SunGuide and OOCEA Data Server
Travel Time Production Comparison

1. Purpose

FDOT has expressed an interest in comparing the implementation of SunGuide's travel time algorithm with the OOCEA Data Server's implementation with the intent of possibly making enhancements to the SunGuide in order to better the performance and accuracy of its travel time dissemination mechanisms. This document will summarize the current design of both SunGuide's and the OOCEA Data Server's travel time production.

2. SunGuide Travel Time Functionality

2.1. Speed and Travel Time Data Flow

SunGuide utilizes a number of subsystems to acquire traffic sensor data, calculate travel time data, and disseminate that data to FL-ATIS and Dynamic Message Signs (DMS). The diagram in Figure 1 depicts the steps the data takes and the subsystems that process this data.

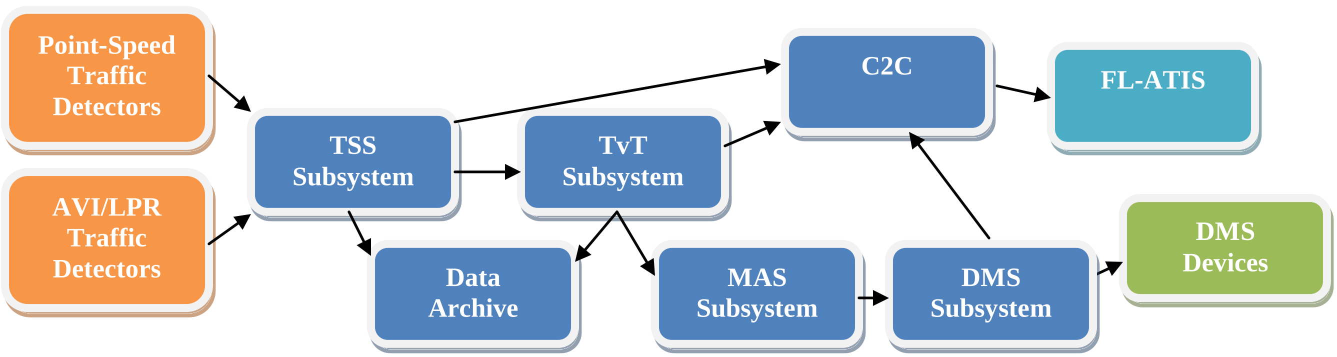


Figure 1: SunGuide Travel Time Data Flow

SunGuide is designed to accept data from point-speed traffic detectors as well as Advanced Vehicle Identifiers (AVI) or License Plate Readers (LPR). Point-speed traffic detectors are devices that determines approximate vehicle speeds and/or volume and occupancy at a single point along a roadway. AVI and LPR require a pair of detectors to identify individual vehicles and match the individual vehicles downstream in order to calculate travel times.

Detector data within SunGuide is handled within the TSS Subsystem. Regardless of which technology is used to detect and report vehicle speeds or travel times, the TSS Subsystem equates reported speeds and travel times to configurable roadway links called TSS Links. The TSS Subsystem then provides TSS Link data to a Data Archive and to the TvT Subsystem.

The TSS and TvT Subsystems provide data to Center-to-Center (C2C) software which makes both TSS and TvT data available to FL-ATIS and possibly other SunGuide deployments. The TvT Subsystem also generates Dynamic Message Sign (DMS) messages from travel time data and provides these messages SunGuide's Message Arbitration Subsystem (MAS). The MAS manages messages to be sent to DMS and sends these messages to the DMS Subsystem which controls and monitors the status of DMS.

2.2. **TSS and TvT Configuration**

The TvT Subsystem takes the TSS Links data and aggregates the links into longer TvT Links. TvT Links are often used to report commonly traveled routes across one or more roadways. The diagram in Figure 2 shows how TSS Links and TvT Links are related.

