ORIGINATOR Director, Bureau of Highway Operations	3-4-10
CHAPTER 3	Project Scoping Process & Geometric Design Considerations
SECTION 4	Operational Considerations
SUBJECT 10	Interchanges

SELECTION OF INTERCHANGE SIGNAL OPERATIONS

A common question relating to the design of signals at diamond interchange ramp terminals is whether to use one or two controllers. There *may* be advantages or disadvantages to either alternative. This subject presents typical applications and some of the differences between these alternatives.

When deciding how many controllers and what type of phasing *should* be used, consider the following general factors: required flexibility in signal operation/timing plan, physical interchange size, nature/volume of ramp traffic, mainline coordination with adjacent signals, vehicle storage requirements, and motorist expectancy. In any case, the Regional Traffic Engineer **shall** make the final determination regarding the type of operation at signalized interchanges.

Table 1 indicates some of the advantages and disadvantages of various interchange operations discussed below.

SINGLE CONTROLLER INTERCHANGE APPLICATIONS

Single controllers are typically used at interchanges with tightly spaced ramp terminals (less than 500 ft) where vehicle storage *may* be an issue. Signals at interchange ramps that use a single controller will generally use the following types of phasing options:

- TTI phasing (a.k.a. Sequential) is commonly used at interchanges with relatively consistent, heavy ramp volumes. When this type of phasing is used, right-of-way is assigned to a single mainline approach which is followed up with the ramp on the same side of the interchange. Next, right-of-way is assigned to the opposing mainline approach which is then followed up with the ramp movement on that side of the interchange. Put differently, the mainline approaches (followed up by their "complimentary" ramp movement) are alternated.

  Vehicles will store on the outside of the ramp terminals; this will eliminate queuing on the roadway between the ramps. Phasing is appropriate for tightly spaced

interchanges. It is advantageous because mainline movements will only be stopped once in the interchange area, due to leading protected left turn phasing on the mainline approach of the interchange. A schematic diagram that depicts this phasing alternative is shown in TSDM Subject 3-4-4, TTI Phasing.

- Dual Ring with Overlaps phasing *may* be preferred over TTI Phasing particularly if ramp volumes are more variable or unbalanced. External mainline movements are assigned to phases 1 and 5. Ramp movements are assigned to phases 3 and 4. Internal mainline through and left turn movements are assigned to overlaps within phases 1 through 6. Similar to a standard four-legged intersection, any non-conflicting phases that have demand can be serviced simultaneously. Also, within these phases multiple movements that have been assigned to overlaps can be serviced.

  Ramp spacing *should* be great enough to accommodate queuing between ramp terminals. As such, a queue analysis *should* be performed. Refer to TSDM Subject 3-4-4 for example overlap diagrams. A schematic diagram that depicts this phasing alternative is shown in TSDM Subject 3-4-4, Dual Ring with Overlaps Phasing.

- Simultaneous Ramp Release *may* be either leading or lagging relative to the mainline through movements. With this type of phasing, traffic on opposing ramps are released at the same time and stored within the interchange. Next opposing interior through and left turn movements are released. This interval is followed by opposing exterior mainline through movements. Exterior mainline through vehicles that want to access the freeway by turning left at the opposite ramp terminal will also need to store within the interchange while the opposing through movement times out concurrently. This *may* necessitate multiple stops within the same interchange.

  This phasing requires that ramp spacing be great enough to accommodate queuing of the ramp traffic between terminals. As such, this phasing will not typically be appropriate for interchanges with tightly spaced ramp terminals and moderate to heavy ramp traffic. Even locations with relatively light ramp volumes would need to be considered closely. As with the Dual Ring phasing alternative above, a queue analysis *should* be performed. This type of interchange phasing is not normally used by WisDOT. As such, the Regional Traffic Engineer **shall** be consulted prior considering it's use.

