Cronbach's α as a Performance Measure to Assess Link-level Reliability
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ABSTRACT

Travel time reliability is commonly used in reference to the level of consistency in transportation service for a trip, corridor, mode or route. Traditional indicators of reliability are Buffer Time Index (BTI) and Planning Time Index (PTI). Since these indices are evaluated for a single arrayed data set, they only measure the reliability in one dimension. However, travel time variation due to congestion depends on time-of-the-day, day-of-the-week, and week-of-the-year (involves multiple factors or dimensions). The one dimensional measures, while addressing the reliability of a link, confine themselves to the trips of a given time-of-the-day and day-of-the-week. Overall comparison of reliability of two links is therefore not possible. To address this limitation, this research proposes and demonstrates the use of Cronbach's α (a two-dimensional measure) as a performance measure complementing the traditional indicators to assess link-level reliability (on the basis of travel times observed on the links). INRIX travel time data for Charlotte, Mecklenburg County, North Carolina for the year 2009, comprising about 300 Traffic Message Channel (TMC) codes (links), were used in the current research to demonstrate the methodology. The most reliable travel time values for trips on each link were determined based on their level of reliability while also categorizing the link performance into different levels of reliability using the scores that are evaluated in this research.

Keywords: Travel Time, Reliability, Performance, Measure, Buffer Time Index, Planning Time Index, Cronbach's α

INTRODUCTION

In a nation-wide assessment of urban interstate congestion, North Carolina is ranked 48th among the 50 states *(1)*. In addition to this, the congestion levels in North Carolina are expected to double in the next 25 years *(2)*. This clearly indicates the necessity of efforts in terms of combating congestion, and, hence a compelling demand for allocation of funds in easing congestion. Minimizing/reducing travel times is one such approach that is being looked at as a prospective means of minimizing congestion. States such as North Carolina need to spend over $12 billion to get rid of the existing congestion on urban roads and to tackle the growing congestion trends as predicted for the next 25 years *(2)*. Assessing and identifying unreliable segments will help effectively utilize available limited transportation dollars. The primary goal of this research is to evaluate the reliability of the road links for a given road network.

Travel time is the duration of the trip on a link (road) and is a measure of service quality of the link. When the traffic flows on a link change, their associated travel times also change. Since the traffic flows are not constant over all days in the year, for that matter even within a single day, the trend of the variation is of utmost importance to estimate the probable travel times for any future trip; hence bringing the concept of consistency and reliability of travel times into context.

The consistency of a given trip's travel time is defined as the travel time reliability. In other words, it can be defined as "the dependability or consistency in travel times, as measured from day to day or/and across different times-of-the-day" *(3)*. One way to look at travel time reliability is through the historical sense, in which the distribution of travel times from trip history are used to compute statistical parameters such as mean, median, mode, standard deviation, BTI, and PTI. These parameters are indicators of degree of travel time variability of single category trips on a link. In this approach, travel time variation is understood as the degree of travel time variability based on trip history data. Likewise, in a real-time sense, reliability can be considered as experiencing the same trip length (duration-wise) over and over again, i.e., a trip being taken now is compared to some sort of pre-set standard travel time (by the traveler). If large number of repeated trips on a link fall well within the previously observed trip lengths (expected based on any of the characteristics of the trip such as time-of-the-day, day-of-the-week, week-of-the-year, etc.), it is said to be a reliable link; no otherwise.

Any trip on a link has its corresponding time-of-the-day, day-of-the-week, and week-of-the-year. Each trip has an associated travel time which is a function of these variables. Here, time-of-the-day, day-of-the-week, and week-of-the-year can be treated as the independent variables and travel time as the dependent variable. The variability of travel times can be studied by keeping either one or two of these independent variables unchanged to reduce the number of dimensions. For example, BTI is a reliability index that is often evaluated keeping time-of-the-day and day-of-the-week as constants, making it a one dimensional measure i.e., only one variable (in this case, week-of-the-year) changes and the index for the associated travel times is evaluated. Hence, BTI can only be used to address the reliability of travel times on a link for a given time-of-the-day and day-of-the-week. However, if one has to compare the reliabilities of two different days of the week, or reliabilities of Mondays over weekdays, it is not possible using the traditional BTI measure. This limitation is further explained in the next section of this paper. This inability to compare the reliabilities of different groups limits such indices from determining the most reliable groups and the most reliable travel times. Hence, a two-dimensional measure is preferred so that different groups can be compared and reliable groups can be determined. This research paper proposes and demonstrates the working of one such multi-dimensional reliability measure (Cronbach's α). Also, with absolute reliability scores of the road links, relative comparisons of the links can be made and delays associated with incorrect travel time expectations can be addressed. This enables planners and decision makers prioritize their future investments.

