A Study of Left-Hand Exit Ramps on Freeways

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This paper reviews pertinent literature on operational aspects of left-hand ramps and gives a summary of the status of knowledge, along with a list of the more important references.

Time-lapse photography was used in making field studies of three left-hand exit ramps and one right-hand exit ramp on the Congress Street Expressway in Chicago. Detailed analyses of volume, speeds, density, exiting paths, and hazardous maneuvers were carried out and the results used to check a hypothetical formulation of the operational characteristics to be expected for left-hand exit ramps.

Special analyses were made of operational characteristics of "familiar" vs "unfamiliar" drivers, as determined by interviewing drivers after they had exited from the freeway. It was concluded that the left-hand exit ramps studied operate quite satisfactorily.

• PREVIOUSLY, most freeway ramps have been constructed on the right of the through traffic lanes, adjacent to the slowest-moving freeway lane. Observation, experience, and research have built up sufficient knowledge about traffic behavior in the vicinity of these right-hand ramps so that the engineer is able to state with a fair amount of certainty what is desirable in such cases.

Occasions arise, however, when it is expedient, desirable or even essential that the ramps be placed on the left of the through lanes. Observations have indicated that difficulties have occurred at left-hand ramps in some locations. However, little factual information is available on the traffic and physical conditions associated with operational problems.

It was, therefore, the purpose of this study to examine the present status of knowledge about left-hand ramps, to study the operational behavior patterns of traffic at some high-volume left-hand exit ramps in Illinois, and to draw conclusions about the suitability of such ramps.

PRESENT PRACTICE AND STATUS OF KNOWLEDGE

An annotated bibliography, prepared to provide a background for this study, revealed that most of the previous studies of ramps had dealt with right-hand entrance ramps. Right-hand exit ramps were considered in only a few studies, and left-hand ramps, either on- or off-ramps, generally were mentioned only in passing.

Because published data about left-hand ramps were so limited, a questionnaire was sent to all State highway departments in July 1961, requesting information about the extent of use of left-hand ramps, experience in their design and operation, and present and anticipated future plans and policy with regard to them. A 98 percent response was obtained by March 1963.

Analysis of the replies received to the questionnaire showed that 33 States had left-

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hand ramps in operation and 10 others had some left-hand ramps planned or under construction. Only 8 States had no left-hand ramps, with none planned or under construction. It is possibly significant that only 6 percent of the total number of interchanges reported were located in these 8 States which reported no left-hand ramps.

It was found that 332 left-hand ramps were reported as in operation, 123 under construction, and 405 being planned. Urban and suburban locations together had 75 to 80 percent of those interchanges incorporating the left-hand ramp. An average of 7.01 left-hand ramps per 100 interchanges was reported. One State reporting 410 interchanges (Texas) had 19 left-hand ramps per 100 interchanges.

There appeared to be no significant tendency to use left-hand ramps for either on- or off-ramps only. Left-hand ramps were mainly incorporated in directional interchanges, with about one-half that number in modified diamonds, and the balance in semi-directional and three-legged interchanges.

The considerations reported by the States as reasons for adopting left-hand ramps are summarized as follows, the number in brackets indicating the number of States so replying:

1. To meet a demand for a high-volume directional movement (23).
2. Economic considerations, mainly structural and land costs (16).
3. Right-of-way limitations (29).
4. Topography and natural barriers such as a river or a lake requiring special geometric treatment (19).
5. The elimination of weaving; for example, where it was necessary to provide exit facilities immediately downstream of an entrance ramp terminal, weaving conflicts between entering and exiting traffic could be avoided by placing one ramp terminal on the left of the through lanes (6).
6. Lack of left-turn storage at diamond interchanges. With left-hand on-ramps, it is possible to use the center lane on the cross-street as storage for both left-turn movements onto the freeway, without any restriction on length of the storage lane.
7. Left-hand off-ramps can also provide higher capacity at the cross-street by arranging for left-turning movements which do not cross each other.
8. To provide access to service and rest areas located in a widened median, as is done on some toll roads.
9. As part of a sequence of right-hand off-ramps and left-hand on-ramps, to provide service to several cross-streets in the central area which are situated too close together to permit providing access to these streets from one side of the freeway only; for example, Northwest Expressway, west of Chicago's Loop.

In the design of left-hand ramps, a few States reported that special consideration is given to some factors, such as adequate attention to signing (Oregon suggested the additional use of pavement messages approaching a left-hand exit), sight distance, target value, and interchange spacing.

Some States suggested that acceleration and deceleration lanes should be longer for left-hand ramps. California, before discontinuing the construction of left-hand ramps, required a parallel lane 1,000 ft long ahead of the exit nose, and Georgia suggested the use of a 1,500-ft deceleration lane. Washington and Illinois reported that the length of acceleration lanes should be based on merging requirements rather than on speed-change criteria, whereas Arizona, the District of Columbia, and Georgia suggested the continuation of an additional through lane to accommodate traffic entering from a left-hand on-ramp. Forty-three States reported no specific design standards for left-hand ramps.

A general reluctance to use left-hand ramps was evident on the part of the majority of responding States. As of April 1959, California had decided to eliminate the further use of left-hand ramps. The main considerations involved in this decision were those of safety and the reported adverse effect on capacity of the freeway because of slower-moving traffic weaving across the through lanes to an exit on the left. Michigan reported that all entrances and exits shall be on the right except (a) at directional ramps serving business-route traffic into or from a major city, (b) at major expressway interchanges based on traffic volume needs, and (c) at the beginning or end of dual sections of major routes, where the ramp design speed is never below 50 mph.

