Technical Description

For

Modular Remote Weigh Station
Model 351

Including

Quartz Weigh-In-Motion Sensors and Inductive Loop Sensors

TRANSPORT DATA SYSTEMS

TDS
TRANSPORT DATA SYSTEMS

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1.0 INTRODUCTION/SUMMARY

The purpose of this document is to define the modular design of the TDS Model 351 Remote Weigh Station. This system provides the capability of providing vehicle weight, vehicle length, axle count, and speed in a single lane or open road application.

This design is based upon TDS's extensive experience in the field of automatic vehicle classification, license plate capture and violation enforcement. TDS has over 400 lanes of high accuracy vehicle classifiers and image capture systems in operation today.

The TDS Remote WIM design includes the use of two inductive loop sensors to provide vehicle separation and speed and two quartz strips to provide vehicle weight, vehicle length and axle count. The accurate velocity that is required when using quartz sensors for weight calculations is achieved by constructing two rows of quartz sensors at a specific interval determined by average vehicle speed. Typical spacing of the quartz sensor strips is four meters.

An image capture option is available with this system to allow the capture of violations for enforcement and prosecution. The integration of image capture with weigh-in-motion enables the user to significantly enhance weight enforcement and infrastructure planning. The inclusion of this system into a weight enforcement strategy holds significant benefits in terms of improved commercial vehicle safety, ensuring equitable competition in the commercial carrier industry and protecting public and private road assets from excessive and accelerated damage caused by overloaded commercial vehicles.

This technology has a number of applications in commercial vehicle weight enforcement, infrastructure development and road asset maintenance planning. It can be used to augment permanent weigh station operations by providing images for mainline WIM pre-screening systems, monitoring vehicle compliance to WIM sorter traffic signals and traffic signs, and for monitoring weigh stations evasion routes. It may also be deployed in conjunction with mobile and remote weight enforcement as a pre-screening system, or an automated stand-alone monitoring system on remote routes. The data from this system can provide agencies with a visual record from which to engage in discussions with particular carriers detected as chronic violators, or to assign preferred carrier status. The system may also be deployed in support of transportation planning activities to assist traffic engineers to evaluate future capital developments or help road asset managers plan preservation programs across specified segments of the road infrastructure. Other applications include urban weight enforcement and concentrated haul road weight enforcement.

2.0 CUSTOMER REQUIREMENTS

2.1 Vehicle Selection

The processor implements a complex table lookup selection system to allow generation of alarms based upon various parameters associated with the vehicle. This table can be easily modified to meet unique customer requirements. Selection criteria include vehicle length, speed and individual axle/wheel weights. The system can be set to issue an alarm if any combination of the above characteristics is exceeded.

2.2 Image Capture

The RWS can be equipped with a high resolution camera system which will capture an image of the vehicle for use in determining the ownership of the vehicle. The image capture system can be set up to capture either the front license plate of the vehicle or the right hand side of the vehicle including the USDOT number.

2.3 Accuracy

The weight measurements shall have an accuracy of +/- 3% (typically within +/- 1%) irrespective of the speed of the vehicle.

2.4 RWS Vehicle Separation Performance

The RWS system will differentiate between vehicles separated by a minimum of 2 meters at speeds of less than 50 miles per hour.

2.5 Interfaces

The processor includes an Ethernet port and an RS-232 port for sending vehicle information including images to a host computer.

3.0 SYSTEM DESIGN

The RWS system consists of two inductive loop sensors along with two quartz sensors. Each quartz sensor can be from .75 to 2 meters in length. The system can also be delivered with a one or two high resolution cameras for capturing side and front views of the vehicle.

The block diagram of a generalized single lane RWS is shown in Figure 3.0-1. This design can be extended to multiple lanes. The block diagram includes two cameras for side and front image capture. These are optional.

