Truck Blockage of Signals

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A previously developed and validated model of truck blockage of the line of sight of traffic signals was used to determine the extent of expected blockage as a function of signal location, traffic volume, and composition of approaching traffic. Both parametric analysis and simulation experiments were used. It was found that the relative effectiveness of various possible signal locations in minimizing expected truck blockage varied between one- and two-lane approaches and between the left and right lane of two-lane approaches. The simulation studies covered a wide range of speed, volume, and truck percentage conditions for 10 common two-head signal configurations as well as for 1 single-head configuration. Both horizontal and vertical locations of the individual signal heads were found to have an effect on expected blockage. Increasing volume and increasing truck percentage result in an increase in expected blockage.

A traffic control signal is an information source transmitting on the line of sight. Any interruption of the line of sight between a traffic control signal and a driver adversely affects the timely and accurate reception of the information concerning signal presence and state of the signal. Minimizing the potential of such line of sight interruption is, therefore, a critical element in the design of traffic signal installation. For that reason it received considerable attention as part of National Cooperative Highway Research Program Project 3-23 (1).

A common cause of interruption of the line of sight is the presence of large trucks or buses operating in the traffic stream. The extent of this blockage phenomenon was evaluated by developing an analytical model of the blockage geometry and applying it to highway traffic conditions. The analytical model that has been developed (1) generates a set of blockage curves that are used in the subsequent analysis.

GEOMETRIC PARAMETERS

It is assumed that the intersection approach is a straight and level road throughout the region of interest. In our application, we restrict the length of the approach to 305 m (1000 ft) as measured from the traffic signal position. The lateral position of the traffic signals can be within or beyond the lateral roadway boundaries; signal height is also variable. All trucks and vehicles are assumed to be centered within their respective lanes. Each truck is represented as a rectangular solid in order to simplify the geometrics.

The motorist's eye is assumed to be 1.4 m (4.6 ft) to the right of the left edge of its lane and 1.2 m (4.0 ft) above the pavement. The size of the truck (length, width, and height) and the lane location of the truck can be varied. An average lane width of 3.7 m (12 ft) is assumed; however, this value can be varied. The analysis considers truck blockage for all combinations of truck and vehicle positions. The two basic situations treated are: (a) truck and vehicle in the same lane and (b) truck and vehicle in different lanes. In the first situation, the line of sight blockage is due mainly to the rear profile of the truck; in the other, blockage is caused primarily by the side profile of the truck.

For any given truck-to-signal distance and any vehicle-to-truck separation, a determination can be made of whether the view of the signal from a vehicle is obstructed. A set of curves has been produced that separate the intersection approach into blocked and unblocked regions as a function of the stated specifications. These curves have been designed for use with the Urban Traffic Control System 1 (UTCS-1) traffic simulation model to determine the percentage of time that vehicles are blocked when approaching an intersection. Three general heights were used: 4.9 and 6.1 m (16 and 20 ft) for overhead signals and 2.7 m (9 ft) for post-top mounted signals.

One signal position at a time was analyzed, and multiple signal arrangements were analyzed by combining the results obtained for each signal.

After several trial runs truck height was found to be the most sensitive variable and truck length was found to be the least important. Truck widths do not vary much, and a value of 8 ft (2.4 m) was used throughout.

Because of the insensitivity of truck length, only two truck sizes were selected. These sizes, given in meters, are as follows (1 m = 3.28 ft):

Height	Width	Length
3.0	2.4	10.7
3.8	2.4	10.7

These variable values define the following set of cases that were run:

1. Fourteen lateral signal positions [-8.2 m (-27 ft) and -4.6 m (-15 ft) to +8.2 m (+27 ft) in 0.9-m (0.3-ft) increments];
2. Three signal heights [4.9 and 6.1 m (16 and 20 ft) for all 14 lateral locations and 2.7 m (9 ft) for -8.2, 7.3, and 8.2 m (-27, 24, and 27 ft)]; and
3. Two truck sizes.

PARAMETRIC STUDIES

The effect on truck blockage for the following common signal positions was studied:

1. Far right, post mounted;
2. Far left, post mounted;
3. Center of intersection;
4. Center of each lane, far side of intersection overhead; and
5. Lane line.

Post-mounted signals were assumed to be at a height of 2.7 m (9 ft). Overhead signals were evaluated at two different heights—4.9 and 6.1 m (16 and 20 ft). For this study, the traffic signal is considered to be a point source. The signal positions used are shown in Figure 1.

The results for the single-lane case are shown in Figure 2; the results for the two-lane case are shown in Figures 3 and 4. In each figure, the area to the left of the line corresponding to a given signal position defines the blockage region.

One-Lane Case

Of the five individual signal positions tested, the low-mounted, far left position gave the least blockage; the overhead, center of lane position, at 4.9 m (16 ft), gave the most blockage. The other three signal positions yielded intermediate amounts of blockage with a maximum difference of 8 percent in time of blockage between them.