Of the 33 States having left-hand ramps in operation, 6 States reported no available data on operational problems, and 9 indicated no discernible problems. The main problems mentioned by the remaining States can be summarized as follows:

1. Repeated and hazardous lane changing by trucks and other vehicles moving at speeds slower than freeway running speeds, especially where trucks must enter or leave on an ascending grade. This problem was reported from California and Michigan, the States with the highest percentage of State highway completed to full freeway standards. Significantly, California is one of the three States having the mandatory requirements that all heavier trucks shall keep to the right.[1] The State of Michigan does not have such a legal requirement, but the City of Detroit (which accounts for a considerable percentage of controlled-access highway mileage in the State), does have a similar requirement.
2. An increase in weaving at left-hand off- and on-ramps. This is especially prevalent where interchanges are spaced close together and where the left-hand ramp is "isolated." (A left-hand ramp is considered to be "isolated" when it is the only left-hand ramp on the section of freeway, or when it is the first left-hand ramp encountered after traversing a freeway section with only right-hand ramps.)
3. The left-hand lane, the traditional high-speed lane, is slowed down as a result of merging maneuvers.
4. Some driver confusion and hesitancy results from being confronted by a left-hand off-ramp, especially where signing is poor and the facility is one carrying a high percentage of out-of-state traffic.
5. Increased accidents and hazardous maneuvers at left-hand on- and off-ramps were reported by Michigan, New Jersey, California, and Oregon. The prevalent type of accident appeared to be exiting from the wrong lane, and rear-end collisions caused by vehicles slowing up before exiting. The Michigan study (4), conducted at seven locations, found that left-hand exits had almost five times as many accidents as right-hand exits and that they were twelve times as severe and that left-hand entrances accounted for four times as many accidents which were six times as severe. Generally speaking, the information on the accident studies was suprisingly meager. Forty-three States, of which 26 have left-hand ramps in operation, reported that no accident data had been assembled on left-hand ramps.

Overall, the questionnaire study revealed considerable interest in left-hand ramps, but specific data on the operational problems just outlined were scarce.

TRAFFIC BEHAVIOR PATTERNS AND PARAMETERS

An hypothetical study of expected behavior of traffic at left-hand off-ramps was made, to aid in identifying the freeway flow parameters that should be investigated (8). Based on this analysis and the study of the literature, the following parameters were selected as those likely to be the most sensitive and effective indexes for use in a composite suitability rating for left-hand exit ramps:

1. The distribution of freeway volume by lane and the composition of flow (that is, the percentage of trucks) on the section of freeway immediately upstream from the off-ramp.
2. The distribution of speeds by lane at this upstream location, and the difference between the speeds of vehicles exiting and of vehicles continuing through in the adjacent lane.

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[1] Delaware and Vermont also require trucks to travel in the right-hand lanes. Section 525.3 of the California Vehicle Code reads: "When any vehicle included in Section 515 is being driven on any highway, it shall be driven in the right-hand lane for traffic or as close as practicable to the right edge or curb, except when overtaking and passing another vehicle proceeding in the same direction, or when preparing for a left turn at an intersection or into a private road or driveway." Section 515 includes, "(1) Any motor truck and trailer, (2) Any motor truck alone or truck tractor with semitrailer having a gross weight, of vehicle and load or of such vehicles and load of 25,000 pounds or more."

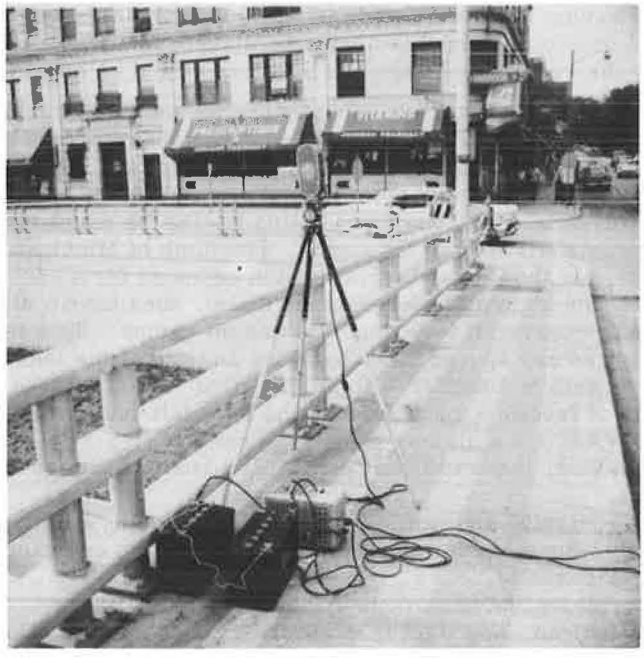

Figure 1. Time-lapse camera, with batteries and inverter set up on Oak Park Avenue overpass.

3. The point of exit onto the deceleration lane.
4. The frequency of occurrence of hazardous maneuvers and weaving in general.

The field studies were carried out by means of time-lapse photography, using 16-mm movie cameras driven by synchronous electric motors at either 60 or 100 frames per minute, powered either from a 110-v power supply or from a power pack consisting of a 12-v battery and an inverter (Fig. 1). The cameras were mounted in elevated positions, usually on suitable overpasses, but sometimes on a frontage road or clamped to utility poles. Generally, two and frequently three or more cameras were operated simultaneously. To provide a spatial base for analysis, whitewash lines were placed on the roadway shoulder at 50- or 100-ft intervals in the camera field of view. A check on the speed of the camera was obtained by placing a colored filter in front of the lens at specific intervals of time. Color film was used to facilitate identification of the same vehicles on films taken simultaneously at two separate locations.

The analysis of the films was carried out in the laboratory with the aid of commercial movie projectors, which back-projected the images onto ground glass screens (Fig. 2). A parallactic grid was constructed on this screen from the shoulder markings, thus giving a distance base. The projector had provision for advancing the film one frame at a time. A frame counter provided the time base.

Films were taken of operations at four ramps on the Congress Street Expressway, which runs west from the center of Chicago. The film studies were carried out at the Harlem westbound left-hand exit, the Harlem eastbound left-hand exit, and the Austin eastbound left-hand exit. For comparative purposes, studies were made of the First Avenue westbound right-hand exit. At the Harlem Avenue westbound left-hand exit, films were also taken of traffic for a distance of 3,300 feet back from the ramp itself.