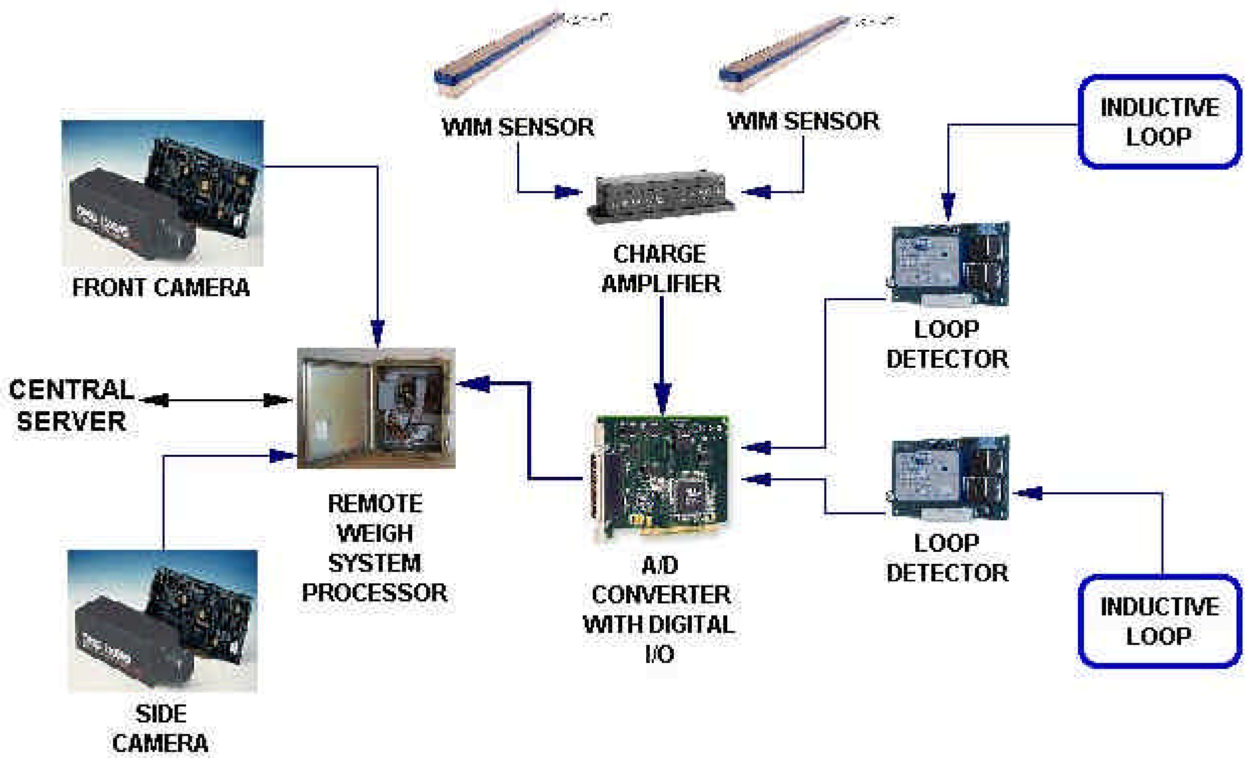


Figure 3.0-1: Single Lane RWS Block Diagram

The lane layout for the two lane RWS is shown in Figure 3.0-2 below:

