4-06.1 INTERCHANGE JUSTIFICATION. Interchanges are considered where conflicting high traffic volumes exceed those which can be handled efficiently and safely with at-grade intersections, and with controlling access to the ingress and egress to the main highway. The location study recommends interchange location and type. Approximate traffic capacities for at-grade intersections without signals are given in Table 4-05.2. Similar data for traffic capacities of signalized intersections are given in Chapter VIII. These traffic capacities are used as a guide only, since local conditions will sometimes affect the capacity and dictate the need for and design of an interchange. A more precise analysis can be performed by means of the Highway Capacity Manual computer programs available in each design office.

Justification for new or revised access to the interstate system requires Washington office approval from FHWA. For guidance on the analysis and documentation requirements necessary, contact GHQ Design.

It is MoDOT’s intention to provide access for all traffic movements at interchanges on the state highway system. In some instances, traffic volumes may not warrant the provision of ramps at the time of initial construction. However, right of way should be purchased to provide for the “future ramps”. The plans for initial construction of the interchange should show the location of “future” ramps, which provide for these traffic movements.

4-06.2 INTERCHANGE TYPES. Basic interchange types are classified as:

- Diamond
- Folded Diamond
- Cloverleaf
- Trumpet
- Directional
- Single Point

Chapter 10 of the AASHTO Green Book provides examples of these interchange types. Controlling factors in the selection of the type of interchange are: the right of way requirements, speed and traffic volume demands, terrain conditions, type of access, control and the economics. Interchanges are designed to fit specific local conditions and should be of similar interchange types to provide a consistent expectancy for the driver. Diamond-type interchanges are used where the crossroad is minor, the control of traffic at the ramp intersection with the crossroad will not seriously inconvenience the crossroad traffic, and where the addition of the two intersections on the crossroad is not objectionable. Cloverleaf or directional type interchanges are used at major crossroads with access control and where the additional at-grade intersections are objectionable. Directional interchanges are used for heavy traffic turning movements, to reduce travel distance, increase speed and capacity and eliminate weaving movements. Trumpet type interchanges are used at "T" and "Y" intersections. A single point urban interchange (SPUI) or a tight diamond urban interchange (TDUI) should be considered when there exists a high traffic volume and when right of way is restricted or expensive. A SPUI generally uses less right of way than an TDUI, but requires a longer bridge span when used as an overpass interchange.

4-06.3 RAMP CAPACITIES. Ramp design traffic capacities are subject to variation and are limited by the capacity of the ramp proper, the capacity of the ramp termini, the capacity of the weaving sections and the volume of through traffic. Procedures and methods for evaluating these capacities are given in the "Highway Capacity Manual" and AASHTO Green Book. The application of these procedures is facilitated by the use of the highway capacity computer programs.

4-06.4 RAMP BASE LINES. See Subsection 4-04.3(10). Ramp base lines are always equated to the survey centerline and other ramp base line intersection points or the cross road centerline intersection point. The equations include offsets and intersection angles.

4-06.5 RAMP IDENTIFICATION. Diamond-type interchange ramps, cloverleaf type interchange ramps, directional and trumpet type interchange ramps are numbered for identification.

4-06.6 INTERCHANGE GEOMETRICS. Diamond-type interchange geometrics are approved from the schematic drawing shown on the preliminary plan. Other interchange types require the preparation of a plan sheet and a profile grade sheet by the district for submission to the Project Development Liaison Engineer for review and comment.

4-06.6 (1) PREPARATION. Drawings covering detail interchange geometrics are developed to the same scale that will be used on the plans and on standard size, 22" x 34" [560 mm x 865 mm] sheets. These dimensions are available in our CADD software. Either sheet will be acceptable during the interim transition. The drawing includes complete alignment details for ramp base lines and shows the limits of pavements. A supplemental standard size full profile sheet or cross section sheet is used for plotting profiles and developing ramp grades. The profile is plotted to the horizontal scale that will be used on the plans, and to a vertical scale of 1" = 10' [1:100]. If a standard size sheet is too small, additional standard size sheets are used, with match lines, or the layout may be prepared on a sheet of multiples of the standard size. The plan is developed to the best possible accuracy since this sheet becomes a master tracing from which later drawings for grade separation reports and plans are traced. Grades are considered tentative at this stage, and the ramp grades are developed similar to the requirements for preliminary plans. The plan sheet(s) includes complete traffic data for the intersection, including all turning movements. The traffic data is shown with the design hourly volume (DHV) over the average daily traffic (ADT) and also the percent of trucks. Other interchange types require similar details.