Figures 3 and 4 show aerial views of Harlem and Austin interchanges, respectively. These interchanges are situated 8.6 and 7.5 mi west of Chicago's Loop and the expressway is depressed below ground level here. Figures 5 and 6 show the Harlem westbound left-hand exit ramp and the approaches to the exit. This ramp may be taken as typical

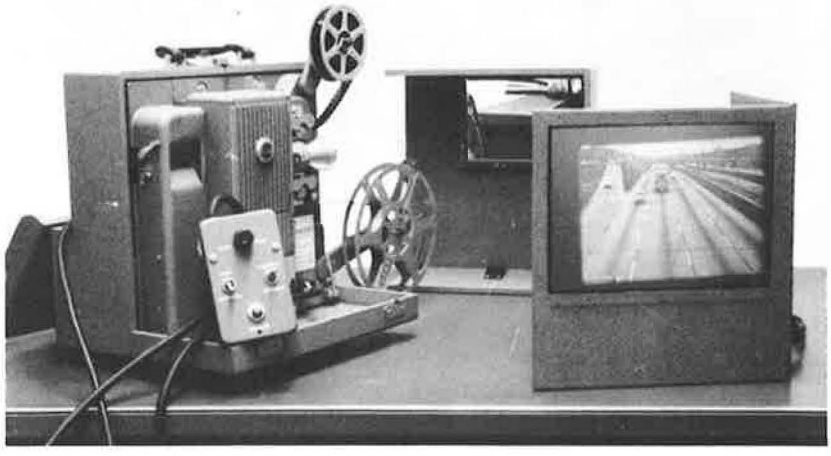

Figure 2. Kodak Analyst II projection apparatus.

of the left-hand exit ramps studied. On the approaches, the freeway lanes are 12 ft wide with distinctive lane markings on the concrete pavement.

Bituminous shoulders 10 ft wide are provided on both sides, and immediately ahead of the ramp the median is some 70 ft wide. The deceleration lane is paved in red concrete, is 450 ft long, and at the maximum point is 30 ft wide. The ramp proper, 900 ft long, has an upgrade of approximately 3 percent and terminates at a signalized intersection. The design provides an ample width for a single-lane take-off with provision for two lanes of traffic at the signalized intersection.

The First Avenue right-hand exit is located on the westbound section 10.4 mi west of Chicago's Loop. The approaching freeway lanes are level, with a well-designed high-speed exit which has an upgrade of approximately 0.5 percent.

To aid in the evaluation of the performance of the freeway at the left-hand exits, the flow characteristics were also compared with those for an "average" section of six-lane freeway. The flow characteristics for the "average" section had been developed by May (3), who summed up the results of six separate studies conducted in California, Michigan, New Jersey and Texas.

Volume Distribution by Lane

Because left-hand exit ramps undoubtedly have an effect on volume distribution by lane, this volume distribution was investigated for each of the four exit ramps, three left-hand and one right-hand, at points just ahead of the deceleration lanes. Also, in the case of the Harlem westbound exit ramp, volume distribution was investigated 1,900 ft and 3,300 ft upstream from the nose. These lane distribution results were then compared with those for the "average" section, for three levels of flow, as follows: "Low," corresponding to 25-54 vehicles per minute (vpm); "Med" to 54-85 vpm; "High" to a volume greater than 85 vpm.

Figure 7 shows the percentage of total volume carried in each lane on an "average" section of freeway for these three levels of flow. Figure 8a shows the percent volume carried in each lane at the beginning of the deceleration lane at the Harlem Avenue westbound left-hand exit ramp, also for the three levels of flow. This ramp had the highest volume of any of the left-hand ramps investigated, with 24-hr ramp volumes of 9,300 vehicles, and 800 vph from 4 to 5 PM. The three freeway lanes at a point just ahead of the ramp carried a 24-hr volume of 53,600 vehicles with 6,100 vph from 4 to 5 PM. The ramp was studied on two different occasions. The volume distributions found just ahead of the deceleration lane for each of the two separate studies agreed quite closely.

Figure 8a shows that, for the low range of traffic volumes, the percentage of vehicles in the left lane at the approach to the left-hand exit ramp was 5 percent higher than for

Figure 3. Aerial view, Congress-Harlem interchange.

Figure 4. Aerial view, Congress-Austin interchange.

the "average" distribution. As the total volume increased, the variation grew less. Particularly noticeable is the similarity between the volumes carried in the left and center lanes, at all total volumes.

At a point downstream, opposite the nose of the ramp terminal, at all levels of flow the traffic was distributed so that about 25 percent of the total volume was in the left lane, 25 percent in the right lane, and the remaining 50 percent in the center lane. Even with a total volume of 6,100 vph approaching the ramp terminal, and about 12 percent exiting, one-quarter of the through traffic chose to remain in the left lane, indicating that the presence of the left-hand off-ramp did not deter through traffic from using the left lane.

Figures 8b and 8c show the distribution of traffic 1,900 ft and 3,300 ft before the nose. At all three volume levels, the percent of vehicles using the left lane increased somewhat as traffic approached the left-hand off-ramp, as might be expected.

The volume distribution by lane found just upstream of the deceleration lane at the right-hand exit ramp at First Avenue, 1.8 mi west of Harlem interchange, is also

Figure 5. Freeway lanes and Harlem Avenue left-hand exit from Home Avenue pedestrian overpass looking west.

Figure 6. Freeway lanes approaching Harlem Avenue left-hand exit from Home Avenue pedestrian overpass looking east.

plotted for the three levels of flow (Fig. 9). At this right-hand exit, there was, generally speaking, a greater percent of traffic in the right lane than on the "average" freeway section, as would also be expected.

An interesting comparison apparent from these figures is that, at high total volumes, the volume distributions by lane upstream from both the left-hand and the right-hand exits were quite similar to that for May's average freeway section. At low volume levels, the left lane at the approach to the left-hand off-ramp carried an appreciably greater volume than at the approach to the right-hand ramp.