A traffic stream of 600 vehicles/h/lane at 48 km/h (30 mph) results in a mean space headway of 80.5 m (264 ft). This is equivalent, for the assumed 10.7-m (35-ft) truck, to a vehicle-truck separation of 69.8 m (229 ft). Reference to Figure 2 shows that, at this separation, there is no blockage at any time of the post-

Figure 1. Signal position.

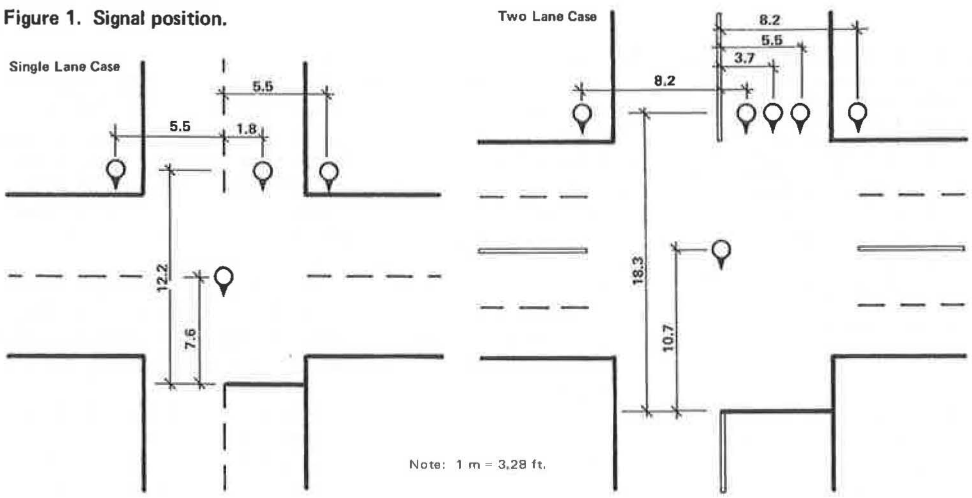
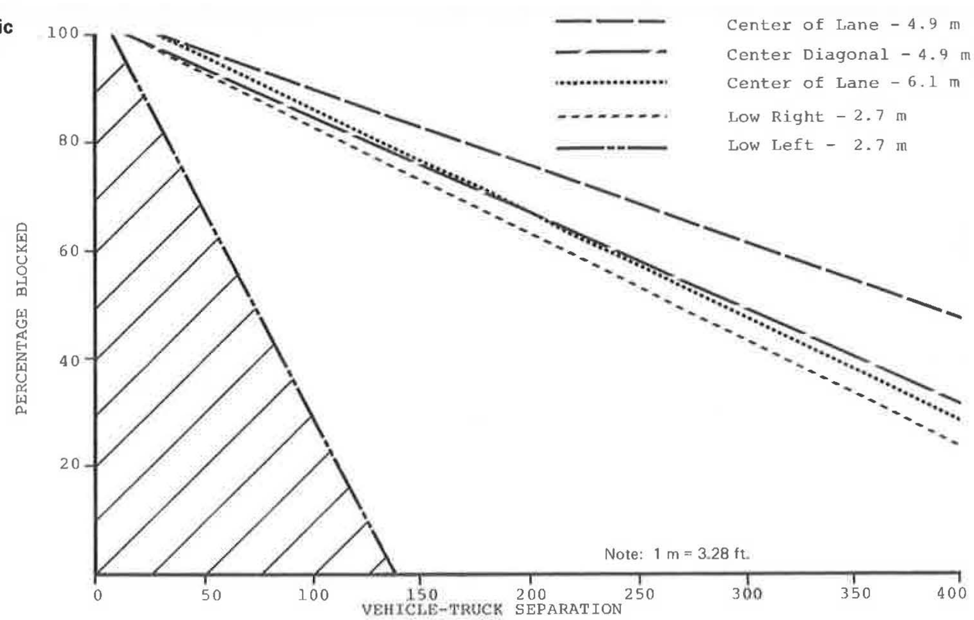


Figure 2. Truck blockage parametric study, single-lane case.



mounted, far left signal head. On the other hand, blockage percentages for the other four positions are as follows (1 m = 3.28 ft):

Position	Blockage
Center of lane at 4.9 m	72
Center diagonal at 4.9 m	62
Center of lane at 6.1 m	62
Post mounted, far right	58

An appreciable amount of blockage (>20 percent) of the far left, post-mounted signal will not occur until the vehicle-truck separation is reduced to 34.1 m (112 ft). This is the mean separation to be expected in a traffic stream of 600 vehicles/h/lane at 27.3 km/h (17 mph) or in a traffic stream of 1080 vehicles/h/lane at 48.2 km/h (30 mph). These values represent D or E level of service according to the Highway Capacity Manual (2). Under these conditions, car-following behavior, rather than signal-observance behavior, is the rule and potential

Figure 3. Truck blockage parametric study, two-lane case (car lane = 2, truck lane = 2).

