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RESEARCH REPORT

VALIDATION AND AUGMENTATION OF INRIX ARTERIAL TRAVEL TIME DATA USING INDEPENDENT SOURCES

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16. Abstract

Travel time data is a key input to Intelligent Transportation Systems (ITS) applications. Advancement in vehicle tracking and identification technologies and proliferation of location-aware and connected devices has made network-wide travel time data available to transportation management agencies. The trend started with data collection on freeways has been quickly extended to arterials. Although freeway travel time data has been validated extensively in recent years, the quality of arterial travel time data is not well known. This project presents a comprehensive validation scheme for arterial travel time data based on GPS probe and Bluetooth generated data as two independent sources. Since travel time on arterials is subject to a higher degree of variation compared to freeways mainly due to presence of signals, a new validation methodology based on coefficient of variation was introduced. Moreover, a Context Dependent (CD) based travel time fusion framework was developed to improve the reliability of travel time information by fusing data from multiple sources. The entire 2012 data on a busy arterial corridor consisting of six segments in Maryland was used to demonstrate the proposed comparison and augmentation model.

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1. INTRODUCTION

Urban traffic congestion has become a common phenomenon in most metropolitan areas. Transportation agencies utilize Intelligent Transportation Systems (ITS) to provide the traveling public with real-time reliable traffic information in order to improve mobility. Travel time is a vital component of such systems since it is a direct indicator of delay and is easily understood by the general public. In recent years several vehicle tracking and identification technologies including Automatic License Plate Reader (ALPR), Electronic Toll Tag matching, Bluetooth and WiFi detectors have been successfully developed to measure travel time data [1, 2, 3, 4].

Recent advancements in vehicle tracking technologies along with dramatic increase in the number of location-aware and internet-enabled mobile devices carried by travelers has created new possibilities for collecting and reporting travel time data on a large scale. Private sector companies such as INRIX take advantage of these resources to provide real-time information both on arterials and freeways mainly by capturing, consolidating and filtering GPS tracks reported by such devices [5]. In addition, Bluetooth (BT) travel time collection technologies proven to be a success due to its low cost and high privacy protection properties [6, 7]. Quality of both probe and BT freeway data have been extensively validated and examined in recent years [8]. However the quality of arterial data is not well known. Traffic in the arterials is heavily impacted by intersections as well as signal timing scheme on a given corridor [9, 10]. Moreover, lower traffic volumes and larger variance in travel time introduces unique challenges to the arterial performance measurement compared to freeways [11]. Therefore, it is necessary to develop proper quality assessment methods for arterial travel time data. Meanwhile, when travel time data is available from multiple sources, the possibility and effectiveness of merging such data in order to increase reliability of travel time data on arterials needs to be investigated. The following is a summary of major efforts to address the abovementioned issues.

In the first validation report prepared for the I-95 Vehicle Probe Project (VPP), data was divided into four classes (i.e. speed bins) based on the observed mean speed in each time interval then verification was performed for each category [8]. With the same purpose, a paired-t method was proposed as an alternative approach to validate INRIX reported data with BT datasets, and this method was shown to be effective when there were few ground truth observations [12]. Although a few arterial validation studies were conducted for the VPP based on the same methodology, the majority of the validation was focused on freeways. Data post-analysis and consolidation are the key components to provide users with more reliable data. Since more and more independent traffic related data sources emerged recently, data fusion is becoming a popular approach to merge data in order to achieve higher accuracy and resolution. A comprehensive survey in terms of data fusion progress and challenges in ITS was reported in Faouzi et al. [13]. Based on the characteristics of the fused data, data sources can be further classified into two categories, i.e. heterogeneous and parallel. From the perspective of heterogeneous fusion, Anusha et al. [9] fused location based flow data and sparse travel time data obtained from probe vehicles to determine the stream flow travel speed. In addition, fusion models with heterogeneous data from underground loop detectors and GPS-equipped probe vehicles were also proposed for urban arterial corridors [14, 15]. When it comes to fusion techniques with parallel datasets, Soriguera et al. [15] took advantage of Context Dependent (CD) based fusion operator [16], which was well adopted in the field of image processing, to generate fuzzed travel time in a conservative way. However, data reliability and consistency were not addressed in their work.

Based on the aforementioned work, contributions of this project are twofold. First, a new coefficient-of-variation (CV) based travel time validation scheme was developed to compare and validate the GPS probe data reported by INRIX against the BT travel time for arterials. In addition to time of day impact, various traffic conditions were evaluated in the analysis. Second, a Context Dependent (CD) based travel time fusion framework was developed by using data from INRIX and BT datasets to improve the reported data quality. Although the fusion framework was examined on INRIX and BT as two independent data sources, it can be flexibly modified and extended to any other type of data.

2. DATA DESCRIPTION

Data from several sources were obtained for this study. This section provides a summary description for each data set.

2.1. Probe Vehicle Data from INRIX

INRIX is a private company that provides historical and real-time traffic information as well as traffic forecasts in many countries [17, 18]. Travel time information provided by INRIX is mainly based on probe technology that takes advantage of location-aware and internet-enabled devices which are either installed in vehicles or carried by travelers. The travel time data from INRIX is reported on Traffic Message Channel (TMC) codes. Specifically, INRIX reports average travel time as a normalized measure of the real-time traffic condition on each TMC segment, along with a confidence score in one or five minute intervals. The confidence score is an internal quality measure which indicates whether the reported travel time is based on real-time GPS tracks (score 30), archival data (score 10) or a combination of both (score 20). In this project, the INRIX reported travel time data was retrieved from the Regional Integrated Transportation Information System (RITIS).

2.2. Detection and Matching Data from Bluetooth

Bluetooth (BT) travel time data collection method is proven to be a success due to its low cost and high privacy protection properties [6, 7]. In order to collect travel time data on a particular travel path segment, two Bluetooth detection devices must be deployed at the beginning and end of the path respectively (i.e. upstream detector and downstream detector). Each sensor records the MAC ID of active BT devices as the vehicle passes through the detection zone. Travel time of a vehicle that carries BT device can be calculated by comparing the recorded time stamps at upstream and downstream detection zones. After filtering outlier observations, travel time samples are aggregated to generate average travel time for the desired time intervals [6]. Bluetooth detection data was obtained from four permanent BT detection devices deployed in the studied arterial corridor (i.e. MD 355).

2.3. Data from HERE North America LLC

Access license to the National Performance Management Research Data Set (NPMRDS) is primarily restricted to DOT’s, MPOs etc. The Center for Advanced Transportation Technology (CATT) Lab at the University of Maryland has been assigned a unique access account to download and process the data from HERE’s database. The research team was granted access to the dataset through the CATT Lab.

However, using HERE data that comes in raw GPS form is not a straight-forward process. The CATT Lab has put great effort into pre-preprocessing and archiving the original NPMRDS data. Specifically, they have come up with a process that accounts for the location referencing differences between INRIX (which uses the TeleAtlas implementation of the TMC codes) and HERE (which uses the NAVTEQ implementation of the TMC codes). However, the HERE referencing information is ragged and prone to errors. The research team used the processed HERE data instead of the original dataset.

Comprehensive investigations and test cases showed that the project could not benefit from HERE data for the arterial segments. First, the accuracy of NPMRDS (HERE) data is not satisfactory based on validation studies conducted by CATT. More importantly, the data fusion models aim at merging data from independent sources to increase reliability. Travel time data from HERE is not necessarily independent of INRIX data since both are generated from GPS tracks on the same segment. Therefore, it was decided that the travel time data from HERE is not of interest in this project.

2.4. Signal Timing Data

Signal timing information of intersections located in the study area on MD 355 were obtained from the Maryland State Highway Administration (SHA). The intersections are located between MD 124 to MD 28 and MD 28 to I-495. The signal timing information is distributed in several Synchro files that included the following information:

- The timing information for year 2011;
- Signal timing scheme for morning peak and afternoon peak hours;
- The peak-hour design volume of each approach;
- The control type of each intersection including actuated and coordinated;
- The estimated cycle splits of each approach based on the assumed approaching hourly demand;
- Timing offsets to the master intersection.

Since the signal control type is actuated, real-time traffic volume is of great significance to measure the actual real-time average delay and travel time of a specific passage segment. In other words, to validate and augment the real-time travel time data, one cannot simply run simulations with deterministic traffic volume, especially when the coordinated intersections are based on actuated control. According to some key research in the literature, intersection delay is mainly determined by two significant factors, i.e. signal timing and arrival rate. Zheng and Henk (2010) have analytically developed a set of comprehensive arterial link delay distribution equations [19]. Their validation work indicates that the travel time (or delay) distribution on an arterial link is highly dependent on the arrival patterns and arrival rate. An example is shown in Figure 1. Therefore, the signal timing data must be accompanied with actual time-dependent volume data, otherwise, it will introduce unnecessary data disturbance.

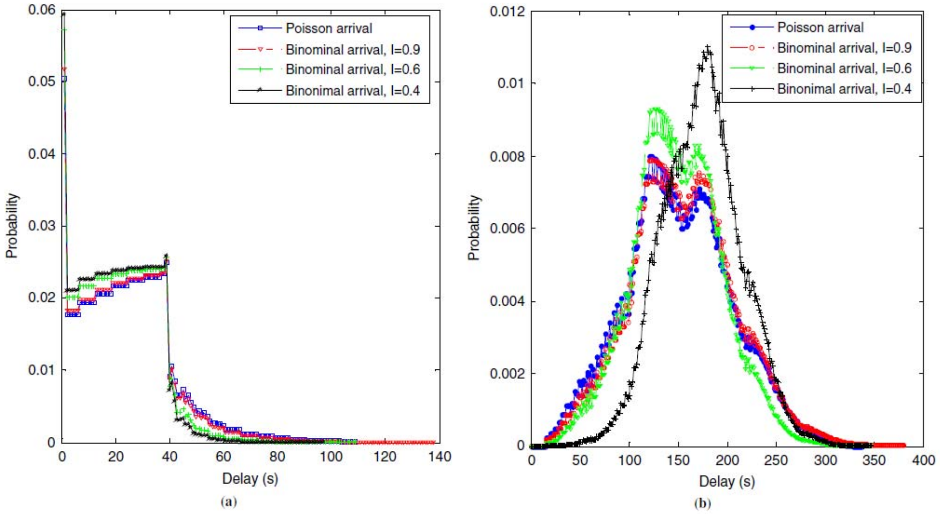


Figure 1: Delay distribution with Poisson arrivals and binomial arrivals: (a) undersaturated condition and (b) oversaturated condition (Zheng and Henk, 2010)

Since historical time-dependent traffic volume data was not availabe for the studied segment, the signal timing information was not included in validation and augmentation models.

3. VALIDATION MODEL

3.1. Spatial and Temporal Alignment of Validation Segment

Comparing and validating reported travel time of one data source by using data from another data source requires both spatial and temporal alignment of the validation segment. Travel time data provider companies that utilize probe technology usually report data on Traffic Message

Channel (TMC) codes. A travel path consists of one or multiple consecutive TMC segments. For each time interval, an estimated average travel time data point is accompanied by a data confidence score for every TMC segment. On the other hand, location of sensors and configuration of segments is more flexible when using Bluetooth detectors [6, 7, 8]. In order to make data comparable between the sources, it is important to deploy Bluetooth sensors in line with the corresponding TMC segments as shown in figure 2.

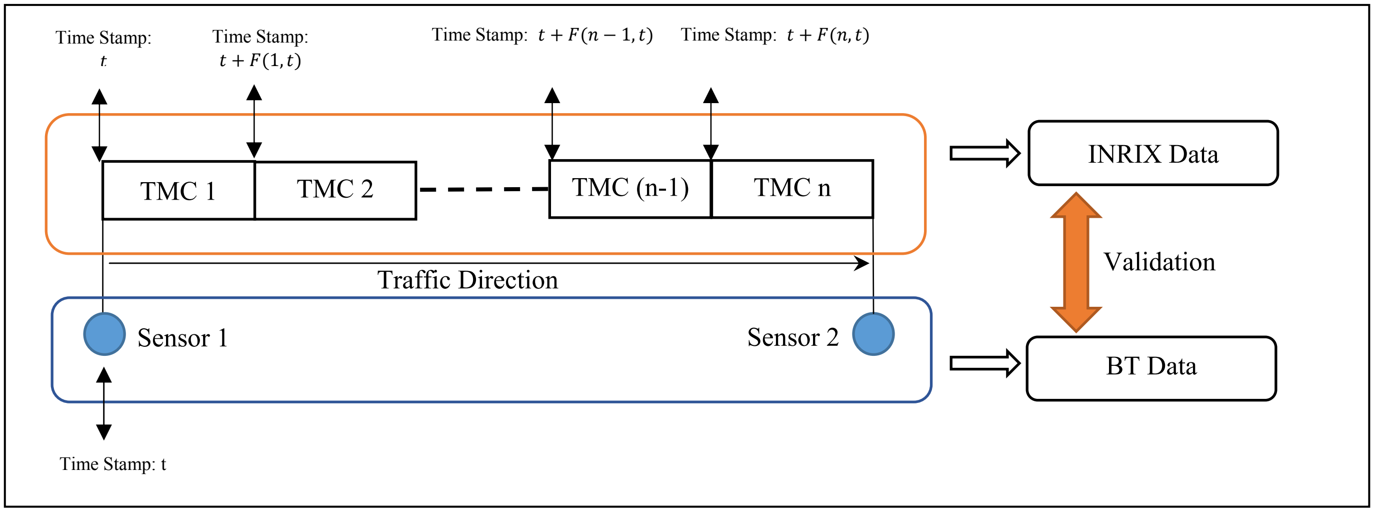


Figure 2: Spatial and Temporal Alignment of the Validation Segment

General definition of path travel time at a particular time point *t* is the duration of time that a vehicle spends to get through the segment given the entrance time equals to *t*. Based on this definition, the measured travel time by BT is exactly the data of interest. This is not the case for the INRIX dataset since INRIX only provides travel time of each TMC segment, which is usually part of a multi-segment path. Hence, equivalent path travel time from INRIX must be calculated by consolidating data for the TMC segments in the path. A simple summation of travel time of the TMC's for the same time interval is not consistent with the real path travel time. To obtain the real path travel time, a backtracking algorithm is used, which can be described by the following recursive equations.

$$F(k,t) = F(k-1,t) + T[k, t+F(k-1,t)], k = 2,3, \dots N \tag{1}$$

$$F(1,t) = T(1,t) \tag{2}$$

where, $T(k,t)$ is the reported travel time of the k$^{\text{th}}$ TMC at time point t, and $F(k,t)$ is the real path travel time from the first TMC to the k$^{\text{th}}$ at time point t. N is the total number of the aligned TMCs. Path travel time from the start of the first segment to the end of the last TMC segment can be obtained by calculating $F(N,t)$, given the starting time point t (or time interval t).

3.2. Coefficient of Variation (CV) based Validation

Data validation is the process of ensuring that the target data set meets certain quality measures when compared against ground truth. This section describes two general statistical validation methods that have been used for freeway data and proposes a new method that emphasizes on travel time variability as a main characteristic of arterial travel time.

3.2.1. Validation Method 1: Aggregate Mean Comparison

A typical way to compare one time series against another time series is a pairwise data point subtraction where mean absolute percentage difference (MAPD) is defined as an indicator to quantitatively measure the difference.

$$MAPD_S = \frac{1}{|S|}\sum_{\forall i \in S} \frac{|T^i_{INRIX} - T^i_{BLT}|}{T^i_{BLT}} \tag{3}$$

Where, T^i_{INRIX} and T^i_{BLT} are the reported travel time from INRIX and BT datasets at time point (or interval) i, respectively. |S| is the size of the validation data set S. As the name suggests, MAPD yields an average of the absolute difference (i.e. difference) between the validated dataset and the ground truth dataset. Higher value of MAPD is an indicator of deviation from the ground-truth. MAPD is usually calculated separately for different categories of data (e.g. time of day, day of week or traffic condition).

3.2.2. Validation Method 2: t-test Based Comparison

Another effective way to validate the reported travel time by using independent detection samples is t-test method. BT dataset reports individual travel time of each valid detected vehicle within a specific time interval. Thus the hypothesis that *reported INRIX travel time is significantly different from the BT mean travel time* for any specific time interval with a valid set of BT observations can be statistically tested. The mean travel time confidence band is formed using the following equation.

$$B^i_{n,100(1-\alpha)} = \overline{T^i_n} \pm t_{n-1,1-\alpha/2} \cdot \sqrt{Var(T^i_n)} \tag{4}$$

$$Var(\overline{T^i_n}) = \frac{\sum_j (T^i_j - \overline{T^i_n})^2}{n(n-1)} \tag{5}$$

Where, n is the number of samples within time interval i. T^i_j is the observed travel time of jth sample in this time interval. $\overline{T^i_n}$ is the sample mean, and $Var\left(\overline{T^i_n}\right)$ is the corresponding variance of sample mean. $t_{n-1,1-\alpha/2}$ is the student t-test value for degree (n-1) and $100(1-\alpha)$ percent confidence. If the reported INRIX travel time value T^i_{INRIX} is located in this confidence band, the hypothesis is rejected. In other words, it can be concluded that the difference between reported INRIX travel time and the BT mean travel time is not statistically significant for the target interval. For each target interval with valid BT and INRIX travel time data, a t-test comparing the INRIX mean value and BT sampling value is conducted. Specifically, the null hypothesis that the reported INRIX data is same with the BT detected data is rejected when T^i_{INRIX} is not covered by the confidence interval. In this case, the data validation does not pass the test. Further, the percentage of time intervals of category S that pass the test can be reported as the acceptance ratio for this category, which is calculated in equation (6). For any specified paired category (validation subsets), the higher the acceptance ratio is, the more similar the paired data is.

$$Accept\_Ratio_S = 100\% \cdot \frac{1}{|S|} \cdot \sum_{i \in S} 1_{\{T^i_{INRIX} \in B^i_{n,100(1-\alpha)}\}} \tag{6}$$

Where, $1_{\{State(i)\}}$ is indicator function yielding 1 when statement $State(i)$ is true and 0 otherwise.