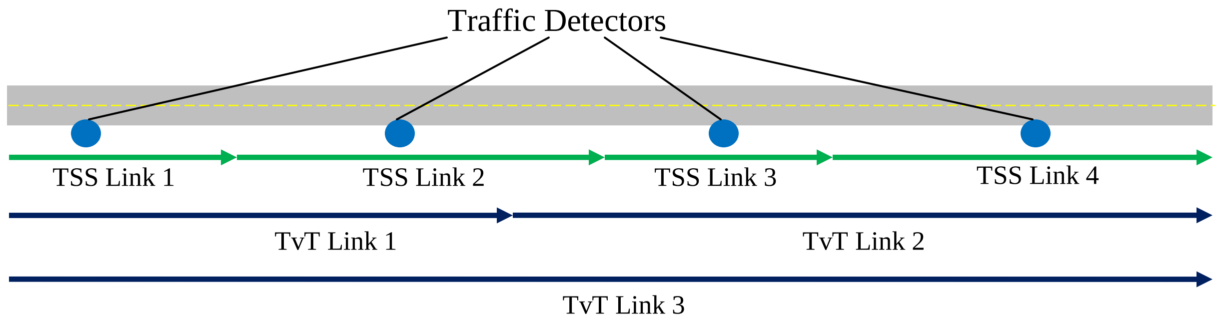


Figure 2: TSS and TvT Links

Each TSS Link is associated with one point-speed traffic detector or one pair of AVI or LPR detectors. Each TSS Link is configured the link's speed limit, link length, and alerting speed and occupancy values. The alerting values are used to generate TSS alerts (discussed later in this document). The length of each TSS Link depends on the physical spacing of traffic detectors, although they are typically configured so that contiguous TSS Links occur serially along the roadway with little to no overlap from one TSS Link and the next.

2.3. **Speed and Travel Time Calculations**

The TSS Subsystem reports "smoothed" speeds, volumes, and occupancy values to the TvT Subsystem. Smoothing is performed by averaging a configurable number of reads. If the this number is 5, for example, and SunGuide is configured to collect TSS Link data once every 20 seconds, then it will average the last 5 reads, or the last 100 seconds of data.

$$\text{TSS Data}_{\text{smoothed}} = \sum \text{TSS Data}_{i}$$

i = Configured Number of Reads

TvT Links are typically configured using multiple TSS Links or portions of TSS Links. Each TSS Link associated with a TvT are configured with a link length, allowing the TvT to use an entire TSS Link or a prorated fraction of a TSS Link. TSS Links can also be reused in multiple TvT Links, this allows TvT Links to overlap.

TvT Link speed data is calculated by averaging the smoothed speeds reported by the TSS links, weighed by TSS link length. TvT Link speed data is then capped to the configured speed limit so that no TvT Link speed is reported faster than the speed limit. TvT travel time data is calculated by adding the configured lengths of all TSS Links associated with the TvT Link and dividing it by the TvT Link speed.

$$\text{TvT Link Speed} = \sum \left(\text{TSS Link Speed}_{i} \, / \, \text{TSS Link Length}_{i}\right)$$

$$\text{TvT Link Travel Time} = \left(\sum \text{TSS Link Length}_i\right) / \text{TvT Link Speed}$$

i = Configured Number TSS Links

SunGuide has a set of globally defined thresholds that filter out outliers. These thresholds include expiring old tag reads and removing extreme-case travel speeds (i.e. negative speeds and speeds over a configurable speed).

3. OOCEA Data Server Travel Time Functionality

3.1. Speed and Travel Time Data Flow

The OOCEA Data Server has a similar architecture to SunGuide in that it uses multiple independently running processes to acquire traffic sensor data, calculate travel time data, and disseminate that data to FL-ATIS and Dynamic Message Signs (DMS). The diagram in Figure 3 depicts the steps the data takes and the subsystems that process this data.