4-06.6 (2) SUBMISSION. Two prints of the interchange geometric sheets are submitted to the Project Development Liaison Engineer for review and comment. Three prints are submitted on all interstate projects to obtain concurrence from FHWA.

4-06.6 (3) ALIGNMENT FOR DIAMOND-TYPE INTERCHANGES. Alignment controls for diamond-type interchanges are illustrated on Figures 4-06.1, 4-06.2, 4-02.7, 4-02.8 and 4-02.9. The ramp curvature at the ramp nose or gore area should have a minimum radius of 6 degrees or less [295 meters]. The delta for this curve should be as small as the ramp grade and location of the ramp terminal at the crossroad will permit. If practicable, the ramp curvature is established so that both ends of the curve are a minimum of 100 ft. [30 m] from the ramp nose measured along the ramp base line. Alignment controls for folded diamond-type interchanges involving 2-lane and 4-lane minor roads are illustrated on Figure 4-06.7.

TABLE 4-06.1
RAMP DESIGN SPEEDS

HIGHWAY DESIGN SPEED, mph	RAMP DESIGN SPEED mph		
	UPPER RANGE (85%)	MIDDLE RANGE (70%)	LOWER RANGE (50%)
30	25	20	15
40	35	30	20
50	45	35	25
60	50	45	30
70	60	50	35

HIGHWAY DESIGN SPEED, km/h	RAMP DESIGN SPEED km/h		
	UPPER RANGE (85%)	MIDDLE RANGE (70%)	LOWER RANGE (50%)
50	40	30	20
60	50	40	30
70	60	50	40
80	70	60	40

90	80	60	50
100	90	70	50
110	100	80	60
120	110	90	70

Refer to Chapter 10 of the AASHTO Green Book for additional discussion of ramp design speeds.

4-06.6 (4) **OTHER INTERCHANGE TYPES.** Desirably, the ramp design speed in other types of interchanges should approximate the low volume running speed on the intersecting highway. This design speed is not always practical; therefore, the desirable ramp speed is 0.7 of the thruway design speed, but should not be less than the minimum shown in Table 4-06.1. This table shows the desirable ramp design speed for the corresponding highway design speed. The value shown on Table 4-06.1 applies to the controlling ramp curve, usually on the ramp proper. These speeds are not applicable to the ramp where it joins at-grade with a major cross road or street.

For highway design speeds of more than 50 mph [80 km/h], the loop design speed should not be less than 25 mph, with a minimum loop radius of 150 ft. [40 km/h, with a minimum loop radius of 50 m]. Loop ramp design speeds above 25 mph [50 km/h] in urban areas and 30 mph [60 km/h] in rural areas seldom are practical. For a 5 mph [10 km/h] increase in design speed on loop ramps, the travel distance increases over 50 percent and the required right of way increases about 130 percent. If practicable, a speed change transition curve of 430 ft. [130 m] radius or 230 ft. [70 m] at least is used at the loop terminals, depending upon the corresponding highway speed.

This radius curve is compounded with a shorter radius curve for the central portion of the loop. The speed transition curve extends at least 100 ft. [30 m] beyond the ramp nose and should begin or end at least 50 ft. [15 m] from the end of the grade separation structure. Minimum radii for design turning speeds are shown in Table 4-06.2.