LITERATURE REVIEW

Several researchers have focused on the concept of travel time reliability in recent years. The probability of network nodes being connected or disconnected (a binary approach) is defined as connectivity reliability *(4)*. Explaining the limitation of this binary approach *(5)*, various other indicators such as travel time reliability *(6)*, socio-economic impact of unreliability and travel demand reduction *(7)*, capacity reliability *(8)*, and travel demand satisfaction reliability *(9)* were developed by researchers. Among all these reliability indicators, travel time reliability is considered as the most superior measure by both network users and planners.

Since the inception of the concept of travel time reliability, there has been increased research to explore methods for travel time reliability measurement. There are essentially two types of approaches involved in the measurement of travel time reliability - heuristic measurements and statistical measurements. Asakura and Kashiwadani *(6)* first proposed the use of travel time reliability, and defined it as the probability of successfully completing a trip for a given origin-destination pair within a given interval of time at a specified level of service (LOS). On the same concept, various mathematical models have been developed which measure travel time reliability of a transportation system. Small et al. *(10)* found that both passenger trips and freight trips were not predicted to a desired level of accuracy by the agencies and hence the passengers and the freight carriers opposed in having their trips scheduled. Chen et al. *(11)* and Abdel-Aty et al. *(12)* studied the effect of including travel time variability and risk-taking behavior into the route choice models, under demand and supply variation, to estimate travel time reliability. Haitham and Emam *(13)* developed a methodology for degraded link capacity and varying travel demand to estimate travel time reliability and capacity reliability. They estimated the expected travel time at a degraded link to be lesser than the free flow travel time for the link with a specific tolerance level. This tolerance pertains to the desired LOS for the link even after its capacity has degraded. Heydecker et al. *(14)* proposed a travel demand satisfaction ratio which can be used to evaluate the performance of a road network. For some conditions, the demand satisfaction ratio can be equivalent to the travel time reliabilities *(14)*. Based on the traditional user equilibrium principle, Chen et al. *(15)* proposed a multi-objective reliable network design problem model that took into account the travel time reliability and capacity reliability in order to determine the optimum enhancement of the link capacity.

In the statistical approach of measurements, Florida Department of Transportation (FDOT) used the median of travel time plus a pre-established percentage of median travel time (residual or error term) to estimate the travel time during any period of interest *(16)*. The United States Federal Highway Administration (FHWA) defines travel time reliability to be the consistency in travel time on a daily or timely basis *(17)*. The performance indicators introduced are 95th percentile travel time, BTI, and PTI. These measures are currently the most widely used measures for reliability. These statistical measures are mainly derived from the travel time distribution.

Clark and Watling *(18)* proposed a technique for estimating the probability distribution of total network travel time, which considers the daily variations in the travel demand matrix over a transportation network. Differences and similarities in characteristics (average travel time, 95th percentile travel time, standard deviation, coefficient of variation, buffer time, and BTI) were investigated on a radial route by Higatani et al. *(19)*. Bates et al. *(20)* reviewed traveler's valuation of travel time reliability and empirical issues in data collection. The authors found that the punctuality of the public transit is highly valued by the travelers *(20)*.

Literature indicates that most of the researchers in the past have used BTI and PTI as a measure of reliability and travel time index as a measure of congestion index *(17)*. Each index is computed for a data set (single array) which has all the recorded travel times of the trips that fall in one category. For example, an array can have travel times of all Mondays on a link and for a particular time interval.