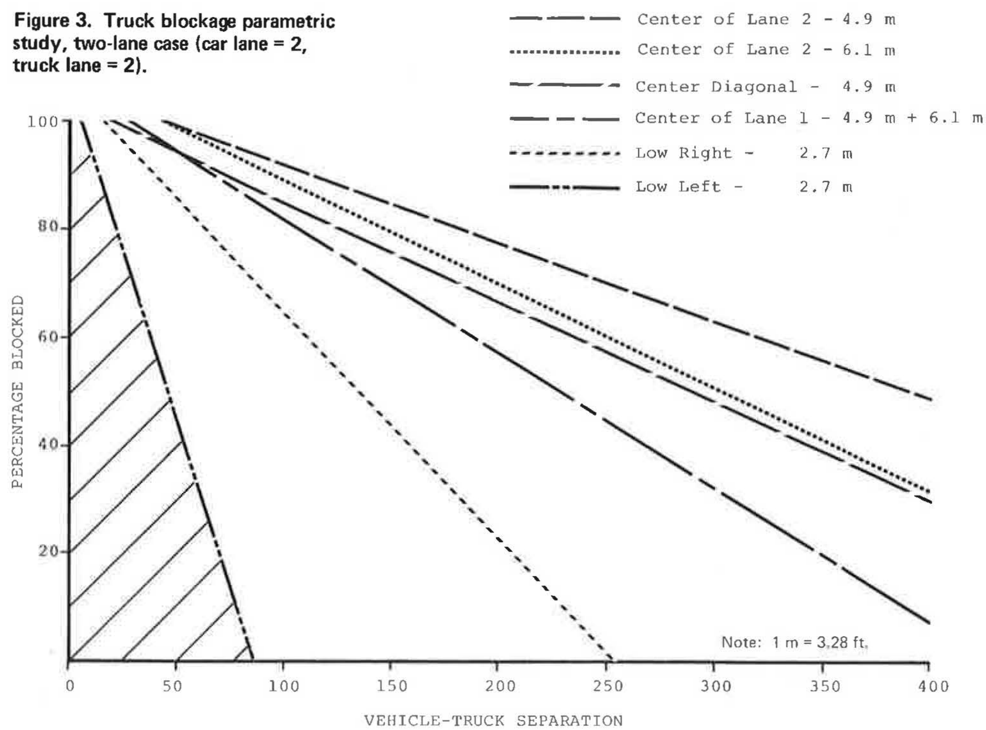
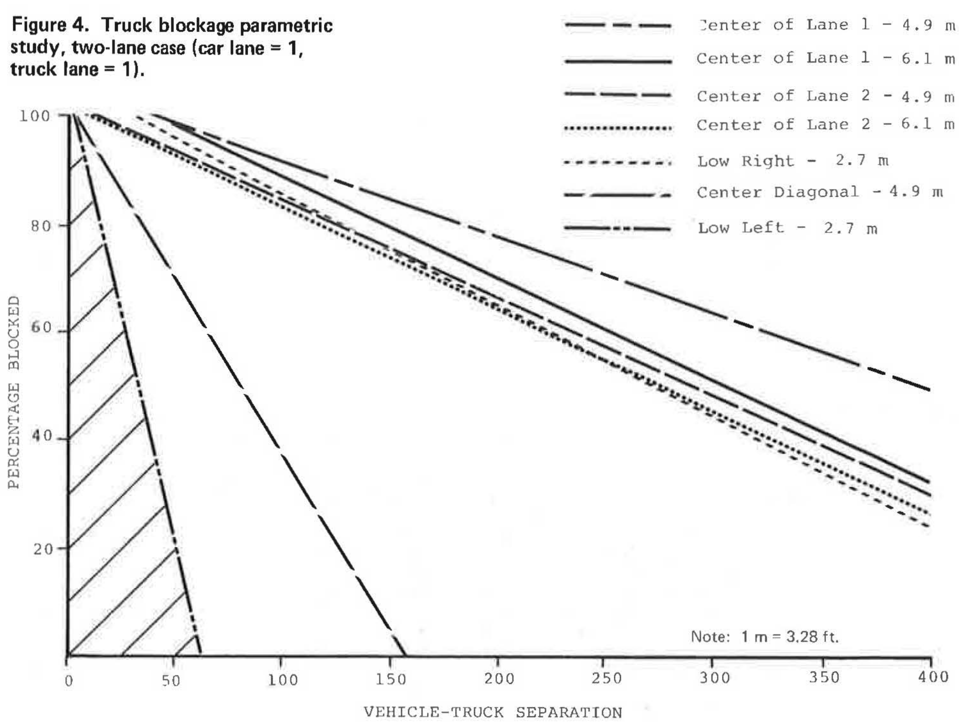


Figure 4. Truck blockage parametric study, two-lane case (car lane = 1, truck lane = 1).



blockage assumes a lesser importance. A similar set of parameters for the other signal positions is given in Table 1.