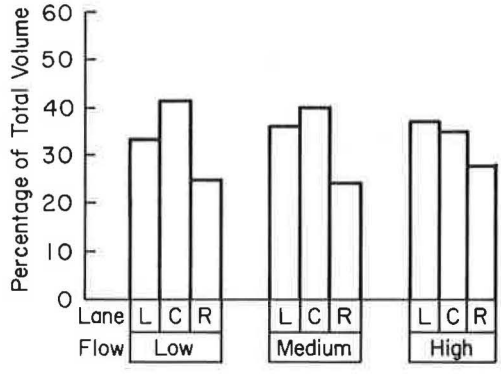

Figure 7. Volume distribution by lane for "average" section of freeway (3).

These studies of volume distribution by lane indicate that level freeways with left-hand exit ramps can carry high volumes. Even though the percentage of vehicles in the left lane was high, the pattern of volume distribution by lane showed no substantial changes as the ramp was approached. It appears that total volumes in the region of 6,000 vph can easily be handled on a level three-lane section of freeway adjacent to a left-hand exit, where 13 percent of the total flow exits, provided that the exiting maneuver be executed at high speed.

Speed

A left-hand exit ramp could have an adverse effect on speed in either of two ways: (a) so many vehicles would use the left-hand lane that sheer congestion would cause a lowering of the speed in that lane as compared with the speed in the other two lanes, and (b) slow-moving vehicles moving into the left-hand lane to exit could cause a reduction in the speed of other vehicles in the left lane. Investigations were, therefore, carried out on the various ramps studied to compare for left-hand and right-hand exit ramps, the speeds in the three lanes just upstream from the deceleration lane, and also to compare the speeds of the exiting vehicles with the speeds of through vehicles in the adjacent lane.

Figure 10a shows the average speed in each lane, for three volume groupings just upstream from the Harlem Avenue westbound left-hand exit ramp. Figures 10b, 10c, and 10d show similar information for one right-hand exit location (First Avenue west-

bound) and for two other locations with left-hand ramps (Austin Avenue eastbound and Harlem Avenue eastbound).

Investigation of the speed-volume relationships at these four exit ramps indicated that the left-hand exit ramps did not adversely affect the freeway flow. At low volumes, average speeds were above 50 mph for left lanes approaching all three left-hand exit ramps, and were higher than the average speed for the left lane at the right-hand exit at First Avenue. At medium volume levels at the three left-hand exits, average speeds for left lanes were also close to 50 mph. At high-volume levels, constrictions of flow downstream from the two left-hand exits and the right-hand exit reduced average speeds in all lanes.

Analysis was made of the speeds of vehicles exiting at each study location and the speeds of vehicles proceeding through in the lane adjacent to the deceleration lane at that location. Figures 11a and 11b show the relationships found for the Harlem Avenue westbound left-hand exit and First Avenue westbound right-hand exit. At low volume only, the average speeds of the exiting vehicles at both left- and right-hand ramps were noticeably lower than the average speeds of through vehicles.

As the total volume rose, the differential between the exiting and through speeds decreased in a similar manner for both left- and right-hand exit ramps. It was felt, therefore, that because the greater differential in exiting and through speeds occurred at lower volumes where the effect would be less noticeable and, because this difference was not apparent at higher levels of flow, the presence of the exiting vehicles in the left lane approaching the left-hand off-ramp apparently did not affect the speeds in that lane, for these locations on this level freeway.

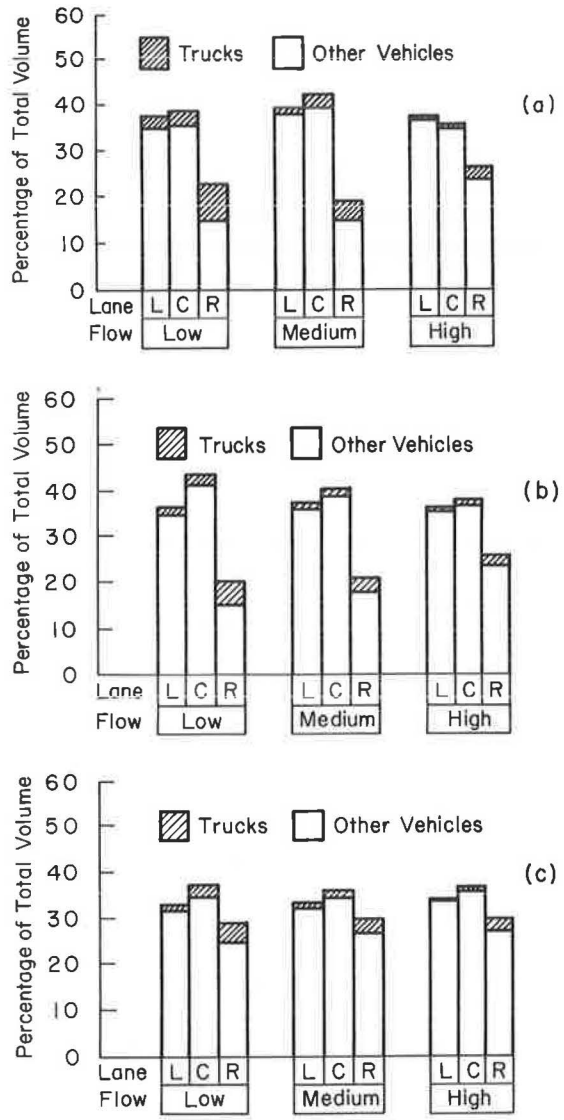

Figure 8. Volume distribution by lane approaching left-hand exit ramp, Harlem Avenue westbound, Thursday, June 29, 1961: (a) at beginning of deceleration lane; (b) 1,900 ft upstream from deceleration lane; (c) 3,000 ft upstream from deceleration lane.

It can be concluded that a left-hand exit ramp, with a high exiting design speed, generally does not have an adverse effect on the speed of operation of the traffic on a level freeway merely because it is situated on the left-hand side of the through pavement.

