Chapter 6 – Sample Application of Model

6.0 Method of Application

The I-81 network developed simulated five different conditions for both the AM and PM peak conditions along the I-81 section of interest. In order to do so, the number of cars for each peak period was held constant while the different types of trucks used were varied. For instance, the first four simulations of INTEGRATION were done using all cars (base case), 100 lb/hp, 200 lb/hp, and 300 lb/hp trucks, while the fifth used a combination of all three trucks, that is, one-third of the three types of trucks. The results presented below are not conclusive, but show the different types of analysis that can be performed from projects of this kind.

6.1 Analysis of Results

As mentioned at the beginning of this chapter, there were five different scenarios that were tested for both the AM and PM peak volumes. The first scenario was the simulation of the network for cars only, the base case, followed by the 100lb/hp, 200lb/hp, and 300lb/hp trucks, and a combination of all three different types of trucks. Both sets of results turned out to be fairly consistent with each other. The first set of results examined was the AM peak.

6.1.1 Results for AM Peak

The results that were obtained from the AM peak turned out to be quite interesting. They showed that as the lb/hp ratio of the trucks increased, so did the average travel time for both the trucks and the cars. Although the travel time for cars remained lower than that of the trucks when the simulation was performed for the individual trucks, the absolute difference in average travel time between the trucks and cars remained somewhat constant. The base case showed a considerably lower travel time since there were no trucks to interfere with the traffic flow through overtaking maneuvers. Figure 6.1 illustrates how the average travel time for each vehicle type varied with the truck characteristics.

This figure also shows how the combination of all three trucks affected the travel time on the I-81 network. It shows that with 33% mixed of the three different types of trucks, the average travel time for the trucks turned out to be very close. For instance, the average travel time for the 100lb/hp, 200lb/hp, and 300 lb/hp trucks turned out to be 954 veh-sec, 960 veh-sec, and 912veh-sec, respectively, while the travel time for the base case was 628 veh-sec. Although the travel time for the 300 lb/hp trucks was expected to be a bit higher, it can be attributed to the fact that there were trucks overtaking cars down the grades. Table 6.1 shows a summary of the simulated results. The combination network also resulted in a travel time for cars that was slightly higher than the travel time for cars on the 100lb/hp truck network as shown in Figure 6.1.

