Percentile-based Route PDFs from Segment PDFs George List, PhD, PE, NC State University November 29, 2012

It has long been generally accepted by experts in traffic flow analysis, including statisticians, that the variability of travel time for a segment cannot be determined by summing the variability in travel time of sections comprising the segment. For example, you cannot obtain the variance for a segment by first partitioning the segment into sections, determining the variance for each one, and adding the variances together. The same is true for the standard deviation and various other measures of reliability, such as the Planning Time Index (i.e. the Travel Time Index for the 95th percentile of the Travel Time Distribution)

The prohibition against adding segment variances (and similar calculations) is considered inviolable and poses many challenges, for example the inability to determine a measure of the travel time variability for a freeway section or an O-D pair based on summing the same measure of the variability of their parts.

A late-emergent finding from LO2 is that one can create defensible distributions of travel times for a route (for specific regimes) by summing the percentile travel times across the segments that comprise the route (for the same regime). This is to say that *if* you have distributions of *individual vehicle travel times* for the *segments* that comprise a specific route (for a given regime), it is possible to create the distribution of *individual vehicle travel times* for the *route* (for that same regime) by summing the travel times for *specific percentiles* across the segments.

Consider the example shown in Table 1. Columns 2, 3, and 4 contain the travel times by percentile for a three-segment route along I-5 south of downtown Sacramento. The route starts at monitoring station #39 and proceeds past monitoring stations #9 and #10 and ends at monitoring station #11. So the first row in sub-table (a) shows the 5th percentile travel times on segments 39-9 (0.810 minutes), 9-10 (0.757 minutes), and 10-11 (0.778 minutes) under uncongested conditions. The fifth column shows the sum of these values (e.g., 0.810 + 0.757 + 0.778 = 4.450). The sixth column shows the percentile travel time that was actually observed for vehicles that traveled the entire route (e.g., the observed 5th percentile travel time for uncongested conditions was 4.500 minutes). The 7th column shows the percentage difference between the synthesized sum and the true, observed value. Sub-table (a) shows these values for uncongested conditions; sub-table (b) shows the results for low congestion; sub-table (c) for moderate congestion; and sub-table (d) for high congestion. Only when congestion on the facility is high can one see differences that are more than 1%. Moreover, not only are the percentage differences small, but adding the percentile values reproduces the multi-modal (two modal) distribution that was observed for the entire route, as shown in Figure 1.

This finding produces excitement that there may be a very simple way to estimate *individual vehicle* travel time distributions for routes on the basis of corresponding distributions for the segments that comprise the route (without being confined to utilize only the travel times of vehicles that actually

traversed the route. If it proves to be true generally, traffic management centers will be able to provide estimates of the density functions for user-requested routes by combining in this manner the density functions for the intervening segments.

If this idea could be tested more extensively, it would be of great benefit to the practicing traffic engineering community. While the idea upon which it is based is completely consistent with a premise upon which all traffic simulation models are based – that drivers consistently seek to achieve facility-dependent desired speeds as they make their trips through the network – it has only been demonstrated to be defensible on one multi-section stretch of I-5 in Sacramento. Finding that it is true far more generally would be a very significant contribution to knowledge.

Table 1: A Comparison of actual percentile travel times for a given route against values obtained by summing the travel times for the same percentile on the individual segments

