Cronbach's α as a Performance Measure to Assess Link-level Reliability (TRB Paper # 15-5369)

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ABSTRACT

Traditional indicators of reliability (Buffer Time Index - BTI and Planning Time Index - PTI) 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. INRIX travel time data for Charlotte, Mecklenburg County, North Carolina for the year 2009, comprising about 296 Traffic Message Channel (TMC) codes (links), were used in the current research to demonstrate the working of the methodology.

INTRODUCTION

- Consistency of a given trip's travel time is defined as the travel time reliability (FHWA, 2006).
- To estimate the average travel time of a trip, it is important to identify the appropriate category of trips for which the average is evaluated. Hence, the trips that are grouped into a category/set should not have much variance among themselves, in other words, the category should be more reliable.
- Traditional reliability indicators are evaluated for a set of travel time data in which sample points differ only in one characteristic of the trip.
- In reality, travel time of a trip is influenced by many factors and, hence, a multi-dimensional measure gives a better picture and helps identify the patterns better.
- Cronbach's coefficient is a 2-dimensional parameter that uses a dataset in which sample points differ in at least one of the two trip attributes considered.
- Time-of-the-day, week-of-the-year, weekday/weekend, and day-of-the-week are some example trip attributes.

RELIABILITY - EXAMPLE MEASURES

- Reliability - probability of successfully completing a trip for a given O-D pair within a given time at a specified LOS (Asakura and Kashiwadani, 1991).
- Capacity reliability - probability that network can accommodate certain traffic demand at a required LOS, accounting for drivers' route choices (Chen et al., 2002).
- Travel demand satisfaction reliability (Heydecker, 2000).
- Median of travel time + residual or error term (Florida Department of Transportation, Douglas, 2000).
- 95th percentile travel time, BTI, and PTI (FHWA, 2006).

LIMITATIONS OF TRADITIONAL MEASURES

- 1-dimensional measures only show the reliabilities based on a single attribute of the trip, usually limited to a time-interval-of-the-day.
- Week-of-the-year is not generally considered though traffic flow and travel time vary by month (example, long weekends).
- Reliabilities evaluated cannot be used to compare overall reliabilities of the links.
- It is not possible to compare the overall reliability of weekday category over Monday category (Table 1).

TABLE 1 Illustration of BTI computations - weekday & time-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

CRONBACH'S COEFFICIENT

- α is a correlation coefficient that measures internal consistency of a test.
- α is measured in terms of the ratio of true score variance to observed score variance.
- Primary factor: Main factor that contributes to the variance in scores (Students in Table 2).
- Secondary factor: Secondary source of variance in the scores (Questions in Table 2).

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

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

σ_X^2 is the variance of the observed total test scores of a person;
$\sigma_{Y_i}^2$ is the variance of the sums of scores of a question for all the five persons.

TABLE 2 Illustrating α evaluation with an example

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	0.2	0.3	0.2	
Variance of Totals				0.8

METHODOLOGY

- Aggregate the raw INRIX data at 30 minute intervals.
- Group the processed data by day-of-the-week and weekday/weekend separately, with primary and secondary factors as shown in Table 2 (for every TMC).
- Evaluate Variance 1 and Variance 2 and associated α for each scenario.
- Scenario giving the maximum α (for a TMC) marks that combination to be the most reliable one.
- Most reliable travel time of any trip on a link is obtained by identifying the scenario with maximum α for that link and taking the average of travel times for the category used in the scenario.

Table 3 Characteristics of each category of Cronbach's 'α'

	Category	Primary factor	Secondary factor	Travel Time Measure Used
α1	Day-of-the-week	Time-of-the-day	Week-of-the-year	85th Percentile
α2	Weekday/Weekend	Time-of-the-day	Week-of-the-year	85th Percentile
α3	Day-of-the-week	Week-of-the-year	Time-of-the-day	85th Percentile
α4	Weekday/Weekend	Week-of-the-year	Time-of-the-day	85th Percentile
α5	Day-of-the-week	Time-of-the-day	Week-of-the-year	Average
α6	Weekday/Weekend	Time-of-the-day	Week-of-the-year	Average
α7	Day-of-the-week	Week-of-the-year	Time-of-the-day	Average
α8	Weekday/Weekend	Week-of-the-year	Time-of-the-day	Average

CASE STUDY

- City of Charlotte, Mecklenburg County, NC, is considered as the study area.
- INRIX travel time data for 296 road links in Charlotte area for the year 2009 was used in the analysis.

Table 4 Cronbach's 'α's evaluated 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

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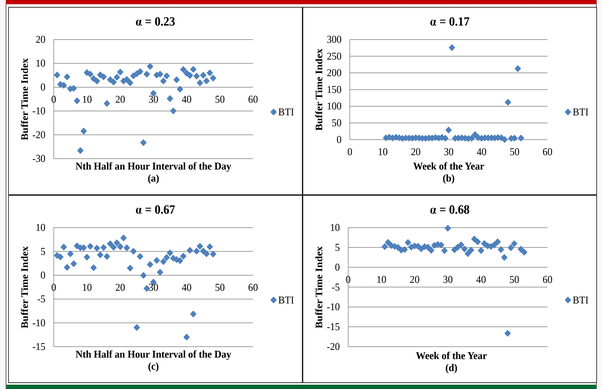
RESULTS & CONCLUSIONS

- Average travel times of the trips aggregated for any time interval from the data yield more reliable estimates than compared to 85th percentile travel times.
- Weekend trips are not time dependent but are week-of-the-year dependent.
- Weekday trips are time dependent in most of the cases.
- Weekday/weekend category gives the most reliable travel times.
- 49% have α ≥ 0.9; 37% have 0.9 < α ≥ 0.7; 13% have 0.7 < α ≥ 0.5.

TABLE 6 % of links with maximum corresponding 'α' - year 2009

	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

FIGURE 1 Comparison of BTIs evaluated by category of trips



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