, the evaluation of a queue warning system would include an assessment of crash experience *and* traffic operations using a before-after type of study for the roadway segment expected to be affected by the QWS. However for this current effort, because the before period operations data is unavailable and only limited crash data is available (for the West Loop site only), the evaluation focus was on estimating system benefits using available crash data.

CRASH DATA ANALYSIS

The Highway Safety Manual recommends three to five years of both before and after data for comparative studies in order to account for the inherent randomness in crash occurrences, although shorter durations can be used with lower likelihood of statistically significant results. Due to limitation on availability of older crash data sets and differences in recording formats for crashes, researchers used one year before (September 2005 to August 2006) and one year after crash data for this analysis (October 2006 to September 2007 not including the month of September, 2006 when system was deployed and activated. Though some additional crash data from January 2005 to August 2005 were available, it was decided to include same months of the year to minimize the impact of seasonal variations in traffic patterns and crashes.

As part of this analysis, researchers explored the possibility of obtaining historical traffic volume data for the TxDOT radar volume data collection station at IH 610 at Fournace to determine if there were any significant traffic volumes changes that might have contributed to a change in the number of crashes. However, the earliest available archived data from this radar station is from October 2006 (during the "after" period). For this evaluation, researchers were not able to determine if traffic volumes in the study segment had remained same or changed significantly enough from before to after period so as to make an impact on the number of crashes in the study area.

However, for this evaluation, researchers obtained crash data from years 2005, 2006, and 2007, but before going into further detail about the data analysis, it should be noted that TxDOT crash data management system went through various changes during this time frame and data for each year was recorded in a different format and is also different than the Crash Records Information System currently in use by TxDOT. The crash data were obtained for crashes occurring on the mainlanes of I-610 from cross street of Beechnut Street to US 59 interchange and on the mainlanes of US 59 from Bellaire Blvd to I-610 interchange using block numbers as the criteria to define the segments. It was necessary to use block numbers for defining the segments as cross street names are sometimes identified as 'NOT REPORTED' in the dataset.

For detailed analysis, it was necessary to isolate crashes for the study segment for each QWS location as US 59 crosses the I-610 Loop freeway at two locations and block numbers were found to be duplicate along both US 59 and I-610 Loop as both freeways pass through different jurisdictions and have nomenclature additional to the numbering nomenclature. For the I-610 mainlane QWS location, researchers were able to isolate the crashes for the study segment using the following criteria:

- Highway Name – IH 610, I-610, 610, West Loop, and W Loop
- City ID – Bellaire
- Travel Direction - North

However for the US 59, it was not possible to isolate the crashes for the QWS study segment as both block numbers and City ID were found to be duplicate for the study segment as well as for the US 59 segment north of I-610 North Loop. Therefore, it was decided to complete the analysis for only one QWS location (I-610 location).

CRASH DATA FINDINGS

Crash data were analyzed to identify the number of total crashes and number of events for each level of injury severity. Note that each crash can have multiple persons injured at different severity level. Table 1 presents the number of crashes and number of persons involved by injury severity for the before period and after period. Table 1 also shows the difference in number of crashes and number of person injuries from before to after period.

Table 1. Total Number of Crashes and Number of Persons Involved by Injury Severity for the Before and After Period on IH-610 (West Loop).

Period	Total # of Crashes	Number of Persons Involved by Injury Severity						
		Incapacit-ating	Non Incapacit-ating	Poss. Injury	No Injury	Unknown Injury	Fatal	Total
Before (September 2005 to August 2006)	214	12	36	161	559	49	0	817
After (October 2006 to September 2007)	206	2	16	112	626	40	0	796
Difference *(After-Before)	**-8**	**-10**	**-20**	**-49**	**67**	**-9**	**0**	**-21**

*negative values suggest a positive (desired) impact of the QWS on crashes.

Table 1 shows that there was a reduction in the total number of crashes after the QWS was installed as compared to the before period, and it was interesting to note that crashes with no injury increased as the total number of injury crashes decreased. There are many confounding factors (changes in traffic volumes from before to after period, changes in crash data recording, uncertainty with old crash data and inherent randomness in crash occurrences) that might have contributed to the noted reduction in total number of crashes in the after period as compared to before period, it may appear that the QWS deployment may have had some impact on the number and severity of crashes.

In order to estimate the monetary benefits of reduction in number of crashes and reduction in number of persons with higher levels of injury severity, researchers used the National Safety Council's estimates of average costs of fatal and nonfatal unintentional injuries. Table 2 below shows the average comprehensive cost by injury severity in 2013 dollars developed by the National Safety Council. Using CPI from Bureau of Labor Statistics, these costs were calculated for year 2006.