3.2.3. Validation Method 3: Travel Time Variation Categorization

Validation methods 1 and 2 have been widely used to validate freeway data. The measures have also been reported for several data categories based on “time of day”, “day of week” or “speed bins.” Vehicle probe data reported by INRIX consists of a single data point and does not show variability of travel time. However Bluetooth travel time data is generated by aggregating several travel time observations for each specific interval. This allows the calculation of travel time variance in addition to a simple average. Since freeway segments are not subject to major flow disruptions caused by intersections and traffic signals, travel time variance across time intervals is not significant and thus is not useful for categorizing data. On the other hand for an arterial corridor, travel time variability can be significant. Validation method 3 takes advantage of this characteristic to divide data into subsets formed by their degree of variation. Coefficient of variation (CV) is an effective indicator to quantify travel time variability based on the detected samples. CV is defined as the ratio of the standard deviation to the mean, and is considered a normalized measure of dispersion of a probability distribution. From the Bluetooth data, average $\bar{T}_{BLT}^{t}$ and standard deviation σ_{BLT}^{t} for each time interval t is obtained by aggregating valid travel time samples of detected vehicles (Equation 7).

$$CV^{t} = \frac{\sigma_{BLT}^{t}}{\bar{T}_{BLT}^{t}} \tag{7}$$

Statistically speaking and with sufficient samples, mean travel time reported for intervals with lower CV is more likely to be reliable since the detections show a more similar pattern. Consequently, the validation results with lower difference between INRIX and BT data for intervals with smaller CV are more desirable. Because in this case, one could consider the data from either source is of high reliability. Therefore, the research team proposes to use the CV indicator as a classification threshold to further construct and categorize the validation set S in order to describe validation results in a new format. Given the entire time series dataset for a particular time period (e.g. one month or a year), the validation set is divided based on the following set classification operator.

$$S_{time\_n,CV_m} = \{T_{INRIX}^{i} \ and \ T_{BLT}^{i} \mid \forall i \in time\_n \ and \ CV^{t} \in CV_m\} \tag{8}$$

Where, S_{time_n,CV_m} is the target validation data set with “time of the day” and “day of the week” specified as $time\_n$ and traffic variation limited within CV interval CV_m. Hence, validation of the INRIX travel time data compared to BT travel time data can be conducted in different scenarios with respect to different traffic variability states as well as different times of day. This method is applied to a case study and the results are discussed later in the report.

4. DATA FUSION METHODOLOGY

This section describes a data fusion framework for blending GPS probe and Bluetooth generated travel time data for an arterial path. The objective of such an approach is twofold. First, it can increase temporal data coverage by benefiting from the complementation of multiple data sources. Second, by taking advantage of the data fusion logic, the accuracy of the estimated travel time will be enhanced.

4.1. Data Reliability Considerations

Data provided by different sources can be either parallel or heterogeneous. For instance, both INRIX and Bluetooth sources may provide average travel time of a particular time interval in parallel. Meanwhile, each data source comes with other data elements that describe travel time data. As for INRIX dataset, average travel time is always accompanied with another numerical indicator called confidence score which has a value of 10, 20 or 30. The higher the confidence score, the more reliable is the reported travel time. On the Bluetooth data set, in addition to average travel time other indicators such as number of samples and variance around mean can be calculated. One simplistic approach to data fusion is to calculate and report average travel time obtained from the two sources without considering other factors. However to increase the reliability and accuracy of the data fusion engine, other valuable information such as confidence score and variation must be brought into the framework.

As mentioned before, the reported travel time of INRIX dataset is based on TMC. The corresponding confidence score takes value from $\{10, 20, 30\}$. When generating travel time of a particular path for a specific time stamp, a weighted average of confidence scores for the TMC codes across the path must be calculated. That is, for a studied path consisting of n consecutive TMC segments, the expected confidence score for time point t is calculated as,

$$conf_t = average\{c_t^1, c_{t+T_{1-2}^t}^2, c_{t+T_{1-3}^t}^3, \dots, c_{t+T_{1-n}^t}^n\} \tag{9}$$

Where, c_t^j is the reported confidence score of the jth TMC segment at time point t and belongs to $\{10, 20, 30\}$, and T_{1-j}^t denotes the travel time from the start of 1st TMC segment to the start of jth TMC segment at time point t. In other words, T_{1-j}^t is just the travel time of the path consisting of TMC segments, 1, 2, … ,(j-1) measured at time point t.

When it comes to the Bluetooth data, since Bluetooth detectors are located at both ends of the path, coefficient of variation (CV) as well as number of samples for each time interval can be calculated based on travel time samples belonging to the interval. Intuitively speaking, when the CV is high and the number of detections is relatively low, the corresponding measured travel time (the mean or the median travel time) might not be reliable. Instead, when the CV is low and the number of detections is relatively high, one would have much more confidence in the measured travel time drawn from these detection samples.

4.2. Context Dependent Based Fusion Operator

Any data augmentation and fusion method can be classified as a specific type of fusion operator depending on its fusion behavior [16]. Bloch [16] proposed a classification of the operators in three classes and further showed that any specific operator fits in one of the classes. They are Context Independent Constant Behavior (CICB) Operators, Context Independent Variable Behavior (CIVB) Operators, and Context Dependent (CD) Operators. In this section, a CD fusion operator to fuse and augment the travel time with INRIX and Bluetooth datasets is proposed. In this operator not only the value itself plays an important role in the fusion process, but also data source reliability and data conflicts are taken into consideration.

As discussed previously, the average confidence score obtained from the INRIX dataset can reveal some reliability information on the reported travel time. Thus it is used as an indicator to quantitatively describe the reliability of the reported travel time value within a given time interval (or at a given time point). The context proposed here is a binary logic, where 1 means the reported data is reliable and 0 means unreliable.

$$R_{INRIX}^{t} = \begin{cases} 1, \ if \ conf_t \geq \alpha \\ 0, if \ conf_t < \alpha \end{cases} \tag{10}$$

Where R_{INRIX}^{t} is the INRIX data reliability indicator of the studied path at the time interval t. α is a user defined threshold and takes value within [10, 30].

Within a specific time interval, number of detections (or observations) is viewed as a significant indicator of the reliability when it comes to the Bluetooth data. Given all of the valid observations within time interval t, CV reflects the variation of the traffic state. Thus it can also be used as a proxy for travel time reliability. The higher number of observations is an indicator of a more reliable Bluetooth estimated travel time in a given time interval.

$$R_{BLT}^{t} = \begin{cases} 1, & if\ N_t \geq k(i) \\ 0, & if\ N_t < k(i) \end{cases} \tag{11}$$

Where, R_{BLT}^{t} is the BT data reliability indicator of the studied path at time interval t. N_t is the corresponding detection rate during that time interval. $k(i)$ is a segment-dependent criterion indicating the reliability of the detection data. A discussion related to choosing an appropriate value for $k(i)$ can be found in Haghani et al. (2010). The above binary logic is a basis for the fusion and augmentation process when the final target data is generated from multiple independent sources. This is a main advantage of the CD operator since CICB and CIVB operators do not allow consideration of data sources reliability.

Another important issue considered in the proposed framework is conflict and consonance. In some scenarios, even though each independent source claims high reliability of their reported data, significant disagreement between two data sources might exist [16]. Hence, a specific fusion mechanism or logic must be developed to address the conflict issue between these so-called high reliable data. An effective way to quantify the conflict between the reported travel time of INRIX and Bluetooth within the same time bin is to investigate the mean distance of these two data points with consideration of CV. A binary logic to make a decision whether the reported INRIX travel time conflicts with the reported data from BT is developed (or whether the data from these two sources are consonant).

$$Consonant^{t} = \begin{cases} 1, if\ T_{INRIX}^{t} \in B_{n,100(1-\alpha)}^{t} \\ \quad 0, otherwise \end{cases} \tag{12}$$

Where $Consonant^{t}$ is a binary indicator with value 1 meaning the reported travel time of INRIX for time interval t is consonant with that of BT detection data and 0 means otherwise. T_{INRIX}^{t} and T_{BLT}^{t} are the mean value of travel time from INRIX and BT, respectively. $B_{n,100(1-\alpha)}^{i}$ denotes the confidence band of mean time interval t. In other words, $Consonant^{t}$ equal to 1 means the reported value of travel time from INRIX is statistically captured by the BT dataset.

The proposed fusion operator is a context dependent operator defined in Bloch [16]. It is necessary to define all of the possible context combinations. Their definitions are

- NR-NR context:

$$R_{INRIX}^{t} = 0 \; and \; R_{BLT}^{t} = 0$$

- NR-R context:

$$R_{INRIX}^{t} = 0 \; and \; R_{BLT}^{t} = 1$$

- R-NR context:

$$R_{INRIX}^{t} = 1 \; and \; R_{BLT}^{t} = 0$$

- R-R & C context:

$$R_{INRIX}^{t} = 1 \; and \; R_{BLT}^{t} = 1 \; and \; Consonant^{t} = 1$$

- R-R & NC context:

$$R_{INRIX}^{t} = 1 \; and \; R_{BLT}^{t} = 1 \; and \; Consonant^{t} = 0$$

The last two contexts take the "consonant" logic into consideration. In other words, when any of the multiple data providers shows an unreliable behavior, they are unlikely to be trusted in the current time interval. Therefore, whether the data is consonant with each other has a lower priority in comparison with their reliability.

4.2.1. First Level Fusion Operator

In the context of NR-NR (i.e. both data sources are unreliable) a cautious behavior is taken to fuse their reported travel time value. The cautious fusion behavior has the property that $\forall (x, y) \in R^2, \min(x, y) \leq F(x, y) \leq \max(x, y)$, where $F(x, y)$ is the fusion function with respect to datasets x and y. The function chosen here is simply the unweighted average function, which means that the same belief value is used on each dataset. Similarly, in the context of "R-R and NC," both data source are judged to be reliable while the data they provide conflict with each other, hence the unweighted average is chosen as the fusion function. In the context of "R-NR" and "NR-R" (i.e. one of the data sources is not reliable while the other one is reliable) the data from the reliable data source is chosen. The last context is the most desirable scenario, in which both the data sources are reliable and the data they provide is consonant with each other. Therefore, we can either choose the statistical BT mean or the average of BT and INRIX as the fusion output since the single INRIX data is well captured by the sampling group of BT detections. In some particular time intervals with a high travel time variance, although the reported INRIX data is statistically captured by the BT detection data, the mean difference of these two values can still be large. Thus the unweighted average is chosen as the final fusion operator in context “R-R and C.” It is noted that this average value is still within the statistical mean confidence band. Finally, the first level context specific fusion operators are summarized in equation (13). In addition to the fused travel time, another set of fusion outputs, i.e. the belief of fusion, is introduced. This is a significant component of data fusion process that quantitatively indicates the belief of fusion results. As the name suggests, the higher the belief value is, the more trustable the fused data are. The belief is defined in three levels, i.e. with $Bel^t = 0$ meaning the fused result is not reliable, $Bel^t = 1$ meaning the fused result is plausible and $Bel^t = 2$ meaning the fused result is believable. The belief function is given in equation (14). For context “NR-NR,” it is concluded that the fusion is not reliable, since neither source is reliable enough. In context “R-R and NC,” although both sources are claimed to be reliable, they are statistically different from each other, thus the fused results from this context is said to be plausible. On the contrary, when both sources are reliable and statistically consonant with each other, the fused result is claimed as believable. As for the other two contexts, i.e. only one data source is reliable, the fused result is plausible by choosing the data from the reliable data source.

$$T_{fused\_1}^t =$$

$$F(T_{INRIX}^t, T_{BLT}^t) = \begin{cases} \dfrac{T_{INRIX}^t + T_{BLT}^t}{2}, & if\ (NR-NR) or\ (R-R\ and\ NC) or (R-R\ and\ C) \\ \mathbf{1}_{\{R_{INRIX}^t=1\}} \cdot T_{INRIX}^t + \mathbf{1}_{\{R_{BLT}^t=1\}} \cdot T_{BLT}^t, & if\ (NR-R)\ or\ (R-NR) \end{cases} \tag{13}$$

$$Bel^t = \begin{cases} 0, & if\ (NR-NR) \\ 1, & if\ (NR-R) or\ (R-NR) or (R-R\ and\ NC) \\ 2, & if\ (R-R\ and\ C) \end{cases} \tag{14}$$

Where $T_{fused\_1}^t$ is the output from the fusion function $F(T_{INRIX}^t, T_{BLT}^t)$, and $\mathbf{1}_{\{statement\}}$ is the binary indicator function w.r.t. a specific statement.

4.2.2. Second Level Fusion Operator

At the first level of fusion process, the fused travel time is calculated in terms of each specific context, which is defined from the perspectives of data source reliability and data conflict. The fusion process is conducted in a conservative way by extracting and combining the information from both datasets (i.e. vertical fusion). In the second level, based on the fusion outputs from the first level, moving average method is chosen to further eliminate the error disturbance along the time line (i.e. horizontal fusion). The fusion operator is given by equation (15).

$$T_{fused\_2}^{t} = \left\{ \frac{\sum_{i=t-(k-1)/2}^{i=t+(k-1)/2} T_{fused\_1}^{i}}{k} \right\} \tag{15}$$

Where, k is a predefined moving distance and $T_{fused\_1}^{i}$ is the 1st level fusion result at time interval (or time point) i.

5. COMPREHENSIVE NUMERICAL EXPERIMENT

5.1. Sites and Data Introduction

This section presents a comprehensive numerical study of the proposed travel time validation and augmentation model with travel time data collected on MD 355 in Maryland for the entire 2012 year. A Satellite view of the target arterial segments is presented in Figure 3. BT travel time data for these studied segments was collected and processed through four detection devices with AVI settings. The GPS probe travel time data for this arterial included INRIX data points on multiple TMC segments which are consecutively aligned on the studied arterial segment. The spatial and temporal alignment method mentioned earlier was used to generate the path travel time data. The geographic details of the studied segments are listed in Table 1. After the special alignment of BT detectors and TMC segments, there were totally three non-overlapping and bidirectional segments located on MD 355: the segment between S Summit Ave and College Pkwy, the segment between College Pkwy and Country Club Rd, and the segment between Country Club Rd and Strathmore Ave. Since the travel time data was reported (by INRIX) and collected (with BT) for both northbound and southbound traffic, there were totally 6 passage segment being studied. For convenience, each passage segment was assigned a label ID. As demonstrated in Table 1, the three southbound passage segments were labeled as, Path_S_1, Path_S_2 and Path_S_3, respectively. Similarly, the three northbound passage segments were labeled as, Path_N_1, Path_N_2 and Path_N_3, respectively. The studied paths' lengths as well as their coverage of TMCs were given in TABLE 1. The INRIX travel time data was reported in one minute intervals. BT detection produces a travel time data point only when at least one valid vehicle traverses the target segment. Table 2 shows the size of the overall BT detection datasets related to each detection device and studied path. For example, more than four million Bluetooth detections from both sensors were processed to generate more than 110,000 travel time samples in terms of Path_N_2 (the segment from Country Club Rd to College Pkwy). It is also noted that the number of raw detections from BT sensor 1 is relatively small (i.e. 352,138 of weekdays and 118,538 of weekends), which yields a smaller set of valid observations within Path_N_3 and Path_S_1 in comparison with other studied paths.

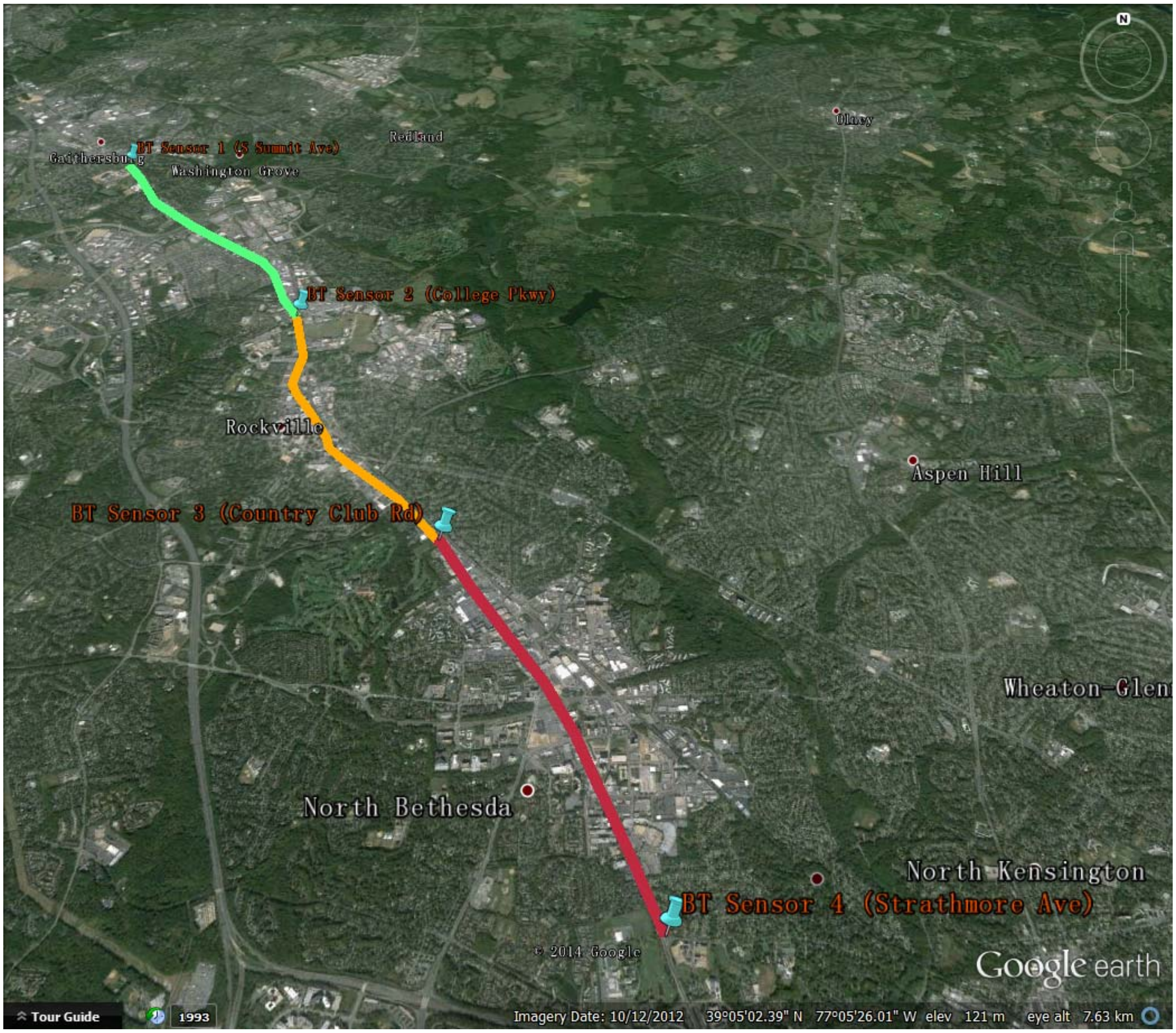


Figure 3: Satellite Picture of Three Bidirectional Segments on MD-355 (Northbound and Southbound Per Segment)