Two-Lane Case

The two-lane case is presented in somewhat more detail because differences with the single-lane case as well as between the two lanes themselves exist.

A greater number of signal head positions could be considered for the two-lane case. Examination of the graphs shows that, for either lane, same lane position always yields more blockage than opposite lane positions yield. A lane-line signal position is better than a center of lane position for the lane 1 case; however, for lane 2, there is no difference between these positions.

An increase in mounting height in over-the-road signal positions leads to a decrease in blockage percentage,

Table 1. Traffic stream parameters and blockage for single-lane case.

	20% Blockage			50% Blockage			80% Blockage		
Signal Position	Space Headway (m)	Speed for 600 Vehicles/h/lane (km)	Volume at 48 km/h (vehicles/h/lane)	Space Headway (m)	Speed for 600 Vehicles/h/lane (km)	Volume at 48 km/h (vehicles/h/lane)	Space Headway (m)	Speed for 600 Vehicles/h/lane (km)	Volume at 48 km/h (vehicles/h/lane)
Far left, post mounted	44.8	27	1080	32.6	20	1480	20.7	12	2330
Far right, post mounted	138.7	83	348	93.0	56	419	46.3	28	1040
Center of lane, 4.9 m	189.9	114	254	127.7	77	378	62.8	38	769
Center of lane, 6.1 m	146.9	88	329	98.4	59	491	51.2	31	943
Center of intersection	153.3	92	315	100.6	60	480	49.4	31	978

Note: 1 m = 3.28 ft. 1 km = 0.621 mile.

Table 2. Traffic stream parameters at 20 percent blockage for two-lane case.

	Space Headway (m)		Speed for 600 Vehicles/h/lane (km)		Volume at 48 km/h (vehicles/h/lane)	
Signal Position	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
Far left, post mounted	26.5	32.0	16	20	1820	1506
Far right, post mounted	137.8	73.1	83	44	351	661
Center of lane, 4.9 m	186.5	116.1	112	70	259	416
Center of lane, 6.1 m	155.7	116.1	94	70	310	416
Center of opposite lane, 4.9 m	150.0	200.2	90	120	322	241
Center of opposite lane, 6.1 m	142.9	151.5	86	91	338	319
Over lane line, 4.9 m	159.7	200.2	96	120	303	241
Center of intersection, 4.9 m	49.7	149.3	30	90	973	324

Note: 1 m = 3.28 ft. 1 km = 0.621 mile.

Table 3. Traffic stream parameters at 50 percent blockage for two-lane case.

	Space Headway (m)		Speed for 600 Vehicles/h/lane (km)		Volume at 48 km/h (vehicles/h/lane)	
Signal Position	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
Far left, post mounted	20.7	24.4	12	15	2322	1978
Far right, post mounted	93.9	51.2	56	31	514	942
Center of lane, 4.9 m	131.7	79.2	79	47	367	609
Center of lane, 6.1 m	104.2	79.2	63	47	463	609
Center of opposite lane, 4.9 m	100.0	130.1	60	78	485	371
Center of opposite lane, 6.1 m	95.4	103.0	57	62	506	469
Over lane line, 4.9 m	108.2	130.1	65	78	446	371
Center of intersection, 4.9 m	36.0	99.1	22	59	134	488

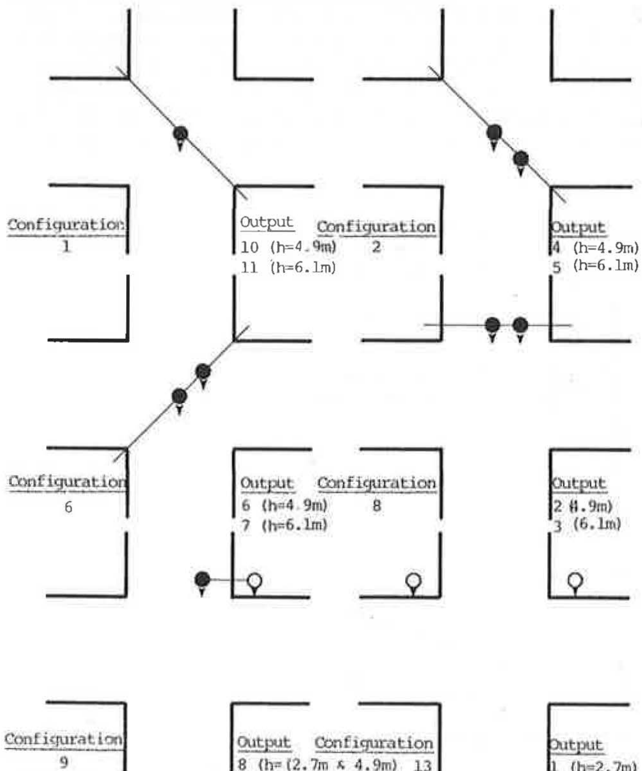
Note: 1 m = 3.28 ft. 1 km = 0.621 mile.