Table 2. Average Comprehensive Cost by Injury Severity (1)

Injury Severity	2013 Dollar Value	2006 Dollar Value*
Death	$4,628,000	$4,026,300
Incapacitating injury	$235,400	$204,700
Non incapacitating evident injury	$60,000	$52,200
Possible injury	$28,600	$24,800
No injury	$2,600	$2,200

*computed using CPI of 0.87 and rounded down to nearest hundred.

In order to apply the average comprehensive cost, Unknown injury and No injury were assumed to have the same comprehensive cost. Tables 5 below shows the average comprehensive cost for the before and after crashes by injury severity. There were no fatalities in the study segment for both the before and after periods, therefore Table 3 does not include the column for Death.

Table 3. Monetary Value of Crashes by Injury Severity in the Before and After Period

Time Period	Incapacitating Injuries	Non Incapacitating Injury	Possible Injury	Unknown + No Injury	Total
Before	$2,456,400	$1,879,200	$3,992,800	$1,337,600	$9,666,000
After	$409,400	$835,200	$2,777,600	$1,465,200	$5,487,400
Difference (after-before)	($2,047,000)	($1,044,000)	($1,215,200)	$127,600	($4,178,600)

Approximate cost of system - $100,000
Approximate monetary savings from crash reductions = $4,178,600
Benefit/Cost Ratio = 41.7

Summary of Findings

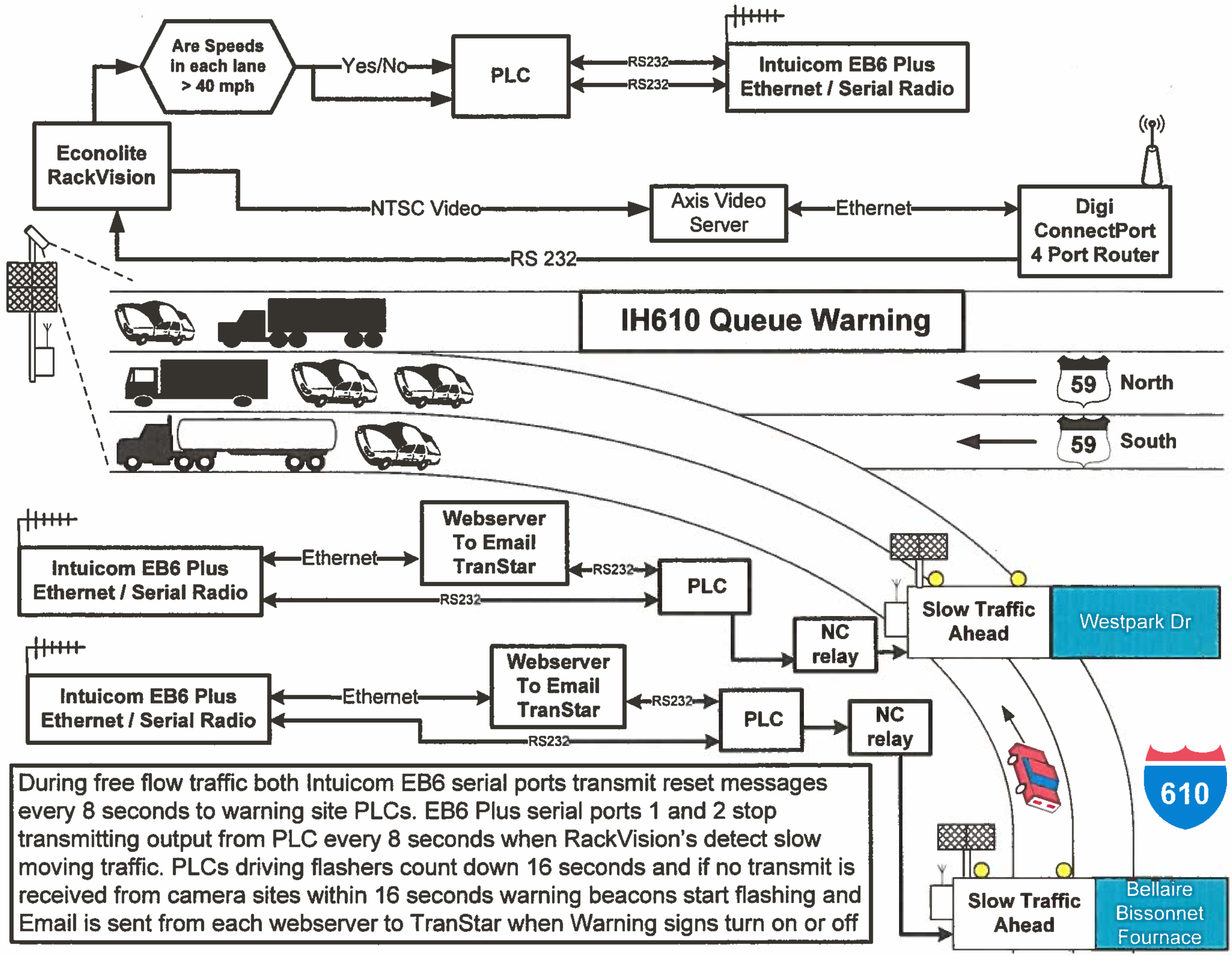
- The crash data analysis shows that there are likely benefits of the system in reducing the number of crashes and number of crashes with higher levels of injury severity. This finding suggests that during the after study period (October 2006 to September 2007), the system was effective in warning drivers of slow speeds ahead, thereby resulting in crashes at reduced speeds and/or crashes leading to higher levels of severity and physical injuries.
- The number of incapacitating injuries and non-incapacitating injuries reduced from 48 in the before period to 18 in the after period, a significant decrease by magnitude.
- Though unavailability of traffic volumes data from the before period and changes in crash data recording system during the study timeframe (from 2005 thru 2007) make it difficult to draw conclusions with statistical significance, the reduction in the number of incapacitating and non-incapacitating injuries shows the likely benefits of the system in reducing speeds and collisions where deployed on the IH-610 West Loop South.