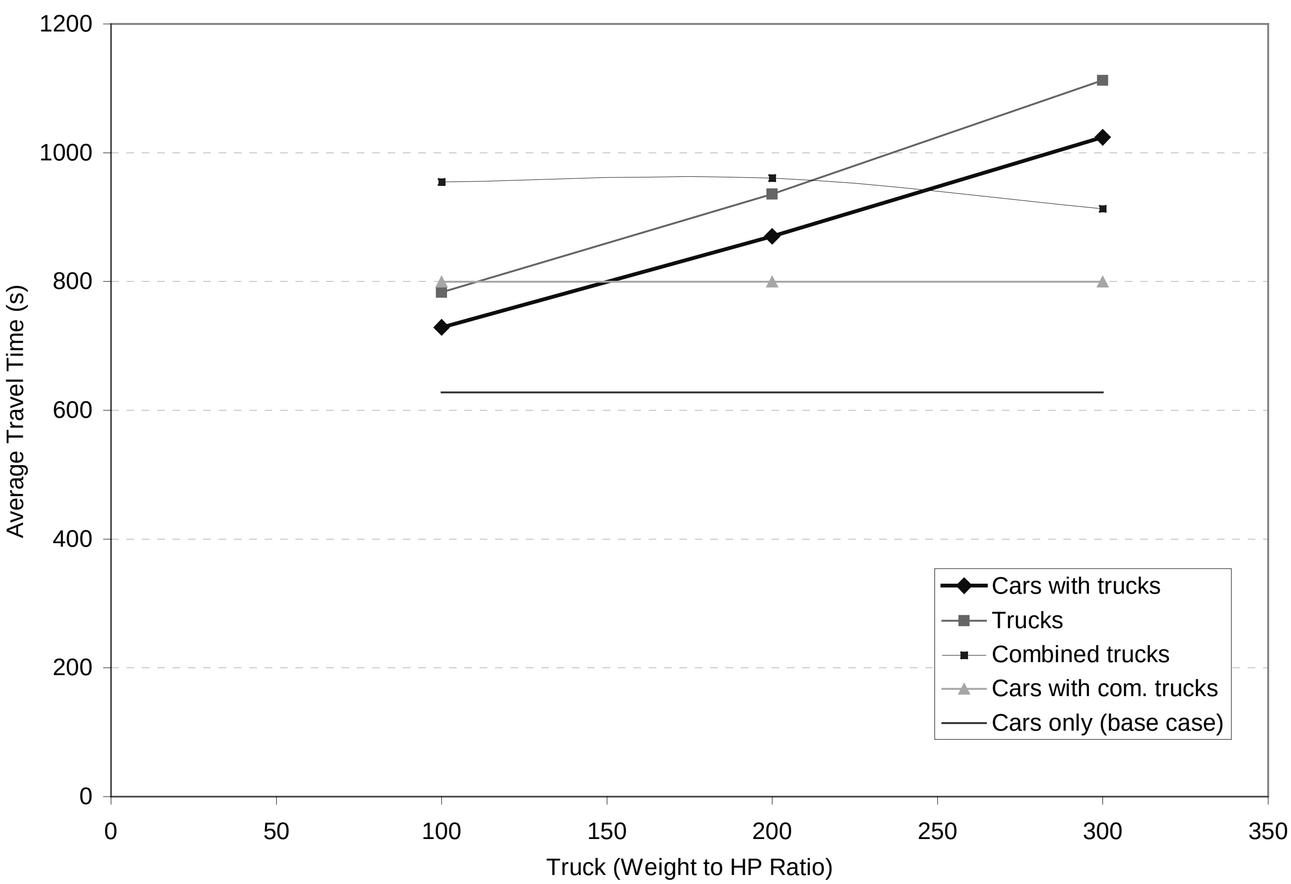

Figure 6.1. Graph showing how average travel time varies with the different types of trucks for the AM peak