Table 4. Traffic stream parameters at 80 percent blockage for two-lane case.

	Space Headway (m)		Speed for 600 Vehicles/h/lane (km)		Volume at 48 km/h (vehicles/h/lane)	
Signal Position	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
Far left, post mounted	12.2	16.8	7	10	3956	2880
Far right, post mounted	47.2	29.9	28	18	1023	1614
Center of lane, 4.9 m	66.1	43.0	40	26	730	1125
Center of lane, 6.1 m	55.8	43.0	33	26	865	1125
Center of opposite lane, 4.9 m	48.8	65.5	29	39	989	736
Center of opposite lane, 6.1 m	47.2	55.2	28	33	1028	876
Over lane line, 4.9 m	57.9	65.5	35	39	833	736
Center of intersection, 4.9 m	21.6	49.7	15	30	2236	973

Note: 1 m = 3.28 ft. 1 km = 0.621 mile.

Figure 5. Configurations used in blockage analysis.



Note: 1 m = 3.28 ft.

except for the lane 2, opposite lane case where it makes no difference. One major difference between these two lane positions is in the relative efficiency of the far right post mount and overhead center positions. For the lane 1 case, the overhead signal position is to be preferred; for the lane 2 case, the post-mounted signal position dominates.

Tables 2, 3, and 4 give some representative average traffic conditions that will yield the degrees of blockage shown in the graphs.

SIMULATION STUDIES

We determined the expected severity of truck blockage given a defined signal configuration and a specific set of traffic stream parameters (volume, composition, and mean speed) by using simulation.

Simulation Model

The simulation was done by means of the UTCS-1 model (3). The curves generated by the blockage program were incorporated in a subroutine. At each time step, each vehicle is checked for visual blockage of the signal heads.

Five possible conditions are defined.

1. Both signals are visible (condition 0),
2. Right signal is not visible (condition 1),
3. Left signal is not visible (condition 2),
4. Both signals are not visible (condition 3), and
5. Only one signal is visible (condition 1 or 2).

Table 5. Relative blockage percentages for various signal configurations at low approach speed.

		Single Lane Approach						Right Lane Approach[a]						Left Lane Approach[a]					
		0		1		2		0		1		2		0		1		2	
Configuration Number	Mounting Height (m)	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red
13	–	15	21	25	30	61	49	12	22	38	46	50	32	8	11	30	46	62	43
8	4.9	44	58	0	0	56	42	23	39	22	23	55	38	31	46	10	14	59	40
	6.1	38	50	0	0	62	50	21	28	14	20	65	52	31	42	5	8	64	50
2	4.9	39	50	4	6	57	44	18	33	30	35	52	32	35	48	2	6	63	46
	6.1	37	46	1	1	63	53	16	27	27	35	57	38	33	44	1	3	66	53
6	4.9	39	49	5	8	57	43	19	36	31	34	50	30	35	48	4	9	61	43
	6.1	37	48	1	1	62	51	17	30	28	35	55	35	34	46	1	3	65	51
9	4.9	39	50	6	9	56	41	35	49	2	3	63	48	27	47	22	20	51	33
	6.1	39	50	1	1	61	49	35	49	1	1	64	50	26	42	22	23	52	35
1	4.9	39	49	61	51	–	–	34	57	66	43	–	–	35	49	65	51	–	–
	6.1	37	48	63	53	–	–	28	48	72	52	–	–	34	47	66	53	–	–

Notes: 1 m = 3.28 ft.
Numbers in column headings refer to number of signal heads visible.
[a]Two approach lanes.

Table 6. Relative blockage percentages for various signal configurations at high approach speed.