References

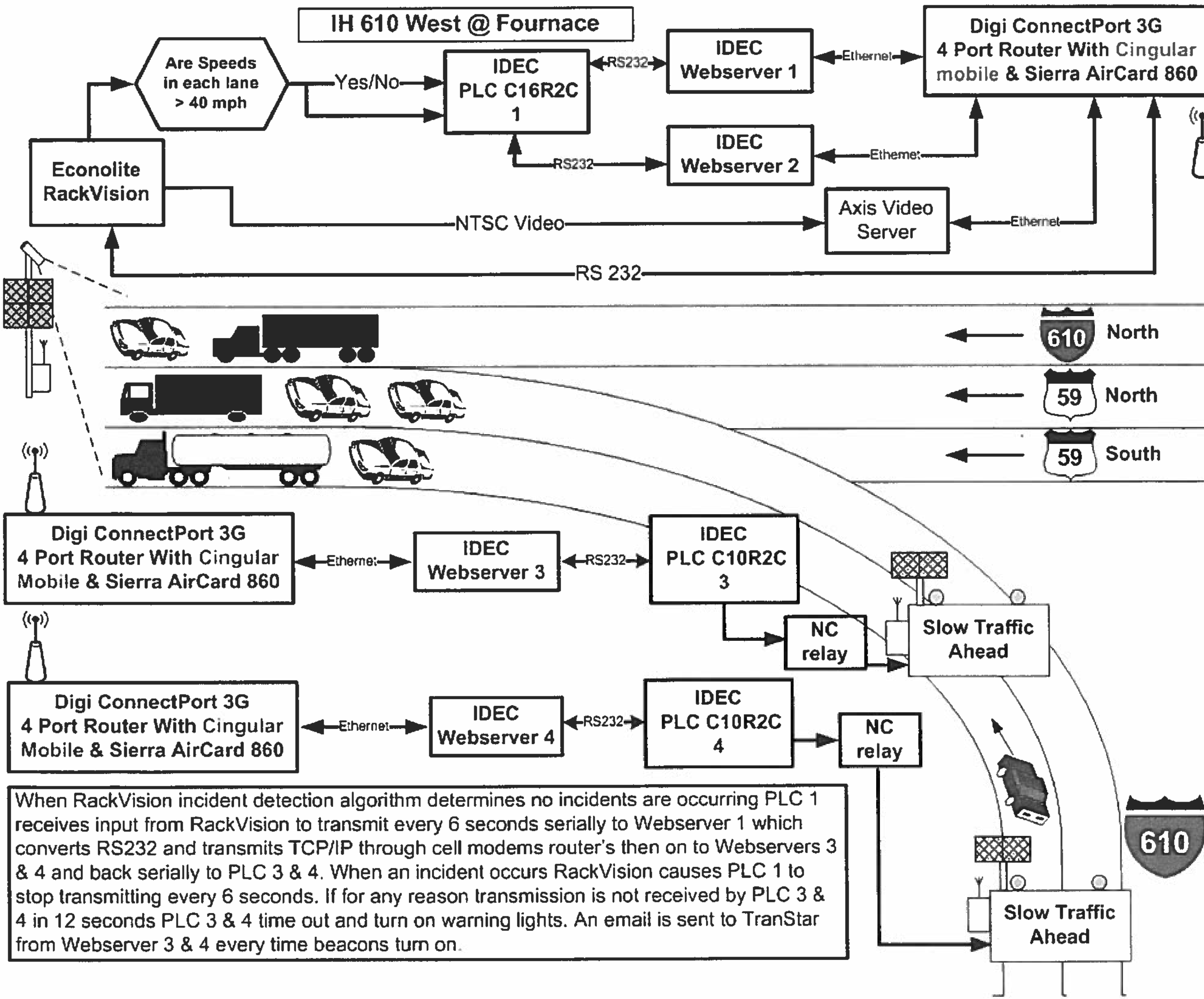
1. Estimating the Costs of Unintentional Injuries, 2013, National Safety Council, April 2015. http://www.nsc.org/NSCDocuments_Corporate/estimating-costs-unintentional-injuries-2015.pdf)