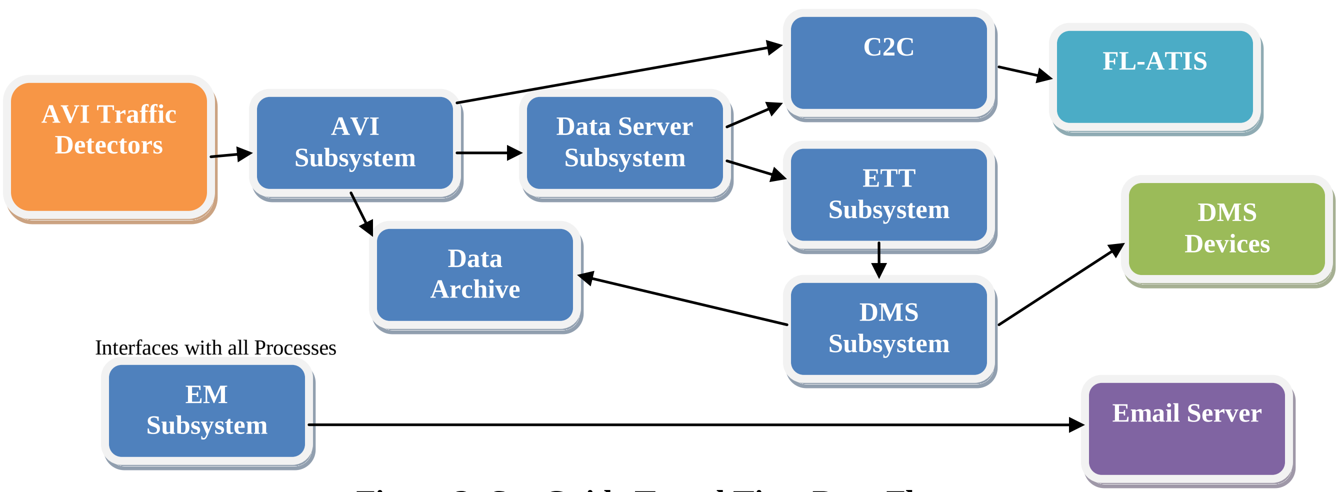


Figure 3: SunGuide Travel Time Data Flow

The Data Server is designed only to accept AVI data. AVI data is provided to the AVI subsystem where travel time and speed data is calculated. Calculated travel time and speed from the AVI Subsystem is archived and provided to the Data Server master process. This master process provides data to C2C and the ETT Subsystem. From C2C, travel time data is provided to FL-ATIS.

The ETT Subsystem generates route travel times from the AVI Subsystem's link travel times. The route travel times are used in the Data Server to generate DMS travel time messages. These messages are composed and then sent to the DMS Subsystem, which passes on the messages to an external DMS control software. The DMS control software handles DMS device management, posts DMS messages, and reports back any messaging errors back to the DMS Subsystem.

The Data Server also has an EM Subsystem that interfaces will all other processes within the Data Server. The functionality of this subsystem is discussed later this in this document.

3.2. **TSS and TvT Configuration**

Calculated travel time and speed is archived and provided to the Data Server master process. This master process provides data to C2C and the ETT subsystem. The ETT subsystem provides functionality to aggregate travel time link data into longer routes, similarly to how TvT Links aggregate TSS Links within SunGuide. Figure 4 shows how these travel time routes

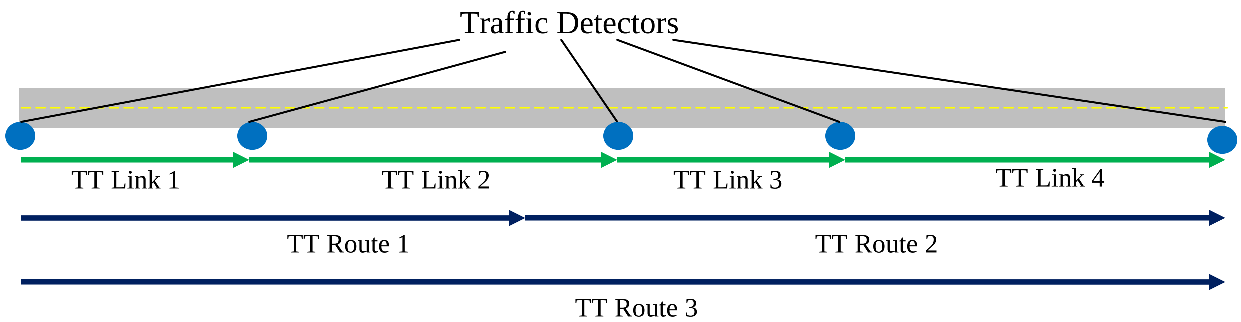


Figure 4: Travel Time Links and Travel Time Routes

Each travel time link is associated with one pair of AVI detectors.

3.3. **Speed and Travel Time Calculations**

Based on configured detector to detector links, the AVI subsystem calculates travel time data by matching vehicle identifiers and subtracting timestamps of the AVI tag reads to acquire a travel time. The matched travel time is then aggregated using three fusion methods. Table 1 below summaries these three fusion methods.

Table 1: OOCEA Data Server Fusion Methods

Fusion Method	Description
FM1: Fixed Time	Calculates fused travel-time and speed based on the valid discrete link travel time during a fixed time window. The default time window is the past one-minute. As an example, the 9:01 time slice fuses matched data where the time of arrival at the second reader is between 9:00:01 and 9:01:00. Fusion Method 1 data is reported each minute. It is possible that no data might be collected within a one-minute time slice. When this occurs, “0” matches are reported.
FM2: Fixed Sample	Calculates fused travel time and speed based on a fixed sample of most recent valid discrete link travel times, regardless of the time the data was collected. The default sample size is the last ten; therefore, Fusion Method 2 will use the past ten valid matches. Fusion Method 2 data is reported each minute.
FM3: Hybrid	Utilizes FM1 if there were ten or more valid discrete link travel times during past minute, otherwise defaults to use FM2. Fusion Method 3 data is reported at each minute. The sample size for this method should always be greater than or equal to ten. By default, the Data Server reports speeds/travel times to FL-ATIS and DMS using Fusion Method 3.