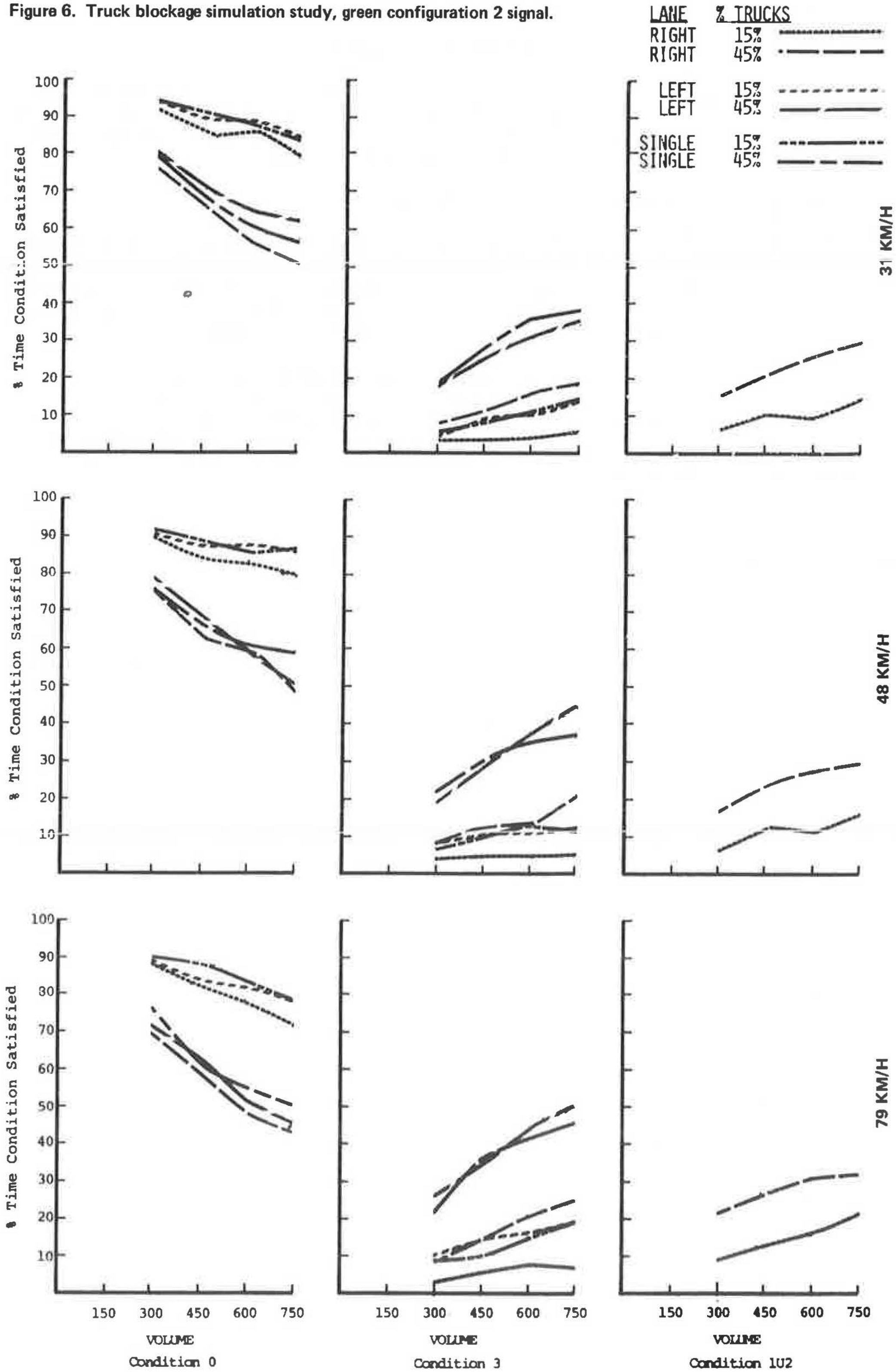
		Single Lane Approach						Right Lane Approach[a]						Left Lane Approach[a]					
		0		1		2		0		1		2		0		1		2	
Configuration Number	Mounting Height (m)	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red
13	–	14	19	31	41	55	40	12	19	38	55	50	26	8	6	30	56	62	38
8	4.9	51	66	0	0	49	34	23	44	22	27	55	29	31	48	10	17	59	35
	6.1	45	59	0	0	55	41	21	34	14	26	65	40	31	45	5	9	64	46
2	4.9	45	59	5	6	50	35	18	36	30	39	52	25	35	54	3	6	62	40
	6.1	43	57	1	1	56	42	16	28	27	39	57	32	33	49	1	3	66	48
6	4.9	45	59	5	7	50	34	19	37	31	39	50	24	35	53	4	8	61	39
	6.1	44	57	1	1	55	42	17	29	28	41	55	30	34	51	1	2	65	47
9	4.9	45	60	6	7	49	33	36	59	2	3	63	38	27	49	22	26	51	25
	6.1	45	59	1	1	54	40	36	59	1	1	63	40	26	44	22	28	52	28
1	4.9	45	59	–	–	55	41	34	53	–	–	66	47	35	54	–	–	65	46
	6.1	44	58	–	–	56	42	28	41	–	–	72	59	34	52	–	–	66	48

Notes: 1 m = 3.28 ft.
Numbers in column headings refer to number of signal heads visible.
[a]Two approach lanes.

If only one signal is present, only conditions 0 and 3 can exist.