Table 1: Geographic Information of Deployed BT Detectors and Corresponding Aligned TMC Segments

	ID	BT Location	Path Length (mile)	Bluetooth ID	Distance to the next BLT sensor (mile)	Latt	Long	Offset (mile) (Distance to the start point of the covering TMC)	INRIX ID (Sequentially aranged from Southbound/ Northbound)	Length (mile)	start latt	start long	end latt	end long
Entire **S**outhbound Path (with BLT covered)	BT1	S Summit Ave	N/A	MD_355_SUM	3.232274266	39.138339	-77.1942	0	110N11345	0.036240048	39.138202	-77.19463	39.137823	-77.19416
	Path S_1		3.232274266						110-11344	1.266705258	39.137823	-77.19416	39.123622	-77.17946
									110N11344	0.077072242	39.123622	-77.17946	39.122887	-77.17838
									110-11343	0.005797662	39.122887	-77.17838	39.122836	-77.1783
									110N11343	0.044423886	39.122836	-77.1783	39.122448	-77.17764
									110-11342	0.774954154	39.122448	-77.17764	39.115564	-77.16627
									110-11341	0.68997149	39.115564	-77.16627	39.107501	-77.15917
									110N11341	0.077109526	39.107501	-77.15917	39.106506	-77.15852
	BT2	College Pkwy	N/A	MD_355_COL	2.80439593	39.103442	-77.15571	0.26	110-11340	1.033319846	39.106506	-77.15852	39.092427	-77.15346
	Path S_2		2.80439593						110N11340	0.03719079	39.092427	-77.15346	39.091895	-77.15335
									110-06993	0.739205012	39.091895	-77.15335	39.082599	-77.1467
									110N06993	0.117562666	39.082599	-77.1467	39.081236	-77.1455
									110-06992	0.429089128	39.081236	-77.1455	39.077067	-77.13958
									110N06992	0.008028488	39.077067	-77.13958	39.076982	-77.13948
	BT3	Country Club Rd	N/A	MD_355_CCR	2.73157013	39.069697	-77.1305861	0.7	110-06991	2.031213678	39.076982	-77.13948	39.05345	-77.11704
	Path S_3		2.73157013						110N06991	0.096957042	39.05345	-77.11704	39.052225	-77.11616
									110-07798	1.26339941	39.052225	-77.11616	39.035316	-77.1072
	BT4	Strathmore Ave	N/A	MD_355_547	N/A	39.034769	-77.10661	0.04	110N07798	0.08538036	39.035316	-77.1072	39.034122	-77.10679
Entire **N**orthbound Path (with BLT covered)	BT4	Strathmore Ave	N/A	MD_355_547	2.74392	39.034769	-77.10661	0.09000	110P07798	0.130220584	39.033541	-77.10638	39.035356	-77.10704
	Path N_1		2.74392						110+06991	1.269725262	39.035356	-77.10704	39.052357	-77.11602
									110P06991	0.083975996	39.052357	-77.11602	39.05342	-77.11678
	BT3	Country Club Rd	N/A	MD_355_CCR	2.79731	39.069697	-77.1305861	1.35000	110+06992	2.043436616	39.05342	-77.11678	39.077096	-77.13936
	Path N_2		2.79731						110P06992	0.00795392	39.077096	-77.13936	39.077173	-77.13947
									110+06993	0.397242378	39.077173	-77.13947	39.081052	-77.14493
									110P06993	0.076407344	39.081052	-77.14493	39.081803	-77.14597
									110+11340	0.806061438	39.081803	-77.14597	39.09195	-77.1532
									110P11340	0.036208978	39.09195	-77.1532	39.092468	-77.1533
	BT2	College Pkwy	N/A	MD_355_COL	3.21890	39.103442	-77.15571	0.78000	110+11341	0.98240233	39.092468	-77.1533	39.105924	-77.15785
	Path N_3		3.21890						110P11341	0.055857646	39.105924	-77.15785	39.106627	-77.15837
									110+11342	0.767192868	39.106627	-77.15837	39.11568	-77.16615
									110+11343	0.696514832	39.11568	-77.16615	39.121842	-77.17639
									110P11343	0.111889284	39.121842	-77.17639	39.12285	-77.17801
									110+11344	0.01715064	39.12285	-77.17801	39.123014	-77.17825
									110P11344	0.208411346	39.123014	-77.17825	39.125004	-77.18117
									110+11345	1.139479822	39.125004	-77.18117	39.13798	-77.19411
	BT1	S Summit Ave	N/A	MD_355_SUM	N/A	39.138339	-77.1942	0.02000	110P11345	0.034152144	39.13798	-77.19411	39.138335	-77.19456

Table 2: Size Description of Overall Datasets

		BT Sensor 1	BT Sensor 2	BT Sensor 3	BT Sensor 4
Number of Raw MAC ID Records	*Weekdays*	352,138	956,553	1,311,423	976,148
	Weekends	118,538	295,963	457,435	325,963
Number of Valid Observations (i.e. matched and filtered)	*Weekdays Path_N_3*	28,371			
	Weekends Path_N_3	9,923			
	Weekdays Path_N_2		78,565		
	Weekends Path_N_2		24,686		
	Weekdays Path_N_1			47,626	
	Weekends Path_N_1			15,731	
	Weekdays Path_S_3			54,641	
	Weekends Path_S_3			15,547	
	Weekdays Path_S_2		88,502		
	Weekends Path_S_2		24,863		
	Weekdays Path_S_1	26,437			
	Weekends Path_S_1	9,330			

5.2. Data Validation Results

In this subsection, the proposed validation model was applied to the abovementioned six arterial segments using archived 2012 data. For each studied segment, travel time data samples (of 5-minute) were further classified based on their CV values. Based on the work of Haghani et al (2010), the reliability threshold was set at three samples in five minutes, and if the number of samples was higher than the threshold the calculated mean travel time was deemed reliable. This threshold was not time dependent. Figures 4 through 9 plot the CV distribution of BT travel time on each segment in 5-minute time bins for both weekdays and weekends. As discussed previously, a 5-minute time bin with higher CV value indicates a higher traffic variance during this time period.

Classifying the validation time bins based on their CV values in addition to the time of day was necessary as discussed in validation method 3. Generally speaking, CV value greater than 0.1 for a 5-minute interval indicates a high traffic variance. For the sampling data on weekdays, the cumulative percentages of time bins with CV greater than 0.1 on Path_S_1, Path_S_2, Path_S_3, Path_N_1, Path_N_2, and Path_N_3 were approximately, 55%, 50%, 61%, 58%, 57% and 60%, respectively. For all paths except Path_N_3, this percentage values were a little bit lower for weekend. For Path_N_3, the corresponding percentage value of weekends was approximately 45%, 15% lower in comparison with that of weekdays. This might be explained by the difference of traffic patterns during weekdays and weekends. In other words, higher percentage of "high" CV means travel time varies more on weekdays.

Tables 3 through14 demonstrate the CV based validation results of each studied segment for both weekdays and weekends. The difference of the traffic patterns during weekdays and weekends can be inexplicitly reflected from the distribution of number of valid observations throughout the day. BT detectors collected the most passage data around 1:00 PM during weekends for both southbound and northbound segments. During weekdays, BT detectors were able to collect more valid data around 8:00 AM for the southbound segments, and more around 5:00 PM for the northbound segments. This phenomenon can be easily explained since the studied arterial segments are north of a major metropolitan center, Washington D.C. area. The southbound traffic volume is higher in weekday mornings when people commute to work, while the northbound traffic volume is higher in weekday evenings. However, on weekends, the traffic is uniformly distributed during the daytime. Therefore, conducting the comparison and validation work with time of day further divided into two types (i.e. weekdays and weekends) is necessary.

As for the three southbound segments (i.e. Path_S_1, Path_S_2 and Path_S_3), the number of valid validation time bins (i.e. time bin with both reported BT and INRIX data) during the weekday morning peak period (8:00 AM) were much higher than that of other time periods of day. Hence, the comparison and validation results coming from this time period are more trustable. Based on the results from both validation model 1 (MAPD) and validation model 2 (t-test), INRIX travel time and BT travel time of morning peak periods were of high agreement for these three southbound segments. For example, the weekday validation results of Path_S_2 within 8:00AM – 9:00 AM indicates, for time bins with CV within 0-0.2, the MAPD was approximately 16% and the t-test acceptance ratio was around 95% for time bins with CV in 0.1-0.2 . However, for Path_S_1, the data difference was relatively higher during the morning peak. There are two possible explanations for this phenomenon. One is that the number of valid BT time bins used for validation during these periods was small, and the other might be the number of valid probe vehicles (providing real-time data for INRIX) during these periods was small. Hence, the difference of travel time data reported by INRIX and measured by BT technique on

Path_S_1 was higher during these periods in comparison with those of Path_S_2 and Path_S_3 on weekdays. As for the data reported and measured in weekends, the validation results indicated a higher difference across the entire daytime in comparison with that of weekdays during non-peak hours. As mentioned above, this might be caused by the “uniform” traffic pattern of weekends. In other words, during non-peak hours on weekends, the traffic is always of high variance due to the larger traffic volume in comparison with that of weekdays. Meanwhile, the lower number of probe vehicle samples and BT samples in weekends might also be an explanation for this phenomenon.

As for the three northbound segments (i.e. Path_N_1, Path_N_2 and Path_N_3), the number of valid validation time bins during the weekday afternoon peak period (around 5:00 PM) was much higher than that of other time periods of day. Similarly, validation results for this time period were more trustable. For Path_N_1, INRIX reported data and BT data were of high agreement during the afternoon peak period (around 5:00 PM). The data difference of the period 7:00PM-8:00PM was very high, and the number of validation time bins was relatively small (i.e. 103 time bins under 0.0-0.1 CV category, and 82 time bins under 0.1-0.2 CV category). Thus the comparison results might not be of high reliability. For Path_N_2 and Path_N_3, as anticipated, data difference during afternoon peak periods (around 5:00 PM) was higher than that of other time of day. The weekend validation results were very similar to those of the southbound segments. In summary, there are four key findings from the analysis of the overall validation results.

- Comparison and validation results vary for weekdays and weekends. For weekends, the data difference was relatively high throughout the day, but in general lower than that of weekday peak hour period.
- For southbound segments, INRIX travel time data has a very high agreement with BT measured data during the morning peak period (i.e. around 8:00AM). This indicates the high INRIX data quality during this period, since the corresponding valid validation samples are of large size.
- For northbound segments, INRIX travel time data has a relatively higher difference from BT data for peak period 5:00-7:00 PM in comparison with the southbound peak hour (around 7:00-9:00 AM) validation results. This indicates a higher data disagreement

during this period, since the corresponding valid validation samples is of large size. Specifically, the data reported for northbound afternoon peak period is of lower quality compared with the southbound segments data.

- MAPD method and t-test method produce different deviation patterns in different CV categories. For time interval with high travel time variance, although the difference of the mean travel time between INRIX and BT data is high, the reported travel time from INRIX is more likely to be statistically consistent with that of BT detection data. In this case, the reported travel time data is valid and should be considered with a higher variance (e.g. the travel time reliability is low).

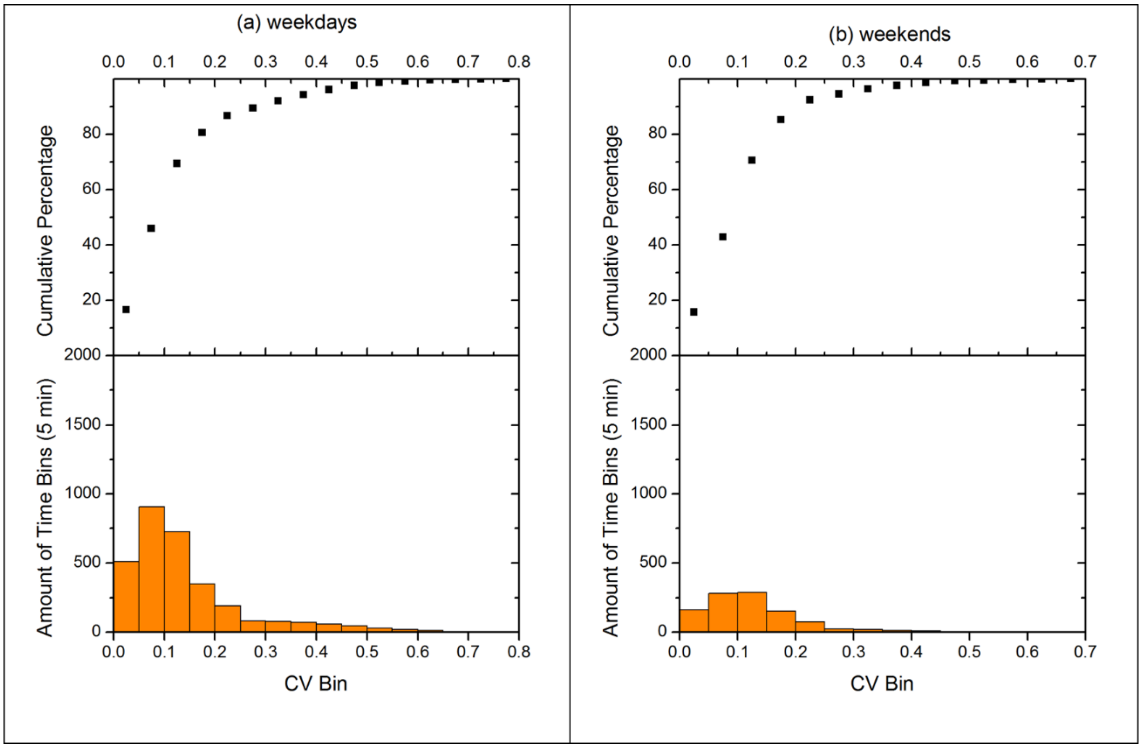


Figure 4: Histogram plots of Path_S_1's CV distribution based on BT detection data

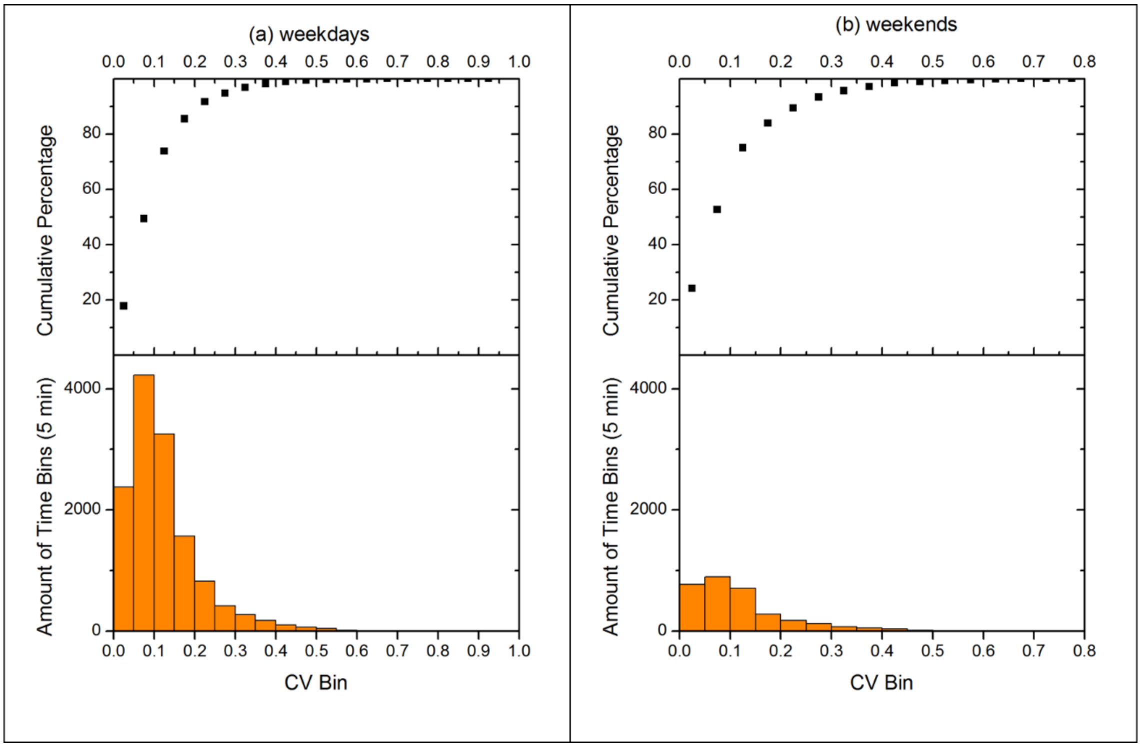


Figure 5: Histogram plots of Path_S_2's CV distribution based on BT detection data