The resulting travel time calculated using the three fusion methods is used to calculate the averaged speed. Average speed is calculated by used the configured actual distance between the physical detectors and dividing by the calculated travel time.

$$Speed_{average} = \text{Physical Distance Between Detectors / FM Travel Time Data}$$

Each travel time link is configured the link's speed limit, link length, and filtering thresholds. The length of each travel time link depends on the physical spacing of traffic detectors. The filtering thresholds allow the Data Server to filter out outlier data. The filtering threshold values are configured based on the traffic characteristics of the roadway links. The filtering algorithm is outlined in the block diagram in Figure 5.

Filtering uses the following five thresholds:

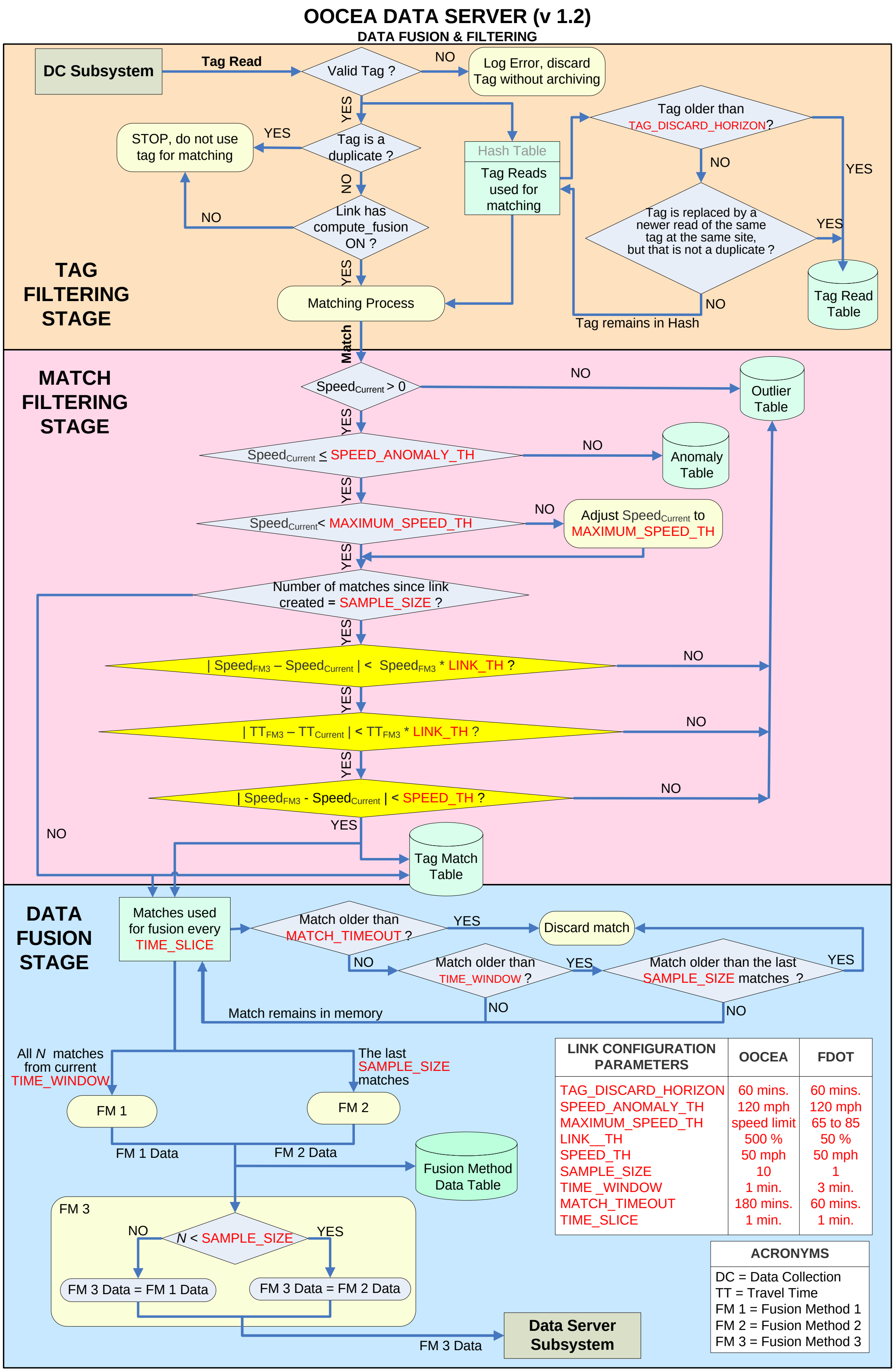
Link Threshold (percentage) – The Data Server will exclude from all fusion method calculations any discrete tag match record in which the speed/travel time is a percentage greater or less than the fused statistic (mean speed/travel time) for the previous time slice. This assumes that the average perturbation from the previous time slice to the current time slice will not exceed the Link Threshold percentage.