Volume Density

Studies were made of lane densities in a 300-ft section of freeway approaching each exit ramp. These densities were determined from the time-lapse films by counting the number of vehicles in each lane in the 300-ft sections. Samples were taken for every other frame for each of 503 15-sec periods for the same 2 hr of traffic that was

studied for volumes and speeds (Figs. 7 through 10). Average 15-sec lane volumes were then computed for all 15-sec samples with the same lane-density grouping.

Table 1 gives the average 15-sec lane volumes, $\bar{v}$, as obtained for each lane-density grouping above 30 vehicles per mile for westbound freeway sections approaching the Harlem Avenue left-hand exit, and for the First Avenue right-hand exit. The number of 15-sec samples are given as n in the table.

There was considerable scatter in the 15-sec lane volumes for each 10-vpm density grouping, so it is not possible to state that the average lane volumes for different density groupings in Table 1 are significantly greater for the left-hand exit location, as compared with the First Avenue location.

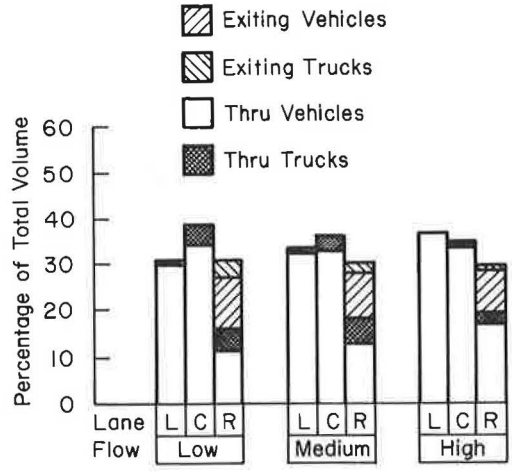

Figure 9. Volume distribution by lane at right-hand exit ramp, First Avenue westbound, Monday, March 5, 1962.

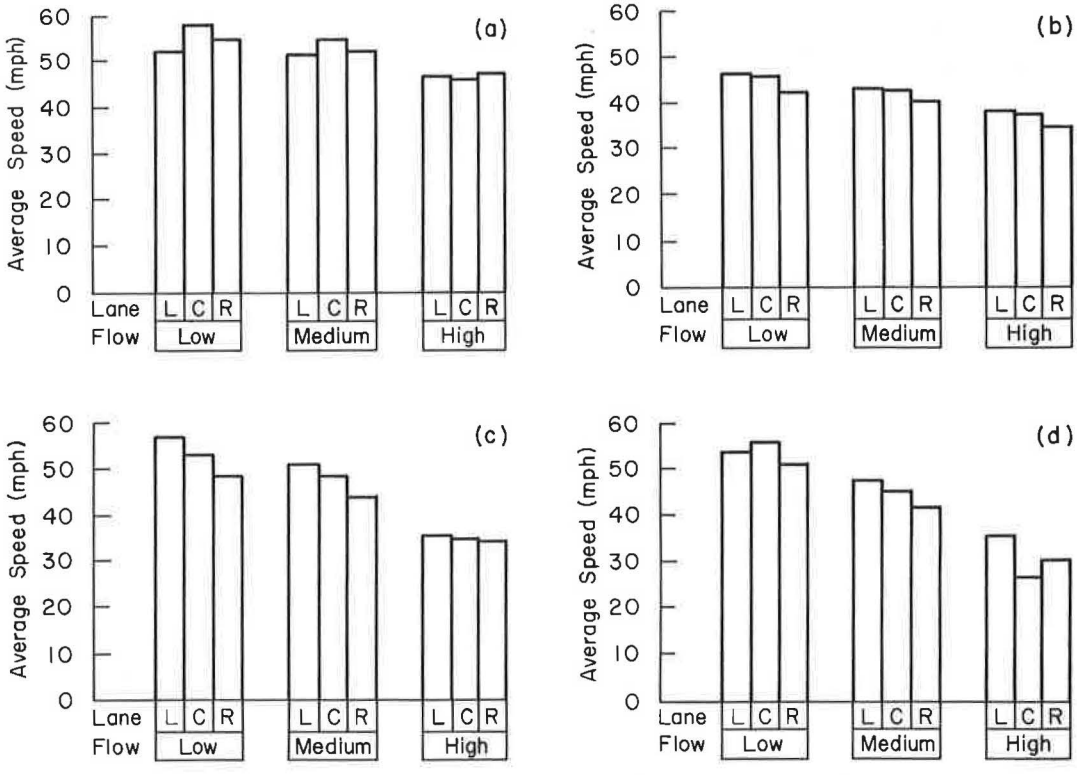

Figure 10. Mean speeds by lane at three volume levels at beginning of deceleration lanes on Congress Street Expressway: (a) left-hand exit, Harlem Avenue westbound, Tuesday, March 20, 1962; (b) right-hand exit, First Avenue westbound, Monday, March 19, 1962; (c) left-hand exit, Austin Avenue eastbound, Tuesday, March 20, 1962; (d) left-hand exit, Harlem Avenue eastbound, Thursday, March 22, 1962.

TABLE 1

AVERAGE 15-SEC LANE VOLUMES ($\bar{v}$), AT DIFFERENT LANE DENSITIES IN APPROACHES TO TWO EXIT RAMPS ON CONGRESS STREET EXPRESSWAY, SPRING 1962

Exit Ramp	Lane	30 to 49 Veh/Mi		40 to 49 Veh/Mi		50 to 59 Veh/Mi		60 to 69 Veh/Mi		70 to 79 Veh/Mi		80 to 120 Veh/Mi	
		n	$\bar{v}$	n	$\bar{v}$	n	$\bar{v}$	n	$\bar{v}$	n	$\bar{v}$	n	$\bar{v}$
Left-hand[1]	Left	28	5.9	28	8.5	13	9.5	3	9.9	1	10	--	--
	Center	30	7.8	23	9.3	16	9.7	2	10	3	10	--	--
	Right	18	6.6	13	7.7	2	8	1	9	--	--	--	--
Right-hand[2]	Left	26	5.2	26	5.8	10	7.6	19	8.2	13	8.2	3	10
	Center	27	6.1	26	7.6	16	8.7	25	8.8	13	9.5	3	10
	Right	18	5.3	21	6.8	20	8.0	22	8.6	18	9.4	16	10.4

[1] Harlem Avenue westbound.
[2] First Avenue westbound.