Table 6.1. Summary table for AM peak

	CARS				TRUCKS			TOTAL(CARS+TRUCKS)			COMBINED TRUCKS			
											CARS	TRUCKS		
	Cars Only	100	200	300	100	200	300	100	200	300		100	200	300
vehicles	8085	6479	6479	6479	1606	1606	1606	8085	8085	8085	6479	551	530	525
veh-secs	5077997	4723909	5639417	6635655	1257461	1503298	1785924	5981370	7142715	8421579	5181646	526132	509114	479313
veh-km	127763	100871	100919	100922	27009	27022	27023	127880	127941	127945	100898	9760	8878	8382
veh-stops	6392	17659	21223	23783	4163	5372	6171	21822	26595	29954	25618	1876	1683	1561
wrng turn	0	0	0	0	0	0	0	0	0	0	0	0	0	0
fuel (l)	13062	11189	11203	11426	2949	2985	3053	14138	14188	14479	11807	1074	975	922
HC (g)	21444	22319	29863	37605	5906	7870	9960	28225	37733	47565	26489	2795	2850	2678
CO (g)	32339	28566	44814	60658	7494	11741	16029	36060	56555	76687	37800	4175	4455	4190
NO (g)	18058	15005	16534	17794	4002	4404	4747	19007	20938	22541	15880	1584	1494	1410
acc* 10e6	44241	34938	9353	34923	9353	9353	9346	44291	18706	44269	34940	3381	3073	2897
tot delay	228	2361	1895	12849	682	1895	3772	3043	3790	16621	3865	412	582	427
stp delay	151	2222	1846	12617	647	1846	3714	2869	3692	16331	3703	395	564	410
ac/dc del	76	139	48	231	35	48	58	174	96	289	161	17	18	16
persons	77	140	49	232	36	49	59	176	98	291	162	18	19	17
per-hrs	119	169	296	565	161	296	565	330	592	1130	163	170	2660	121
per-km	80	143	52	234	38	52	61	181	104	295	164	20	63	19
vehicles	1	1	1	1	1	1	1	1	1	1	1	1	1	1
veh-secs	628.076	729.111	870.415	1024.179	782.977	936.051	1112.033	739.81	883.45	1041.63	799.76	954.869	960.593	912.979
veh-km	15.802	15.569	15.576	15.577	16.818	16.826	16.827	15.82	15.82	15.82	15.573	17.713	16.751	15.967
veh-stops	0.791	2.726	3.276	3.671	2.592	3.345	3.843	2.70	3.29	3.70	3.954	3.406	3.176	2.975
wrng turn	0	0	0	0	0	0	0	0	0	0	0	0	0	0
fuel (l)	1.616	1.727	1.729	1.764	1.836	1.859	1.901	1.75	1.75	1.79	1.822	1.95	1.84	1.756
HC (g)	2.652	3.445	4.609	5.804	3.678	4.901	6.202	3.49	4.67	5.88	4.088	5.074	5.378	5.101
CO (g)	4.000	4.409	6.917	9.362	4.667	7.311	9.981	4.46	7.00	9.49	5.834	7.578	8.407	7.982
NO (g)	2.234	2.316	2.552	2.747	2.492	2.742	2.956	2.35	2.59	2.79	2.451	2.876	2.82	2.686
acc* 10e6	5.472	5.393	5.824	5.39	5.824	5.824	5.82	5.48	2.31	5.48	5.393	6.137	5.799	5.519
tot delay	0.028	0.365	1.18	1.983	0.425	1.18	2.349	0.38	0.47	2.06	0.597	0.749	1.098	0.814
stp delay	0.019	0.343	1.15	1.947	0.403	1.15	2.313	0.35	0.46	2.02	0.572	0.718	1.064	0.782
ac/dc del	0.009	0.022	0.03	0.036	0.022	0.03	0.036	0.02	0.01	0.04	0.025	0.031	0.034	0.032
persons	1	1	1	1	1	1	1	0.02	0.01	0.04	1	1	1	1
per-hrs	1.536	1.204	5.928	2.434	4.463	5.928	9.572	0.04	0.07	0.14	1.008	9.365	139.355	6.792
per-km	1.031	1.017	1.048	1.01	1.067	1.048	1.041	0.02	0.01	0.04	1.015	1.133	3.329	1.114

In addition to the average travel time, there were quite a few more analyses that were made. These included veh-stops, fuel consumption and emissions such as HC (g), CO (g), NO (g), and total delays. Figure 6.2 shows the average MOE estimates for trucks and cars. In terms of vehicle-minutes, it can be seen that the network with the 100lb/hp ratio trucks turned out to be the most efficient, followed by the combination trucks, 200lb/hp, and the 300lb/hp, respectively. The 100 lb/hp, 200 lb/hp, 300 lb/hp, and combined trucks coursed a 16, 38, 63, and 45 percent increase, respectively, in the average travel time for cars. This pattern could also be seen for the HC, CO, and NO emissions. The fuel consumption for the four different scenarios was very similar, that is 1.74, 1.75, 1.79, and 1.82 liters for the 100, 200, 300 lb/hp, and combined trucks, respectively. The number of vehicle stops observed increased with the lb/hp ratio but increased more with the combined trucks.