BTIs for two data sets are shown in the Table 1. The part (a) of the Table 1 shows travel times based on the category of a weekday (260 weekdays in year) and part (b) of the Table 1 shows for a category day-of-the-week (52 Monday's in a year) for a given year. From Table 1, one can notice that for each time interval/time-of-the-day (first column) there is an associated BTI (last column). The computed BTI values from the two datasets are used to infer which category is more reliable. BTI for each time interval is compared in the two categories and the category with lower BTI is highlighted, showing it is more reliable for that time interval. But, based on this comparison, it is difficult to judge which category (weekday or Monday) is appropriate or suitable when looking at all the time intervals together (i.e., over a day). This is due to multiple BTI values associated with a link in a category. In other words, it can be said that these indices possess only a one-dimensional ability to measure the reliabilities of links. Also, week-of-the-year was hardly considered in the past studies while addressing reliability. The week-of-the-year, which gives information about the month of the trip, might well influence the travel time (for example, weeks with long weekends). This research introduces and proposes the use of a new performance measures (Cronbach's α) to evaluate a single index associated for each category (considering week-of-the-year) of travel time data. The proposed performance measure also helps compare which category or group is reliable.

TABLE 1 Illustration of BTI Computations for a Weekday and Day-of-the-week

Time Interval	Weekday #				BTI	Monday				BTI
	1	2	…	260		1	2	-	52	
12:00am-1:00am	.	.	.	.	**1.2**	.	.	.	.	2.9
1:00am-2:00am	.	.	.	.	9.3	.	.	.	.	**3.1**
..	.	.	.	.	.	.	.	.	.	.
11:30pm-12:00am	.	.	.	.	8.7	.	.	.	.	**3.7**

(a) (b)

Data Description

The city of Charlotte, in Mecklenburg County, North Carolina is considered as the study area. INRIX travel time data for 296 road links (TMCs) in Charlotte area for the year 2009 was gathered. The data obtained has travel time data aggregated for every one minute interval with other trip characteristics such as date, time, average travel speed, and identified TMC code. The raw data obtained from INRIX was aggregated for every 30 minutes to evaluate travel time reliabilities for the study links for every half-hour intervals (48 intervals) in a day. The associated trip characteristics such as week-of-the-year, day-of-the-week, and weekday/weekend information are also evaluated from the 'date of trip' available in INRIX database.

CRONBACH'S α

In statistics, Cronbach's α is used as a measure of internal consistency or an estimate of reliability of a test. It is a measure of squared correlation between observed scores and true scores *(21)*. In other words, reliability is measured in terms of the ratio of true score variance to observed score variance. The observed score is equal to the true score plus the measurement error. It is assumed that a reliable test should minimize the measurement error so that the error is not highly correlated with the true score. On the other hand, the relationship between true score and observed score should be strong for a test to be a reliable one. The coefficient has been widely used in the fields of psychology, social sciences, and nursing.

The following example illustrates the working of Cronbach's α. Consider a case where one needs to determine the reliability of three questions in measuring an entity, say, analytical ability of five persons with various educational levels. The test is intended to rate the persons based on their ability to analyze a given dataset. Note that the assumption in this case is that the ability depends on one's education and are testing the reliability of the questions in the test. The results of the test are recorded as shown in Table 2, where scores for questions are recorded as binary variables.

TABLE 2 Summary of Results from Test Scores

Students	Questions			Total
	Q1	Q2	Q3	
S.1	0	1	1	2
S.2	0	0	1	1
S.3	0	1	0	1
S.4	0	0	1	1
S.5	1	1	1	3
Item Variances	0.16 (0.19)	0.24 (0.25)	0.16	
Variance of Totals				0.64 (0.24)

From Table 2,
Sum of individual variances (V1) = 0.16 + 0.24 + 0.16 = 0.56
Variance of the total scores (V2) = 0.64
Number of questions (items; K) = 3

For the aforementioned problem, Cronbach's α is computed using the following expression *(22)*.

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K}\sigma_{Y_i}^2}{\sigma_X^2}\right) or\ \frac{K}{K-1}\left(1 - \frac{V1}{V2}\right)$$

$$V1 = \sum_{i=1}^{K}\sigma_{Y_i}^2\,;\ V2 = \sigma_X^2$$

where, K is the number of questions,

σ_X^2 is the variance of the observed total test scores of a person, and,

$\sigma_{Y_i}^2$ is the variance of the sums of scores of a question for all the five persons.

