and the unusual direction of traffic rounding a long radius curve. The double roadway may encourage improper entrance of the off-ramp by surface street traffic.

c. Design to Assure Entrance to Surface Streets at Appropriate Speeds.

One of the main functions of a traffic interchange is to provide for a transition from expressway to surface street speeds in leaving the expressway and vice versa in entering the expressway. Proper elements in obtaining this result are adequate acceleration and deceleration areas along the expressway, sufficient length of ramps and proper detail at the surface street intersection.

At an exit to the surface street, the design must insure the entrance of traffic into the surface street at controlled speeds which will not conflict with the traffic along the surface street. The function of the exit is to discharge the traffic from the expressway into the street without delay, but from that point, traffic must of necessity conform to the limitations of traffic along the surface street. There is, therefore, usually no advantage in large radii turns or other features which would encourage rapid and uncontrolled entrance of traffic into the surface artery.

It may be necessary to control traffic entering the surface street by boulevard stop or traffic signal.

d. Positive Elimination of Left Turns.

If it is possible to provide convenient access to and from the expressway by prohibiting left turns on the surface artery, this may be accomplished by an actual barrier consisting of a raised curbed island along the center of the artery. Such barriers may also be used to discourage illegal turns into exit ramps. Auxiliary roadways on grade separation bridges may be provided across the expressway to permit "U" turns between one-way frontage roads without the necessity of traffic entering the main roadway of the surface artery. An auxiliary roadway of this type is illustrated on the drawing of Type "c" interchange.

e. Protection of Left-Turning Movements Along the Surface Artery by Center Island Construction.

In some cases it may be possible to shield left-turning movements by construction of a wide center island along the surface artery. Such islands, which should have a width of 20 to 25 feet, will reduce the interference of left-turning traffic with smooth flow of traffic along the artery.

5. Consideration of Traffic Safety and Volumes Justifying Each Type of Interchange.

In describing each of the above-listed types of interchanges, the general effect on traffic safety and volumes has already been discussed. No definite rule can be established nor measurement made as to when any one type of interchange should be used. Further experience with and study of existing interchanges will be most helpful in establishing the traffic volumes which may be handled by each type of interchange and its traffic safety factor. A reliable estimate of the traffic to be handled and the number of turning movements is essential in the selection and design of the traffic interchange. Having this information the data gathered by the Committee on Highway Capacity, Highway Research Board, will be a helpful guide in the selection and design of interchanges. Each design must be based on a careful analysis of the situation and requires close cooperation between the designer and the traffic engineer.

BRIDGING EXISTING STREETS

In the location and design of a controlled access, urban expressway, bridging existing streets poses two problems: (1), Carrying some existing streets over or under the expressway; and, (2) grade separation of feeder streets in areas tributary to the expressway, to accommodate present or anticipated local overloads.

1. Expressway Grade Separations.

A controlled access expressway presents a barrier to movements of traffic from one side to the other unless cross roadways are under- or over-

passed. However, all local streets and roadways in an urban area cannot be so bridged. The cost would be prohibitive. Crossings can be constructed only at reasonable spaced intervals unless traffic demands or other controlling factors require more frequent facilities for cross movement.

Crossings are ordinarily provided at or near expressway interchanges and ramp connections. Thus, necessary interchange facilities spaced at intervals along the route of an expressway, the locations of which are primarily determined by heavy traffic demands that must be accommodated and which are adjusted to physical conditions, automatically include reasonably adequate provision, in most instances, for cross movement of both local and expressway traffic. Since such interchanges or ramps are usually at or near points of intersection of the expressway with main cross and feeder roadways which carry heaviest traffic and which provide best distribution, the problem remains of determining what other cross roadways should be bridged for local reasons.

Studies of present and future traffic loadings will indicate the effect of the expressway on the local street system and if the development of the areas it serves will increase, reduce, or shift the traffic load at various points along its course. Such studies will also indicate the measure of intermediate traffic demands for cross movement. Traffic needs thus determined must then be balanced with physical conditions and cost to establish the best locations for necessary intermediate or local crossings. Since the location of grade separations must be adjusted to elevations, adequate bridge clearances, railroad structures, public utilities, streams, local drainage and other physical factors, they cannot always be placed to greatest traffic advantage.