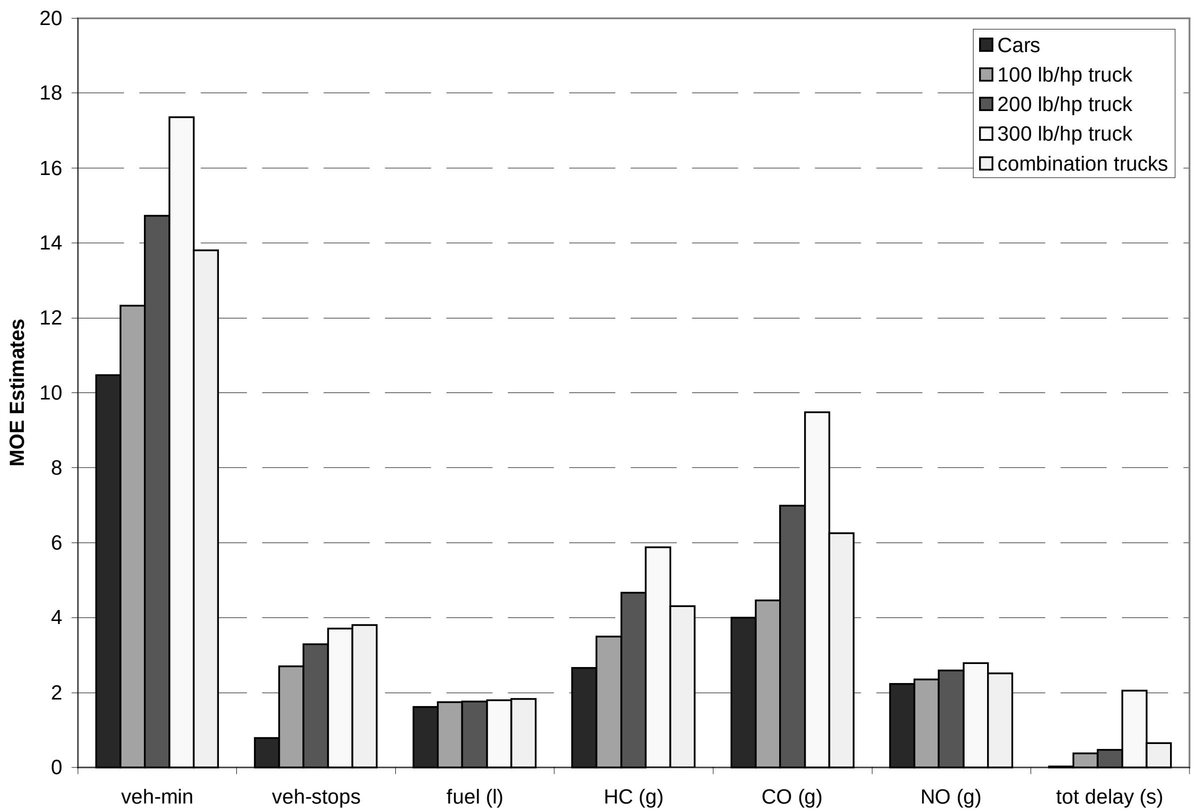

Figure 6.2. Graph showing MOE estimates for cars and trucks (AM peak)

The higher number of stops for the combined truck scenario results from the fact that the differences in truck power result in overtaking maneuvers that increase vehicle interaction, thus increasing the number of partial stops. In terms of delay (though small) it can be seen that the 300 lb/hp trucks generated the greatest delay. This occurrence was also due to the vehicle maneuvers. On average, trucks experienced a 12% increase in delay over cars.

6.1.2 Results for PM Peak

The results from the PM peak were identical to that of the AM peak with a few minor exceptions. Figure 6.3 shows a similar pattern to Figure 6.1, but a small increase in the average travel time for the 300lb/hp trucks is shown rather than a decrease, as in the case of the AM peak for the combined scenario. The average travel time for cars also turned out to be a little more than the 100lb/hp case. There was a 26, 75, 120, and 48 percent increase in the average travel time for cars when the 100 lb/hp, 200 lb/hp, 300 lb/hp, and combined trucks, respectively, were simulated against the base case. Table 6.2 also summarizes these results.