Based on K and computed V1 and V2 from Table 2,

$$\alpha = \frac{3}{3-1}\left(1 - \frac{0.56}{0.64}\right) = 0.1875$$

A 'zero' value of α indicates that the questions does not measure the same entity, in this case their analytical ability. On the other hand, if α is 'one', it indicates that all the questions designed did a perfect job. This happens when the scores of a student remain same for all questions making him score either 3 or 0 in total. The computed Cronbach's α in the above example is 0.1875, indicating that the questions are very less reliable in measuring the analytical ability of the person.

From the above equation, it can be observed that when variance 1 (V1) is greater than (or far less than) variance 2 (V2), a negative value (or value greater than one) for Cronbach's coefficient is obtained. But, this occurs only when the sample data is incomplete (i.e., when there are missing fields within the data) and V2 is affected. The sample shown in Table 2 demonstrates the occurrence of absurd values in evaluation of Cronbach's coefficient. When some values in Table 2 are omitted, V1 and V2 are affected (V1 = 0.6; V2 = 0.24) giving a Cronbach's coefficient of -2.23. In such cases, either the missing cells should be filled with an average value or the sum of the scores (final column in Table 2) should be proportionately increased to accommodate the missing values. The later was applied in the current analysis to counter the incomplete data for the validity of results. However, if the number of missing cells is more, this approach might not fix the issue.

In the above example, the persons are the primary source of variance while questions are the secondary source of variance. In our research, time-of-the-day and week-of-the-year are considered as sources of variance, both primary and secondary. Taking one combination at a time i.e., Cronbach's α is evaluated once with time-of-the-day as primary factor and next with week-of-the-year as primary factor. In general, the primary factor causes the changes in the observations and correlation is evaluated over the secondary factor (test items).

In summary, Cronbach's α measures the correlation between the results coming from various items i.e., the correlation between the columns in the above table or simply, it is the correlation of test with itself. Whereas, $(1 - \alpha^2)$ gives the index of measurement error *(21)*.

APPLICATION OF CRONBACH'S α TO ASSESS RELIABILITY

Travel time reliability is measured on the basis of various categories of travel times (day-of-the-week, weekend/weekday, time-of-the-day, etc.). A sample data of travel times for 'Monday' and 'weekday' category is shown in Table 1 (b). In the table, the 'week-of-the-year' corresponds to the secondary factor and the 'time-of-the-day' corresponds to the primary factor i.e., the travel time is expected to vary with time-of-the-day and is checked for the consistency (reliability) over the 52 weeks of a given year. A higher value of Cronbach's α is obtained when the travel times over the day are well correlated between the 52 weeks of the year. The maximum of '1' is obtained when all the 52 weeks have identical travel times for any time interval of the day (maintaining certain variance within the various time intervals of the day). Reliability scores are compared by changing the primary and secondary factors (like transposing rows and columns in Table 1 (b)), and the most reliable groups that give the best expected travel times are identified.

CASE STUDY

A 2-mile section of freeway on I-85 Northbound direction in the city of Charlotte, NC with TMC code '125+04629' is considered as the case study to illustrate the working of the methodology. Travel time data for the year 2009 was considered to evaluate reliability based on two categories - day-of the-week and weekday/weekend.

Two different travel time measures, 85th percentile travel times and average travel times, were considered to evaluate reliable trip lengths, hence yielding 8 categories of 'α' values as summarized in Table 3. The summary of all the 'α' scores computed for the abovementioned TMC code, for each day-of-the-week, are shown in Table 4.

TABLE 3 Characteristics of Each Category of Cronbach's 'α'

	Category	Primary factor	Secondary factor	Travel Time Measure Used	% of Trips Reliable
α1	Day-of-the-week	Time-of-the-day	Week-of-the-year	85th Percentile	2.22
α2	Weekday/Weekend	Time-of-the-day	Week-of-the-year	85th Percentile	9.56
α3	Day-of-the-week	Week-of-the-year	Time-of-the-day	85th Percentile	2.03
α4	Weekday/Weekend	Week-of-the-year	Time-of-the-day	85th Percentile	2.36
α5	Day-of-the-week	Time-of-the-day	Week-of-the-year	Average	6.37
α6	Weekday/Weekend	Time-of-the-day	Week-of-the-year	Average	29.92
α7	Day-of-the-week	Week-of-the-year	Time-of-the-day	Average	11.10
α8	Weekday/Weekend	Week-of-the-year	Time-of-the-day	Average	36.44

TABLE 4 Cronbach's 'α' associated for Varying Categories, Primary and Secondary Factors for a TMC