Appendix

QWS Plans Showing System Devices and Warning Sign Locations



During free flow traffic both Intuicom EB6 serial ports transmit reset messages every 8 seconds to warning site PLCs. EB6 Plus serial ports 1 and 2 stop transmitting output from PLC every 8 seconds when RackVision's detect slow moving traffic. PLCs driving flashers count down 16 seconds and if no transmit is received from camera sites within 16 seconds warning beacons start flashing and Email is sent from each webserver to TranStar when Warning signs turn on or off

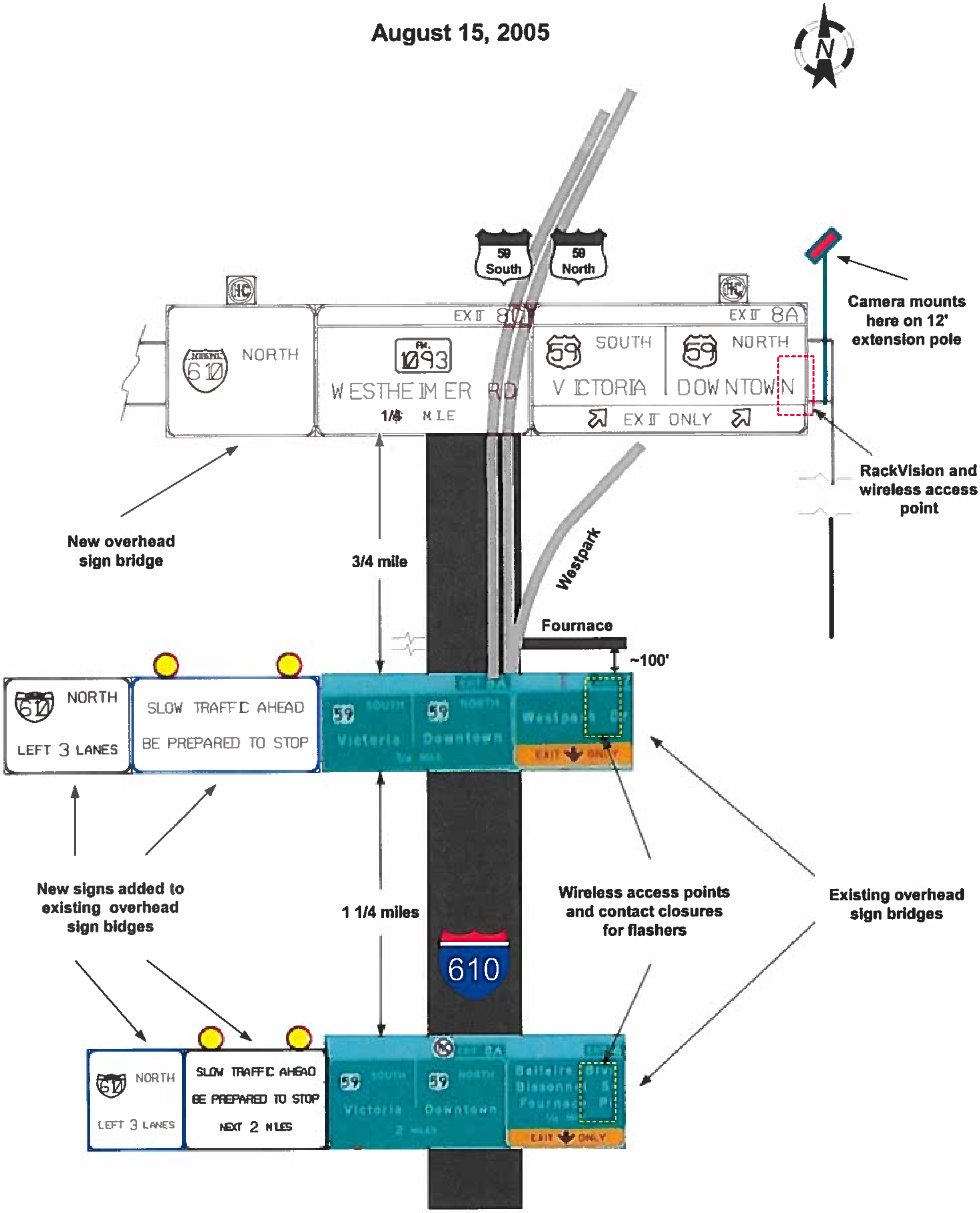


When RackVision incident detection algorithm determines no incidents are occurring PLC 1 receives input from RackVision to transmit every 6 seconds serially to Webserver 1 which converts RS232 and transmits TCP/IP through cell modems router's then on to Webservers 3 & 4 and back serially to PLC 3 & 4. When an incident occurs RackVision causes PLC 1 to stop transmitting every 6 seconds. If for any reason transmission is not received by PLC 3 & 4 in 12 seconds PLC 3 & 4 time out and turn on warning lights. An email is sent to TranStar from Webserver 3 & 4 every time beacons turn on.