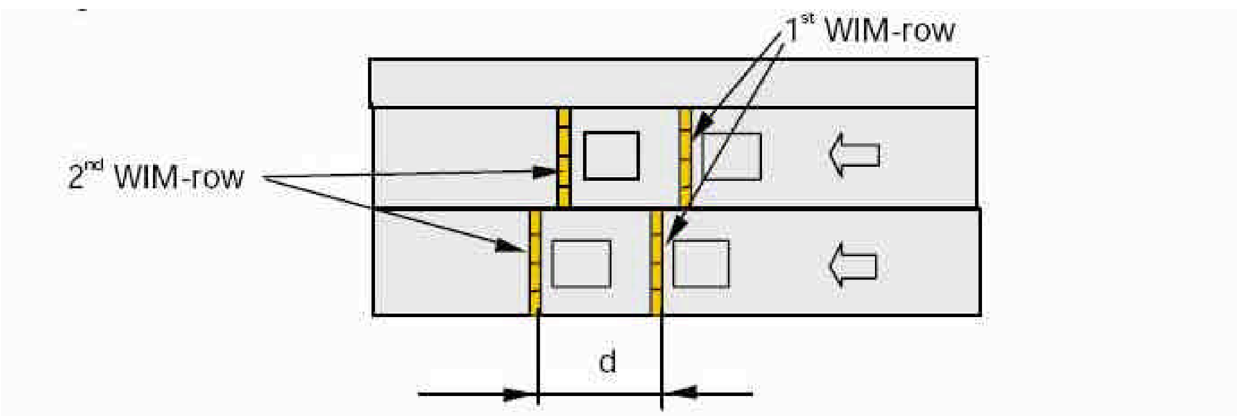


Figure 3.0-2: Dual Lane RWS Sensor Layout

The system will generate alarms according to a set of rules. Table 3.0-1 shows a SAMPLE set of rules. The rule generation is extremely flexible and can be readily matched to particular customer requirements.

Table 3.0-1; RWS Produced Alarms - Sample

Vehicle Type	Alarm Number	Alarm Criteria	Vehicle Detection Criteria
2 Axle Truck	1	Rear Axle Weight > 5000 lbs.	Two Axles, Length
3 Axle Truck	2	Rear Axle Weight > 8,000 lbs.	Three Axles, Length
4 or More Axle Trucks	3	Axle Weight > 15,000 lbs.	Axle Count, Length

The TDS RWS processor:

- Meets all of the individual classification requirements Section 3.1 fare classes based on axles, vehicle weight, and length of the vehicle.
- Allows easy modification of classification categories to readily accommodate future rate structure changes or additional classes.
- Provides accurate vehicle velocity (max and/or average) – accuracy = 1% +/- 0.2 mph.
- Maintains the position of the vehicle at all times while in the collection zone. This includes stop and go operation as well as reverse motion.
- Transmits entry and exit information to the host processor.
- Is composed of off-the-shelf technology from major suppliers.
- Has a system MTBF in excess of 20,000 hours.

3.1 RWS Operational Philosophy

Vehicle detection, speed, vehicle length, axle weight are accomplished by processing the sensor data from the inductive loop sensors and the quartz weigh-in-motion sensors. The axle sensor inputs are sampled each time a message is received from the inductive loop sensor. The vehicle detection process begins when the loop sensor detects the presence of a vehicle.

Speed is calculated based on trigger timeframe between the two inductive loop sensors. This information is used along with the data from the quartz weigh-in-motion sensors to determine axle weight. Accurate velocity is essential as it directly affects weight estimation accuracy. Vehicle length and separation are also achieved by signals retrieved from the inductive loop sensors. The test results are then correlated with a table of characteristic values that is configured for the user classification schedule. This table of characteristics is stored in a configuration file that is separate from the RWS application software. This provides an easy method for updating the class schedule should the user require modifications. After the classification has been determined the classification message is transmitted to the remote weigh system processor application. The classification message includes the velocity of the vehicle measured between the two inductive loop sensors. The message also includes the vehicle axle weights and length as well as the total axle count.

3.2 Image Capture System (Optional)

The Transport Data Systems license plate capture system uses a 1030 by 1300 digital area scan camera capable of operating in the full visible spectrum or in the near IR band.

This camera will provide high-resolution lane coverage over a capture area of approximately 10 feet wide by 6 feet high. The size of this coverage coupled with accurate triggering insures that a single image will include the vehicle license plate. The resolution of the camera coupled with the low noise performance provides an excellent image for optical character recognition. TDS has developed a companion OCR package for use with this camera.