	Segm	ent Travel	Times (Unc	ongs)				Seg	gment Trav	el Times (Lo	ow)		
Percentile	Seg 39-9	Seg 9-10	Seg 1011	Sum	Route 39-11	% Diff	Percentile	Seg 39-9	Seg 9-10	Seg 1011	Sum	Route 39-11	% Diff
5%	0.810	0.757	0.778	4.450	4.500	1.11%	5%	0.806	0.743	0.778	4.417	4.467	1.12%
10%	0.829	0.773	0.814	4.566	4.600	0.74%	10%	0.824	0.773	0.797	4.534	4.567	0.72%
15%	0.843	0.788	0.833	4.650	4.667	0.36%	15%	0.838	0.788	0.814	4.617	4.650	0.71%
20%	0.856	0.803	0.852	4.733	4.733	0.00%	20%	0.849	0.803	0.833	4.691	4.717	0.55%
25%	0.866	0.818	0.861	4.792	4.800	0.17%	25%	0.861	0.818	0.852	4.767	4.767	0.00%
30%	0.875	0.834	0.870	4.850	4.867	0.35%	30%	0.870	0.818	0.861	4.808	4.833	0.52%
35%	0.884	0.848	0.889	4.916	4.917	0.02%	35%	0.880	0.834	0.870	4.867	4.883	0.33%
40%	0.896	0.864	0.908	4.992	4.983	0.18%	40%	0.889	0.848	0.889	4.933	4.942	0.18%
45%	0.903	0.871	0.926	5.041	5.050	0.18%	45%	0.898	0.864	0.908	5.000	5.000	0.00%
50%	0.917	0.886	0.944	5.125	5.117	0.16%	50%	0.908	0.879	0.926	5.067	5.067	0.00%
55%	0.926	0.902	0.972	5.200	5.200	0.00%	55%	0.921	0.894	0.944	5.150	5.150	0.00%
60%	0.940	0.916	0.991	5.283	5.300	0.32%	60%	0.933	0.909	0.972	5.233	5.233	0.00%
65%	0.958	0.939	1.000	5.383	5.433	0.92%	65%	0.949	0.925	0.991	5.326	5.350	0.45%
70%	0.977	0.955	1.019	5.484	5.550	1.19%	70%	0.968	0.939	1.009	5.424	5.467	0.79%
75%	0.995	0.977	1.037	5.591	5.625	0.60%	75%	0.986	0.962	1.019	5.525	5.567	0.75%
80%	1.012	1.000	1.056	5.692	5.700	0.14%	80%	1.002	0.985	1.037	5.624	5.650	0.46%
85%	1.028	1.015	1.074	5.784	5.783	0.02%	85%	1.019	1.000	1.064	5.725	5.733	0.14%
90%	1.046	1.038	1.092	5.892	5.875	0.29%	90%	1.037 1.060	1.030 1.061	1.092 1.130	5.849 6.001	5.817 5.950	0.55%
95%	1.074	1.075	1.130	6.067	6.017	0.83%	95%	1.060	1.061		6.001	5.950	0.86%
(a)							(b)						
			el Times (M					_		el Times (Hi	-		
Percentile	Seg 39-9	Seg 9-10	Seg 1011	Sum	Route 39-11	% Diff	Percentile	Seg 39-9	Seg 9-10	Seg 1011	Sum	Route 39-11	% Diff
5%	Seg 39-9 0.810	Seg 9-10 0.743	Seg 1011 0.778	Sum 4.434	4.500	1.47%	5%	Seg 39-9 0.861	Seg 9-10 0.773	Seg 1011 0.814	Sum 4.683	4.767	1.76%
5% 10%	Seg 39-9 0.810 0.829	Seg 9-10 0.743 0.773	Seg 1011 0.778 0.797	Sum 4.434 4.550	4.500 4.583	1.47% 0.72%	5% 10%	Seg 39-9 0.861 0.884	Seg 9-10 0.773 0.803	Seg 1011 0.814 0.833	Sum 4.683 4.816	4.767 4.867	1.76% 1.05%
5% 10% 15%	Seg 39-9 0.810 0.829 0.838	Seg 9-10 0.743 0.773 0.788	Seg 1011 0.778 0.797 0.814	Sum 4.434 4.550 4.617	4.500 4.583 4.650	1.47% 0.72% 0.71%	5% 10% 15%	Seg 39-9 0.861 0.884 0.903	Seg 9-10 0.773 0.803 0.818	Seg 1011 0.814 0.833 0.852	Sum 4.683 4.816 4.917	4.767 4.867 4.967	1.76% 1.05% 1.01%
5% 10% 15% 20%	Seg 39-9 0.810 0.829 0.838 0.847	Seg 9-10 0.743 0.773 0.788 0.795	Seg 1011 0.778 0.797 0.814 0.833	Sum 4.434 4.550 4.617 4.675	4.500 4.583 4.650 4.700	1.47% 0.72% 0.71% 0.53%	5% 10% 15% 20%	Seg 39-9 0.861 0.884 0.903 0.919	Seg 9-10 0.773 0.803 0.818 0.818	Seg 1011 0.814 0.833 0.852 0.870	Sum 4.683 4.816 4.917 4.991	4.767 4.867 4.967 5.050	1.76% 1.05% 1.01% 1.17%
5% 10% 15% 20% 25%	Seg 39-9 0.810 0.829 0.838 0.847 0.858	Seg 9-10 0.743 0.773 0.788 0.795 0.803	Seg 1011 0.778 0.797 0.814 0.833 0.842	Sum 4.434 4.550 4.617 4.675 4.729	4.500 4.583 4.650 4.700 4.767	1.47% 0.72% 0.71% 0.53% 0.81%	5% 10% 15% 20% 25%	Seg 39-9 0.861 0.884 0.903 0.919 0.938	Seg 9-10 0.773 0.803 0.818 0.818 0.834	Seg 1011 0.814 0.833 0.852 0.870 0.889	Sum 4.683 4.816 4.917 4.991 5.092	4.767 4.867 4.967 5.050 5.150	1.76% 1.05% 1.01% 1.17% 1.13%
5% 10% 15% 20% 25% 30%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852	Sum 4.434 4.550 4.617 4.675 4.729 4.784	4.500 4.583 4.650 4.700 4.767 4.817	1.47% 0.72% 0.71% 0.53% 0.81% 0.69%	5% 10% 15% 20% 25% 30%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908	Sum 4.683 4.816 4.917 4.991 5.092 5.200	4.767 4.867 4.967 5.050 5.150 5.250	1.76% 1.05% 1.01% 1.17% 1.13% 0.95%
5% 10% 15% 20% 25% 30% 35%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850	4.500 4.583 4.650 4.700 4.767 4.817 4.867	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35%	5% 10% 15% 20% 25% 30% 35%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292	4.767 4.867 4.967 5.050 5.150 5.250 5.367	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40%
5% 10% 15% 20% 25% 30% 35% 40%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.841	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.908	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18%	5% 10% 15% 20% 25% 30% 35% 40%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82%