It was quite apparent, however, that for each density grouping, all lanes at the approach to the left-hand exit were carrying higher volumes (and at higher speeds) than the corresponding lanes at a point upstream from the right-hand exit.

Therefore, this density analysis did not reveal any data indicating that this left-hand exit ramp was not operating satisfactorily. In contrast, it indicates that the section in advance of the left-hand exit ramp was operating better than the section in advance of the right-hand exit ramp, for these particular periods of filming.

Density analyses were also made for each lane approaching the two left-hand exit ramps on the eastbound roadway of Congress Street Expressway. Because the density values were affected by the backup of queues caused by restrictions downstream from each ramp, the results are not presented here. The data presented for the two ramps in Table 1 are for conditions when there generally was no backup affecting the flow through the exit ramp terminals.

Truck Considerations

One of the major reasons for questioning the suitability of the left-hand ramp has been the possible problems resulting when trucks and other slower vehicles, which normally travel in the right-hand lane, attempt to enter or leave via a left-hand ramp. This problem therefore, was given special study.

As a first step, data were taken of the composition of flow by lane just upstream from the three left-hand exit ramps and the one right-hand exit ramp. The results obtained for left-hand exit ramps were compared with results for the First Avenue right-hand exit ramp (Figs. 8 and 9).

There is no mandatory requirement that trucks should keep to the right on Congress Street Expressway; there is only a sign stating "Slower Traffic Keep Right." However, it is apparent that the greater percentage of trucks do travel in the right-hand lane, at both right-hand and left-hand exit locations. It was found that the left lane carried a larger percentage of trucks on the approach to a left-hand than on the approach to a right-hand ramp, due to the need for some trucks to get into the left lane to exit.

The movements of trucks in the left-hand lane of the Congress Street Expressway were also traced over a filming period of 16 min at the Harlem westbound off-ramp for a distance of 3,300 ft ahead of the exit, utilizing several cameras operating simultaneously. It was found that 80 percent of the exiting trucks were already in the left-hand lane 3,300 ft ahead of the ramp. The other 20 percent of the exiting trucks did not appear to have had difficulty in reaching the left-hand lane, on this level section of freeway.

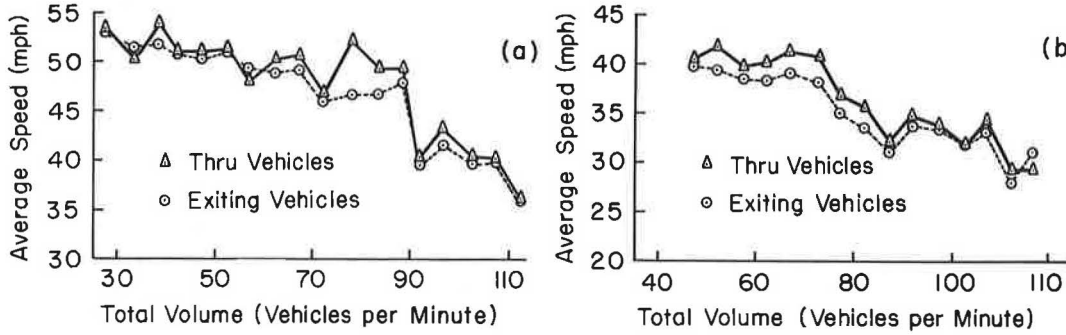

Figure 11. Speeds of exiting and through vehicles upstream from ramp, in lane adjacent to ramp, Congress Street Expressway: (a) Harlem Avenue westbound, left-hand exit, Tuesday, March 20, 1962; (b) First Avenue westbound, right-hand exit, Monday, March 19, 1962.

Although this study was made on a level freeway, it can be expected that adverse grades would have had an effect on truck speeds. Previous investigation (5) has revealed that grades as low as 1.7 percent may affect operations somewhat even when truck volumes are as low as 2 or 3 percent. A recent analysis (1) shows, however, that sustained grades up to 2.7 percent do not cause trucks with a weight-power ratio lower than 200 to decrease speed below an initial 50 mph, and it is only when the weight-power ratio is 300 or 400 that the decrease in speed is considerable. This would appear to indicate that further studies of the operational effects of different types of trucks would be warranted at locations with ascending grades.

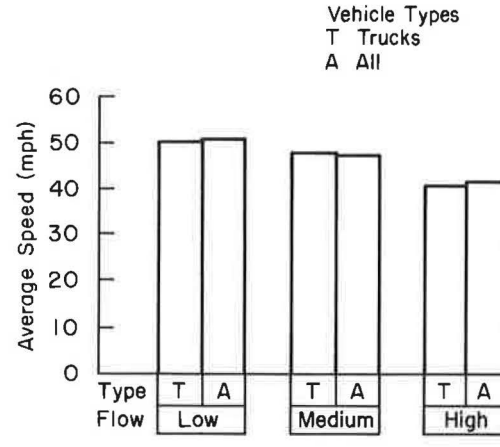

Figure 12. Speeds of exiting trucks vs all exiting vehicles, Harlem Avenue westbound, left-hand exit, Tuesday, March 20, 1962.

A comparison was made of the average exiting speeds of trucks and the average exiting speeds of all vehicles at the Harlem Avenue westbound left-hand exit ramp. Figure 12 shows the results. At low and high flows, the average truck speed was only 0.8 mph less than the average speed of all exiting vehicles, whereas at intermediate flows, the speed of exiting trucks actually averaged 0.3 mph higher than that of all exiting vehicles.

It was concluded that the operation of the left-hand exit ramps studied was not adversely affected by the percentage of trucks normally using the freeway or the ramps, at this level section of freeway.