In sections where additional grade separations are determined to be necessary, locations should be selected that will serve the greatest total cross flow of traffic and as many other streets in the area as possible should be connected to the crossing by service roads parallel to the expressway, if the local street system does not serve this purpose.

Criteria for additional crossings include consideration of the following factors:

a. Important through streets or highways, now connecting significant traffic generating areas which will be divided by the expressway, cannot normally be dead-ended and must be over - or under-passed or detoured and combined with other crossings.

b. Cross movement of fire apparatus and other emergency services must be facilitated by reasonably direct routings.

c. Schools, other important public functions and services, business centers and churches require direct or at least reasonably satisfactory cross traffic connections or pedestrian overpasses.

d. Important transit facilities, that cannot be re-routed, will require accommodation for cross movement without excessive detour.

e. Conveniently direct access for vehicles and pedestrians to transportation terminals or stations must be arranged if other cross connections and parallel streets or service roads do not already provide this accommodation.

f. Pedestrian movements.

2. Bridging Streets in Tributary Area.

The construction of an urban expressway frequently increases the traffic load and intensifies congestion on local feeder streets in tributary areas. The utility of a costly expressway will be seriously reduced if these conditions result in retarding or blocking the local collection, discharge and dispersal of expressway traffic. Circulation of local traffic will also be seriously interfered with.

Thus, the construction of an expressway requires coordinated action on the part of state and local officials to take all necessary steps to reduce present and anticipated traffic congestion to an acceptable level. In some instances, grade separation of important local street intersections may be required. Such grade separations are costly and should be undertaken only after all other alternatives have been

thoroughly explored and found to be inadequate to meet requirements.

Alternatives include steps listed below under "Opening New Streets and Improvement of Existing Streets". An analysis should also be made of local ramp and interchange facilities to the expressway which, together with service roads, may be capable of arrangement to distribute the traffic load and to ease the burden on local streets that will be seriously affected. Thus, it is often possible, by means of expressway service roads, to collect and disperse local traffic over a number of local streets rather than to concentrate the load on one or more main arteries. This may also avoid grade separations of important feeder streets.

Assuming that all possible lesser steps to relieve present and anticipated congestion are taken and that traffic demands will still exceed the capacity of local intersections, one or more grade separations may be indicated. However, unless the benefit cost ratio, calculated for each such separation, is two to one or greater or other major local controlling factors prevail construction of such grade separations may well be postponed or avoided because of excessive cost and marginal benefits.

OPENING NEW STREETS AND IMPROVEMENT OF EXISTING STREETS

Plans for the development of a controlled access urban expressway should include consideration of street improvements that may be required in tributary areas to provide suitable expressway access and egress and ample street capacity to meet local traffic demands.

1. Opening New Streets.

Steps listed in the next section, "Improving Existing Streets" should be thoroughly explored to determine if limited improvements and better management of traffic and of traffic facilities will provide the relief required.

Service roadways parallel to an urban expressway, and usually but not always within its right-of-way, should be constructed where necessary to afford street frontage and access to adjacent property and to facilitate local collection, distribution and interchange of expressway traffic.

Right-of-way and design requirements of an expressway may necessitate the closing of some local streets and the substitution of new ones.

Adaption of local streets to expressway service roads and to interchanges and access ramps may require new street connections for more direct access and traffic reservoir capacity or to segregate, detour or by-pass traffic.

Future development and expansion of local industrial, commercial or residential traffic generating areas may require construction of or provision for new streets to serve as feeders to the expressway.

Additional streets may be needed to add traffic capacity to the existing street system or to permit the establishment of balanced pairs of one-way streets so that heavy increases of local traffic, generated by the expressway, may be accommodated.

2. Improving Existing Streets.

Streets reasonably adjacent and parallel to the expressway can often be improved and adapted to function as service roads to the expressway. Rights-of-way, preferably 100 feet wide or more, and greater widths on streets of unusual importance, should be provided on all major streets carrying local expressway traffic. Provision should also be made that major streets through all new subdivisions conform to these width standards. Such streets should carry at least two lanes of moving traffic and one lane for loading and parking at the curb in each direction and be provided with sidewalks of reasonable width. Where funds or other circumstances do not permit initial widening, set back ordinances may be passed to develop necessary widths of rights-of-way in the future as new buildings are constructed or old ones remodeled.

Other steps that may be taken to the extent necessary to insure that the local street system has adequate capacity to accommodate increased local traffic