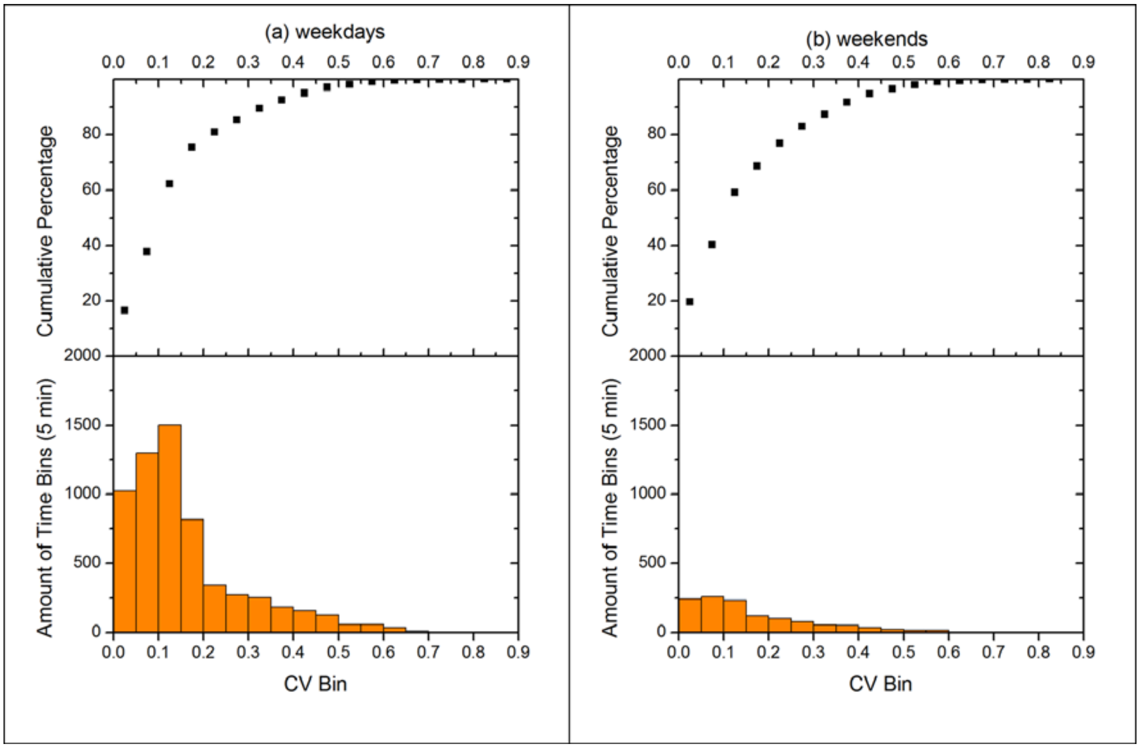


Figure 6: Histogram plots of Path_S_3's CV distribution based on BT detection data

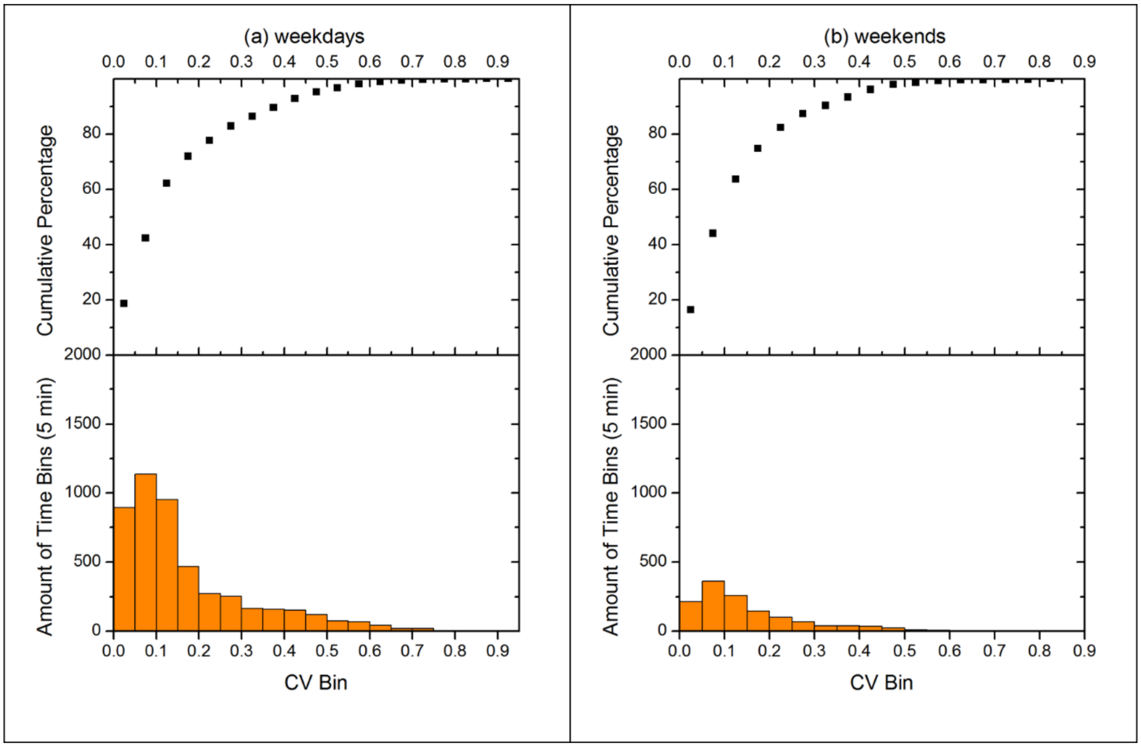


Figure 7: Histogram plots of Path_N_1's CV distribution based on BT detection data

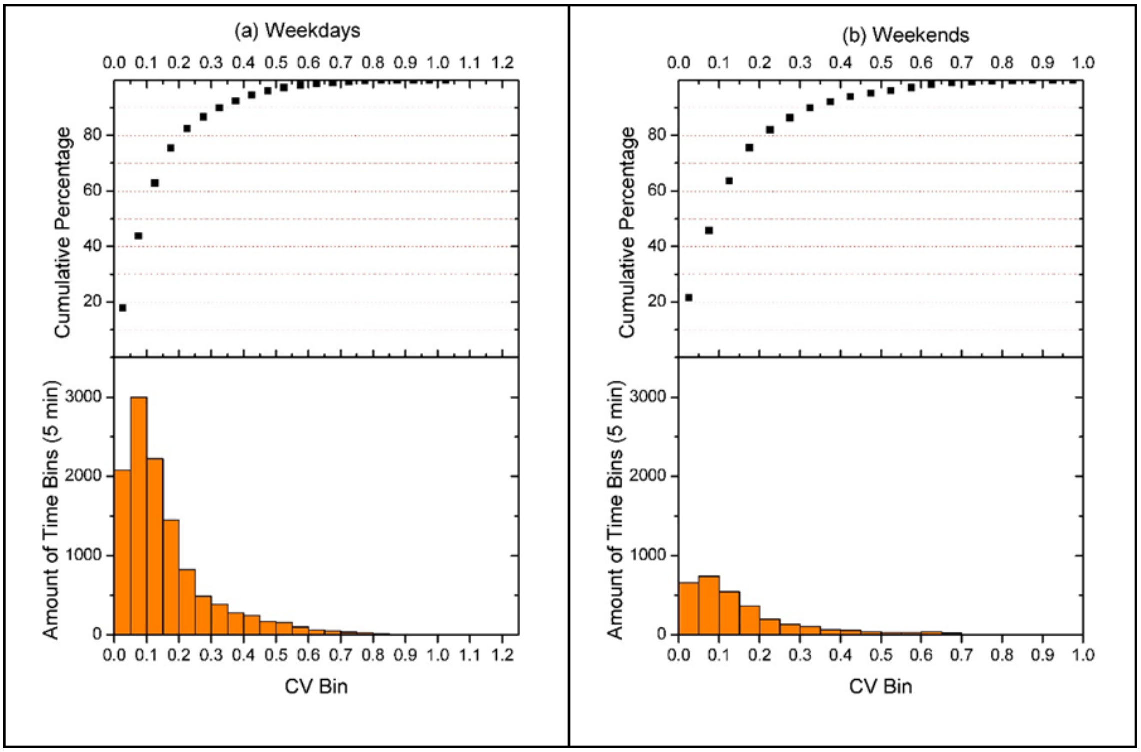


Figure 8: Histogram plots of Path_N_2's CV distribution based on BT detection data

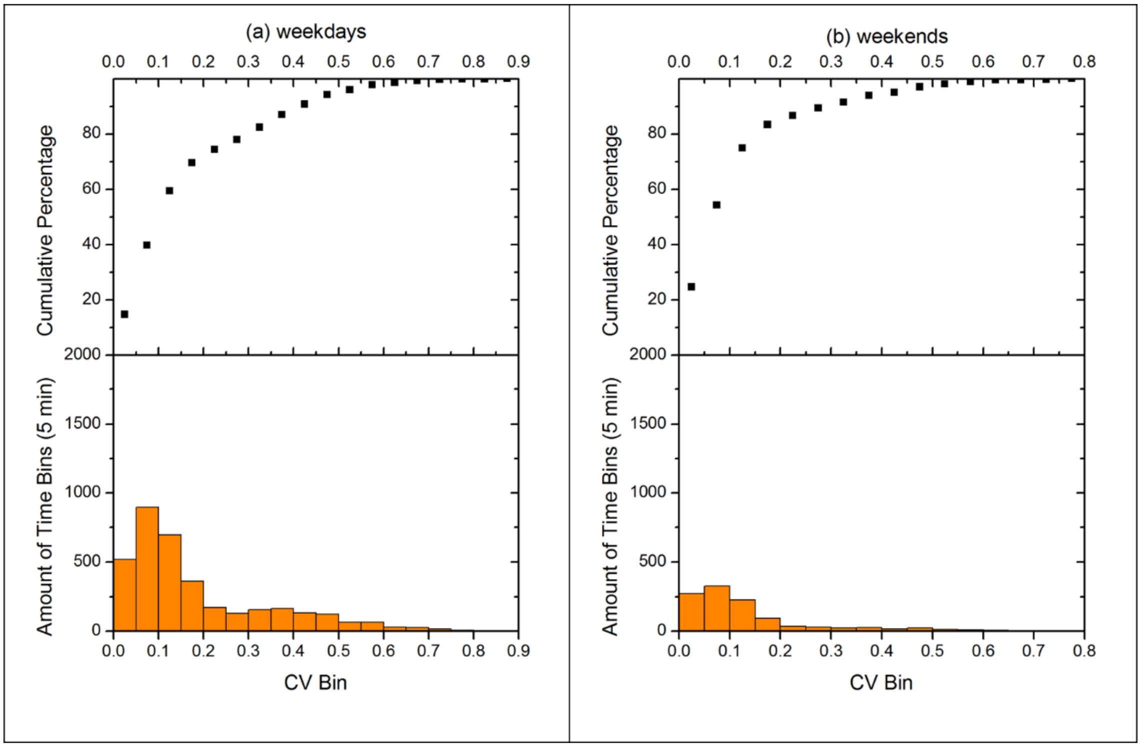


Figure 9: Histogram plots of Path_N_3's CV distribution based on BT detection data

Table 3: CV based Comparison and Validation Results of Path_S_1 in Weekdays

Time of Day	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	17.2%	13.1%	N\A	N\A	N\A	N\A	N\A	116	3	0	0	0	0	0	33%	N\A	N\A	N\A	N\A	N\A
1-2 AM	15.8%	N\A	N\A	N\A	N\A	N\A	N\A	49	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
2-3 AM	20.4%	N\A	N\A	N\A	N\A	N\A	N\A	59	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
3-4 AM	35.4%	64.6%	N\A	N\A	N\A	N\A	N\A	42	2	0	0	0	0	0	0%	N\A	N\A	N\A	N\A	N\A
4-5 AM	16.9%	N\A	N\A	N\A	N\A	N\A	N\A	54	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
5-6 AM	16.9%	7.0%	9.2%	N\A	36.1%	39.2%	33.3%	305	5	4	0	2	2	1	80%	100%	N\A	100%	100%	100%
6-7 AM	19.3%	10.4%	10.0%	12.3%	20.6%	32.6%	31.8%	586	40	87	21	11	12	19	70%	99%	100%	100%	100%	100%
7-8 AM	19.4%	17.2%	17.1%	16.8%	27.2%	35.1%	28.5%	539	233	169	33	23	8	7	52%	96%	100%	100%	100%	100%
8-9 AM	19.1%	20.5%	19.2%	23.6%	38.1%	36.9%	59.6%	543	261	156	28	16	2	1	40%	92%	100%	100%	100%	100%
9-10 AM	23.0%	21.6%	20.3%	24.6%	39.0%	36.6%	41.5%	609	94	89	36	24	18	5	39%	91%	100%	100%	100%	100%
10-11 AM	22.3%	20.5%	18.6%	31.1%	39.3%	43.8%	38.9%	611	61	36	18	12	9	12	46%	92%	100%	100%	100%	100%
11-12 AM	22.0%	20.4%	19.6%	25.0%	41.3%	49.0%	47.1%	679	71	47	15	13	5	6	42%	96%	100%	100%	100%	100%
0-1 PM	22.7%	22.8%	19.2%	23.4%	46.9%	43.4%	44.4%	676	94	49	15	3	5	2	36%	98%	100%	100%	100%	100%
1-2 PM	22.9%	22.6%	20.8%	28.4%	34.7%	53.6%	52.4%	688	81	56	12	7	5	3	33%	98%	100%	100%	100%	100%
2-3 PM	24.7%	24.4%	20.7%	33.0%	42.5%	47.0%	47.7%	666	87	65	13	8	11	1	25%	95%	100%	100%	100%	100%
3-4 PM	23.2%	20.7%	23.9%	28.1%	46.3%	40.3%	51.2%	682	86	60	14	8	7	1	45%	93%	100%	100%	100%	100%
4-5 PM	25.0%	27.0%	22.5%	29.2%	44.7%	50.8%	50.7%	668	72	43	14	9	5	8	15%	93%	100%	100%	100%	100%
5-6 PM	27.9%	28.5%	25.9%	32.5%	46.9%	50.1%	49.9%	647	62	61	12	7	7	6	16%	87%	100%	100%	100%	100%
6-7 PM	25.2%	26.1%	24.1%	28.9%	45.7%	48.0%	49.6%	630	70	59	11	5	2	2	26%	92%	100%	100%	100%	100%
7-8 PM	22.3%	20.4%	19.6%	25.5%	28.3%	41.2%	40.2%	613	30	40	13	2	2	1	50%	98%	100%	100%	100%	100%
8-9 PM	19.3%	19.6%	21.0%	17.9%	N\A	53.0%	N\A	544	34	27	6	0	1	0	53%	96%	100%	N\A	100%	N\A
9-10 PM	20.1%	18.9%	19.4%	22.8%	N\A	N\A	N\A	507	19	18	6	0	0	0	47%	100%	100%	N\A	N\A	N\A
10-11 PM	25.7%	28.8%	27.6%	17.8%	52.0%	43.8%	44.2%	420	13	7	4	1	1	1	31%	100%	100%	100%	100%	100%
11-12 PM	23.1%	N\A	24.5%	28.6%	N\A	N\A	N\A	232	0	2	1	0	0	0	N\A	100%	100%	N\A	N\A	N\A

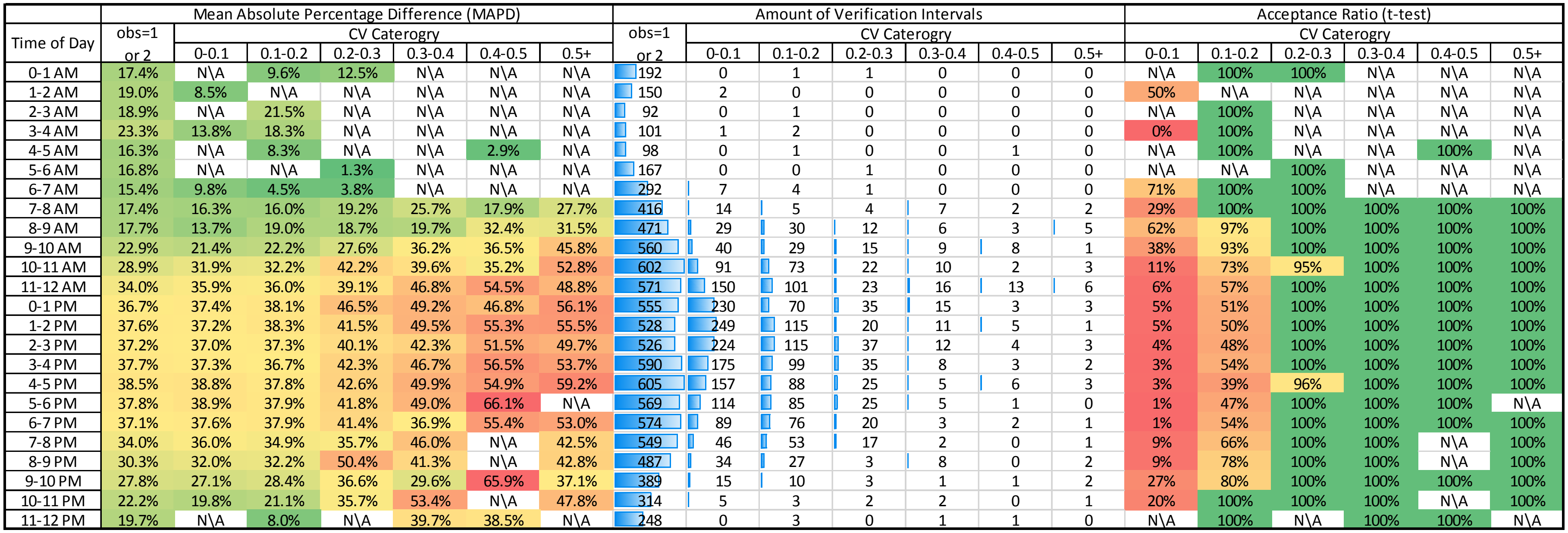
Table 4: CV based Comparison and Validation Results of Path_S_1 in Weekends