At each time step, each vehicle (beginning with the one furthest upstream) is examined to determine the conditions that exist for that vehicle. First, the nearest truck in front of the car in the same lane is determined. If no truck is present, no blockage occurs for that vehicle. If the truck blocks both signals, any truck in the other lane (if it exists) cannot alter the blockage result and no further analysis is needed. If only one signal is blocked, the model finds the first truck in the opposite lane and determines the blockage due to it. Note that trucks themselves are not considered vehicles, and that only the nearest truck in front of the car in the same

Figure 6. Truck blockage simulation study, green configuration 2 signal.

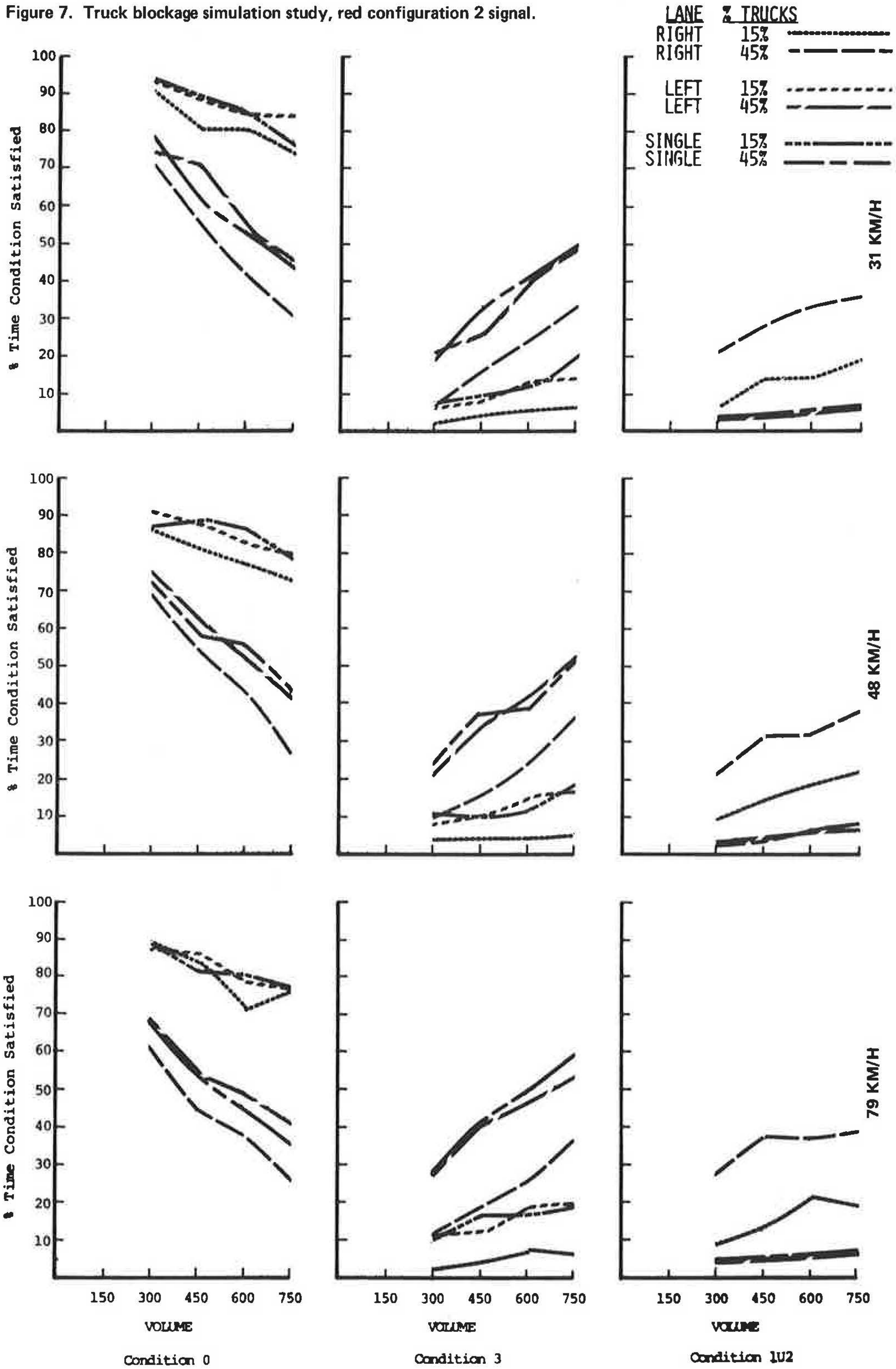


lane is examined, but all trucks in the parallel lane are examined. This analysis is done for all configurations and for each vehicle on the roadway. After the required volume of vehicles is examined, the simulation output yields the accumulated statistics by configuration for the particular case examined.

Selection of Configurations

Eleven signal configurations were examined in detail and are shown in Figure 5. For overhead signals, two mounting heights [4.9 and 6.1 m (16 and 20 ft)] were used.