TMC Code	DOW	WD	α1	α2	α3	α4	α5	α6	α7	α8	Max(α)
125+04629	1	0	0.41	0.17	0.53	**0.68**	0.58	0.18	0.62	0.63	0.68
125+04629	2	1	0.34	0.36	0.12	0.62	0.37	0.38	0.15	**0.67**	0.67
125+04629	3	1	0.35	0.36	0.52	0.62	0.38	0.38	0.57	**0.67**	0.67
125+04629	4	1	0.50	0.36	**0.75**	0.62	0.31	0.38	0.69	0.67	0.75
125+04629	5	1	0.44	0.36	0.60	0.62	0.38	0.38	0.58	**0.67**	0.67
125+04629	6	1	0.61	0.36	0.49	0.62	0.61	0.38	0.57	**0.67**	0.67
125+04629	7	0	0.23	0.17	0.67	**0.68**	0.25	0.18	0.62	0.63	0.68

*DOW stands for day-of-the-week with Sunday coded as 1, Monday as 2, and so on
*WD represents weekday, coded with 1 for weekday and 0 for weekend

Cronbach's α Computed for the 'Day-of-the-week' category with 'Week-of-the-year' as Primary Factor (α3, α7)

'Week-of-the-year' is considered as the primary factor and Cronbach's α is computed for every 'day-of-the-week' (category). In this case, the assumption is that the primary source of variation in travel times on the link is the 'week-of–the-year' associated with the trip. For each day-of-the-week, the corresponding values of α (α3 and α7) are reported in the Table 4.

It can be observed from Table 4 that Mondays are least reliable with this combination while Wednesdays are the most reliable. Cronbach's α values lying between [0.9, 1], [0.7, 0.9], [0.5, 0.7], [0.4, 0.5], and [0, 0.4] fall in the categories of A (Excellent), B (Highly Reliable), C (Reliable), D (Poorly Reliable), E (Unreliable) respectively. They are same as those used in other studies related to Cronbach's α *(23, 24)*.

Cronbach's α Computed for the 'Day-of-the-week' category with 'Time-of-the-Day' as Primary Factor

'Time–of-the-day' is considered as the primary factor to evaluate the reliability score (α). Hence, the assumption in this case is that the primary variance in the travel times is due to the time-of-the-day associated with each trip. One can refer to Table 4 for Cronbach's α value (α1 and α5) for each week-of-the-day based on varying time-of-the-day. It can be observed from Table 4 that none of the values is greater than 0.7 (on absolute scale) nor comparable to the maximum α value for corresponding days (on relative scale) except for Saturdays where α1 (0.61) and α5 (0.61) are comparable to the maximum α8 (0.67). This indicates that the above combination is not the most reliable for any of the seven days-of-the-week.

Cronbach's α Computed for the 'Weekday/Weekend' category with Varying Primary Factors

The results found after aggregation of data for weekday and weekend are shown as α2, α4, α6, α8 in Table 4. The primary and secondary factors as well as the travel time statistic associated with each 'α' are shown in Table 3.

The tool and results can be used to predict transportation network condition in the future. As an example, a traveler wants to make a travel plan on 14th of February 2015 between 10:00 AM to 10:30 AM on the above mentioned TMC and wants to know his/her travel time. The tool developed from this study uses the following steps to make an expectation.

1) Identify the day-of-the-week, which is Saturday, a weekend.
2) Identify the week-of-the-year, which is 7th week-of-the-year 2015.
3) Select the maximum 'α' and note the combination associated with the 'α'.

In this case, α4 is the highest. This implies that the category is weekend and the travel time is week-of-the-year dependent (refer Table 3). Hence, one has to take the average of the 85th percentile travel times observed for the weekend category trips for the 7th week-of-the-year. The result gives the expected travel time of the trip. Figure 1 shows the expected travel times (ETT) for weekend category based on the 2009 data with primary factor as 'week-of-the-year'. One can observe that the ETT depends on the week-of-the-year with each point representing each week-of-the-year in Figure 1 (total 52 points). Since the data is not available for the first 9 weeks of the year, one does not see any points corresponding to them. This shows the limitation of this approach which is further explained in the later sections. However, the basic idea is to compute the Cronbach's α for all the combinations and take the maximum of these 8 values for any day and then compute the most reliable travel time for any trip.