	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
Time of Day	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	18.0%	14.3%	N\A	N\A	18.9%	N\A	N\A	88	2	0	0	1	0	0	0%	N\A	N\A	100%	N\A	N\A
1-2 AM	14.3%	N\A	N\A	N\A	N\A	N\A	N\A	49	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
2-3 AM	13.7%	N\A	N\A	N\A	N\A	N\A	N\A	26	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
3-4 AM	14.8%	N\A	N\A	N\A	N\A	N\A	N\A	28	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
4-5 AM	21.7%	N\A	N\A	N\A	N\A	N\A	N\A	25	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
5-6 AM	16.4%	N\A	N\A	N\A	N\A	N\A	N\A	43	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
6-7 AM	17.1%	N\A	11.7%	N\A	N\A	53.5%	N\A	128	0	2	0	0	1	0	N\A	100%	N\A	N\A	100%	N\A
7-8 AM	16.3%	5.0%	8.9%	36.6%	45.8%	N\A	39.6%	146	2	2	1	1	0	2	100%	100%	100%	100%	N\A	100%
8-9 AM	21.7%	16.7%	23.2%	25.3%	47.5%	44.4%	N\A	184	6	6	2	3	4	0	67%	100%	100%	100%	100%	N\A
9-10 AM	25.1%	25.7%	30.7%	31.9%	33.2%	N\A	N\A	215	21	12	3	1	0	0	38%	58%	100%	100%	N\A	N\A
10-11 AM	28.8%	28.9%	22.9%	38.3%	13.8%	37.3%	N\A	241	27	17	5	1	1	0	15%	94%	100%	100%	100%	N\A
11-12 AM	22.9%	21.3%	18.9%	29.6%	34.1%	N\A	51.6%	249	33	42	6	4	0	1	33%	100%	100%	100%	N\A	100%
0-1 PM	22.6%	24.3%	24.1%	25.2%	45.0%	49.0%	35.4%	248	45	29	9	2	2	1	18%	93%	100%	100%	100%	100%
1-2 PM	26.0%	27.3%	23.1%	24.7%	42.3%	36.3%	N\A	271	44	40	7	4	1	0	14%	98%	100%	100%	100%	N\A
2-3 PM	23.7%	25.4%	22.8%	22.3%	52.1%	15.2%	N\A	264	45	52	9	3	1	0	31%	90%	100%	100%	100%	N\A
3-4 PM	22.6%	25.1%	23.1%	24.9%	38.4%	47.7%	54.1%	265	38	46	7	1	3	1	34%	93%	100%	100%	100%	100%
4-5 PM	23.3%	23.5%	24.8%	25.2%	33.7%	9.1%	N\A	261	43	57	10	1	1	0	28%	96%	100%	100%	100%	N\A
5-6 PM	23.5%	22.0%	23.2%	28.5%	57.7%	N\A	50.5%	258	38	40	16	1	0	1	39%	95%	100%	100%	N\A	100%
6-7 PM	21.3%	21.5%	20.5%	24.4%	33.9%	N\A	N\A	276	31	45	8	1	0	0	42%	100%	100%	100%	N\A	N\A
7-8 PM	22.9%	22.1%	24.5%	24.7%	27.6%	23.7%	N\A	253	22	24	6	3	2	0	41%	79%	100%	100%	100%	N\A
8-9 PM	22.2%	21.9%	20.3%	28.0%	39.4%	N\A	N\A	239	20	12	2	4	0	0	20%	92%	100%	100%	N\A	N\A
9-10 PM	20.5%	23.0%	22.3%	30.0%	27.2%	28.5%	35.7%	211	14	11	4	1	1	1	36%	73%	100%	100%	100%	100%
10-11 PM	25.2%	24.4%	27.9%	27.3%	N\A	N\A	55.8%	161	10	2	1	0	0	1	20%	100%	100%	N\A	N\A	100%
11-12 PM	23.5%	24.3%	N\A	N\A	N\A	N\A	N\A	118	2	0	0	0	0	0	0%	N\A	N\A	N\A	N\A	N\A

Table 5: CV based Comparison and Validation Results of Path_S_2 in Weekdays

Time of Day	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	21.0%	7.0%	13.1%	11.5%	N\A	26.8%	N\A	315	4	5	1	0	1	0	25%	100%	100%	N\A	100%	N\A
1-2 AM	19.5%	N\A	N\A	N\A	27.1%	N\A	N\A	263	0	0	0	1	0	0	N\A	N\A	N\A	100%	N\A	N\A
2-3 AM	24.7%	N\A	N\A	N\A	N\A	N\A	N\A	166	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
3-4 AM	23.8%	40.0%	7.0%	N\A	N\A	N\A	N\A	272	1	1	0	0	0	0	0%	100%	N\A	N\A	N\A	N\A
4-5 AM	17.5%	13.0%	N\A	N\A	N\A	27.3%	N\A	514	2	0	0	0	1	0	50%	N\A	N\A	N\A	100%	N\A
5-6 AM	15.4%	11.7%	9.5%	18.2%	55.6%	N\A	37.0%	855	8	15	3	1	0	1	50%	100%	100%	100%	N\A	100%
6-7 AM	19.2%	19.8%	11.4%	11.3%	13.3%	12.4%	25.0%	1388	313	334	88	22	20	8	40%	98%	100%	100%	100%	100%
7-8 AM	16.6%	16.4%	14.6%	20.0%	22.8%	29.8%	37.9%	607	817	818	219	76	16	8	56%	95%	100%	100%	100%	100%
8-9 AM	16.0%	17.9%	15.2%	17.1%	22.1%	32.5%	39.7%	591	1003	778	135	32	8	4	51%	94%	100%	100%	100%	100%
9-10 AM	20.5%	18.5%	16.4%	19.5%	26.6%	30.8%	32.6%	1152	524	487	143	72	36	17	51%	96%	100%	100%	100%	100%
10-11 AM	24.3%	22.7%	23.0%	29.7%	39.3%	38.1%	43.6%	1360	367	303	106	53	20	10	34%	92%	100%	100%	100%	100%
11-12 AM	25.4%	24.9%	25.2%	31.3%	39.7%	38.6%	41.4%	1423	442	250	69	25	8	5	27%	89%	100%	100%	100%	100%
0-1 PM	27.9%	26.0%	27.8%	35.1%	39.8%	46.6%	47.2%	1363	546	232	54	20	6	2	21%	81%	100%	100%	100%	100%
1-2 PM	27.8%	26.2%	27.6%	34.9%	38.6%	43.7%	42.4%	1374	502	225	58	22	12	2	19%	84%	100%	100%	100%	100%
2-3 PM	29.9%	29.0%	28.9%	38.1%	41.5%	47.0%	45.6%	1385	472	193	58	22	8	2	15%	79%	98%	100%	100%	100%
3-4 PM	30.1%	30.4%	30.6%	36.9%	40.7%	46.8%	55.0%	1382	354	284	57	26	7	6	14%	80%	100%	100%	100%	100%
4-5 PM	32.5%	31.6%	31.5%	38.8%	46.5%	55.4%	46.6%	1420	323	232	68	20	7	1	11%	72%	100%	100%	100%	100%
5-6 PM	36.1%	36.9%	35.7%	43.5%	49.1%	44.3%	53.3%	1353	406	256	58	9	6	3	3%	61%	100%	100%	100%	100%
6-7 PM	33.1%	33.5%	34.0%	39.2%	44.5%	59.7%	52.7%	1435	280	204	52	23	3	2	8%	69%	100%	100%	100%	100%
7-8 PM	35.2%	34.4%	37.2%	38.9%	39.7%	46.9%	49.8%	1330	134	119	39	12	5	1	7%	55%	97%	100%	100%	100%
8-9 PM	31.7%	33.7%	31.2%	33.3%	45.0%	44.5%	N\A	1185	68	55	21	10	5	0	1%	91%	100%	100%	100%	N\A
9-10 PM	27.0%	27.9%	27.7%	37.6%	37.1%	41.4%	39.8%	887	17	21	7	5	1	2	24%	86%	100%	100%	100%	100%
10-11 PM	22.9%	22.4%	21.4%	29.1%	17.7%	N\A	N\A	691	13	8	6	3	0	0	31%	100%	100%	100%	N\A	N\A
11-12 PM	19.6%	26.6%	16.1%	N\A	N\A	N\A	33.1%	560	5	5	0	0	0	1	40%	100%	N\A	N\A	N\A	100%

Table 6: CV based Comparison and Validation Results of Path_S_2 in Weekends



Time of Day	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	17.4%	N\A	9.6%	12.5%	N\A	N\A	N\A	192	0	1	1	0	0	0	N\A	100%	100%	N\A	N\A	N\A
1-2 AM	19.0%	8.5%	N\A	N\A	N\A	N\A	N\A	150	2	0	0	0	0	0	50%	N\A	N\A	N\A	N\A	N\A
2-3 AM	18.9%	N\A	21.5%	N\A	N\A	N\A	N\A	92	0	1	0	0	0	0	N\A	100%	N\A	N\A	N\A	N\A
3-4 AM	23.3%	13.8%	18.3%	N\A	N\A	N\A	N\A	101	1	2	0	0	0	0	0%	100%	N\A	N\A	N\A	N\A
4-5 AM	16.3%	N\A	8.3%	N\A	N\A	2.9%	N\A	98	0	1	0	0	1	0	N\A	100%	N\A	N\A	100%	N\A
5-6 AM	16.8%	N\A	N\A	1.3%	N\A	N\A	N\A	167	0	0	1	0	0	0	N\A	N\A	100%	N\A	N\A	N\A
6-7 AM	15.4%	9.8%	4.5%	3.8%	N\A	N\A	N\A	292	7	4	1	0	0	0	71%	100%	100%	N\A	N\A	N\A
7-8 AM	17.4%	16.3%	16.0%	19.2%	25.7%	17.9%	27.7%	416	14	5	4	7	2	2	29%	100%	100%	100%	100%	100%
8-9 AM	17.7%	13.7%	19.0%	18.7%	19.7%	32.4%	31.5%	471	29	30	12	6	3	5	62%	97%	100%	100%	100%	100%
9-10 AM	22.9%	21.4%	22.2%	27.6%	36.2%	36.5%	45.8%	560	40	29	15	9	8	1	38%	93%	100%	100%	100%	100%
10-11 AM	28.9%	31.9%	32.2%	42.2%	39.6%	35.2%	52.8%	602	91	73	22	10	2	3	11%	73%	95%	100%	100%	100%
11-12 AM	34.0%	35.9%	36.0%	39.1%	46.8%	54.5%	48.8%	571	150	101	23	16	13	6	6%	57%	100%	100%	100%	100%
0-1 PM	36.7%	37.4%	38.1%	46.5%	49.2%	46.8%	56.1%	555	230	70	35	15	3	3	5%	51%	100%	100%	100%	100%
1-2 PM	37.6%	37.2%	38.3%	41.5%	49.5%	55.3%	55.5%	528	249	115	20	11	5	1	5%	50%	100%	100%	100%	100%
2-3 PM	37.2%	37.0%	37.3%	40.1%	42.3%	51.5%	49.7%	526	224	115	37	12	4	3	4%	48%	100%	100%	100%	100%
3-4 PM	37.7%	37.3%	36.7%	42.3%	46.7%	56.5%	53.7%	590	175	99	35	8	3	2	3%	54%	100%	100%	100%	100%
4-5 PM	38.5%	38.8%	37.8%	42.6%	49.9%	54.9%	59.2%	605	157	88	25	5	6	3	3%	39%	96%	100%	100%	100%
5-6 PM	37.8%	38.9%	37.9%	41.8%	49.0%	66.1%	N\A	569	114	85	25	5	1	0	1%	47%	100%	100%	100%	N\A
6-7 PM	37.1%	37.6%	37.9%	41.4%	36.9%	55.4%	53.0%	574	89	76	20	3	2	1	1%	54%	100%	100%	100%	100%
7-8 PM	34.0%	36.0%	34.9%	35.7%	46.0%	N\A	42.5%	549	46	53	17	2	0	1	9%	66%	100%	100%	N\A	100%
8-9 PM	30.3%	32.0%	32.2%	50.4%	41.3%	N\A	42.8%	487	34	27	3	8	0	2	9%	78%	100%	100%	N\A	100%
9-10 PM	27.8%	27.1%	28.4%	36.6%	29.6%	65.9%	37.1%	389	15	10	3	1	1	2	27%	80%	100%	100%	100%	100%
10-11 PM	22.2%	19.8%	21.1%	35.7%	53.4%	N\A	47.8%	314	5	3	2	2	0	1	20%	100%	100%	100%	N\A	100%
11-12 PM	19.7%	N\A	8.0%	N\A	39.7%	38.5%	N\A	248	0	3	0	1	1	0	N\A	100%	N\A	100%	100%	N\A

Table 7: CV based Comparison and Validation Results of Path_S_3 in Weekdays

Time of Day	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	18.9%	20.5%	27.4%	10.5%	N\A	N\A	N\A	270	1	2	1	0	0	0	0%	100%	100%	N\A	N\A	N\A
1-2 AM	26.0%	22.5%	N\A	N\A	N\A	N\A	N\A	195	3	0	0	0	0	0	33%	N\A	N\A	N\A	N\A	N\A
2-3 AM	26.1%	16.7%	35.8%	N\A	N\A	N\A	N\A	164	1	1	0	0	0	0	0%	100%	N\A	N\A	N\A	N\A
3-4 AM	30.1%	46.9%	N\A	N\A	N\A	34.7%	N\A	166	1	0	0	0	1	0	0%	N\A	N\A	N\A	100%	N\A
4-5 AM	16.6%	N\A	10.0%	N\A	N\A	N\A	36.2%	345	0	4	0	0	0	1	N\A	100%	N\A	N\A	N\A	100%
5-6 AM	22.4%	20.2%	11.5%	8.3%	21.1%	N\A	N\A	605	5	3	1	2	0	0	0%	100%	100%	100%	N\A	N\A
6-7 AM	15.2%	8.8%	13.1%	13.7%	19.2%	16.9%	43.3%	1385	133	118	50	22	7	12	80%	98%	100%	100%	100%	100%
7-8 AM	15.9%	14.1%	13.0%	19.7%	27.0%	33.1%	36.6%	1119	349	626	103	31	16	10	66%	99%	100%	100%	100%	100%
8-9 AM	17.4%	15.4%	12.3%	22.2%	31.5%	37.2%	40.6%	1211	333	467	57	46	16	17	55%	99%	100%	100%	100%	100%
9-10 AM	21.2%	17.5%	14.7%	25.8%	34.9%	40.1%	43.9%	1383	196	208	55	37	33	22	54%	97%	100%	100%	100%	100%
10-11 AM	22.9%	18.3%	20.2%	34.1%	37.3%	40.3%	38.6%	1349	143	139	45	38	28	15	52%	95%	100%	100%	100%	100%
11-12 AM	25.1%	20.5%	18.6%	30.6%	39.3%	46.8%	45.4%	1339	97	89	31	29	28	17	43%	94%	100%	100%	100%	100%
0-1 PM	26.7%	22.0%	24.5%	37.1%	42.4%	42.8%	45.9%	1370	140	73	26	30	29	6	32%	92%	100%	100%	100%	100%
1-2 PM	28.1%	25.2%	24.8%	35.4%	45.6%	44.2%	46.3%	1365	142	76	29	18	15	11	28%	88%	100%	100%	100%	100%
2-3 PM	28.3%	24.7%	27.8%	36.2%	42.5%	45.1%	48.0%	1377	127	88	49	38	27	12	31%	83%	100%	100%	100%	100%
3-4 PM	32.5%	30.5%	28.1%	41.0%	46.7%	52.1%	50.2%	1424	139	74	28	34	19	15	18%	85%	96%	100%	100%	100%
4-5 PM	35.6%	32.0%	32.2%	43.5%	50.0%	50.2%	48.7%	1325	98	63	24	22	19	7	12%	89%	100%	100%	100%	100%
5-6 PM	36.7%	35.3%	37.0%	43.4%	52.4%	54.6%	53.0%	1315	124	68	21	22	11	3	5%	54%	100%	100%	100%	100%
6-7 PM	37.4%	35.1%	37.7%	48.2%	49.9%	58.3%	54.0%	1312	117	56	24	23	4	2	4%	64%	100%	100%	100%	100%
7-8 PM	29.5%	28.7%	25.2%	31.6%	40.4%	50.5%	44.4%	1242	59	61	25	26	9	8	14%	92%	100%	100%	100%	100%
8-9 PM	26.4%	24.7%	21.0%	32.3%	37.0%	50.0%	40.3%	1140	40	45	15	7	10	5	15%	93%	100%	100%	100%	100%
9-10 PM	21.3%	20.5%	14.6%	23.8%	42.1%	41.7%	49.7%	1125	37	48	21	9	9	12	51%	98%	100%	100%	100%	100%
10-11 PM	22.7%	19.1%	20.5%	40.1%	39.3%	36.1%	52.3%	819	24	8	2	2	1	4	46%	100%	100%	100%	100%	100%
11-12 PM	20.4%	18.3%	21.9%	19.2%	43.2%	59.2%	53.2%	608	12	2	4	1	1	2	67%	100%	100%	100%	100%	100%

Table 8: CV based Comparison and Validation Results of Path_S_3 in Weekends

Time of Day	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	20.7%	11.1%	16.8%	4.3%	0.0%	0.0%	0.0%	249	6	2	1	0	0	0	50%	100%	100%	N\A	N\A	N\A
1-2 AM	18.6%	14.8%	0.0%	0.0%	0.0%	0.0%	0.0%	152	3	0	0	0	0	0	67%	N\A	N\A	N\A	N\A	N\A
2-3 AM	24.0%	N\A	20.4%	N\A	N\A	N\A	N\A	119	0	1	0	0	0	0	N\A	100%	N\A	N\A	N\A	N\A
3-4 AM	25.0%	N\A	N\A	N\A	N\A	N\A	N\A	95	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
4-5 AM	22.7%	N\A	N\A	N\A	N\A	N\A	N\A	75	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
5-6 AM	21.5%	N\A	N\A	N\A	N\A	N\A	N\A	100	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
6-7 AM	19.2%	13.2%	7.0%	19.5%	N\A	36.0%	N\A	240	6	2	2	0	1	0	33%	100%	100%	N\A	100%	N\A
7-8 AM	20.2%	16.3%	23.4%	15.4%	37.1%	N\A	62.2%	285	3	3	1	2	0	1	67%	100%	100%	100%	N\A	100%
8-9 AM	21.1%	13.7%	17.4%	36.6%	40.9%	33.3%	57.8%	388	7	14	9	7	5	1	86%	93%	100%	100%	100%	100%
9-10 AM	27.5%	32.0%	27.1%	33.9%	45.1%	33.7%	50.7%	407	10	8	6	5	3	3	10%	88%	100%	100%	100%	100%
10-11 AM	28.8%	29.4%	34.8%	44.3%	47.4%	46.2%	52.2%	481	19	14	6	5	3	4	16%	50%	100%	100%	100%	100%
11-12 AM	34.7%	33.2%	33.9%	40.7%	50.7%	49.8%	46.8%	491	32	26	16	3	7	7	16%	65%	100%	100%	100%	100%
0-1 PM	37.9%	36.5%	34.0%	46.3%	49.6%	51.2%	30.2%	529	44	27	16	10	7	1	9%	52%	94%	100%	100%	100%
1-2 PM	39.8%	36.8%	39.1%	49.1%	51.9%	45.9%	52.4%	525	58	18	18	12	2	2	7%	67%	100%	100%	100%	100%
2-3 PM	42.5%	41.1%	38.1%	45.6%	52.1%	62.3%	56.8%	518	56	31	17	11	2	1	4%	52%	100%	100%	100%	100%
3-4 PM	41.4%	40.6%	39.8%	47.0%	57.0%	54.7%	N\A	537	49	43	11	9	7	0	2%	63%	100%	100%	100%	N\A
4-5 PM	41.3%	40.1%	36.9%	46.8%	53.0%	50.9%	53.0%	493	53	26	15	18	3	5	6%	65%	100%	100%	100%	100%
5-6 PM	37.6%	39.1%	34.0%	47.0%	44.9%	58.9%	56.5%	551	44	31	12	7	4	2	2%	61%	100%	100%	100%	100%
6-7 PM	34.9%	34.6%	35.7%	44.5%	50.7%	47.8%	42.7%	547	34	25	16	7	3	1	3%	68%	100%	100%	100%	100%
7-8 PM	31.0%	33.2%	35.1%	36.3%	47.2%	48.7%	37.8%	516	24	34	10	4	4	4	4%	68%	90%	100%	100%	100%
8-9 PM	26.3%	25.3%	19.3%	46.4%	47.4%	44.6%	41.5%	472	19	17	9	2	5	5	32%	94%	78%	100%	100%	100%
9-10 PM	21.6%	21.4%	22.9%	27.3%	20.1%	42.2%	46.6%	411	12	21	9	3	3	6	33%	86%	100%	100%	100%	100%
10-11 PM	20.8%	26.0%	29.4%	27.9%	31.9%	N\A	6.7%	336	12	5	3	1	0	1	8%	80%	100%	100%	N\A	100%
11-12 PM	19.6%	13.4%	28.6%	29.0%	32.5%	N\A	N\A	282	7	2	1	1	0	0	57%	100%	100%	100%	N\A	N\A