TDS can supply the image capture system with one camera for front or side image capture.

TDC can also supply the capture system with the necessary filters and LED illumination to allow operation in the near IR band. This method of operation provides enhanced plate detection and optical character recognition. The use of IR illumination eliminates the bright lights associated with full spectrum operation. This is especially important when front plates are being captured as it removes the safety hazard associated with blinding the driver of the vehicle. The privacy issue is also addressed as the image does not produce a recognizable picture of the driver. However, during nighttime operation, the image also does not include the vehicle. Only the license plate itself is visible. TDS recommends that the front camera operate in the near IR band.

The digital video image is transmitted via a fiber link to a digital capture board located in a PCI slot in the processor. A serial RS422 link from the digital capture board provides a means for initialization and control of the camera by the processor.

3.3 Image Capture Triggering

Each of the cameras is independently triggered. The LPR image capture software receives a trigger from the triggering application. The trigger is developed by the remote weigh processor from the lane sensor information derived from the inputs of the vehicle separator system.

The trigger is generated when a vehicle enters the capture zone defined by the lane sensor. This integrated mechanism provides an accurate trigger for both cameras. The lane geometry for a two camera installation is shown in **Figure 3.0-2: Dual Lane RWS Sensor Layout**

3.4 Image Capture Software

The image capture software application receives the trigger and triggers the camera to capture an image. The camera captures the image and then downloads the data to the Processor memory via the high-speed digital fiber interface. The image is then stored on the hard drive in an uncompressed raw format. The application then either uploads the image to the central server or performs the OCR process locally.

3.5 Optical Character Recognition Software (Optional)

Transport Data Systems has developed and tested a plate locater and associated optical character recognition package specifically designed to extract ASCII representations from license plates that have been photographed using the Wintriss Engineering 1500 series camera. This OCR can be implemented in the Remote Weigh Processor. The OCR process works best with uncompressed images. This system will perform the OCR process on the uncompressed images and then compress the images for storage and transmission to the central server. The extraction of the license number at the remote weigh station will also enhance the ability of the remote weigh station system to select and examine specific transactions and to provide this selection capability externally through a web interface. Furthermore should the end user decide to outsource the alarm processing, the alarm processing vendor would not have to deal with the OCR process for the specific image capture process as implemented by the end user.

As each alarm transaction is generated, it will be processed and entered into the database. The associated images will be processed by the OCR software and then compressed. The compressed images will be stored in the database along with the license plate number and the quality data developed during the OCR process.

3.6 RWS Software

The RWS software can provide any/all of the following functions:

- Receipt of data from the inductive loop detector.
- Receipt of data from the axle detection and weighing equipment
- Camera triggering and image capture for front or side view cameras.
- Image storage and transaction storage – Offending vehicles.
- Vehicle presence detection
- Vehicle position tracking through the collection zone.
- Determination of the vehicle classification based on sensor inputs.
- Vehicle speed
- RWS system diagnostics (remote or local)
- Error reporting to the central server
- Output of data the central server

The processor will be able to handle all types of vehicle motion including negative speeds. It will identify back-outs and terminate the transaction.

If an alarm is generated, the remote weigh system processor generates a transaction for upload to the central server. The transaction will include the pertinent alarm data as well as the images if desired.

4.0 DETAILED DESCRIPTION – EQUIPMENT

4.1 Axle/Weight Detection System

The axle detector will consist of two 1-meter quartz sensors connected to a charge amplifier.

4.1.1. Quartz Sensor

Kistler's LINEAS WIM Type 9195C is a force sensor with quartz elements. The sensor is a modular element that is installed into a slot that is saw-cut across an asphalt or concrete road. When a force is applied to the sensor surface, the quartz disks yield an electric charge proportional to the applied force through the piezoelectric effect. The electric charge is converted by a charge amplifier into a proportional voltage that can then be processed as required. Key characteristics include:

- Excellent long-term stability.
- Measure very accurately at both walking and freeway speeds.
- Insensitive to temperature changes.
- Frost-resistant and protective against ingress of water.
- Quasistatic and dynamic calibration is possible.
- Wide measuring range.