5% 10% 15% 20% 25% 30% 35% 40% 45%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.894	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.841 0.848	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889 0.908	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.908 4.967	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18% 0.00%	5% 10% 15% 20% 25% 30% 35% 40% 45%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000 1.026	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.864	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.583	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.33%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.894	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.841 0.848 0.864	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889 0.908	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.908 4.967 5.033	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967 5.033	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18% 0.00%	5% 10% 15% 20% 25% 30% 35% 40% 45% 50%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000 1.026 1.051	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.864 0.879	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944 0.963	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509 5.625	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.583 5.700	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.33%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.894 0.903	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.841 0.848 0.864	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889 0.908 0.926	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.908 4.967 5.033 5.117	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967 5.033 5.117	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18% 0.00% 0.00%	5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000 1.026 1.051	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.864 0.879 0.886 0.894	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944 0.963 0.981	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509 5.625 5.774	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.583 5.700 5.783	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.33% 0.16%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.894 0.903 0.917 0.928	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.841 0.848 0.864 0.879 0.894	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889 0.908 0.926 0.944	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.908 4.967 5.033 5.117 5.192	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967 5.033 5.117 5.200	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18% 0.00% 0.00% 0.00%	5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000 1.026 1.051 1.086	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.864 0.879 0.886 0.894 0.909	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944 0.963 0.981 1.000	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509 5.625 5.774 5.933	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.583 5.700 5.783 5.883	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.33% 0.16% 0.85%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.903 0.917 0.928 0.942	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.844 0.848 0.864 0.879 0.894 0.916	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.989 0.908 0.926 0.944 0.963	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.967 5.033 5.117 5.192 5.283	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967 5.033 5.117 5.200 5.317	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.18% 0.00% 0.00% 0.00% 0.00% 0.15%	5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000 1.026 1.051 1.086 1.120 1.153	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.856 0.879 0.886 0.894 0.909 0.925	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944 0.963 0.981 1.000 1.019	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509 5.625 5.774 5.933 6.084	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.583 5.700 5.783 5.883 6.000	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.33% 0.16% 0.85% 1.40%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.903 0.917 0.928 0.942 0.961	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.844 0.864 0.879 