Table 9: CV based Comparison and Validation Results of Path_N_1 in Weekdays

	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
Time of Day	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	22.4%	21.9%	18.0%	25.0%	N\A	N\A	N\A	332	5	1	1	0	0	0	60%	100%	100%	N\A	N\A	N\A
1-2 AM	28.4%	N\A	47.1%	N\A	N\A	N\A	N\A	203	0	1	0	0	0	0	N\A	0%	N\A	N\A	N\A	N\A
2-3 AM	28.0%	10.3%	N\A	N\A	N\A	N\A	N\A	127	1	0	0	0	0	0	0%	N\A	N\A	N\A	N\A	N\A
3-4 AM	33.3%	N\A	N\A	18.1%	N\A	N\A	N\A	136	0	0	1	0	0	0	N\A	N\A	100%	N\A	N\A	N\A
4-5 AM	21.2%	23.9%	5.7%	N\A	N\A	N\A	N\A	281	2	1	0	0	0	0	0%	100%	N\A	N\A	N\A	N\A
5-6 AM	18.8%	20.5%	18.1%	23.7%	N\A	N\A	31.7%	676	2	3	2	0	0	2	50%	100%	100%	N\A	N\A	100%
6-7 AM	22.1%	19.7%	22.0%	24.6%	36.1%	N\A	42.9%	753	6	8	1	1	0	1	50%	88%	100%	100%	N\A	100%
7-8 AM	28.1%	23.7%	24.4%	34.7%	38.2%	50.3%	46.0%	1015	33	26	20	18	8	4	27%	92%	100%	100%	100%	100%
8-9 AM	28.3%	23.8%	26.3%	41.2%	40.3%	45.5%	48.3%	1318	83	48	21	14	17	6	28%	90%	100%	100%	100%	100%
9-10 AM	27.3%	22.3%	24.5%	33.8%	39.0%	43.0%	43.1%	1332	104	66	29	18	19	10	39%	91%	100%	100%	100%	100%
10-11 AM	25.4%	21.6%	22.8%	32.7%	38.5%	43.6%	46.9%	1297	117	79	40	21	22	23	36%	90%	100%	100%	100%	100%
11-12 AM	27.3%	26.1%	26.0%	35.5%	39.5%	47.2%	45.8%	1330	136	98	31	18	22	8	23%	92%	100%	100%	100%	100%
0-1 PM	30.3%	27.4%	29.7%	37.2%	41.3%	48.5%	42.4%	1321	159	112	47	20	16	2	20%	77%	96%	100%	100%	100%
1-2 PM	29.6%	29.2%	29.0%	38.6%	43.9%	48.1%	45.4%	1318	156	98	33	24	11	5	17%	78%	97%	100%	100%	100%
2-3 PM	30.2%	27.9%	27.8%	36.7%	44.1%	45.9%	45.9%	1370	126	93	41	29	28	14	25%	85%	100%	100%	100%	100%
3-4 PM	24.3%	19.6%	18.2%	28.0%	35.6%	43.6%	43.5%	1411	144	139	55	38	29	37	45%	95%	100%	100%	100%	100%
4-5 PM	21.5%	19.8%	15.1%	27.0%	29.7%	42.5%	45.4%	1340	224	160	44	22	30	31	44%	99%	98%	100%	100%	100%
5-6 PM	23.9%	22.2%	22.2%	33.0%	38.5%	46.6%	46.1%	1347	272	131	32	30	9	19	36%	89%	97%	100%	100%	100%
6-7 PM	24.6%	24.7%	20.1%	31.3%	37.5%	39.8%	44.1%	1357	255	180	60	31	21	41	34%	92%	98%	100%	100%	100%
7-8 PM	33.4%	31.5%	33.2%	37.4%	43.9%	52.6%	52.4%	1278	103	82	23	20	14	10	10%	71%	100%	100%	100%	100%
8-9 PM	28.9%	26.5%	26.4%	31.2%	44.9%	41.1%	44.6%	1099	42	40	12	7	11	7	19%	85%	100%	100%	100%	100%
9-10 PM	23.3%	25.4%	20.1%	24.1%	34.9%	43.8%	36.8%	959	20	21	15	6	4	3	25%	100%	100%	100%	100%	100%
10-11 PM	18.4%	9.7%	10.6%	16.8%	26.7%	19.7%	39.4%	884	26	26	14	4	5	5	65%	100%	100%	100%	100%	100%
11-12 PM	20.0%	13.6%	5.8%	5.2%	15.6%	27.8%	32.3%	649	14	5	1	2	2	3	50%	100%	100%	100%	100%	100%

Table 10: CV based Comparison and Validation Results of Path_N_1 in Weekends

Time of Day	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	19.8%	15.3%	9.2%	26.0%	N\A	36.3%	46.3%	252	7	3	2	0	1	1	71%	100%	100%	N\A	100%	100%
1-2 AM	23.0%	17.5%	19.5%	N\A	N\A	N\A	N\A	157	4	1	0	0	0	0	50%	100%	N\A	N\A	N\A	N\A
2-3 AM	29.6%	26.4%	N\A	N\A	N\A	N\A	N\A	137	3	0	0	0	0	0	0%	N\A	N\A	N\A	N\A	N\A
3-4 AM	27.4%	10.3%	N\A	N\A	N\A	N\A	N\A	91	2	0	0	0	0	0	100%	N\A	N\A	N\A	N\A	N\A
4-5 AM	21.4%	5.7%	N\A	N\A	N\A	N\A	N\A	64	1	0	0	0	0	0	100%	N\A	N\A	N\A	N\A	N\A
5-6 AM	22.0%	N\A	N\A	N\A	N\A	N\A	N\A	77	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
6-7 AM	22.1%	8.0%	8.3%	N\A	N\A	N\A	N\A	135	2	1	0	0	0	0	50%	100%	N\A	N\A	N\A	N\A
7-8 AM	18.6%	5.9%	6.9%	21.6%	54.1%	20.2%	41.2%	245	6	1	2	1	1	1	67%	100%	100%	100%	100%	100%
8-9 AM	16.7%	12.0%	7.8%	13.4%	34.7%	24.7%	37.0%	390	6	13	3	1	1	1	83%	100%	100%	100%	100%	100%
9-10 AM	19.9%	13.3%	10.8%	13.7%	39.3%	38.8%	41.1%	409	19	17	11	5	6	3	84%	100%	100%	100%	100%	100%
10-11 AM	27.3%	27.3%	24.3%	32.7%	40.5%	48.8%	51.5%	516	38	27	16	11	6	2	29%	89%	100%	100%	100%	100%
11-12 AM	32.8%	35.1%	32.1%	42.5%	41.1%	59.4%	54.0%	539	55	29	10	8	4	3	9%	79%	100%	100%	100%	100%
0-1 PM	38.6%	37.8%	37.9%	47.9%	49.1%	53.5%	46.2%	574	54	45	10	5	5	2	2%	56%	100%	100%	100%	100%
1-2 PM	40.2%	38.3%	39.0%	46.0%	54.2%	55.3%	57.2%	563	66	30	23	6	3	1	5%	53%	100%	100%	100%	100%
2-3 PM	39.2%	39.0%	40.1%	48.5%	57.7%	49.2%	58.3%	533	60	40	13	2	1	1	5%	58%	92%	100%	100%	100%
3-4 PM	40.5%	40.1%	38.8%	49.9%	53.3%	51.9%	54.0%	536	46	33	12	4	9	5	2%	58%	100%	100%	100%	100%
4-5 PM	40.1%	38.8%	36.3%	48.7%	52.7%	47.9%	56.2%	535	61	40	16	13	4	1	3%	55%	94%	100%	100%	100%
5-6 PM	37.4%	35.7%	38.0%	46.6%	47.5%	53.8%	N\A	507	42	39	16	10	5	0	0%	77%	100%	100%	100%	N\A
6-7 PM	33.9%	32.5%	34.4%	40.3%	40.7%	48.3%	56.2%	530	32	34	10	5	2	2	0%	59%	100%	100%	100%	100%
7-8 PM	30.5%	28.2%	30.6%	39.0%	47.0%	44.3%	25.7%	462	32	19	9	4	5	2	9%	84%	100%	100%	100%	100%
8-9 PM	25.0%	21.7%	28.7%	34.8%	44.4%	33.0%	56.3%	417	21	13	3	1	3	1	43%	77%	100%	100%	100%	100%
9-10 PM	21.9%	20.4%	19.2%	40.9%	N\A	39.5%	46.1%	343	9	5	4	0	2	1	56%	100%	100%	N\A	100%	100%
10-11 PM	18.8%	9.9%	8.5%	15.6%	29.3%	60.2%	N\A	341	7	8	4	1	2	0	100%	100%	100%	100%	100%	N\A
11-12 PM	18.5%	19.2%	5.6%	16.4%	11.6%	N\A	27.4%	295	5	6	2	1	0	1	60%	100%	100%	100%	N\A	100%

Table 11: CV based Comparison and Validation Results of Path_N_2 in Weekdays

Time of Day	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	17.7%	10.9%	8.9%	N/A	N/A	N/A	N/A	566	6	10	0	0	0	0	100%	100%	N\A	N\A	N\A	N\A
1-2 AM	20.0%	0.1%	N/A	29.1%	N/A	N/A	N/A	257	1	0	1	0	0	0	100%	N\A	100%	N\A	N\A	N\A
2-3 AM	21.9%	N/A	1.5%	N/A	N/A	N/A	N/A	177	0	1	0	0	0	0	N\A	100%	N\A	N\A	N\A	N\A
3-4 AM	22.3%	N/A	N/A	10.4%	N/A	N/A	N/A	251	0	0	3	0	0	0	N\A	N\A	100%	N\A	N\A	N\A
4-5 AM	20.7%	N/A	N/A	N/A	N/A	N/A	N/A	272	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
5-6 AM	17.7%	21.8%	3.8%	10.6%	N/A	N/A	45.4%	555	1	5	4	0	0	1	0%	100%	100%	N\A	N\A	100%
6-7 AM	14.0%	9.1%	8.5%	13.0%	N/A	37.3%	N/A	802	8	5	3	0	1	0	75%	100%	100%	N\A	100%	N\A
7-8 AM	14.0%	10.7%	12.9%	16.3%	30.7%	48.4%	34.2%	1153	56	31	5	2	2	3	73%	100%	100%	100%	100%	100%
8-9 AM	15.1%	9.0%	13.0%	19.7%	22.0%	39.1%	43.9%	1380	115	95	29	6	6	9	82%	100%	100%	100%	100%	100%
9-10 AM	17.2%	13.4%	13.3%	18.1%	24.0%	26.7%	33.8%	1418	135	113	48	19	8	13	65%	100%	100%	100%	100%	100%
10-11 AM	17.9%	15.0%	14.4%	21.5%	32.3%	35.5%	41.7%	1451	196	150	57	26	28	25	53%	100%	98%	100%	100%	100%
11-12 AM	17.6%	14.7%	14.5%	18.8%	31.4%	35.6%	45.8%	1448	308	173	50	35	29	39	54%	99%	100%	100%	100%	100%
0-1 PM	18.1%	13.8%	16.5%	25.3%	31.4%	41.4%	42.9%	1409	400	196	64	41	20	28	56%	98%	100%	100%	100%	100%
1-2 PM	18.0%	14.2%	17.3%	26.8%	32.4%	38.1%	43.0%	1308	466	272	77	51	31	25	60%	96%	100%	100%	100%	100%
2-3 PM	17.9%	15.2%	18.3%	24.7%	30.3%	39.8%	43.4%	1274	544	263	69	56	36	44	54%	97%	100%	100%	100%	100%
3-4 PM	18.7%	15.4%	13.2%	17.3%	26.5%	29.9%	40.0%	1151	336	437	160	77	64	82	57%	99%	100%	100%	100%	100%
4-5 PM	21.7%	20.9%	16.3%	22.8%	29.7%	35.4%	41.0%	969	518	546	158	79	50	57	38%	95%	99%	100%	100%	100%
5-6 PM	33.3%	34.2%	31.7%	39.6%	38.2%	45.0%	45.2%	950	755	429	159	69	20	27	11%	66%	97%	100%	100%	100%
6-7 PM	31.2%	34.7%	29.8%	33.2%	41.2%	44.4%	46.3%	1035	541	425	150	78	46	43	12%	65%	99%	100%	100%	100%
7-8 PM	27.4%	26.4%	26.5%	33.4%	39.1%	47.3%	46.6%	1371	311	215	82	48	27	29	17%	88%	100%	100%	100%	100%
8-9 PM	24.6%	23.0%	21.3%	26.6%	37.9%	44.2%	47.3%	1336	194	148	83	34	22	17	23%	95%	100%	100%	100%	100%
9-10 PM	22.6%	23.8%	17.5%	19.2%	34.1%	40.2%	38.7%	1342	113	76	69	24	10	13	26%	99%	100%	100%	100%	100%
10-11 PM	18.3%	15.1%	13.4%	16.7%	29.2%	25.1%	30.7%	1204	58	60	29	16	8	4	47%	98%	100%	100%	100%	100%
11-12 PM	16.5%	10.5%	12.7%	15.5%	24.7%	32.5%	12.1%	940	14	25	12	3	3	1	57%	100%	100%	100%	100%	100%

Table 12: CV based Comparison and Validation Results of Path_N_2 in Weekends

Time of Day	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	15.3%	19.9%	7.8%	0.3%	N/A	N/A	N/A	360	11	12	1	0	0	0	36%	100%	100%	N\A	N\A	N\A
1-2 AM	16.8%	15.9%	9.6%	30.5%	N/A	N/A	N/A	191	2	1	1	0	0	0	50%	100%	100%	N\A	N\A	N\A
2-3 AM	21.3%	N/A	N/A	N/A	N/A	N/A	N/A	148	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
3-4 AM	19.4%	10.2%	N/A	N/A	N/A	N/A	N/A	109	1	0	0	0	0	0	0%	N\A	N\A	N\A	N\A	N\A
4-5 AM	20.1%	N/A	N/A	N/A	N/A	N/A	N/A	96	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
5-6 AM	16.8%	N/A	N/A	N/A	N/A	N/A	N/A	98	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
6-7 AM	20.1%	N/A	N/A	N/A	N/A	N/A	N/A	121	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
7-8 AM	17.9%	12.6%	3.7%	24.0%	N/A	53.5%	N/A	292	1	3	2	0	1	0	100%	100%	100%	N\A	100%	N\A
8-9 AM	16.7%	12.9%	11.8%	22.1%	22.9%	N/A	51.7%	367	14	15	4	3	0	1	50%	100%	100%	100%	N\A	100%
9-10 AM	19.8%	17.4%	14.5%	23.7%	16.2%	54.8%	45.2%	484	14	23	9	1	1	7	50%	96%	100%	100%	100%	100%
10-11 AM	21.6%	22.0%	18.6%	24.1%	39.2%	41.2%	48.7%	542	66	43	20	12	4	6	32%	100%	100%	100%	100%	100%
11-12 AM	25.1%	24.4%	26.3%	33.6%	37.7%	46.0%	53.6%	577	98	49	18	10	5	6	15%	90%	100%	100%	100%	100%
0-1 PM	26.2%	25.7%	27.2%	29.3%	42.1%	46.3%	50.5%	607	118	91	27	16	5	10	20%	85%	96%	100%	100%	100%
1-2 PM	28.7%	25.5%	29.4%	37.7%	40.4%	51.8%	49.5%	590	150	75	26	9	7	15	17%	85%	96%	100%	100%	100%
2-3 PM	26.8%	25.2%	28.4%	33.9%	39.8%	44.4%	47.4%	542	181	92	28	21	7	12	16%	88%	100%	100%	100%	100%
3-4 PM	28.2%	25.2%	27.6%	35.8%	44.5%	48.0%	53.5%	561	176	92	27	22	18	22	15%	84%	100%	100%	100%	100%
4-5 PM	29.7%	27.2%	27.8%	31.1%	38.1%	52.2%	54.7%	559	148	110	36	20	12	23	15%	82%	100%	100%	100%	100%
5-6 PM	28.7%	26.5%	28.1%	35.6%	41.1%	46.9%	53.2%	569	141	81	24	14	11	20	13%	80%	100%	100%	100%	100%
6-7 PM	28.2%	26.6%	27.6%	28.6%	40.1%	41.3%	49.0%	573	115	66	39	16	8	11	15%	85%	100%	100%	100%	100%
7-8 PM	26.3%	25.4%	25.2%	23.6%	39.9%	57.3%	49.9%	567	84	49	25	11	3	9	17%	94%	100%	100%	100%	100%
8-9 PM	23.6%	25.7%	19.1%	19.5%	34.2%	33.4%	39.5%	562	42	48	27	11	6	3	12%	100%	100%	100%	100%	100%
9-10 PM	21.6%	24.0%	21.0%	20.3%	28.4%	38.2%	25.2%	555	27	35	10	3	1	1	19%	97%	100%	100%	100%	100%
10-11 PM	17.2%	7.6%	11.1%	12.1%	34.0%	44.0%	37.1%	458	7	21	6	4	2	1	86%	95%	100%	100%	100%	100%
11-12 PM	16.1%	15.2%	7.9%	20.3%	0.0%	23.0%	45.0%	375	7	6	4	0	2	1	71%	100%	100%	N\A	100%	100%