The sensor is not dislodged from the road and can be reground by up to 10 mm in the event of road deformations.

The sensors are available in 0.75 and 1.0 meter lengths. Two or more sensors can be connected together to make a longer single sensor strip. Several sensors that are installed adjacent to one another can be connected electrically in parallel and operated with a single charge amplifier. The output signal then corresponds to the sum of the forces acting simultaneously on all sensors connected.

4.1.2. Charge Amplifier

The industrial charge amplifier (Type 5038A2Y43) is a 2-channel amplifier. Each channel converts the charge output of the Lineas sensor to a proportional voltage. The adjusting potentiometers are designed as plug in units to avoid the need for recalibration when an amplifier is replaced. The unit requires an unregulated 15 to 20 volt DC supply. Its key features include:

- Robust aluminum die cast housing
- Vibration proof
- No adjustments required

4.1.3. Remote weigh system processor Interface

The outputs of the sensor amplifier are brought to the remote weigh system processor over special cables capable of extending the distance from the sensor amplifier to over 80 feet. The signals are fed into a digital processing card that contains a multichannel 12-bit analog to digital converter and 6 bits of digital I/O..

4.2 Vehicle Separation and Speed Detection System

Vehicle separation and speed detection will be accomplished through the use of a pair of loop sensors connected to loop detectors. The loop sensor is a prefabricated loop / lead-in assembly designed to be overlaid with hot asphalt or embedded in concrete. The loops and detectors or manufactured by Reno.

4.3 Camera

The camera will be a Wintriss Engineering Model 1500. It is a digital area scan camera with the following characteristics:

- Resolution: 1300 x 1030 pixels monochrome
- Pixel size: 7.4 mm x 7.4 mm
- Aspect ratio: 5:4
- 8 bit video front end.
- RS422 bi-directional 115kbit/sec serial link for camera initialization and control
- Electronic shutter: 1 millisecond to 10 seconds.
- 330 megabit/second serial digital video fiber output.
- Operation in visible and near IR spectrums.

4.4 Image Capture Board

Each camera is interfaced into a PCI bus image capture card with the following characteristics:

- 256k 32 bit word receiver FIFO
- Sixty-four 32 bit word transmitter FIFO
- DMA access to host memory
- RS422 bi-directional 115kbit/sec serial link for camera initialization and control

Two cameras can be installed in every lane and two associated image capture boards can be installed in the processor assigned to that lane.

4.5 Enclosure

A Pelco enclosure is provided for mounting the camera and power supply. It is a Pelco EH4718-1 Housing. It includes an environmental control unit. Where required, the Pelco SS4718 Sun Shroud is also provided.

4.6 Illumination

4.6.1. Visible Illumination

Visible illumination can be provided by either a halogen floodlight or by an LED illuminator. The halogen provides excellent lighting but has a limited life and consumes considerable more power than an LED illuminator. However, the initial cost of the halogen system is considerably less than the LED illuminator.

Visible Illumination – Halogen

This will be provided by a Regent Light Fixture equipped with a 300 watt halogen bulb.

Visible Illumination – LED

This will be provided by a 192 LED array that consumes approximately 30 watts. The illumination is continuous. This illuminator is identically to the IR illuminator except for the LED's which operate at 660 nanometers.

4.6.2. IR Illumination

This will be provided by a 192 LED array that consumes approximately 30 watts. The illumination is continuous. This illuminator operates at 880 nanometers. It is mounted directly below the camera on the mount so that it points wherever the mount is pointing.

4.7 Mount

TDS uses a variety of PELCO mounts to meet different mount requirements. Under normal conditions the following mounts are provided.