0.894 0.916 0.939	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889 0.926 0.944 0.963 0.981 1.000	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.967 5.033 5.117 5.192 5.283 5.391	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967 5.033 5.117 5.200 5.317 5.450	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18% 0.00% 0.00% 0.00% 0.15% 0.64%	5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000 1.026 1.051 1.086 1.120 1.153 1.185	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.864 0.879 0.886 0.894 0.909 0.925 0.939	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944 0.963 0.981 1.000 1.019 1.037	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509 5.625 5.774 5.933 6.084 6.233	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.583 5.700 5.783 5.883 6.000 6.117	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.33% 0.16% 0.85% 1.40%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.903 0.917 0.928 0.942 0.961 0.981	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.844 0.848 0.864 0.879 0.894 0.916 0.939 0.955	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889 0.908 0.926 0.944 0.963 0.981 1.000 1.019	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.908 4.908 4.903 5.117 5.192 5.283 5.391 5.500	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967 5.033 5.117 5.200 5.317 5.450 5.550	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18% 0.00% 0.00% 0.00% 0.15% 0.64% 1.08% 0.90%	5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.006 1.026 1.051 1.086 1.120 1.153 1.185	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.864 0.879 0.886 0.894 0.909 0.925 0.939 0.955	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944 0.963 0.981 1.000 1.019 1.037	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509 5.625 5.774 5.933 6.084 6.233 6.400	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.583 5.700 5.783 5.883 6.000 6.117 6.233	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.33% 0.16% 0.85% 1.40% 1.90% 2.68%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.903 0.917 0.928 0.942 0.961 0.981	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.841 0.848 0.864 0.879 0.894 0.916 0.939 0.955 0.970	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889 0.908 0.926 0.944 0.963 0.981 1.000 1.019 1.037	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.908 4.903 5.117 5.192 5.283 5.391 5.500 5.595	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967 5.033 5.117 5.200 5.317 5.450 5.633	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18% 0.00% 0.00% 0.15% 0.64% 1.08% 0.90% 0.67%	5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000 1.026 1.051 1.185 1.185 1.218	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.864 0.879 0.886 0.894 0.909 0.925 0.939 0.955	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944 0.963 0.981 1.000 1.019 1.037 1.074 1.092	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509 5.625 5.774 5.933 6.084 6.233 6.400 6.583	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.583 5.700 5.783 5.883 6.000 6.117 6.233 6.378	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.33% 0.16% 0.85% 1.40% 1.90% 2.68% 3.21%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.994 0.903 0.917 0.928 0.942 0.961 0.981 0.999 1.014	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.841 0.848 0.867 0.894 0.916 0.939 0.955 0.970 1.000	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889 0.908 0.926 0.944 0.963 0.981 1.000 1.019 1.037 1.074	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.908 4.967 5.033 5.117 5.192 5.283 5.391 5.500 5.595 5.717	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967 5.033 5.117 5.200 5.317 5.450 5.633 5.700	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18% 0.00% 0.00% 0.00% 0.15% 0.64% 1.08% 0.90% 0.67%	5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000 1.026 1.051 1.086 1.120 1.153 1.185 1.218 1.259	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.864 0.879 0.886 0.8894 0.909 0.925 0.939 0.955 0.970 0.993	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944 0.963 0.981 1.000 1.019 1.037 1.074 1.092 1.130	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509 5.625 5.774 5.933 6.084 6.233 6.400 6.583 6.792	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.583 5.700 5.783 5.883 6.000 6.117 6.233 6.378 6.550	