TABLE 4-06.2
MINIMUM RADII AND SUPERELEVATION FOR TURNING SPEEDS

DESIGN SPEED mph	RADIUS (ft.)	SUPER-ELEVATION (ft/ft)	LENGTH OF CIRCULAR ARC, DESIRABLE (ft.)
15	50	0.00	60
20	90	0.02	60
25	150	0.04	70
30	230	0.06	110
35	310	0.08	140
40	430	0.08	190
45	540	0.08	200

DESIGN SPEED km/h	RADIUS (m)	SUPER-ELEVATION (m/m)	LENGTH OF CIRCULAR ARC, DESIRABLE (m)
15	7	0.00	20
20	10	0.00	20
30	25	0.02	20
40	50	0.04	20
50	80	0.06	40
60	115	0.08	50
70	160	0.08	60

4-06.6 (5) RAMPS FOR RIGHT TURNS. The desirable design speed is usually attainable for these ramps. A design speed of less than 30 mph [50 km/h] should not be used.

4-06.6 (6) DIRECT CONNECTIONS. Desirable design speeds should be used. For the ramps in directional interchanges, the minimum preferably should be 40 mph [70 km/h] and in no case less than 35 mph [60 km/h].

4-06.6 (7) PAVEMENT AND SHOULDER WIDTHS. Ramp pavement widths are shown on the typical sections D-50, D-51 and D-53. Ramp pavements are not usually designed for passing. However, loop ramp designs where the smallest compound radius is less than 400 ft. [120 m], a wider pavement is provided to allow passing should a vehicle break down within the loop.

See Subsection 6-04.6 for criteria on the placement of shoulder rumble strips.

Refer to Chapter 3 of the AASHTO Green Book for additional discussion of pavement and shoulder widths.

4-06.6 (8) BASIC NUMBER OF LANES. There is one fundamental design control that is maintained along a thruway route in addition to lane balance and capacity requirements; that is, the "basic number of lanes". The basic number of lanes is defined as the constant or minimum number of lanes provided throughout a significant length of the thruway route, exclusive of auxiliary lanes. Indiscriminate adding or dropping of basic lanes is discouraged.

4-06.6 (9) COORDINATION OF LANE BALANCE. Proper lane balance is maintained on the thruway at interchanges. The required number of lanes as determined by volume-capacity relations sometimes changes significantly at the point of entrance or exit. Lane balance requirements generally can be applied as follows to both entrance and exit ramp traffic.

- At entrance ramps, the number of lanes beyond the merging of two traffic streams should not be less than the sum of all traffic lanes on the two merging roadways, minus one.
- At exit ramps, the number of approach lanes on the thruway must be equal to or greater than the number of lanes on the thruway beyond the exit plus the number of lanes on the exit ramp, less one.

Refer to Chapter 10 of the AASHTO Green Book for additional discussion of coordination of lane balance and basic number of lanes.

Major fork and branch connection designs may be considered where appropriate as discussed in Chapter 10 of the AASHTO Green Book, along with the appropriate signing to designate the optional exit lane destinations. Separate lanes with separate lane use signing is preferred where major forks occur.

4-06.6 (10) AUXILIARY LANES FOR ACCELERATION AND DECELERATION (Parallel Type). Minimum speed change lengths are given in Exhibits 10-70 and 10-73 of the AASHTO Green Book. Lengths shown in these tables are for grades of 2% or less on the speed change lane. Exhibit 10-71 of the AASHTO Green Book provides adjustment to these lengths for grades over 2%. Speed change lanes are provided at all ramp entrances and exits where the number of through traffic lanes each side of the ramp terminal are equal. In no case should the combined length of full width acceleration lane and taper be less than 600 ft. [180 m]. A minimum 6 ft. [1.8 m] wide shoulder is provided for auxiliary lanes along the through traffic lanes (except a 4-foot [1.2 m] shoulder is to be provided along a median acceleration lane). Auxiliary lane width is the same as the width provided for the through traffic lanes. In rural areas, the ramp nose should be visible to approaching traffic for a distance equal to at least 1.25 times the stopping sight distance on the freeway or expressway. When stopping sight distance can be obtained in rural areas a deceleration lane length of 350 ft. [110 m] is used. (See Figure 4-06.1)

Where interchanges are closely spaced, less than 2500 ft. [760 m], the auxiliary lane for acceleration should be extended to the exit of the next interchange. An entrance lane followed by a lane exiting forms a traffic weaving section which requires added pavement width and a minimum length for weaving capacity. The capacity of the auxiliary lane connecting the on-ramp with the off-ramp should be checked with the highway capacity manual computer programs. The weaving section should have a length and number of lanes based on the appropriate level of service as given in Exhibit 2-32 of the AASHTO Green Book.

