

SUMMARY REPORT 59-4(S)

EFFECTS OF OFF-RAMPS ON FREEWAY OPERATION

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Effects of Off-Ramps on Freeway Operation

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Studies have indicated that the off-ramp is a critical element of a freeway facility and can contribute significantly to both desirable and undesirable operations. If maximum efficiency is to be obtained from a freeway, the off-ramps must be located, designed, and operated to minimize any adverse effects on main-lane freeway flow and to permit maximum utilization of the facility. The original objectives of the off-ramp project were to evaluate the effect on freeway operation of (1) the frequency of off-ramps and (2) various arrangements of off-ramps. Studies of the off-ramp problem led to the conclusion that the objective of the off-ramp project should be expanded to study the total effect of off-ramps rather than the more narrow scope of considering only frequency and arrangement. Consideration of the problem resulted in the definition of several factors of off-ramp location, design, and operation that could affect the operation of the freeway. These factors are enumerated as follows: (1) deceleration distance, (2) off-ramp capacity, (3) short trip generation, (4) weaving maneuvers, (5) access control, and (6) access provision.

Research on the off-ramp project was directed toward an investigation of each of the above factors. A brief discussion of the studies conducted in connection with each factor is presented in the following sections.

Deceleration Distance

Previous research has shown that an inadequate deceleration distance on an off-ramp can cause exiting vehicles to decelerate before leaving the main lanes of the freeway. This deceleration can cause shock waves to be generated near the exit ramp and propagated upstream on the freeway. The shock waves can constitute an accident hazard and cause reduction in the operating efficiency.

Since insufficient data existed from which to evaluate the effects of deceleration distances, studies were designed to investigate these effects. Sites on the Gulf Freeway in Houston and on IH 35 in Fort Worth were chosen for study locations and motion picture and acceleration noise studies were conducted.

Off-Ramp Capacity

Off-ramp capacity is defined here as the ability to move vehicles from the main freeway lanes to a service road or city

street. If inadequate ramp capacity exists at a given location then queues may form causing stalled traffic to back onto the main lanes of the freeway. This creates a very undesirable situation on the freeway and could be one serious effect of off-ramp operation.

Inadequate ramp capacity can result from several conditions. These conditions are as follows:

1. Signalized intersections located in the near proximity of the off-ramp terminal. Traffic queuing against a red signal indication can backup and block the off-ramp movement.
2. Where high volume frontage roads exist, it may become difficult to move from the off-ramp into the frontage road stream.
3. Two or more lanes are sometimes provided on the off-ramp near the exit from a freeway and these lanes then merge into a single lane or diverge into two separate roadways a short distance from the freeway exit point. The necessity to weave into a single lane or into the proper lane for a diverging maneuver can create capacity problems.

After considering the above three cases, it was determined that information existed for conditions 1 and 3 but that no design data were available for condition 2. Research studies were thus directed toward developing capacity-design data which would permit the designer to consider off-ramp capacity. Studies of this capacity aspect were conducted utilizing a computer simulation program.

Short Trip Generation

The generation of short trips on a freeway tends to destroy its integrity as a long trip facility and could seriously affect traffic flow during peak periods. It was thus deemed necessary to investigate the amount of short trip generation on freeways with frequent ramps. Data on the origin and destination of ramp traffic on the Gulf Freeway in Houston and the North Central Expressway in Dallas were obtained to evaluate short trip generation.

Weaving Maneuvers

As the frequency of entrance and exit ramps on a freeway increases the length of weaving sections between entrance and exit ramps decreases which could create a weaving problem. The extent of weaving that may occur in a given freeway section due to the distribution of vehicles over the freeway lanes and the desired exit movements was not well documented and this project sought to study this factor. A "Lights On" study conducted on the North Central Expressway in Dallas which provided lane use data on individual vehicles utilizing the freeway was used for this purpose.