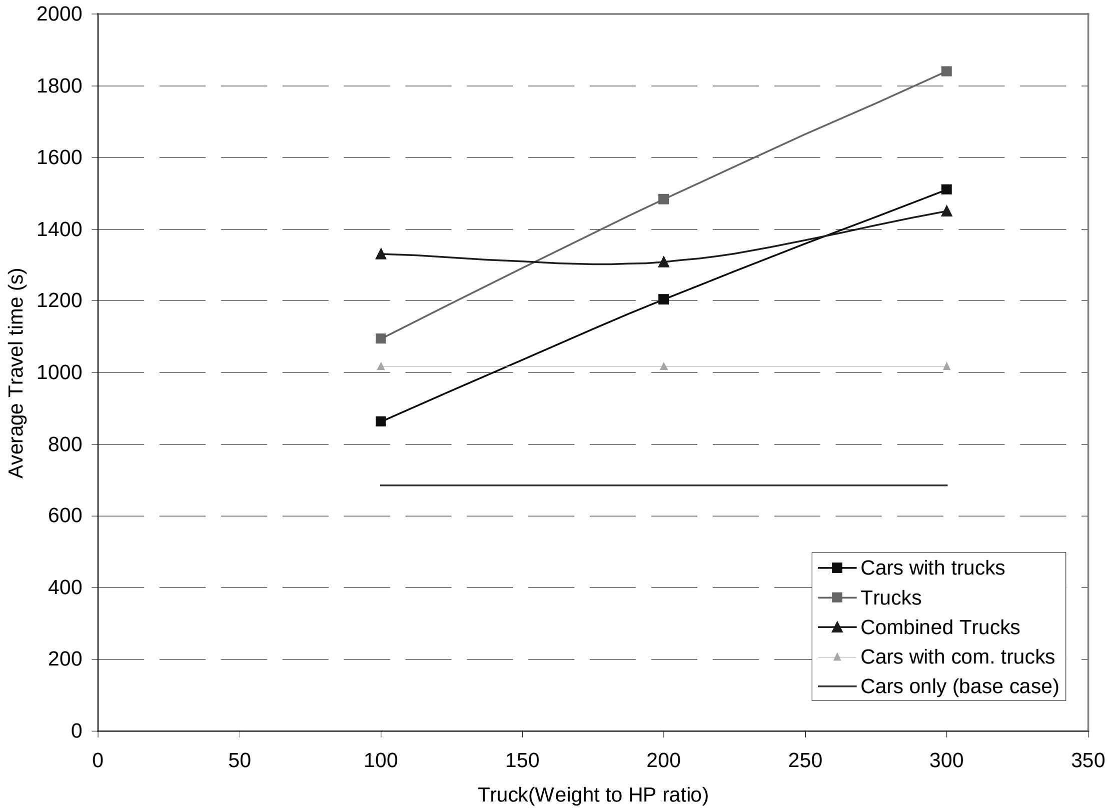

Figure 6.3. Graph showing how average travel time varies with the different types of trucks for PM peak

The next graph presented in Figure 6.4 again shows the same pattern for the MOE estimates. The 100 lb/hp trucks gave the best results followed by the combined trucks, the 200 lb/hp and then the 300lb/hp trucks. One exception to these results was the number of stops. The PM peak showed fewer number of stops for the combined trucks than the 300 lb/hp trucks. The fuel consumption and emissions also gave similar results, that is, the fuel consumption was almost the same for the four different scenarios while the HC, CO, and NO emissions illustrated that the most efficient model was the 100lb/hp trucks followed by the combined model. The average delay per vehicle turned out to be higher than that of the AM peak since there was a greater traffic volume on for the PM peak. For instance, there were a total of 10060 vehicles discharged over one hour for the PM peak while 8085 vehicles were charged for the AM peak. It can also be seen from Figure 6.4 that the magnitude of the delay corresponds to the average travel. Again, it can be seen that the 300 lb/hp trucks created the greatest delay because of vehicle interaction during overtaking maneuvers. Trucks show an average of a 13% increase in delays over cars, but could be as high as 18% as in the case of the 300 lb/hp trucks.