Departure Zones

The point at which vehicles start to leave the through roadway at an exit ramp is an indication of how well the ramp is operating, assuming that the design of the ramp proper is such that no advantage is gained by making a late exit. To this end, a study was made of all the ramps investigated. A vehicle was recorded as departing from the freeway lanes when one wheel was wholly on the auxiliary pavement.

The investigation showed the exit pattern to be very consistent, with over 90 percent of all vehicles exiting within 100 ft of the beginning of the auxiliary pavement in all cases. The volume did not appear greatly to affect the point of departure, although some tendency was noticed for vehicles to make a slightly earlier departure when total volume increased. All the ramps studied had high exit design speeds and flat angles of departure.

Hazardous Maneuvers

Hazardous maneuvers resulting from inattention or faulty judgment of unskilled drivers can occur at either right-hand or left-hand exit ramps. However, a higher frequency of hazardous maneuvers might be expected at left-hand than at right-hand exits because of the following:

1. Drivers planning to leave a freeway may expect the exit to be on the right and thus more of them may be in the wrong lane when approaching a left-hand exit than when approaching a right-hand exit.
2. Slower-moving vehicles, including trucks, may impede the faster vehicles in the left lanes as they force their way across to a left-hand exit ramp.
3. Left-hand exit ramps may be poorly designed (inadequate target value, too short a deceleration section, or inadequate signing), which may have more serious effects because of higher speeds in left-hand lanes.

Studies were made of the frequency of hazardous maneuvers at each of several exit ramps (three left-hand and one right-hand exit ramps). Tables 2 and 3 give results for 120 min of observation.

The most prevalent type of hazardous maneuver was the exit from the center lane. However, the incidence of all hazardous maneuvers was so low that it was not possible to draw any definite conclusions. The incidence was about equal for both left-hand and right-hand exits. Studies of accident experience will be desirable, as more time elapses, to permit a more definitive comparison.

THE UNFAMILIAR DRIVER

In evaluating the suitability of left-hand exit ramps, studies also were made of the hypothesis that a left-hand exit ramp might have more of an adverse effect on the "unfamiliar" driver than on the driver who had previously used that left-hand ramp. It was considered probable that the unfamiliar driver would be more likely to be adversely affected by the left-hand exit ramp. These adverse effects would be reflected in lane use in approaching the ramp, and in speeds and frequency of hazardous maneuvers.

Accordingly, a study procedure was developed to permit identifying the unfamiliar driver and to examine his driving behavior as he approached the left-hand exit ramps.

The classification of drivers was accomplished at the study sites by interviewing the exiting drivers who were stopped by the traffic signal at the top of the ramp. A driver reporting that he had used the ramp before the interview was classified as a "familiar" driver, and those who had not used the ramp before were classified as "unfamiliar."

A separate questionnaire was prepared for each of the two classifications of drivers and the appropriate questionnaire (each of which was identified by a serial number) was handed to each driver interviewed. The interviewer recorded the signal cycle number (referenced from the beginning of filming), the driver's position in the queue at the light, and the questionnaire number. This method allowed the identification on the film of the vehicle of each individual driver interviewed.

Each questionnaire included questions about the type of driver, the familiarity of the driver with the ramp and the expressway, the driver's opinions about the left-hand ramp, and related items.

The film analysis of the performance of the unfamiliar and familiar driver showed that, for low levels of flow, the average exiting speed of the unfamiliar driver was significantly lower than the average exiting speeds of the familiar driver and the through vehicles as well (6). This was not the case at higher levels of flow.

Generally, the point of departure characteristics of the familiar and the unfamiliar

TABLE 2

HAZARDOUS MANEUVERS AT FOUR RAMP TERMINALS ON CONGRESS STREET EXPRESSWAY, TWO HOURS OF OBSERVATIONS, SPRING 1962

Type of Hazardous Maneuver	Number of Maneuvers[1]											
	At Left-Hand Exit, Harlem, Westbound			At Right-Hand Exit, First Westbound			At Left-Hand Exit, Harlem, Eastbound			At Left-Hand Exit, Austin, Eastbound		
	Low Vol.	Med. Vol.	High Vol.	Low Vol.	Med. Vol.	High Vol.	Low Vol.	Med. Vol.	High Vol.	Low Vol.	Med. Vol.	High Vol.
Exit from center lane	2	8	8(1)	5(1)	11	4	14(3)	11(1)	0	0	0	0
Exit from far lane	1	0	0	0	3	0	3(1)	1	0	0	0	0
Off and on	0	4	1	0	3(1)	0	1	0	0	1	0	0
Cutting in	0	0	1	0	0	0	0	1	0	0	0	0
Late exit	3	3(1)	2	0	6	2	0	4	0	2	2	0
Total	6	15	12	5	23	6	18	17	0	3	2	0

[1] Numbers in parentheses refer to hazardous maneuvers executed by trucks.

driver differed little. It was found that at low traffic-volumes a significantly greater number of unfamiliar drivers departed at a distance greater than 100 ft than did familiar drivers.

Of all questionnaires distributed, 58.9 percent were returned. An analysis of these questionnaires revealed the following.

Familiar Drivers

Only a minute percentage of the familiar drivers answering stated that they had not intended to exit at the particular ramp at which they were interviewed. Several of the drivers had planned to exit at the previous right-hand exit, but had been trapped in left lane.

Approximately 80 percent of the familiar drivers remembered that their exit was on the left side of the traveled way. However, slightly more than one-half the familiar drivers stated that they were aware of their proximity to their regular exit by the use of signs. About one-third recognized it by the use of landmarks and similar orienting devices.

Individual opinions about the suitability of left-hand ramps were reported by many of the familiar drivers. The majority reported that a combination of both left- and right-hand exits was "okay"; about one-third felt that left-hand exits should be eliminated in future designs. A large number of familiar drivers expressed the feeling that it did not matter so much on which side of the expressway the exit was placed, so long as the placing was consistent.

Unfamiliar Drivers

Inspection of the returns from the unfamiliar driver showed that about 15 percent had not wanted to exit at the particular ramp at which they were interviewed. Several had missed the previous left-hand exit; others chose to leave because of congestion on the expressway ahead. Some had been trapped in the left lane, but desired to exit at the previous right-hand exit as had been the case for some of the familiar drivers.