Access Control

The problem of access control on exit ramps has been brought to the attention of the public by numerous spectacular crashes involving vehicles which entered an exit ramp travelling in the wrong direction and became involved in a head-on crash with vehicles moving in the opposite direction. The studies in this phase sought to define the extent of the problem by a review of current literature and the collection of data on violations of this type. Types and designs of directional detectors for possible use in data collection were also considered.

Access Provision

The basic need for the freeway off-ramp is, of course, to provide access to abutting property and to provide connections to major arterials of a city's distribution system. Early considerations of this factor indicated that a question existed as to how this access provision and major arterial connection should be made. There are various forms of exit and entrance ramp configurations in use but little attention has been given to the effect of these configurations on freeway operation.

Two common interchange configurations are the Diamond-Type and the X-type Interchange. A third type which has been utilized to a lesser extent is the "Stacked Ramp" configuration which crosses entrance and exit movements by the use of a grade separation. It was found that very little factual data existed to guide the designer in the selection of these types.

In order to consider the effect of ramp arrangement and interchange configuration, studies of traffic desires at interchanges, freeway gap availability, and geometric requirements were conducted. The Gulf Freeway in Houston provided study locations for the collection of operational data.

Presentation of Results

Research work on the project was divided into three basic areas which were as follows:

1. Investigation of the Effects of Off-Ramps on Freeway Operations as Related to Deceleration Distance and Off-Ramp Capacity.
2. Investigation of the Effects of Off-Ramps on Freeway Operations as Related to Short-Trip Generation, Weaving Manuevers, and Access Control.
3. Investigation of the Effects of Off-Ramps on Freeway Operations as Related to Access Provision.

Summary Conclusions

As a result of the research studies conducted to evaluate the previously discussed factors, the following general conclusions were drawn:

1. Off-ramps do exhibit an effect on freeway operation as indicated by speed and acceleration noise measurements. However, in all cases studied this effect was not exceedingly severe and the extent was directly related to the design of the off-ramp. Well designed off-ramps showed considerably less effect than those of less adequate design.

2. Studies of off-ramp capacity pointed to the need for data on merging capacities of off-ramp and frontage road flow. Where frontage road volumes are heavy and where no priority of right-of-way assignment is given to the off-ramp traffic the capacity of the ramp is quite low. This condition can create ramp queues which back into the freeway and seriously affect freeway flow. Through the use of a simulation model, design curves were developed which permit the consideration of possible queue lengths for various traffic conditions.

3. Short trip generation on a freeway is not a serious problem and mainly results from discontinuous frontage roads or difficult surface street routing.

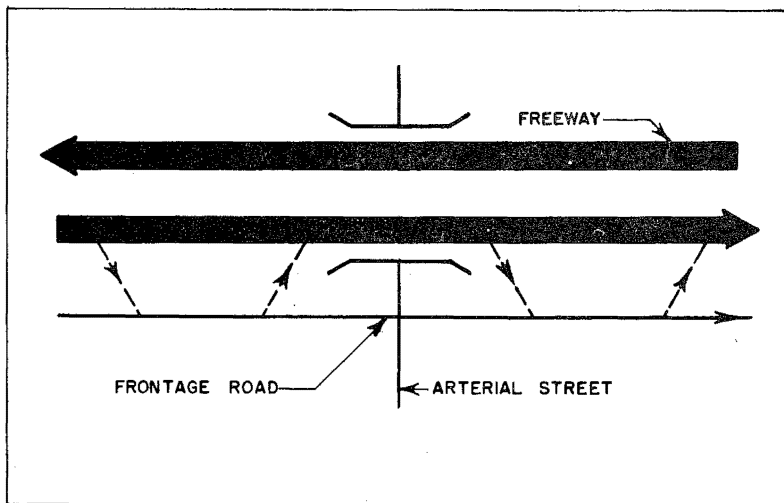
4. Frequent exit ramps do not appear to create serious weaving problems at individual exit locations. Traffic tends to move to the outside lane of the freeway well in advance of the exit point which eliminates the undesirable effect of last-minute weaves across intervening freeway lanes.