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.32% 0.16% 0.85% 1.40% 1.90% 2.68% 3.21%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.994 0.903 0.917 0.928 0.942 0.961 0.991 1.014 1.033	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.841 0.848 0.867 0.894 0.916 0.939 0.955 0.970 1.000 1.015	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889 0.908 0.926 0.944 0.963 0.981 1.000 1.019 1.037 1.074 1.092	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.908 4.967 5.033 5.117 5.192 5.283 5.391 5.500 5.595 5.717 5.817	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967 5.033 5.117 5.200 5.317 5.450 5.550 5.633 5.700 5.800	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18% 0.00% 0.00% 0.00% 0.15% 0.64% 1.08% 0.90% 0.67% 0.30% 0.29%	5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000 1.026 1.051 1.086 1.120 1.153 1.185 1.218 1.259 1.301	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.864 0.879 0.886 0.894 0.909 0.925 0.939 0.955 0.970 0.993 1.023	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944 0.963 0.981 1.000 1.019 1.037 1.074 1.092 1.130 1.176	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509 5.625 5.774 5.933 6.084 6.233 6.400 6.583 6.792 7.049	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.700 5.783 5.883 6.000 6.117 6.233 6.378 6.550 6.750	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.33% 1.32% 0.16% 0.85% 1.40% 1.90% 2.68% 3.21% 3.69% 4.43%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.994 0.903 0.917 0.928 0.942 0.961 0.981 0.999 1.014	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.841 0.848 0.867 0.894 0.916 0.939 0.955 0.970 1.000	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889 0.908 0.926 0.944 0.963 0.981 1.000 1.019 1.037 1.074 1.092 1.139	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.908 4.967 5.033 5.117 5.192 5.283 5.391 5.500 5.595 5.717	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967 5.033 5.117 5.200 5.317 5.450 5.633 5.700	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18% 0.00% 0.00% 0.00% 0.15% 0.64% 1.08% 0.90% 0.67%	5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000 1.026 1.051 1.086 1.120 1.153 1.185 1.218 1.259	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.864 0.879 0.886 0.8894 0.909 0.925 0.939 0.955 0.970 0.993	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944 0.963 0.981 1.000 1.019 1.037 1.074 1.092 1.130 1.176 1.259	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509 5.625 5.774 5.933 6.084 6.233 6.400 6.583 6.792	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.583 5.700 5.783 5.883 6.000 6.117 6.233 6.378 6.550	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.33% 0.16% 0.85% 1.40% 1.90% 2.68% 3.21%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 65% 70% 75% 80% 85% 90%	Seg 39-9 0.810 0.829 0.838 0.847 0.858 0.866 0.875 0.884 0.994 0.903 0.917 0.928 0.942 0.961 0.991 1.014 1.033	Seg 9-10 0.743 0.773 0.788 0.795 0.803 0.818 0.834 0.841 0.848 0.867 0.894 0.916 0.939 0.955 0.970 1.000 1.015	Seg 1011 0.778 0.797 0.814 0.833 0.842 0.852 0.870 0.889 0.908 0.926 0.944 0.963 0.981 1.000 1.019 1.037 1.074 1.092	Sum 4.434 4.550 4.617 4.675 4.729 4.784 4.850 4.908 4.967 5.033 5.117 5.192 5.283 5.391 5.500 5.595 5.717 5.817	4.500 4.583 4.650 4.700 4.767 4.817 4.867 4.917 4.967 5.033 5.117 5.200 5.317 5.450 5.550 5.633 5.700 5.800	1.47% 0.72% 0.71% 0.53% 0.81% 0.69% 0.35% 0.18% 0.00% 0.00% 0.00% 0.15% 0.64% 1.08% 0.90% 0.67% 0.30% 0.29%	5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90%	Seg 39-9 0.861 0.884 0.903 0.919 0.938 0.958 0.977 1.000 1.026 1.051 1.086 1.120 1.153 1.185 1.218 1.259 1.301	Seg 9-10 0.773 0.803 0.818 0.818 0.834 0.848 0.856 0.864 0.879 0.886 0.894 0.909 0.925 0.939 0.955 0.970 0.993 1.023	Seg 1011 0.814 0.833 0.852 0.870 0.889 0.908 0.926 0.926 0.944 0.963 0.981 1.000 1.019 1.037 1.074 1.092 1.130 1.176	Sum 4.683 4.816 4.917 4.991 5.092 5.200 5.292 5.383 5.509 5.625 5.774 5.933 6.084 6.233 6.400 6.583 6.792 7.049	4.767 4.867 4.967 5.050 5.150 5.250 5.367 5.483 5.700 5.783 5.883 6.000 6.117 6.233 6.378 6.550 6.750	1.76% 1.05% 1.01% 1.17% 1.13% 0.95% 1.40% 1.82% 1.33% 0.16% 0.85% 1.40% 1.90% 2.68% 3.21% 3.69% 4.43%

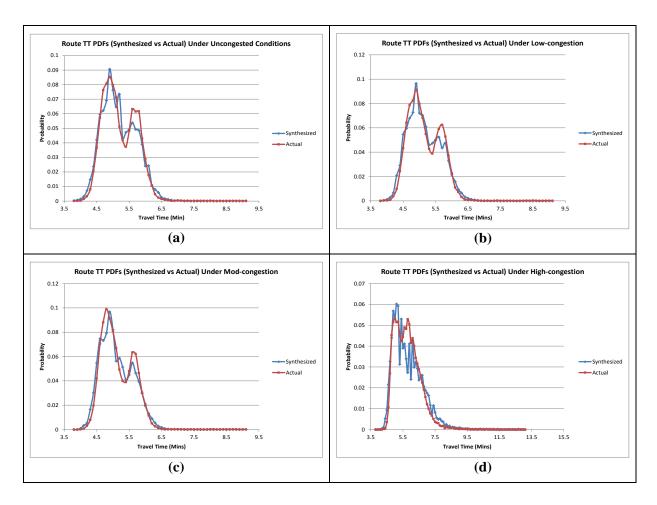


Figure 1: Comparisons between the travel time density functions synthesized from individual segment percentiles (squares) and the observed values (dots).