More than 70 percent of the unfamiliar drivers first knew that the exit was on the left because of a sign; another 14 percent identified the exit because they actually saw

TABLE 3

HAZARDOUS MANEUVERS EXPRESSED AS PERCENT OF VOLUMES ON THE EXPRESSWAY

Flow Included in Volume	At Left-Hand Exit, Harlem, Westbound		At Right-Hand Exit, First, Westbound		At Left-Hand Exit, Harlem, Eastbound		At Left-Hand Exit, Austin, Eastbound	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
Exiting vehicles	1,454	2.27	1,129	3.02	725	4.83	425	1.18
Exiting veh. plus those in adj. lane	4,838	0.68	4,595	0.74	3,101	1.13	2,869	0.17
Exiting veh. plus those in all through lanes	9,856	0.33	9,868	0.34	7,798	0.45	7,728	0.06

the ramp. Of those remembering a sign which was of particular help to them, the greatest proportion of unfamiliar drivers stated that the sign one mile ahead of the ramp was the most help.

A majority of unfamiliar drivers felt that a combination of both left-hand and right-hand exits was "okay," whereas one-third of them suggested that left-hand exits should be eliminated in the future. Here again, as for the familiar driver, several unfamiliar drivers stated that consistency in the placement of exits was the primary factor rather than whether their position was on the left- or right-hand side.

Almost one-half the familiar drivers suggested the need for improvements on the signing approaching a left-hand ramp. A large proportion of unfamiliar drivers stated that more advance warning was needed to improve the efficiency of the left-hand ramps. A slightly smaller proportion felt that nothing need be done.

From this analysis, it appears that the majority of both familiar and unfamiliar drivers rely on adequate directional signing to aid them in using left-hand exit ramps. In general, the drivers were not opposed to a combination of left-hand and right-hand exits.

APPLICABILITY OF RESULTS TO OTHER AREAS

To appraise the applicability of the results of the Congress Street Expressway study to left-hand exit ramps on other freeways where driver characteristics might be expected to differ, a direct evaluation technique was developed. This technique involved manual sampling of volume distribution by lane and samplings of speeds by lane, exit paths, and hazardous maneuvers. The direct evaluation technique was checked against results obtained by time-lapse photography in a controlled test and was found to yield appraisals of suitability that were comparable to those via the use of photography (7).

The direct evaluation technique was used to study a total of five left-hand and four right-hand exit ramps. Two of the left-hand ramps were situated in California; the Fifth Street southbound exit from US 66 in San Bernardino, and the Cabrillo Boulevard northbound exit from US 101, south of Santa Barbara.

The exiting maneuvers at all sites conformed to a pattern consistent with the findings of the Congress Street Expressway study, as modified to allow for the effects of the differences in the physical layout of each site.

Although more investigation is desirable, it appears probable that the findings of the Congress Street Expressway studies are applicable in other parts of the country as well.

CONCLUSIONS

The conclusions stated here are based mainly on results of a study of three left-hand exit ramps and one right-hand exit ramp, located on a six-lane section of the Congress Street Expressway in Chicago, Ill. Although the studies were quite detailed, the scope of ramp and freeway configuration was limited due to the similarity of location and design of the three left-hand exit ramps. The three left-hand exit ramps are elements of two successive diamond interchanges which are the only interchanges along the entire section of the freeway having left-hand ramps. Each ramp studied had a direct, high-type design which permitted high exit speeds. Adequate directional signing was provided in advance of each left-hand exit. During the study, the freeway roadway carried up to 6,100 vph in one direction, with ramp volumes up to 800 vph, including 70 trucks.

For this type and location of left-hand exit ramp, the following can be concluded from this study:

1. The left lane, at an approach to this type of left-hand exit ramp, does not tend to carry an appreciably greater percentage of the total volume than at an approach to a right-hand ramp, except at low volume levels. At intermediate and particularly at high volumes, the through drivers at these left-hand exits apparently tend to compensate for the unbalancing effects of exiting vehicles in the left lane by using the other two lanes.
2. Such left-hand exit ramps generally do not have an adverse effect on the speed of operation of the traffic.
3. No noticeable increases in density, or bunching of vehicles, are found upstream from these left-hand exit ramps, resulting from exit ramp operation.
4. The operation of these left-hand exit ramps is not adversely affected by the percentage of trucks normally using this level freeway or its ramps, under regulations which do not require trucks to keep right.
5. The majority of vehicles begin exiting in the first hundred feet of the deceleration lane.
6. There was no indication from these studies that hazardous maneuvers are more prevalent at this type of left-hand exit than at right-hand exits designed for high-speed exiting.
7. Adequate advance directional signing is relied on to a great extent by the "unfamiliar" drivers to advise them that their exit ramp is on the left-hand side. The "familiar" driver generally remembers when this exit is on the left, but depends largely on directional signing for notification of approach to the particular exit.

RECOMMENDATIONS FOR FURTHER STUDIES

1. Further study is needed to determine the suitability of left-hand ramps under a wider range of conditions, as follows:

   a. Further studies are desirable to determine to what extent these conclusions apply to left-hand exit ramps located on upgrade freeway sections, provided that such sites can be found.
   b. Additional studies of left-hand exit ramps will be desirable to investigate other variables as follows:

      (1) Variations in geometric design other than grade of freeway.
      (2) Variations in traffic volume and composition.
      (3) Variations in the type of interchange which uses the left-hand exit ramps, and variations in the sequencing and location of left-hand and right-hand exit and entrance ramps.

2. In the previous study, the great majority of the exiting vehicles were already in the left-hand lane 3,300 ft ahead of the left-hand exit. Additional studies of the lane-changing practices of exiting vehicles should be made for even greater distances upstream of the exit.
3. As accident data become available, studies should be made of comparative hazard of left-hand ramps under different physical and traffic conditions.
4. The present study of left-hand ramps should be extended to encompass entrance ramps.

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