Table 13: CV based Comparison and Validation Results of Path_N_3 in Weekdays

Time of Day	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	19.3%	0.5%	12.8%	25.6%	N\A	32.6%	N\A	208	1	2	1	0	1	0	100%	100%	100%	N\A	100%	N\A
1-2 AM	17.1%	N\A	N\A	N\A	N\A	N\A	N\A	152	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
2-3 AM	14.1%	3.4%	N\A	N\A	N\A	N\A	N\A	70	2	0	0	0	0	0	50%	N\A	N\A	N\A	N\A	N\A
3-4 AM	15.6%	N\A	N\A	N\A	N\A	N\A	N\A	46	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
4-5 AM	28.4%	N\A	N\A	N\A	N\A	N\A	N\A	72	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
5-6 AM	20.7%	15.4%	N\A	21.0%	N\A	33.7%	N\A	190	5	0	1	0	1	0	80%	N\A	100%	N\A	100%	N\A
6-7 AM	24.9%	44.7%	1.3%	67.8%	53.6%	47.6%	33.2%	349	5	1	1	5	2	4	20%	100%	100%	100%	100%	100%
7-8 AM	24.0%	16.9%	20.5%	20.3%	35.2%	46.0%	38.4%	457	12	8	1	2	2	1	50%	100%	100%	100%	100%	100%
8-9 AM	23.6%	26.3%	14.7%	34.6%	40.3%	6.9%	37.6%	514	17	10	4	8	1	3	29%	100%	100%	100%	100%	100%
9-10 AM	22.0%	15.3%	19.4%	40.2%	38.3%	42.1%	41.0%	648	36	30	9	22	8	4	58%	97%	100%	100%	100%	100%
10-11 AM	17.5%	12.4%	12.7%	27.9%	38.5%	43.4%	42.8%	606	68	40	10	9	12	11	66%	98%	100%	100%	100%	100%
11-12 AM	18.0%	11.8%	14.3%	24.8%	37.9%	37.2%	38.4%	670	65	41	13	21	13	22	83%	98%	100%	100%	100%	100%
0-1 PM	19.5%	10.8%	14.3%	26.9%	33.0%	37.5%	34.9%	694	77	63	19	31	19	7	58%	98%	100%	100%	100%	100%
1-2 PM	20.1%	14.5%	14.9%	26.2%	35.0%	36.5%	43.5%	688	86	68	24	23	26	10	62%	99%	100%	100%	100%	100%
2-3 PM	19.8%	14.4%	12.2%	24.6%	34.5%	38.5%	39.6%	646	86	83	22	23	42	29	70%	99%	100%	100%	100%	100%
3-4 PM	18.1%	13.0%	11.8%	22.9%	34.9%	32.8%	40.3%	655	103	106	30	38	35	40	67%	100%	100%	100%	100%	100%
4-5 PM	20.1%	17.5%	15.3%	22.6%	36.4%	37.1%	40.6%	632	145	138	36	36	39	30	48%	97%	100%	100%	100%	100%
5-6 PM	29.9%	31.6%	28.7%	33.9%	39.3%	48.4%	47.0%	587	243	143	35	31	16	4	14%	78%	100%	100%	100%	100%
6-7 PM	24.9%	23.4%	22.9%	32.8%	38.5%	40.1%	41.8%	551	172	192	63	48	28	22	37%	86%	100%	100%	100%	100%
7-8 PM	20.6%	17.7%	22.0%	33.4%	38.2%	50.7%	43.9%	661	131	58	17	14	7	9	50%	100%	100%	100%	100%	100%
8-9 PM	19.1%	18.2%	23.6%	21.4%	33.8%	N\A	46.8%	623	79	43	4	2	0	6	39%	95%	100%	100%	N\A	100%
9-10 PM	22.3%	21.8%	22.3%	23.7%	38.8%	41.2%	47.1%	646	60	21	2	4	2	2	35%	100%	100%	100%	100%	100%
10-11 PM	22.4%	22.6%	26.5%	30.9%	38.0%	51.2%	33.2%	446	17	10	8	4	1	2	29%	100%	100%	100%	100%	100%
11-12 PM	20.4%	18.4%	8.5%	33.9%	28.5%	27.8%	N\A	372	8	3	2	1	2	0	50%	100%	100%	100%	100%	N\A

Table 14: CV based Comparison and Validation Results of Path_N_3 in Weekends

Time of Day	Mean Absolute Percentage Difference (MAPD)							Amount of Verification Intervals							Acceptance Ratio (t-test)					
	obs=1 or 2	CV Caterogry						obs=1 or 2	CV Caterogry						CV Caterogry					
		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+		0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5+
0-1 AM	17.3%	8.4%	N\A	17.8%	N\A	26.7%	N\A	154	4	0	1	0	1	0	75%	N\A	100%	N\A	100%	N\A
1-2 AM	14.1%	N\A	N\A	N\A	N\A	N\A	N\A	98	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
2-3 AM	13.1%	N\A	10.6%	N\A	N\A	N\A	N\A	38	0	1	0	0	0	0	N\A	100%	N\A	N\A	N\A	N\A
3-4 AM	17.1%	3.0%	N\A	N\A	N\A	N\A	N\A	29	2	0	0	0	0	0	100%	N\A	N\A	N\A	N\A	N\A
4-5 AM	19.6%	N\A	24.0%	N\A	N\A	N\A	N\A	46	0	1	0	0	0	0	N\A	100%	N\A	N\A	N\A	N\A
5-6 AM	14.5%	N\A	N\A	N\A	N\A	23.2%	N\A	59	0	0	0	0	1	0	N\A	N\A	N\A	N\A	100%	N\A
6-7 AM	16.5%	N\A	N\A	N\A	N\A	N\A	N\A	56	0	0	0	0	0	0	N\A	N\A	N\A	N\A	N\A	N\A
7-8 AM	16.7%	8.5%	10.4%	N\A	N\A	N\A	N\A	138	4	1	0	0	0	0	75%	100%	N\A	N\A	N\A	N\A
8-9 AM	21.2%	9.4%	21.7%	21.9%	42.9%	N\A	22.2%	158	6	5	4	3	0	1	83%	100%	100%	100%	N\A	100%
9-10 AM	21.0%	18.7%	21.0%	27.4%	41.3%	15.5%	40.9%	220	9	13	3	4	1	1	56%	100%	100%	100%	100%	100%
10-11 AM	19.3%	18.9%	18.0%	24.5%	38.6%	44.2%	39.9%	252	36	16	4	8	5	3	47%	100%	100%	100%	100%	100%
11-12 AM	19.4%	13.9%	18.2%	23.1%	42.5%	41.0%	47.6%	267	32	27	3	2	6	4	63%	100%	100%	100%	100%	100%
0-1 PM	19.7%	14.1%	22.1%	21.2%	44.5%	44.9%	41.1%	265	52	42	4	4	2	4	60%	93%	100%	100%	100%	100%
1-2 PM	18.7%	14.0%	18.8%	29.7%	30.7%	46.9%	48.5%	266	74	33	8	2	2	1	49%	100%	100%	100%	100%	100%
2-3 PM	17.7%	17.0%	21.1%	22.7%	48.2%	37.2%	38.1%	249	68	41	8	1	3	3	51%	95%	100%	100%	100%	100%
3-4 PM	18.1%	17.4%	22.0%	32.1%	43.0%	43.4%	46.4%	267	64	33	7	7	2	2	42%	94%	100%	100%	100%	100%
4-5 PM	16.6%	13.5%	19.8%	29.3%	35.3%	31.1%	50.8%	275	53	31	12	3	2	3	60%	97%	100%	100%	100%	100%
5-6 PM	16.2%	14.2%	17.3%	32.3%	34.2%	52.7%	40.9%	268	45	30	4	3	2	4	62%	100%	100%	100%	100%	100%
6-7 PM	20.8%	17.7%	20.8%	29.2%	39.3%	42.4%	N\A	291	38	17	4	2	2	0	50%	100%	100%	100%	100%	N\A
7-8 PM	21.1%	19.1%	19.8%	36.7%	45.1%	60.5%	47.3%	248	45	10	2	6	1	3	38%	90%	100%	100%	100%	100%
8-9 PM	22.1%	19.8%	16.3%	N\A	34.5%	41.5%	48.7%	218	26	5	0	2	3	2	31%	100%	N\A	100%	100%	100%
9-10 PM	23.8%	23.0%	35.2%	N\A	N\A	44.5%	53.1%	221	29	4	0	0	1	2	14%	75%	N\A	N\A	100%	100%
10-11 PM	22.4%	20.4%	24.7%	28.8%	55.1%	N\A	N\A	198	8	6	2	1	0	0	25%	100%	100%	100%	N\A	N\A
11-12 PM	19.8%	21.2%	17.9%	26.4%	N\A	28.7%	N\A	180	3	5	1	0	1	0	33%	100%	100%	N\A	100%	N\A

5.3. Data Fusion Results

In this subsection, the proposed data fusion model was applied to the above six arterial segments using INRIX and BT datasets of year 2012. The confidence band used to distinguish the “R-R&NC” and “R-R&C” contexts in equation (12) is set to be 95%. The reported path travel time confidence score of INRIX ranges from 20 to 30. The score threshold to judge the reliability of INRIX data was arbitrarily chosen in this model. Figures 10 through15 plot the percentage of each fusion context among the overall fusion points under different settings of this reliability threshold for each of the six segments. The most ideal fusion context is “R-R&C”, where both INRIX and BT data are reliable and these two reported data are agreed with each other (i.e. INRIX data dropped within the 95% CI band of BT samples). For example, if the INRIX data reliability threshold is set as 24 at Path_S_1, 10.4 percent of the fused data belonging to “R-R & C” context and 5.8 percent of the fused data belonging to “R-R & NC” context. In addition, 28.6 percent of data belonging to “NR-NR” context, which indicates both INRIX and Bluetooth data are unreliable. However, these corresponding values are different in terms of Path_N_2 with α =24, where percentages of “R-R & C”, “R-R & NC” and “NR-NR” are 17.6%, 5.9% and 28.4%, respectively. Moreover, with the increase of reliability threshold chosen for INRIX data, the number of “NR-NR” and “NR-R” fusion points increase linearly and the number of “R-NR”, “R-R and NC” and “R-R and C” fusion points decrease linearly. Since the dataset is too big (i.e. entire year 2012 with 5-minute resolution), only parts of the fusion time series of Path_N_2 are shown in Figures 16 and 17 to demonstrate the output format of the fusion model. The numerical results from the fusion model reveal the following key conclusions.

- Regardless of the specific settings of the reliability threshold of INRIX data, the ratio of “R-R & C” fusion points and “R-R & NC” fusion points remains approximately unchanged for any specific segment. For Path_S_1, Path_S_2, Path_S_3, Path_N_1, Path_N_2 and Path_N_3, the corresponding “R-R & C” and “R-R & NC” ratios are approximately, 1.8, 1.3, 2.6, 2.2, 3.1, and 4.3, respectively. The larger this ratio is, the more statistically in agreement INRIX and BT data is.
- The fusion model performs in a conservative way when combining the data from these two independent data sources. The first-level fusion operator is able to statistically reject extreme data points by considering both the data reliability and agreement.

- By applying the second-level fusion operator, the horizontal disturbance can be improved.

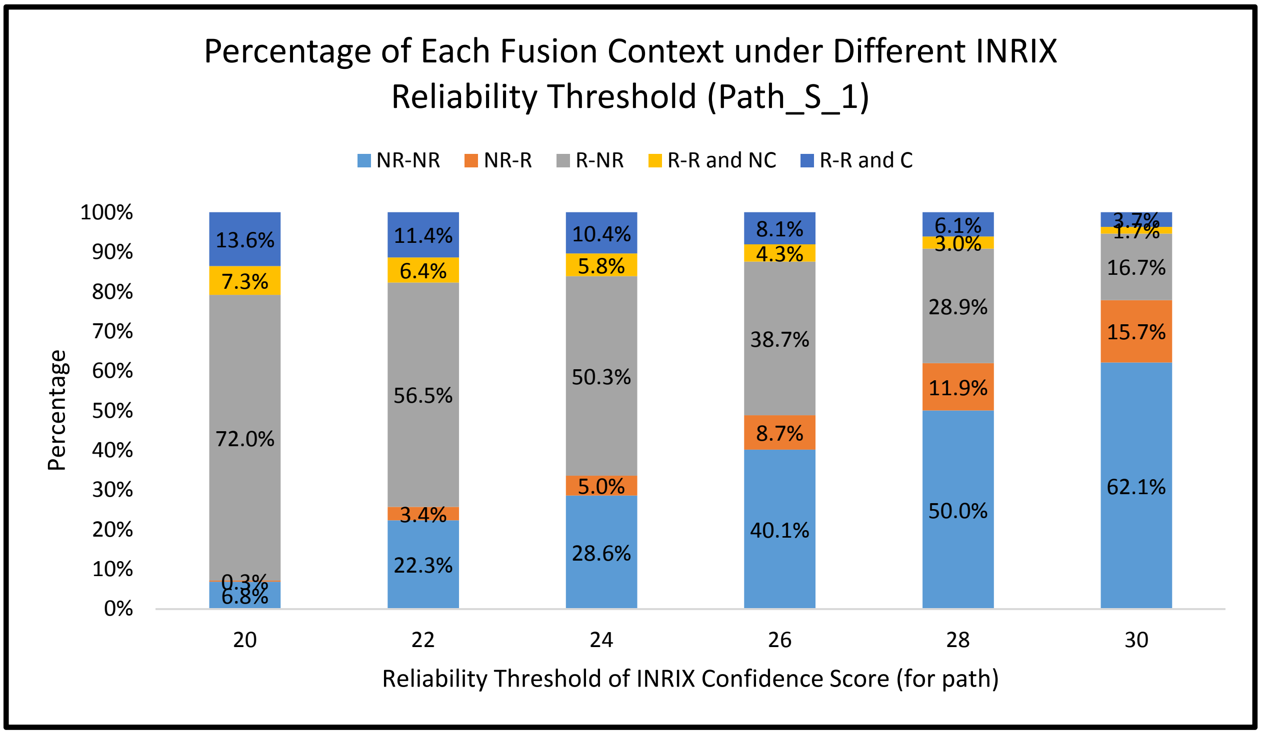


Figure 10: Percentage of Each Fusion Context under Different INRIX Data Reliability Threshold α (Path_S_1)

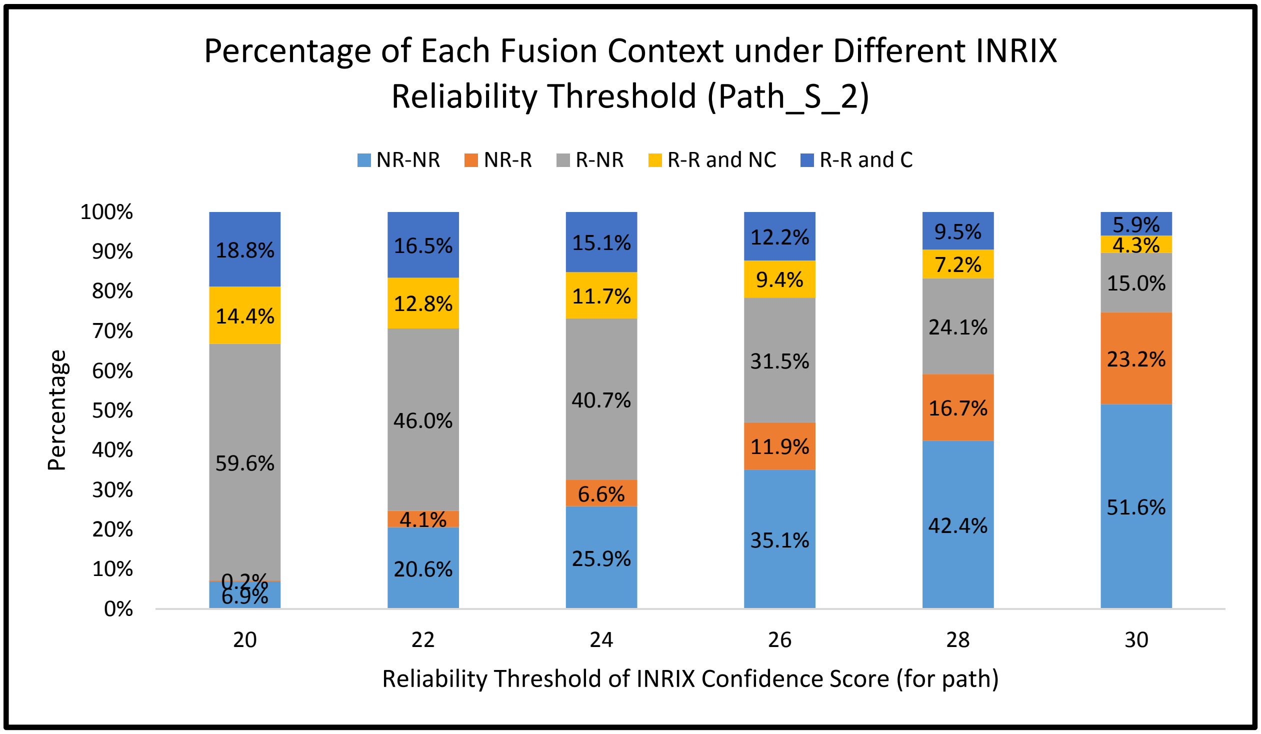


Figure 11: Percentage of Each Fusion Context under Different INRIX Data Reliability Threshold α (Path_S_2)