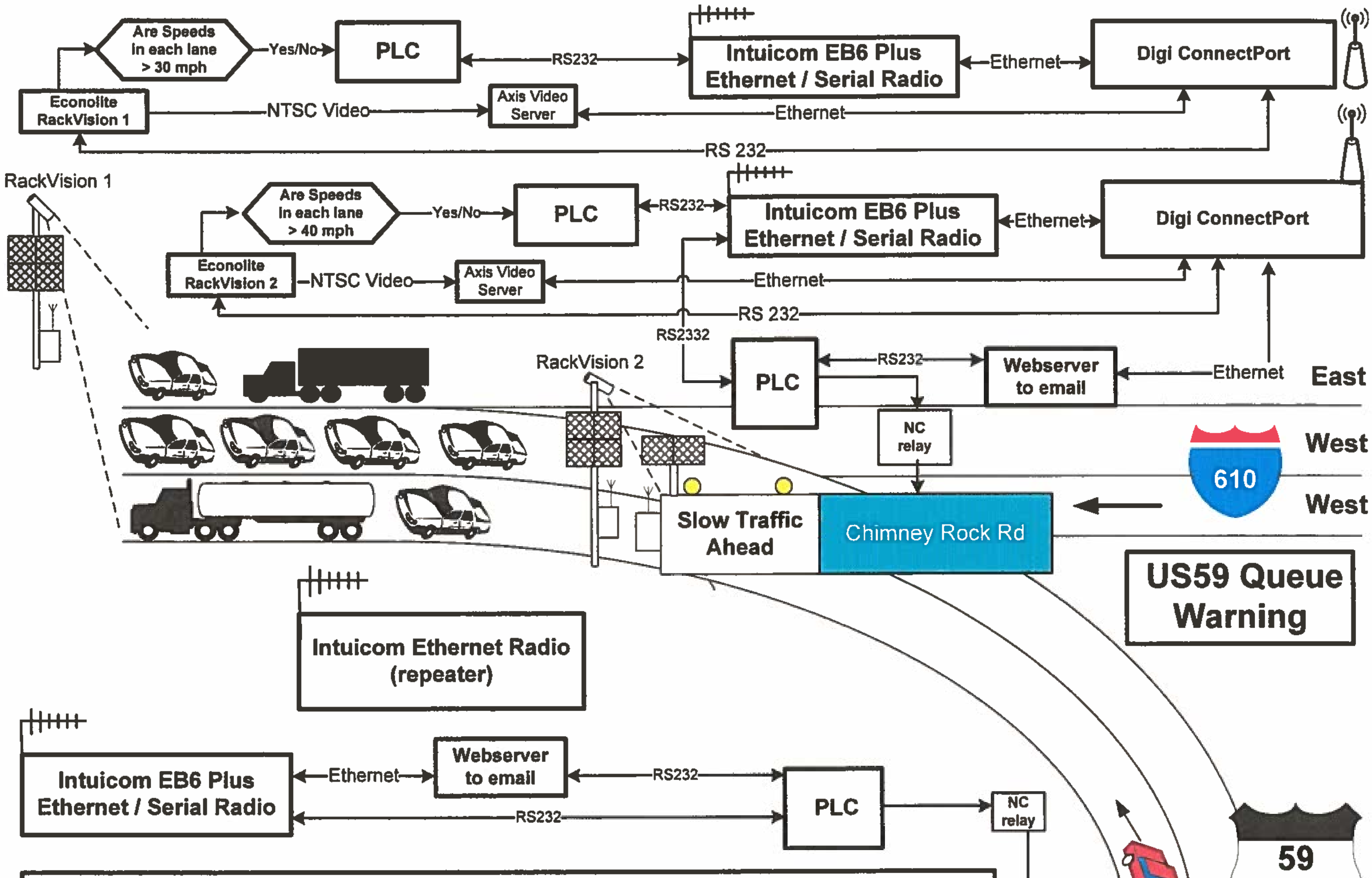
Queue Warning System

IH 610 West @ Fournace

August 15, 2005

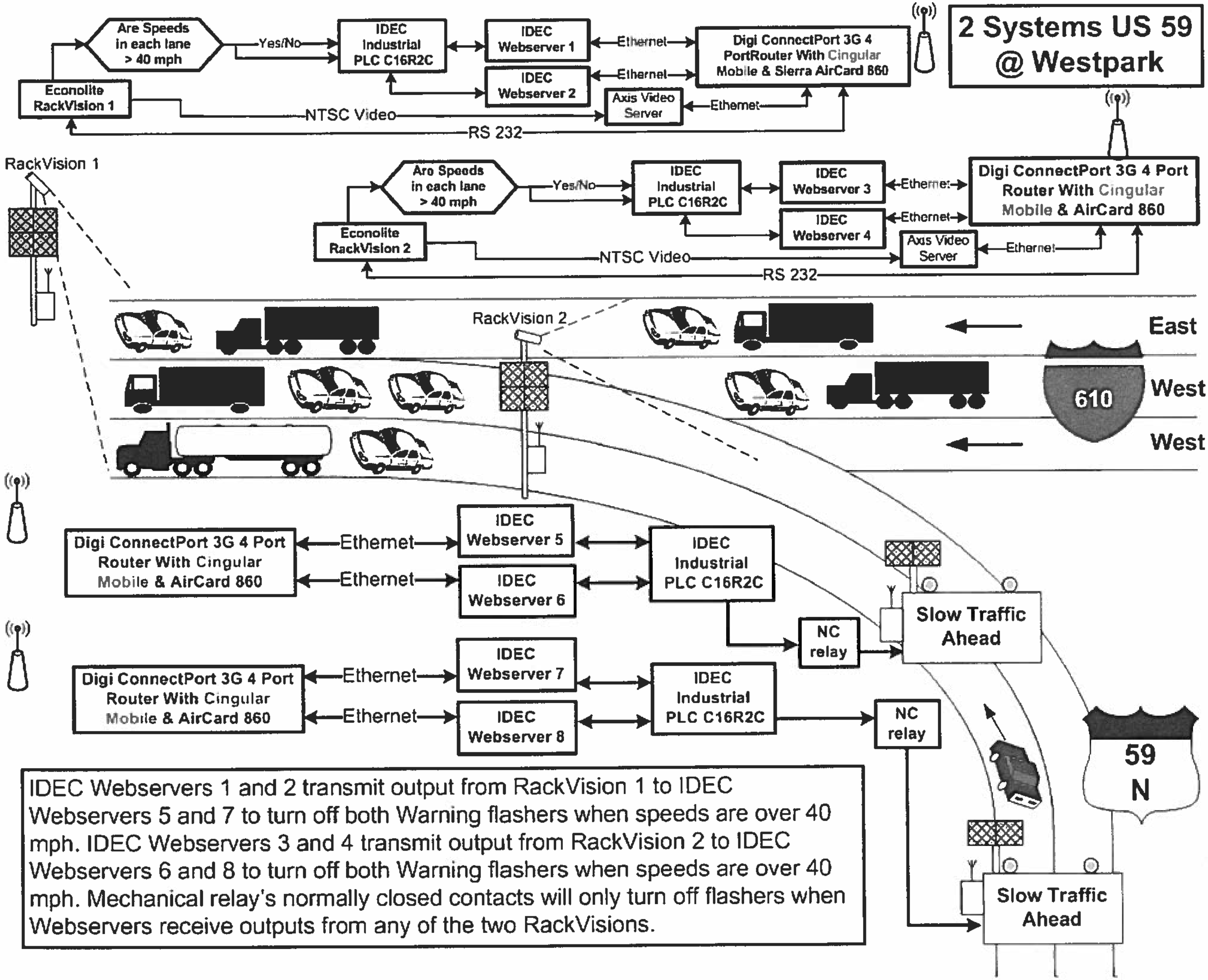


Not to scale



During free flow traffic Intuicom EB6 Ethernet port transmit reset messages every 8 seconds to reset warning site PLC at Chimney Rock. When RackVisions detect slow moving traffic the reset message quits being sent the warning sign PLCs time out and flashers come on. Chimney Rock RackVision output is connected directly to the Chimney Rock warning sign PLC to turn on the Chimney Rock flashers.