- Front Camera: Pelco EM1009U
- Side Camera: Pelco EM1015U and Pelco PM2000

EM10XXU PM2000

RWS Processor

The RWS software module will be installed on an RWS Processor. TDS offers a choice of two different RWS processors. One is for installation inside a controlled environment like the plaza and the other is for external installations.

For the inside installation, the processor is a Dell Series 600 server or equivalent. It includes 128 megabytes of RAM and a 20 Gb hard drive. It will contain an Ethernet port for LAN connection. The unit will run the Linux operating system.

For an external installation, the processor is a hardened PC designed to be installed in tunnels and open-air booths. It includes 128 megabytes of RAM and a 20 Gb hard drive. It will contain an Ethernet port for LAN connection. The unit will run the Linux operating system. The unit is completely sealed. It can be equipped with a heat exchanger if necessary to extend the operational temperature range.

The RWS unit will be equipped with an analog to digital converter board for interfacing to the sensors. The RWS unit will include an RS-232 port and an Ethernet port for interfacing with the central server.

In the event the user system design incorporates a remote weigh system processor running Linux or Windows XP/2000, the RWS software can be integrated into the remote weigh system processor. This does require a development effort by the system integrator.

5.0 INSTALLATION

5.1 Quartz Weigh-In-Motion Sensors

The quartz WIM sensor installation consists of:

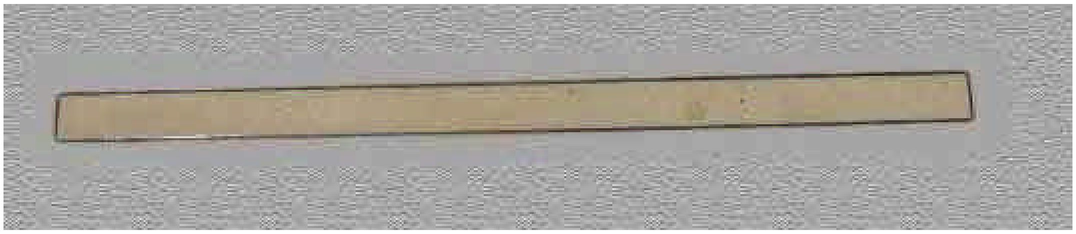
- Cutting slots in the pavement to accommodate the sensor modules and cable run.
- Pull sensor cables to cabinet and check electrically.
- Install WIM strips with grout, level grout with trowel.
- Grind WIM strips and grout level with pavement
- Calibrate and Test

The WIM sensors must be separated by a specific interval which is determined by average vehicle speed. Normal width is 4 meters. Spacing is increased to 4.5 meters if speeds will exceed 60 mph.

5.1.1. Weigh-in-Motion Sensor Installation

5.1.1.1. General

Kistler's LINEAS WIM sensors are modular elements that are assembled into strips and installed into slots that are saw-cut across an asphalt or concrete road. Two sensors are connected together to make a half-length WIM strip. Alternatively, four connected sensors make a full-length WIM strip (see figures on page 2). The WIM site construction contract shall specify whether half-length or full-length WIM strips are used. Kistler-supplied sand/epoxy grout secures the sensor strips into the pavement slots. After curing, the hardened grout and the exposed top surfaces of the sensor modules are ground flush with the surrounding pavement using a belt sander. After grinding, the sensors may be immediately exposed to traffic. An overnight post cure is recommended before calibration and acceptance tests are performed.