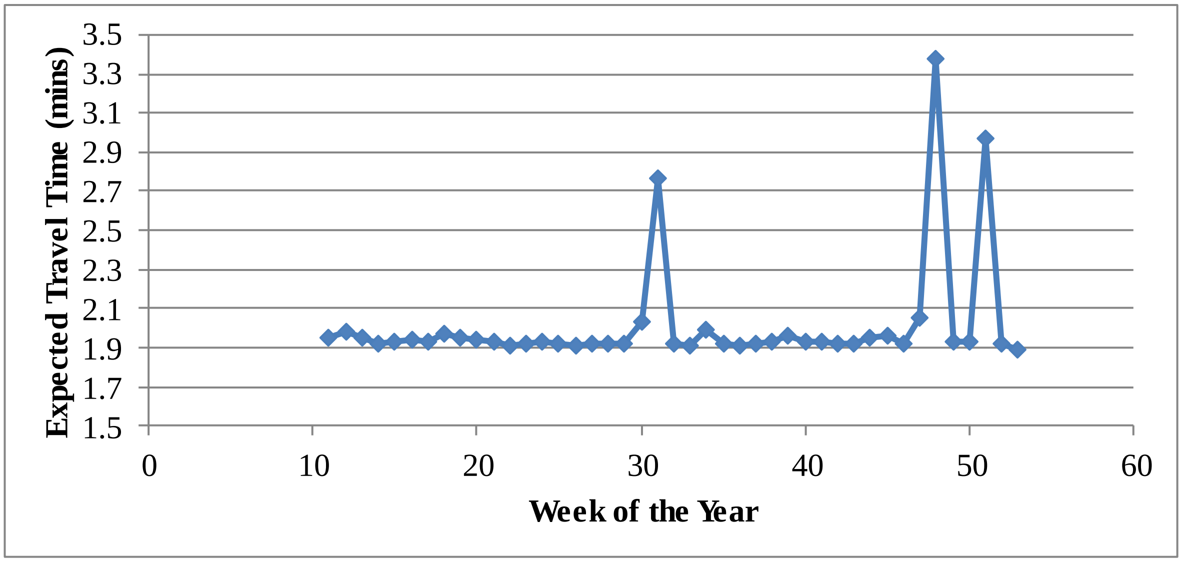

FIGURE 1 Expected travel times for varying week-of-the-year.

Similarly, analysis to evaluate link-level reliability is applied to all the links considered in the study (296 links). Also, ranking the links with these reliability scores (the maximum of the 8 scores is taken for a link) help the traveler choose his/her route from various alternatives. Also, the planning agencies can identify the most unreliable links and make necessary recommendations to improve transportation system performance. The last column of Table 3 shows the percentage of trips that are reliable for a particular combination associated within α. Table 5 shows the same for each day-of-the-week. It can be observed that a majority of the trips have a higher value of Cronbach's α when the average travel time values are taken instead of the 85th percentile values. Since the data used in the study also involves incidents, the 85th percentile travel time values result in an over-estimation. Additionally, weekday/weekend category grouping ($\alpha_6$andα_8) represent the best expected travel time. This implies that, reliability of a trip depends on whether the trip is on a weekday or weekend rather than a particular day-of-the-week. Also, it can be observed that weekday/weekend category grouping with week-of-the-year as primary factor is beneficial for a majority of the weekend trips. This might be because the travel time on a weekend is not much affected by the time-of-the-day as traffic levels are almost equally spread over the day, whereas during weekdays, time-of-the-day is quite defining the travel time. However, the authors do not see a need to generalize here as every link has its own reliable combination to evaluate its reliable travel times.