Where a two-lane entrance ramp or a two-lane exit ramp is needed for capacity or lane balance, the effective length of auxiliary lane should be determined as illustrated in Exhibits 10-76 and 10-77 of the AASHTO Green Book.

4-06.6 (11) CLEAR ZONES. Clear zones should be provided on all ramps, where feasible. See Subsection 4-09.14 for criteria on clear zones.

4-06.6 (12) LANE DROP. Where a reduction in thruway traffic demand shows a need for less traffic capacity, a lane drop or reduction in the number of through lanes is made on the exit ramp preferably one with a high traffic volume. This reduction may be made provided the exit volume is sufficiently large to change the basic number of lanes beyond this point on the route as a whole. A lane drop shall be made on a right hand exit ramp, only. Under no circumstance should a lane drop be made on a left hand exit ramp. This is absolutely unacceptable for safe traffic operation and satisfactory design.

Where a lane drop or a reduction in the number of thruway lanes is made, an "escape lane" or a pavement taper of convergence of 50 to 1 is provided beyond the gore nose for traffic to merge into the remaining through traffic lanes. (See Figure 4-06.9) Similarly, where two lane exit ramps are used, an "escape lane" is provided, if an auxiliary lane for lane balance is not provided beyond the gore nose.

4-06.6 (13) NOSE AND RAMP PAVEMENT WIDTH TRANSITION. Ramp nose treatment and pavement width transition, including additional pavement widths for storage are illustrated on Figures 4-06.1, 4-06.2, 4-06.3, 4-06.4, 4-06.5, 4-06.6, 4-06.7 and 4-06.8.

4-06.7 SUPERELEVATION. Minimum controls for superelevation of short radius curves on ramps is shown on Table 4-06.2. A maximum super elevation rate of 6% is used when a short radius curve is on bridge structure. This is the maximum superelevation suitable for satisfactory traffic safety under snow and ice conditions. The maximum rate of cross slope change is 5% per 100 ft. [30 m] to transition the superelevation cross slope back to normal cross slope. Ramp entrances and exits are designed to reach full superelevation at the ramp nose, if full superelevation can be obtained at this point. Superelevation transition for typical ramp entrances and exits are shown on standard plans. At ramp terminals with the thruway, the maximum algebraic difference in pavement cross slope is 5%.

4-06.8 GRADES. The general grade layout of interchanges, such as cross road over or under and ramp grades is selected and designed with grading economy in mind. The desirable maximum ramp gradient is 5 percent. In special cases, ramp grades as steep as 7 percent may be used. The use of grades steeper than 5 percent is usually restricted to short grades in urban or suburban areas. Vertical curves for ramps, both crest and sag, are designed to meet the requirements given in Section 4-04, based on the desirable ramp design speed, except that passing sight distance is not considered. The ramp grades for diamond-type interchanges at the ramp intersection with the crossroad are designed in accordance with the requirements given in Section 4-04, regardless of whether the ramp grade is up or down in relation to the crossroad. Crossroad grades, ramp grades, and sight distances in the vicinity of diamond-type ramp intersections with the crossroad are developed in accordance with the requirements for other at-grade intersections as given in Section 4-05, considering, in this case, that the crossroad is the main roadway. If the crossroad design speed is unknown, or less than 30 mph [50 km/h], a design speed of 30 mph [50 km/h] is used. Thruway grades are set, if at all possible, prior to developing the geometrics and ramp grades. The best procedure is to develop grades through and adjacent to the interchange in such manner that thruway grades outside the interchange area can be adjusted to finally balance grading quantities, and the crossroad through the interchange can be adjusted as necessary to provide near minimum vertical clearance for the grade separation based upon the final structure layout. This procedure will cause a minimum of revision to the geometrics as the grades are finally adjusted.