Speed Threshold (MPH) – The Data Server will exclude from all fusion method calculations any discrete tag match record in which the speed is a certain amount greater or less than the fused mean speed from the previous time slice. This assumes that the average perturbation in speed from the previous time slice to the current time slice will not exceed the Speed Threshold.

Speed Anomaly Threshold (MPH) – The Data Server will exclude from all fusion method calculations any discrete tag match record in which the speed is greater than the Speed Anomaly Threshold.

Maximum Speed Threshold (MPH) – This is the maximum speed that can be used as an input to the fusion method algorithms. Currently, the Data Server is using the average speed limits over the link for the Maximum Speed Threshold. This means that any discrete speed statistic that is greater than the Maximum Speed Threshold but less than the Speed Anomaly Threshold is overwritten with a tag match record with a speed (and corresponding travel time) equal to the Maximum Speed Threshold.

Tag Discard Horizon (minutes) – The Data Server will retain a tag read in volatile memory until a match is made or until the Tag Discard Horizon is reached, whichever comes first. Tag reads will not be retained in the Data Server longer than the Tag Discard Horizon (i.e. If this value is set to 60 minutes, an unmatched tag read will be discarded after 60 minutes).



LINK CONFIGURATION PARAMETERS	OOCEA	FDOT
TAG_DISCARD_HORIZON	60 mins.	60 mins.
SPEED_ANOMALY_TH	120 mph	120 mph
MAXIMUM_SPEED_TH	speed limit	65 to 85
LINK__TH	500 %	50 %
SPEED_TH	50 mph	50 mph
SAMPLE_SIZE	10	1
TIME _WINDOW	1 min.	3 min.
MATCH_TIMEOUT	180 mins.	60 mins.
TIME_SLICE	1 min.	1 min.

ACRONYMS
DC = Data Collection
TT = Travel Time
FM 1 = Fusion Method 1
FM 2 = Fusion Method 2
FM 3 = Fusion Method 3

Figure 5: OOCEA Data Server Filtering Algorithm

4. SunGuide verses OOCEA Data Server TT Comparison

4.1. Overall Design Differences

Both SunGuide and the Data Server derive much of their source code from TxDOT's TransGuide software. Consequently, there are several similarities between the basic overall designs. For example, both systems rely on a series of independent processes functioning separately yet when orchestrated together, accomplishes overall tasks such as calculating and disseminating travel time information.

There are five primary differences in the travel time production between SunGuide and the Data Server. Table 2 below lists these five differences and summarizes how each system implements the function. Each of these differences is discussed in the subsequent sections of this document.

Table 2: SunGuide and Data Server Differences

Functionality	SunGuide	OOCEA Data Server
Automatic Monitoring of Subsystems	Limited	Implemented
Point-speed Detection Support	Implemented	None
Calculation Methods	Single Method	Three Fusion Methods
Outlier Filtering	Limited, Defined Globally	More Extensive, Defined per Travel Time Link
Travel Time Alerting	Event Alerts, Operator Action	Automatic DMS Alerting

4.2. Calculation Methods

SunGuide currently supports a single calculation method, as described earlier in this document. The Data Server supports two different fusion methods, plus a third that essentially selects the better of the two. Having this intelligence to select between two different methods has the potential of reporting better and/or more accurate travel time information during specific travel conditions. To weigh the actual benefit of this, a more extensive study would be needed to compare SunGuide's single method with the Data Server's multi-method process.

4.3. Outlier Filtering

SunGuide has a few globally-defined filtering parameters that likely eliminate a significant portion of detector reporting anomalies. The Data Server's filtering mechanism has much more flexibly, allowing parameters to be configured per travel time link and hence allowing configuring the system differently for different portions of roadway. The Data Server's additional filtering likely eliminates additional detector reporting anomalies that would not be caught in SunGuide's implementation. To weigh the actual benefit of this, a more extensive study would be needed to compare SunGuide's limited filtering with the Data Server's filtering.