TABLE 5 Percent of Trips with Maximum Corresponding ‘α’ Values

	α1	α2	α3	α4	α5	α6	α7	α8
Sunday	3.72	4.05	2.36	5.07	10.14	16.22	14.19	44.26
Monday	0.34	13.18	0.34	1.35	3.04	38.51	5.41	37.84
Tuesday	2.36	11.49	4.73	1.01	3.72	35.14	6.42	35.14
Wednesday	0.00	11.15	2.70	1.69	4.05	35.14	6.76	38.51
Thursday	0.00	11.82	1.01	1.69	6.08	35.47	5.74	38.18
Friday	4.39	11.49	0.34	1.35	7.09	33.45	11.15	30.74
Saturday	4.73	3.72	2.70	4.39	10.47	15.54	28.04	30.41

Cronbach’s α Complementing Traditional Reliability Measures

With Cronbach’s α measuring the reliability of the link at macro-level and identifying the most reliable base group (category) that closely predicts the travel time, one can use these base groups to compute the traditional reliability measures i.e., BTI and PTI at micro-level. For example, if it is found that weekend travel times are more consistent when the primary factor is the week-of-the-year, then BTIs can be evaluated for each week-of-the-year. It can be observed that these BTIs will be much lower than the BTIs that are computed with time-of-the-day as the base group (category). Lower BTIs imply that those set of travel time values are more consistent within themselves. This way Cronbach’s α can be used to compute lower BTIs by changing their base groups or combinations. This also serves as the justification of this study.

Figure 2 shows the comparison of the BTIs evaluated for different values of ‘α’ for the same example discussed earlier. While calculating BTI, only 4 cases arise instead of 8 (since BTI needs only these categories). Figure 2(a) and Figure 2(c) represent the BTIs for the trips for every half-hour interval of the day (time-of-the-day category). While Figure 2(a) represents Saturday, Figure 2(c) represents weekend. Similarly, Figure 2 (b) and Figure 2(d) are for week-of-the-year category. Figure 2 (b) represents Saturday and Figure 2 (d) represents weekend. From Table 2, since α4 and α8 values are 0.68 and 0.63, respectively which are with the combination of ‘weekend’ category and ‘week-of-the-year’ as primary factor, the associated BTIs are seen close to zero in Figure 2(d) than the others. One can compare these with the BTIs associated with minimum ‘α’ values (α2 and α4) i.e., Figure 2(b). The number of BTIs greater than 10 is more in this case than the other three cases. This reinforces the concept of Cronbach’s α complementing the traditional measures. It is to be noted that the negative values of BTI in Figure 2 indicates the samples with average travel time greater than 95th percentile due to their small size and presence of outliers.