2 Systems US 59 @ Westpark

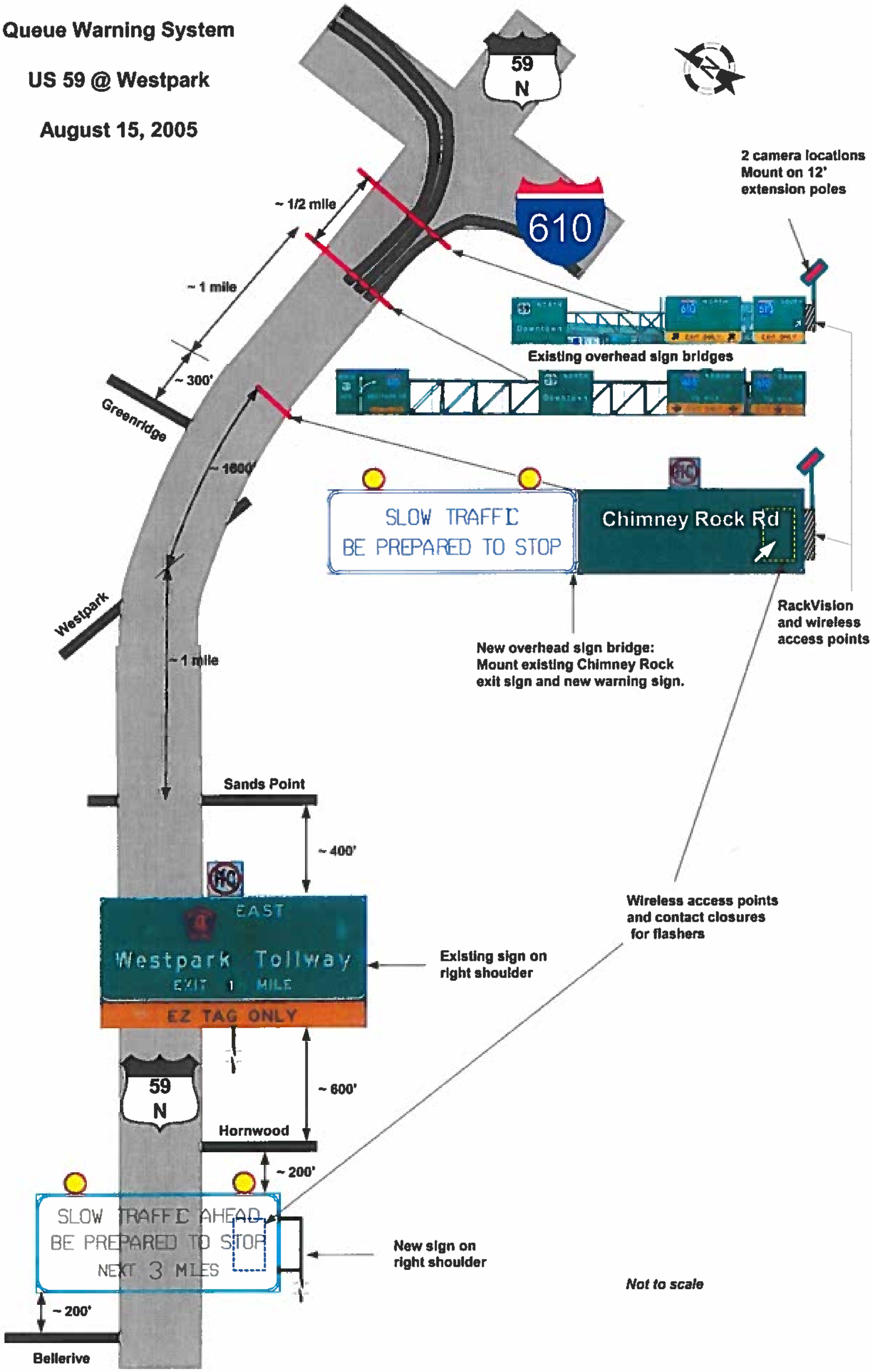


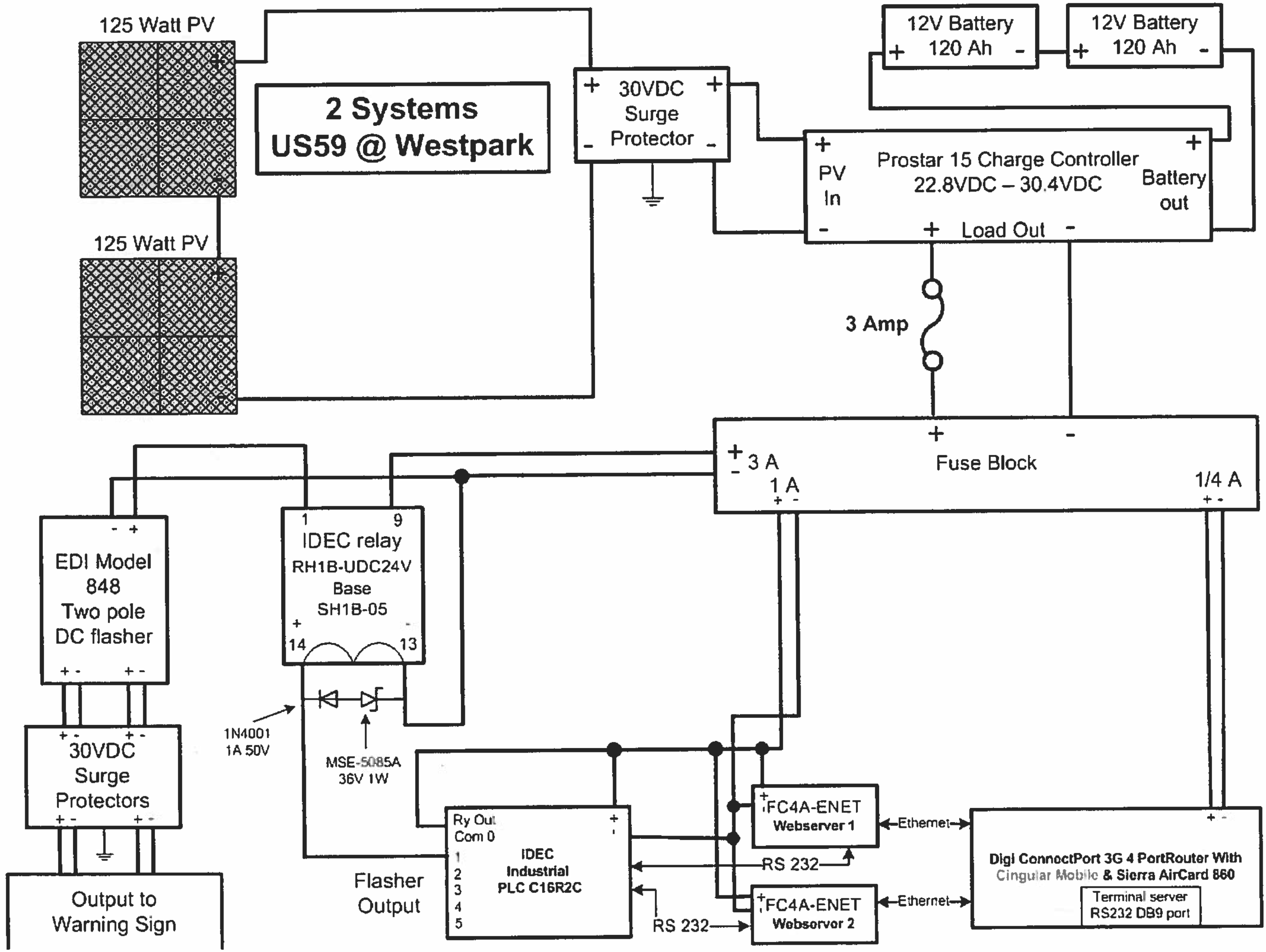
IDEC Webservers 1 and 2 transmit output from RackVision 1 to IDEC Webservers 5 and 7 to turn off both Warning flashers when speeds are over 40 mph. IDEC Webservers 3 and 4 transmit output from RackVision 2 to IDEC Webservers 6 and 8 to turn off both Warning flashers when speeds are over 40 mph. Mechanical relay's normally closed contacts will only turn off flashers when Webservers receive outputs from any of the two RackVisions.

Queue Warning System

US 59 @ Westpark

August 15, 2005





125 Watt PV
125 Watt PV
2 Systems
US59 @ Westpark
30VDC
Surge
Protector
12V Battery
120 Ah
12V Battery
120 Ah
Prostar 15 Charge Controller
22.8VDC – 30.4VDC
PV
In
Battery
out
Load Out
3 Amp
Fuse Block
3 A
1 A
1/4 A
EDI Model
848
Two pole
DC flasher
IDEC relay
RH1B-UDC24V
Base
SH1B-05
30VDC
Surge
Protectors
1N4001
1A 50V
MSE-5085A
36V 1W
Output to
Warning Sign
Flasher
Output
Ry Out
Com 0
IDEC
Industrial
PLC C16R2C
FC4A-ENET
Webserver 1
FC4A-ENET
Webserver 2
RS 232
RS 232
Ethernet
Ethernet
Digi ConnectPort 3G 4 PortRouter With
Cingular Mobile & Sierra AirCard 860
Terminal server
RS232 DB9 port