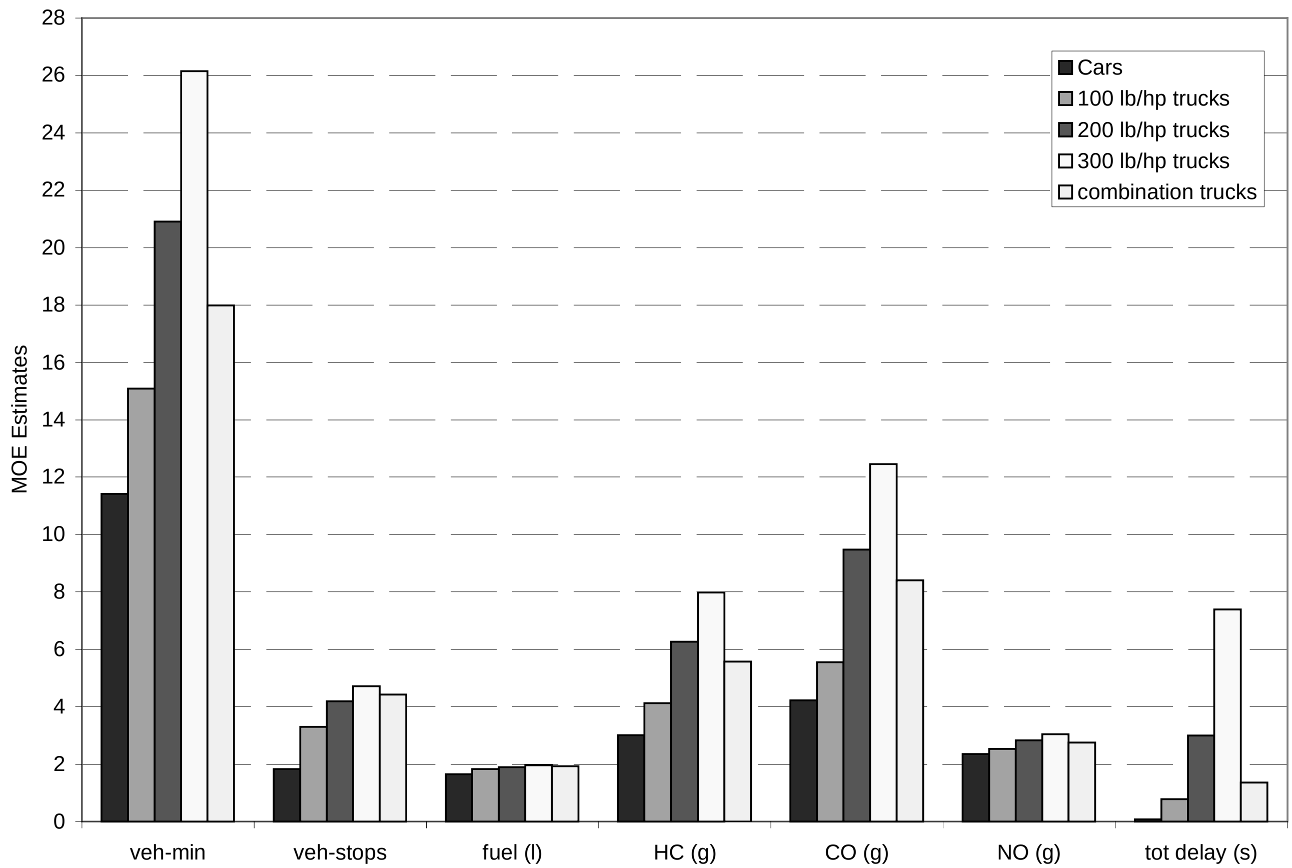

Figure 6.4. Graph showing MOE estimates for cars and trucks (PM peak)