5. The problem of wrong-way entries on off-ramps is a serious one and merits special studies to develop design and/or controls for its elimination.

6. Traffic studies at interchanges indicated a wide variation of desired traffic movements resulting from land development in the area and the existing surface street configuration. It was thus deemed desirable to make provisions for both an on- and off-ramp in the near vicinity of and in each quadrant of an arterial street interchange as shown in Figure 1. If either the on- or off-ramp in any given quadrant cannot be justified in the initial design, then design considerations should be made which would allow stage construction of the ramp at some later date when traffic conditions warrant its construction.

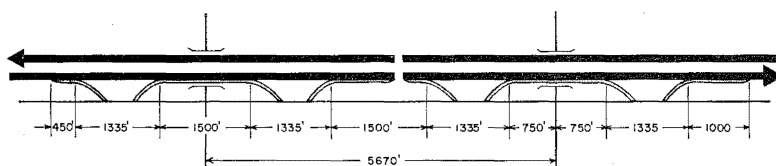
7. Studies of freeway operation, access to abutting property and intersection operation resulted in the conclusion that the most desirable arrangement of ramps is as shown in the freeway layout in Figure 2. This layout maximizes gap availability for on-ramp traffic, provides more direct access to abutting properties, eliminates unnecessary traffic flow through the signalized intersections (frontage road-arterial street) and provides maximum storage space for traffic entering the freeway or waiting against a red indication at a signalized intersection.

8. The type layout recommended in number 7 above could create weaving problems on the frontage road when heavy exit

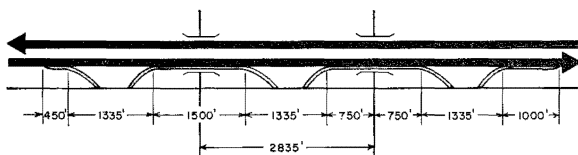


INTERCHANGE LAYOUT

FIGURE 1.



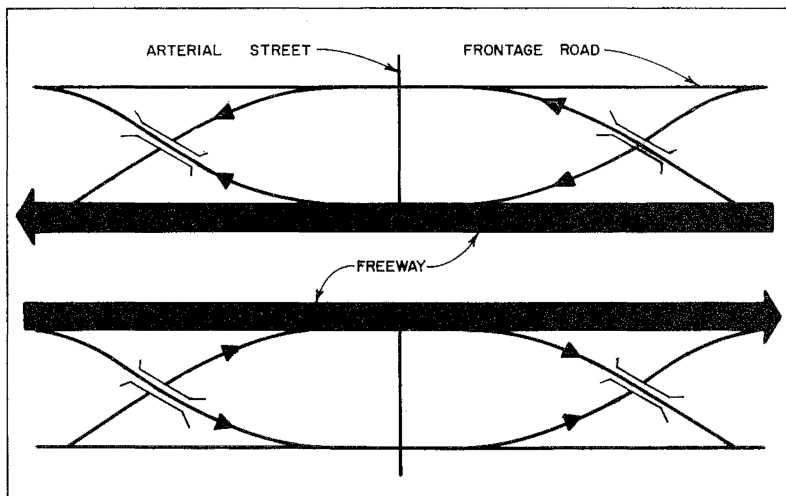
TYPE I FREEWAY LAYOUT
(MINIMUM SPACING DESIGN)



SPECIAL CASE OF A TYPE I FREEWAY LAYOUT
(MINIMUM SPACING DESIGN)

TYPE I FREEWAY LAYOUTS

FIGURE 2.



STACKED RAMPS

FIGURE 3.

and entrance ramp flow exist adjacent to each other. This difficulty could be overcome by the use of a "stacked" ramp arrangement such as shown in Figure 3. Studies of the "stacked" ramp geometrics indicated that such ramp arrangements would not generally be feasible unless warranted by especially high traffic.