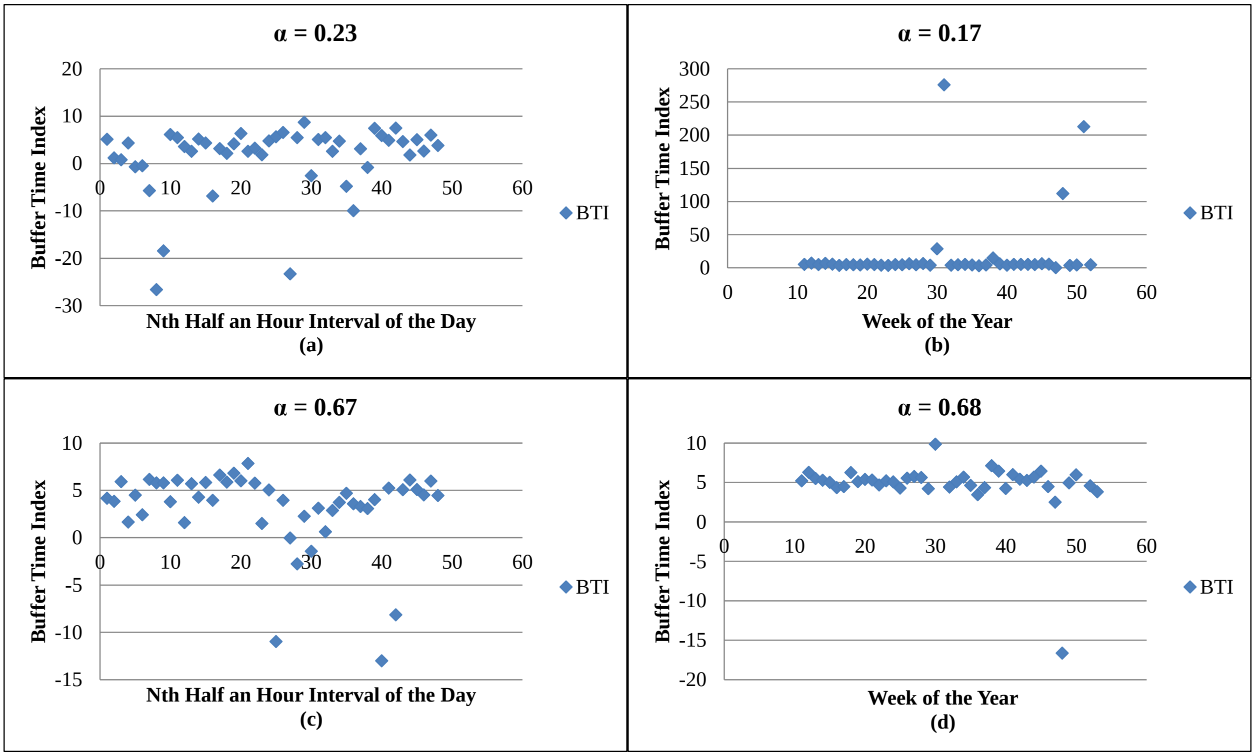

FIGURE 2 Comparison of BTIs evaluated by Category of Trips.

Level of Reliability Based on Value of Cronbach's α

Cronbach's α was used as a performance measure to classify the links/corridors into various LOS categories. Since it is a correlation coefficient, the same threshold values that are used to determine the level of dependence (linear) for various classifications were used. If any of the 'α' is greater than 0.9, the link is said to be very highly reliable for the associated combination and one can expect the value to be at least greater than 0.7 to comment on its reliability. From the complete analysis performed in this study, covering 296 links in the city of Charlotte for the year 2009 consisting around 2,072 different types of trips based on day-of-the-week (296*7 = 2,072), it is observed that 49.13% of TMCs fall in LOS A category, 37.4% in LOS B category, 12.26% in LOS C category, 0.92% in LOS D Category, and 0.29% in LOS E category.

Missing Data and Possible Inaccuracies

Data availability is one of the major requirements for accurate estimates of reliability scores. The formula used to evaluate Cronbach's α uses variance 1 (V1) which is the sum of item variances and variance 2 (V2) which is the variance of total scores. The lower the ratio of V1 to V2, the higher is Cronbach's α. It is to be noted that lower value of V1 should automatically reflect lower value of V2 because when individual values are closer to each other, the sums of those scores should also be closer unless and until some values are missing. In case of missing fields, an over-estimation or under-estimation of Cronbach's α values is observed. If the variance 2 (V2) can be adjusted when missed data is observed, the results can be more credible. Hence, sum of the item scores is proportionately increased to accommodate for all the missing data and to ensure that V2 is a valid representation of the sample. However, the authors understand that this may not depict the true sample but shall improve the validity of the results. The proposed method has fixed the issue to a large extent though there might be little over-estimation or under-estimation in case of missing fields.

CONCLUSIONS

Reliability of a link is crucial to both the users and practitioners of transportation systems. A new reliability measure, Cronbach's α, is proposed to assess reliability of links in the transportation network. This performance measure acts as a macro-level measure of reliability that evaluates the level of consistency of travel times. The proposed reliability measure was found to be a better estimator of expected travel times as compared to the traditional travel time performance measures such as BTI and PTI, which are often evaluated for a fixed criteria (time-of-the-day). This is because the proposed macroscopic measure evaluated reliability not only for a time-of-the-day over the year but also for a week-of-the-year over the time-of-the-day and using both 85^{th} percentile travel times as well as average travel times from the historical data. The reliabilities are evaluated at link-level which also helps identify the most unreliable links in the network.

Overall, results indicate that the average travel times of the trips aggregated for any time interval from the data yields in more reliable estimates than compared to 85^{th} percentile travel times. Also, weekend trips are not time dependent but are week-of-the-year dependent whereas weekday trips are time dependent in most of the cases. Results also indicate that missing field in the data might result in over- or under-estimation of results.

Along with identifying the reliable travel times and reporting absolute reliable scores of the links, a new reliability criteria based on Cronbach scores is proposed. However, a link with LOS 'A' from this study does not mean a perfect case, as the travel times associated might still be very high just that they are reliable and recurring.

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DISCLAIMER

The views, opinions, findings, and conclusions reflected in this paper are the responsibility of the authors only and do not represent the official policy or position of the USDOT/OST-R, NCDOT, UMD, INRIX, or any other State, or the University of North Carolina at Charlotte or other entity. The authors are responsible for the facts and the accuracy of the data presented herein. This paper does not constitute a standard, specification, or regulation.

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