Table 6.2. Summary table for PM peak

											COMBINED TRUCKS			
	CARS				TRUCKS			TOTAL(CARS+TRUCKS)			CARS	TRUCKS		
	Cars Only	**100**	**200**	**300**	**100**	**200**	**300**	**100**	**200**	**300**		**100**	**200**	**300**
vehicles	10060	9188	9188	9188	1992	1992	1992	11180	11180	11180	9188	664	662	665
veh-secs	6895602	7936659	11067482	13880608	2180094	2955139	3665448	10116753	14022621	17546056	9345720	883863	866337	964666
veh-km	164426	142150	142211	142209	40718	40737	40738	182868	182948	182947	142190	13451	12826	14413
veh-stops	8439	29382	37130	41549	7567	9774	11131	36949	46904	52680	40497	3069	2770	3115
wrng turn	0	0	0	0	0	0	0	0	0	0	0	0	0	0
fuel (l)	16583	16014	16558	17151	4491	4644	4808	20505	21202	21959	16974	1511	1434	1604
HC (g)	30252	36260	55223	70377	9947	14821	18948	46207	70044	89325	47631	4655	4687	5287
CO (g)	42553	48887	83700	109658	13179	22298	29590	62066	105998	139248	71142	7139	7389	8344
NO (g)	23564	21966	24729	26541	6209	6953	7477	28175	31682	34018	23793	2290	2230	2509
acc* 10e6	56946	49211	49214	49204	14130	14132	14127	63341	63346	63331	49214	4666	4446	5003
tot delay	814	7157	27312	65838	1548	6175	16853	8705	33487	82691	11616	1209	1088	1213
stp delay	695	6949	27024	65497	1504	6117	16785	8453	33141	82282	11384	1189	1067	1192
ac/dc del	119	207	288	340	44	57	68	251	345	408	231	19	20	20
persons	120	208	289	341	45	58	69	253	347	410	232	20	21	21
per-hrs	256	318	356	386	589	1413	2231	907	1769	2617	330	115	809	800
per-km	125	214	294	347	47	61	71	261	355	418	237	22	24	24
vehicles	1	1	1	1	1	1	1	1	1	1	1	1	1	1
veh-secs	685.448	863.81	1204.56	1510.73	1094.43	1483.50	1840.08	904.90	1254.26	1569.41	1017.17	1331.12	1308.67	1450.63
veh-km	16.345	15.47	15.48	15.48	20.44	20.45	20.45	16.36	16.36	16.36	15.48	20.26	19.38	21.67
veh-stops	0.839	3.20	4.04	4.52	3.80	4.91	5.59	3.30	4.20	4.71	4.41	4.62	4.19	4.68
wrng turn	0	0	0	0	0	0	0	0	0	0	0	0	0	0
fuel (l)	1.648	1.74	1.80	1.87	2.26	2.33	2.41	1.83	1.90	1.96	1.85	2.28	2.17	2.41
HC (g)	3.007	3.95	6.01	7.66	4.99	7.44	9.51	4.13	6.27	7.99	5.18	7.01	7.08	7.95
CO (g)	4.23	5.32	9.11	11.94	6.62	11.19	14.86	5.55	9.48	12.46	7.74	10.75	11.16	12.55
NO (g)	2.342	2.39	2.69	2.89	3.12	3.49	3.75	2.52	2.83	3.04	2.59	3.45	3.37	3.77
acc* 10e6	5.661	5.36	5.36	5.36	7.09	7.10	7.09	5.67	5.67	5.66	5.36	7.03	6.72	7.52
tot delay	0.081	0.78	2.97	7.17	0.78	3.10	8.46	0.78	3.00	7.40	1.26	1.82	1.64	1.83
stp delay	0.069	0.76	2.94	7.13	0.76	3.07	8.43	0.76	2.96	7.36	1.24	1.79	1.61	1.79
ac/dc del	0.012	0.02	0.03	0.04	0.02	0.03	0.03	0.02	0.03	0.04	0.03	0.03	0.03	0.03
persons	1	1.00	1.00	1.00	1.00	1.00	1.00	0.02	0.03	0.04	1.00	1.00	1.00	1.00
per-hrs	2.135	1.52	1.23	1.13	13.01	24.06	32.11	0.08	0.16	0.23	1.42	5.68	37.13	36.57
per-km	1.044	1.03	1.02	1.02	1.05	1.04	1.04	0.02	0.03	0.04	1.02	1.10	1.11	1.11