Figure 7. Truck blockage simulation study, red configuration 2 signal.



Results of Simulation Studies

Figures 6 and 7 show the effect of volume, speed, truck percentage, and signal state on expected amount of truck blockage for configuration 2. Only the results for the lower overhead mounting height are shown. The following general conclusions can be drawn:

1. Truck blockage increases with increasing volumes;
2. Truck blockage increases with increasing truck percentage; and
3. Truck blockage increases with decreasing mean speed.

Truck blockage increases as the mean space headway in the traffic stream decreases, which confirms the same results shown by the parametric studies described earlier.

The simulation study obtained expected blockage percentages for six different common signal configurations. Five of these included overhead-mounted signal heads. These were evaluated at two different heights. Table 5 gives a comparison of these 11 configurations for three lane conditions and a low approach speed. Table 6 gives the same data for high approach speed conditions.

Effect of Configurations

There is relatively little difference among the three configurations that consist of two overhead-mounted signals (configurations 2, 6, and 8). For a single-lane approach, these configurations all showed relatively small percentages of time when only one signal was visible probably because of the small relative lateral displacement of the two signal heads. Consequently, there is very little difference between these configurations and a configuration with a single overhead-mounted signal head (configuration 1).

The two-post-mounted signal (configuration 13) performs best when evaluated on the basis of at least one signal visible. This is due to the excellent performance of the far left signal position as shown in Figures 3 and 4. However, under some conditions, especially in the two-lane cases it performs notably more poorly than some other configurations.

The mixed configuration (configuration 9), in which both signals are in the far right quadrant, shows no appreciable improvement over the all-overhead configurations for the single-lane case. For the two-lane case, there is a considerable difference between the left and right lanes primarily because of the considerable amount of one signal head visibility for the left-lane case.

That the addition of a far left, post-mounted signal head to a two-head overhead or mixed signal configuration would lead to a considerable reduction in truck blockage can be postulated on the basis of this study. A far right high-mounted signal head, although not often used, might even be preferable in preventing cross-traffic and approaching-traffic blockage.

Effect of Mounting Height

Varying the signal mounting height by 1.2 m (4 ft), the maximum variation permitted by the Manual on Uniform Traffic Control Devices (MUTCD) (4) leads to a change in the percentage of signal blockage from 0 to 14 percent. The higher mounting is better whenever a difference exists.

For the three multiple overhead configurations, the difference between mounting heights for any one configuration is greater than the difference between configurations. At their higher mountings, the multiple overhead configurations usually perform marginally better than the two-post configuration for the condition in which two signal heads are visible. However, even at the maximum height, none of the overhead configurations shows as great a percentage as the two-post configuration for the case in which all signals are blocked.

Effect of Approach Speed

Theoretical considerations and the results of the parametric study indicate that the degree of truck blockage to be expected is directly related to the space headway of the truck-vehicle pair. Higher approach speeds, at constant volume, lead to lower densities and, therefore, larger space headways. This basic relationship cannot, however, be equated with the conclusion that blockage is a less severe problem at higher approach speeds.

The amount of blockage to be expected is not a point phenomenon; it must be evaluated over the entire extent of the approach that falls under the influence of signals. This length of approach is not well defined but is definitely speed dependent. For instance, the MUTCD (4) gives a table of minimum sight distances for signals based on 85 percent approach speeds. Translated into travel times, these result in a range of signal viewing times of 3.5 to 8 s. On the other hand, the Traffic Engineering Handbook (5) gives recommended signal head aiming instructions that imply a signal viewing time of approximately 16 s. Therefore, we decided that the simulation study would aggregate blockage over an approach distance equivalent to 10 s at desired mean free speed.

Because of the geometry of the problem (1), the probability that blockage will occur at any point (for a given value of space headway) on the roadway generally increases with the distance of that point from the signal. Because the approach distance increases with specified speed, a far greater prospect for truck blockage for high-speed traffic results because of this factor. Therefore, there are two opposing factors as speed increases: larger space headways and longer approaches corresponding to a constant value of 10-s test period. Examination of the detailed simulation output shows that these two competing factors vary in effect and that the influence of approach speed is not monotonic over all variables. At high volumes, such as 750 vehicles/h/lane, the influence of the configurations incorporating two overhead signal heads generally performed best. If, however, the criterion is changed to require at least one signal head visible, a configuration incorporating a signal head in the far left position has proved to be best.

ACKNOWLEDGMENT

This work was sponsored by the American Association of State Highway and Transportation Officials in cooperation with the Federal Highway Administration and was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Research Council.

The opinions and conclusions expressed or implied in the report are those of the authors. They are not necessarily those of the Transportation Research Board, the National Academy of Sciences, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, or of the individual states participating in the National Cooperative Highway Research Program.

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