4-06.9 GRADING. Grading quantities in interchange areas may be computed by the computer or by manual methods, using cross sections or contours. The method used is optional with the district and is somewhat dependent upon the type of interchange, the terrain, and other factors. The plans include computer sheets, cross sections or contours, depending on the method used to compute the earthwork.

4-06.9 (1) COMPUTER. Conventional cross sections and additional grading quantities may be required to supplement the normal computer output.

4-06.9 (2) CROSS SECTIONS. This method is used to supplement main roadway quantities through the interchange and is most applicable to diamond-type interchanges. The main roadway cross sections extend to beyond the ramps, and supplemented by cross sections along the crossroad, are used by plotting templates for the additional quantities, and computing the quantities by the double-end area method.

4-06.9 (3) CONTOURS. This method is most applicable to interchanges other than the diamond-type. The main roadway grading quantities and the crossroad grading quantities are usually continued through the interchange area, and the contours supplement the normal roadway quantities. The use of contours for computing grading quantities requires the plotting of existing ground contours and finished grade contours. The finished grade contours are plotted to include site grading. The contour method of computing grading quantities is actually similar to the use of cross sections. In the case of contours, the end area used is the area between an existing ground contour and a finished contour (both at the same elevation), which is a cross section in a horizontal plane. Adjacent end areas are obtained in the same manner by using the next contour interval. The distance between the end areas is the contour interval. An advantage of the contour method of computing grading quantities is that the irregularities and sight distance obstructions in the interchange areas can readily be visualized and eliminated by site grading. This method also eliminates the time-consuming task of joining cross sections. The contours are usually plotted to a 2 ft. [0.5 m] contour interval on a plan of the interchange area developed to the detail plan scale.

4-06.9 (4) SITE GRADING. Grading quantities in interchange areas should desirably include site grading necessary to properly handle drainage, to improve appearance, and to eliminate blind intersections. Where possible site grading is done for all interchange areas. Preliminary plans should be reviewed carefully to determine if reduced site grading can be made to provide economy in the design. Requests for reduced site grading in interchange areas should be made to the GHQ Design ahead of finalized design.

Where site grading of an interchange area is made, it is desirable to provide flatter slopes and smoother contour lines, particularly at diamond interchanges. At locations where the crossroad is over the thruway, ramp slopes on the thruway side should be carried from the thruway roadway ditch to the shoulder point of the ramp. This will cause a variable slope between the ramp gore and the crossroad. Slopes on the outside of ramps should not be steeper than 1:3 and carried back to its intersection with the main roadway.

With additional site grading and flatter slopes, it is the intention to use guardrail only to protect bridge ends within the interchange area. The grading and slopes will also aid in reducing sign post sizes and lengths and assist in location.

4-06.10 SIGNALS. When warranted, consideration to the design of traffic signals should be made early in the design process. Such items to consider include lane assignments, signal visibility, pedestrian requirements and placement of the signal posts and bases. The preferred method of signal post design uses conventional signal tubular steel posts, mast arm and bases as shown in the standard plans. This may be accomplished by using traffic islands, if necessary. For single point urban interchanges (SPUI), long span one or two tube steel supports should be avoided. However, if a one or two tube steel support cannot be avoided, a design exception must be obtained from GHQ Design. As with all signal structures, shop drawings and stress calculations must be submitted prior to fabrication for approval.

4-06.11 DRAINAGE. The plans provide adequate facilities for handling drainage through and from the interchange area, including adequate provisions to prevent water or melting snow from running across pavements. Erosion control in the interchange areas is provided for in the design. Storm water detention basins should be considered within an interchange in urban areas.

4-06.12 TYPICAL SECTIONS. The plans include detail typical sections for all ramps and the crossroad not covered on standard plans, including the location of survey and base lines, and the location of the profile grade in relation to the typical section.

4-06.13 PLANS. Detail plans show complete details for the construction of interchanges, including grading, geometrics, paving and drainage. Interchange grading quantities are tabulated on the plans, separated as much as conveniently possible from the main roadway grading quantities. Interchange grading quantities are considered in determining balance points in and adjacent to the interchange area. Details for typical ramp intersections are shown on standard plans. Similar details are required for ramp intersections not covered by the standard plans.