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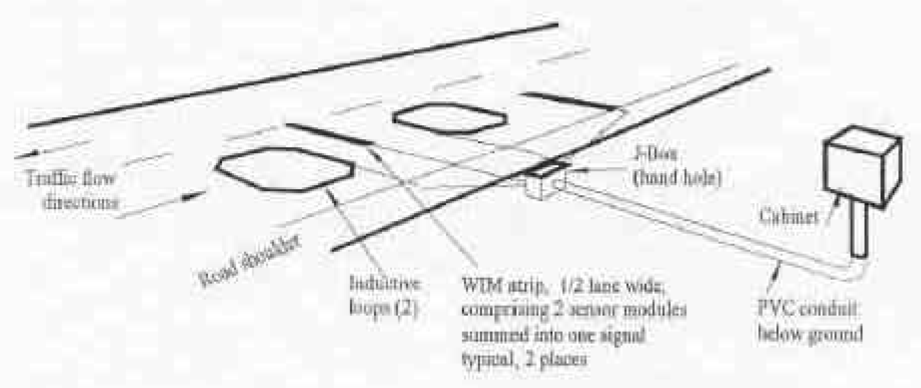
5.1.1.2. WIM Sensor Installation Timeline

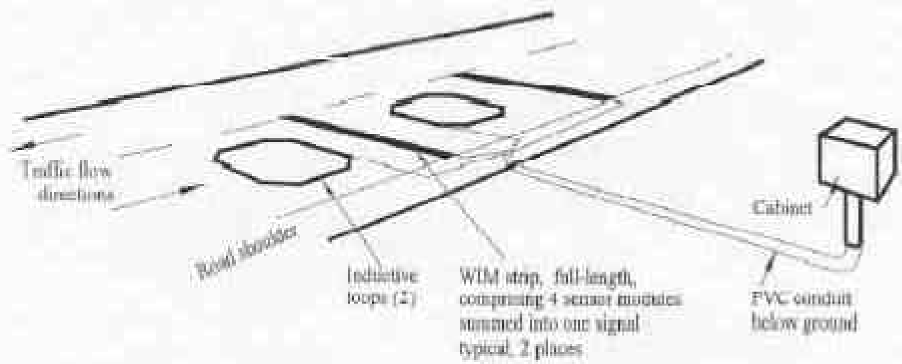
Activity	Time interval
Close lane to traffic	½ hour or as required
Layout & saw-cut sensor and cable-run slots	2 hours
Assemble WIM sensors into strips	Simultaneous with saw-cutting
Install in-pavement plastic conduits (optional)	½ hour
Dry-fit sensors into slots, prepare cables for pulling	½ hour
Pull sensor cables to cabinet and check electrically	1 hour
Install WIM strips with grout, level grout with trowel	½ hour
Cure grout	1 to 3 hours (heat assist in cool weather)
Grind WIM strips + grout until flush with pavement	1 hour for 2 full-length strips (one lane)
Reopen lane to traffic	½ hour
Calibrate and Test	Per contract requirements
Total time (less lane control and system test)	**6-8 hours**

Typical "LINEAS" WIM Site Configurations

Examples below show one lane installed. Multiple lanes typically use one cabinet and data logger. WIM sensors may be installed as full-strips or staggered 1/2-strips. Loop placement may be different than shown and shall be per site construction specification.



Installation using 1/2 length WIM strips and a J-box



Installation with full-length WIM strips and without J-box

5.2 Inductive Loop Sensor Installation

Two inductive loop sensors are installed in the road surface each located downstream from a quartz weigh-in-motion sensor. Loop installation can be done using two methods: asphalt overlay and poured concrete.

5.3 Camera Installation (Optional)

The front camera is determined by the lane characteristics. In a single lane installation, It may be mounted at a height of approximately 1 foot above the ground at a location directly adjacent to the lane. In this instance it is located approximately 18 feet downstream from the laser scanner. In a multilane system, the cameras can be mounted on an overhead gantry at a point approximately 25 feet from the loop.

The illumination is co-located with the camera.

For obvious reasons, a side camera can only be implemented in a single lane situation. The side camera is mounted at a height of approximately 3 feet above the ground. It is located approximately 10 feet upstream from the laser scanner at a distance of about 15 feet from the lane. The illumination is co-located with the camera.

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5.4 RWS Processor Installation

The RWS processor can be located anywhere within 100 feet of the lane.