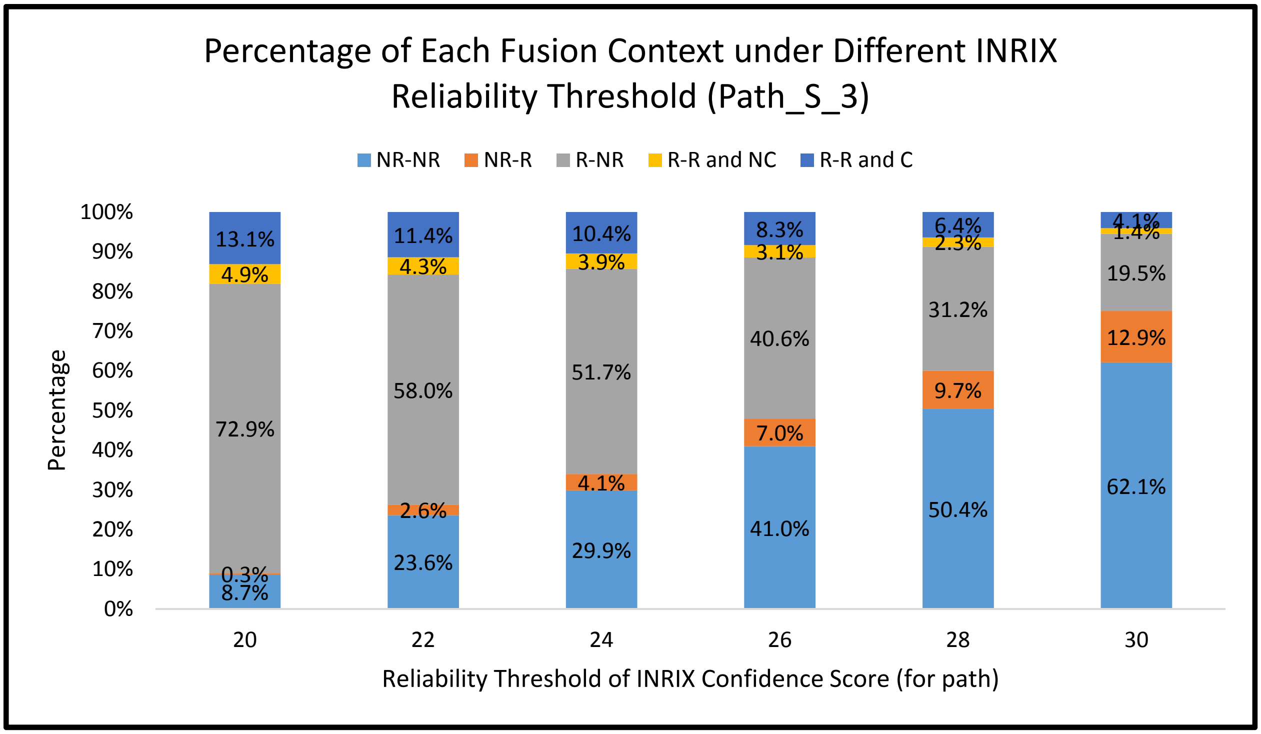


Figure 12: Percentage of Each Fusion Context under Different INRIX Data Reliability Threshold α (Path_S_3)

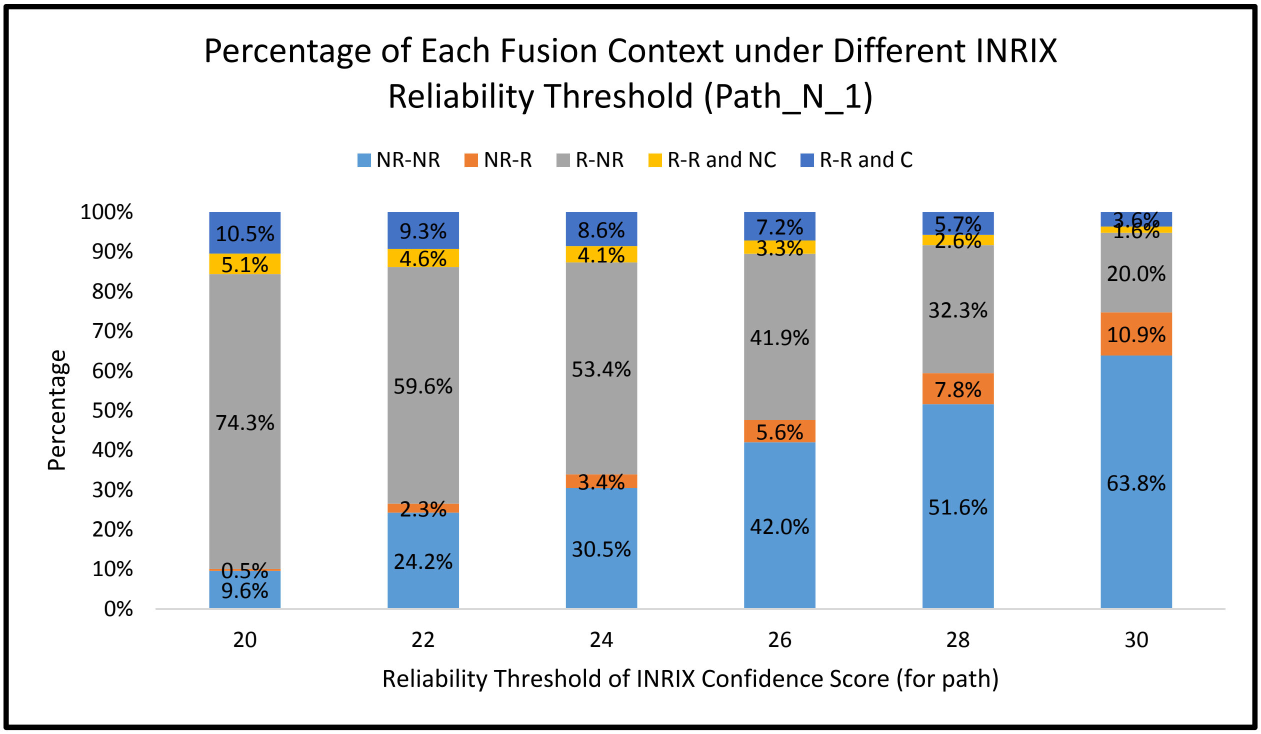


Figure 13: Percentage of Each Fusion Context under Different INRIX Data Reliability Threshold α (Path_N_1)

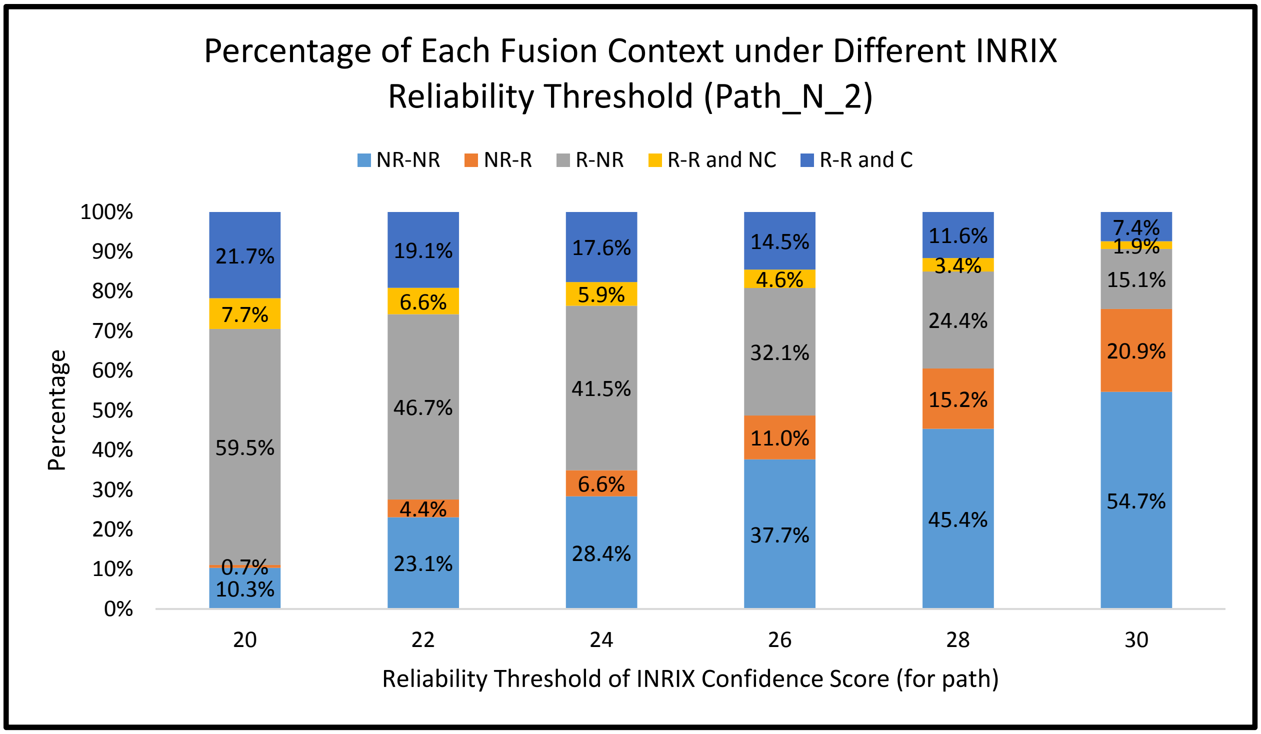


Figure 14: Percentage of Each Fusion Context under Different INRIX Data Reliability Threshold α (Path_N_2)

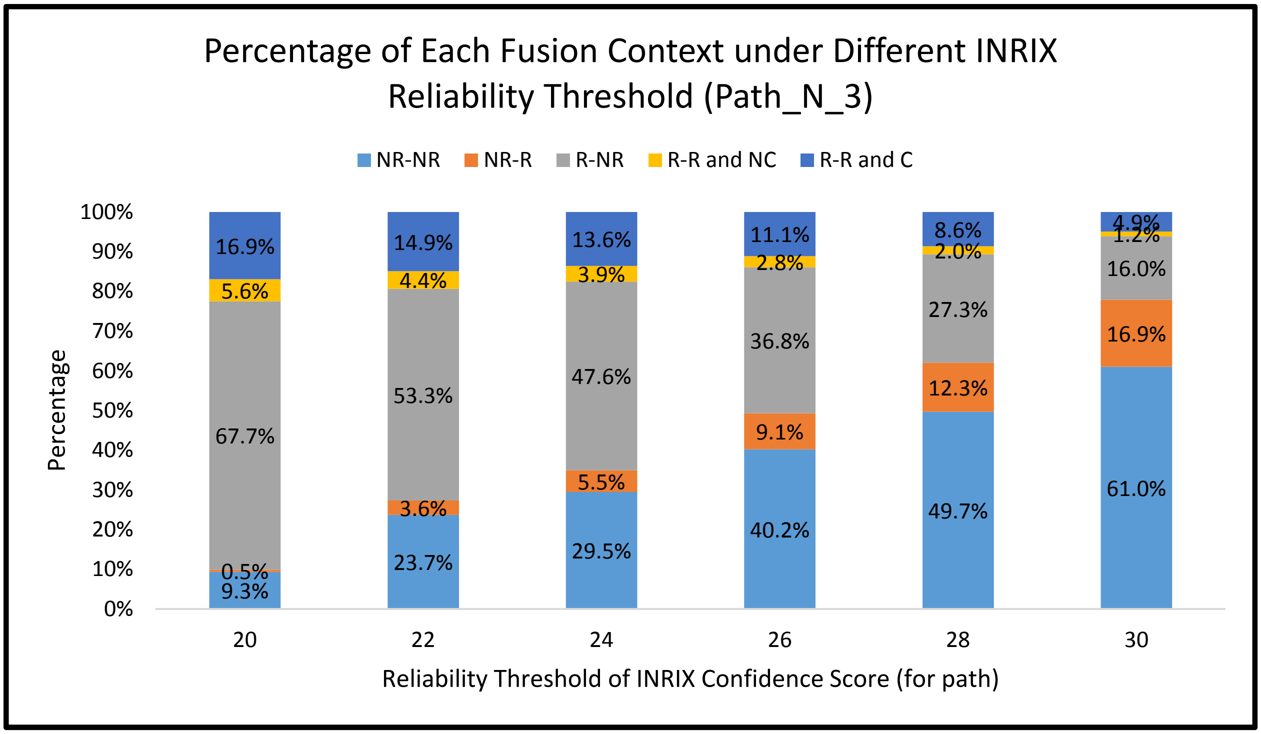


Figure 15: Percentage of Each Fusion Context under Different INRIX Data Reliability Threshold α (Path_N_3)

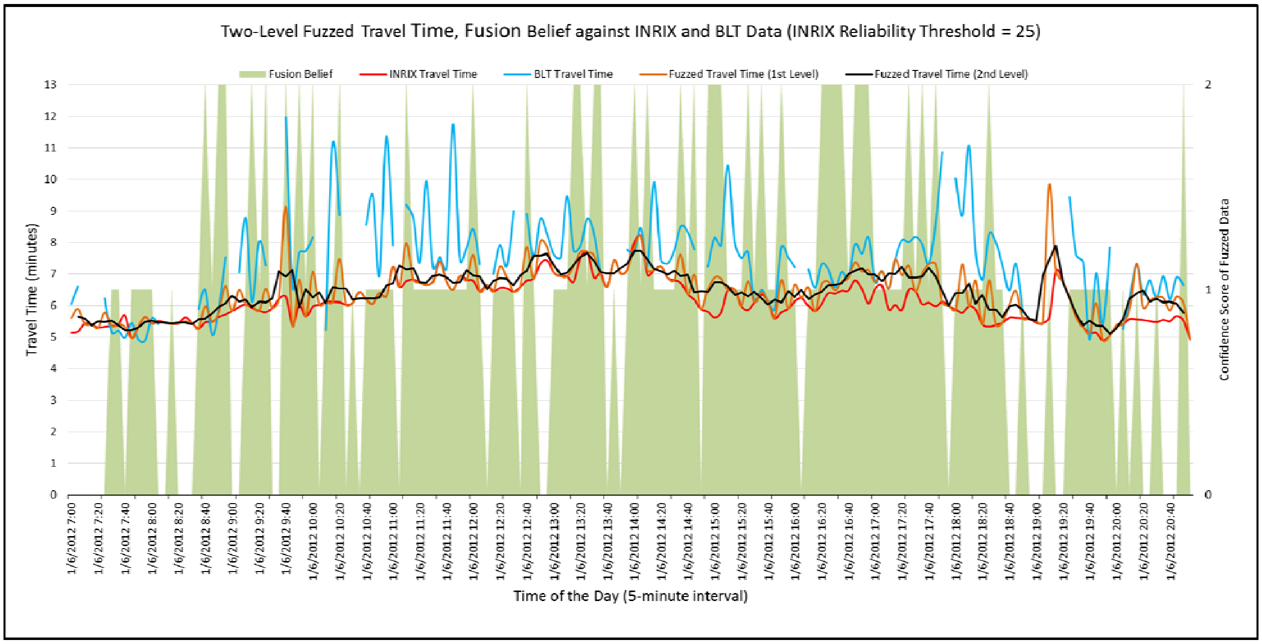


Figure 16: Part Time Series of Fused Travel Time and Fusion Belief against INRIX and Bluetooth Travel Time on Path_N_2 (Daytime of 01/06/2012, INRIX Reliability Threshold=25)

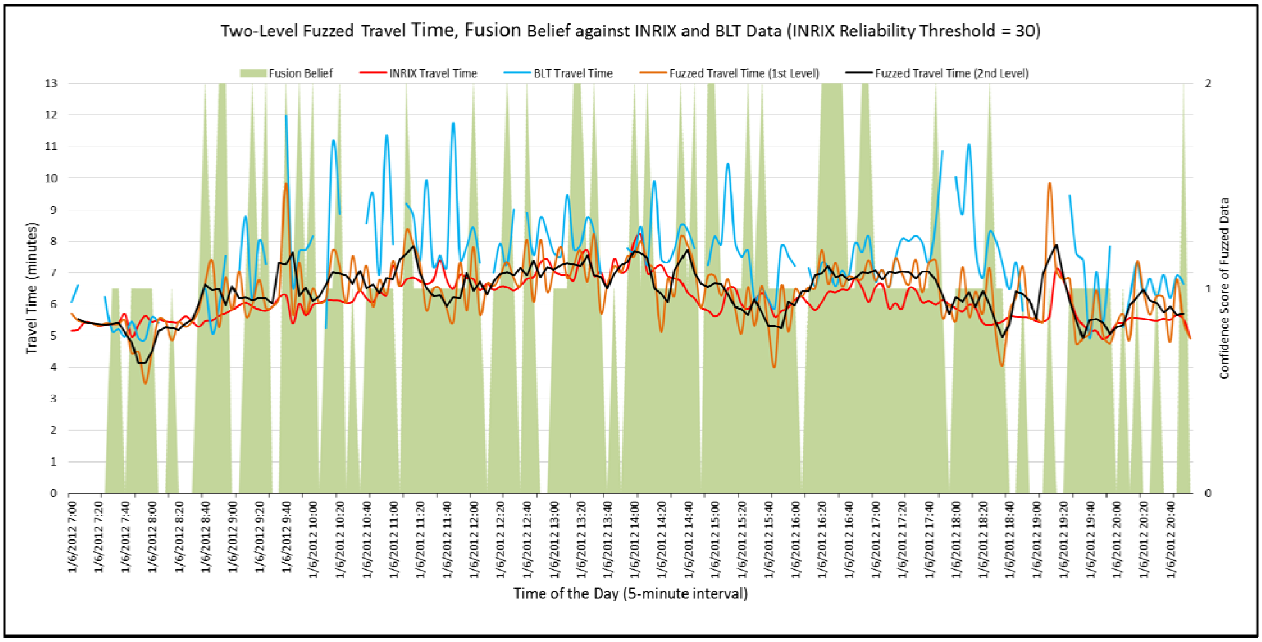


Figure 17: Part Time Series of Fused Travel Time and Fusion Belief against INRIX and Bluetooth Travel Time on Path_N_2 (Daytime of 01/06/2012, INRIX Reliability Threshold=30)

6. SUMMARY

This report described a new validation scheme for comparing travel time data from two independent data sources with an emphasis on arterial applications. By using the validation methods based on CV categories, the independent time series data were comprehensively compared. In addition, a Context Dependent (CD) based travel time fusion framework was developed to integrate data from INRIX and BT datasets in order to improve the data quality. The fusion model took advantage of a fusion belief system to determine the reliability of the fused data. The proposed model can be flexibly applied to scenarios with other independent data sources. The higher-quality fused data can be used in various applications such as travel time prediction and travel time reliability evaluation. Both validation and fusion methodologies were tested in a case study and the results were reported.

7. ACKNOWLEDGEMENTS

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