7.0 Conclusions

Although the results of this project were not the main focus, the results obtained show how INTEGRATION could be used as a simulation tool for modeling of trucks on an interstate with significant grades. As shown from both the AM and PM peak periods, the ability to include grades and different truck combinations to compute average travel times, vehicle stops, delays, and fuel consumption and emissions, just to name a few, is of great importance to any transportation engineer. With acceleration constraints added to INTEGRATION, the model captures vehicle dynamics, vehicle-to-vehicle interaction (car-following and lane-changing behavior), and the vehicle-to-control interaction (e.g. how vehicles behave at traffic signals, stop signs, ramp meters, etc.).

From simulation of the different truck combinations for both the AM and PM peaks, it was illustrated that 100 lb/hp trucks were the most efficient on the network. This was expected since the travel time experienced by these trucks was the most economical. The 200 lb/hp trucks came second, followed by the combined trucks and 300 lb/hp trucks. This was also reflected in the number of vehicle stops that resulted in lower fuel consumption and emissions.

It must also be re-emphasized that the main focus of the project was to show that simulation can be used and must be used in order to capture many of the factors that affect traffic flow on the U.S. highway system due to the increase in complexity. For example, the interactions between vehicles on a highway were not complete, since there were many issues concerning the behavior of trucks that were not addressed.

7.1 Recommendation

The results obtained from project showed how the use of simulation can capture the various traffic flow conditions with the presence trucks having different performance capabilities. It also showed how grades along a highway could impact parameters, such as, travel time and delays. Although these factors are important to transportation engineers, it is believed that more work should be done in other areas in order to maximize the potential for the improvement of traffic flow on interstates. Some of the areas identified to facilitate future studies and research are:

- the need to get data from weigh stations in order to obtain information such as the truck types and weight of trucks.
- the need to consider alternatives to improving long grade sections (e.g. adding climbing lanes, restricting trucks during pick hour)
- to study the impact of trucks during construction
- use of alternate routes
- to expand the network to include the entire I-81 in Virginia

These areas have proved to be of significant importance to traffic flow and can be evaluated with the use the simulation software INTEGRATION, which takes into consideration all of the factors influencing traffic flow on interstates.

References

Demarchi, S., Rakha, H., Van Aerde, M., and Setti, J. R. (1999). *Modeling Truck Dynamics Using a Second-Order Motion Model*. University de Sao Paulo, Brazil.

Fitch, J.W. (1994). *Motor Truck Engineering Handbook.* Society of Automotive Engineers, 4th Edition.

Hoel, A. H.; Vidunas, J. E. (1997). *Exclusive Lanes for Trucks and Passenger Vehicles on Interstate Highways in Virginia*: An Economic Evaluation. Virginia Transportation Research Council

Papacostas, C.S. and Prevedouros, P.D. (1993). *Transportation Engineering and Planning*, Prentice-Hall, Inc., 2nd Edition.

Road Transport Research (1992). *Cargo Routes: Truck Roads and Networks*. Prepared by an OECD Scientific Expert Group.

TRB (1994). *Highway Capacity Manual*. *Special Report 209*. National Research Council, Washington D.C. 3rd Edition.

Truckline (1998). *Trucking Facts and Industry Issues.* http://www.trucking.org/trucking_facts/press/dri2006.htm

Van Aerde, M. (1997). *INTEGRATION Release 2*, User's guide Volumes I and II. Fundamental Model Features.

Van Aerde, M. (1997). *QueensOD Release 2.0*, User's guide. Estimating Dynamic Origin-Destination Traffic Demands from Link Flow Counts.

VDOT (1992). *Interstate Route 81 Corridor Study*. Town of Christiansburg, Montgomery County, Roanoke County, City of Salem, Botetourt County.

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