Splice Cabinets at Single Controller Interchanges

When a single controller is used to operate both terminals, a splice cabinet *may* be located on the opposite side of the interchange at the discretion of the Regional Traffic Engineer. A splice cabinet is a controller cabinet shell that houses the consolidated signal cable conductors from the separate indications for each phase. Once wiring splices have been made in the splicing cabinet, then a multi-conductor signal cable is run back to the controller cabinet on the opposite side of the interchange. Otherwise, a single conductor per indication type and per phase is required to run back to the

controller cabinet for each of these phases. Installing a splice cabinet allows electrical personnel to pull only one cable instead of many, as illustrated:

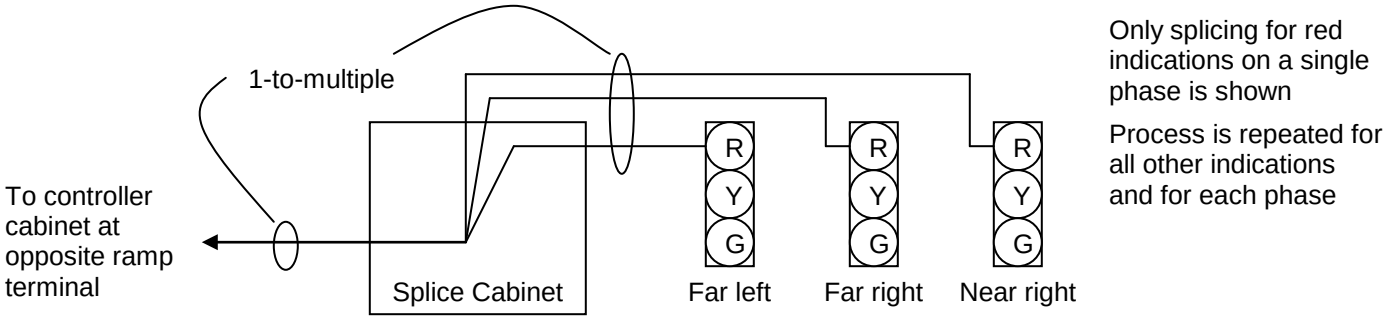

Figure 1. Splicing Cabinet

The splice cabinet *should* be placed in a location where electrical service is accessible. This will allow for placement of a full signal control cabinet in the future, if necessary.

TWO CONTROLLER INTERCHANGE APPLICATIONS

In some situations, it *may* be more appropriate to use a controller for each interchange ramp terminal. This type of arrangement will typically be applied at interchanges with ramp spacing greater than 500 ft. The use of two controllers will likely necessitate the need for coordination. One advantage of dual controller interchange operation is that a conduit crossing the interchange *may* not need conduit on bridge or through bridge, unless interconnected coordination is desired.

Two controller arrangements have greater flexibility for interchange signal operations due to the opportunity to program offsets, yet they are more labor intensive, in terms of coordination, maintenance, and cost when compared to single controller arrangements.

It is essential that two controller interchanges are accurate and remain in step with each other for coordination purposes.

Table 1

General Signalized Interchange Alternative Considerations

Operation or Phasing	Key Factors	Advantages	Disadvantages
Single Controller Applications (ramp terminal spacing < 500 ft)			
TTI	Heavy, consistent volumes at isolated location or where there is a relatively high percentage of left turning movements.	▪ Eliminates queuing within the interchange ▪ Works well in areas of high-demand ▪ Relatively straight-forward, consistent operation -- one movement occupies the interchange at any time ▪ May require only one stop within the interchange	▪ *May* not provide ideal conditions for coordination with adjacent signals ▪ *May* impose higher delay on users during periods of low use ▪ Forces queue outside of interchange ramps ▪ Basically, a pre-timed operation
Dual Ring w/Overlaps	Desire to provide progression on the mainline with more variable/unbalanced ramp volumes.	▪ Can provide improved conditions for coordination with adjacent signals ▪ Ability to provide leading-lagging left-turn phasing ▪ Omits phases 2 & 6 and recalls phases 3 & 4 ▪ Efficient	▪ Inconsistent operation, (penalized ramps (phase 3) must stop)
Simultaneous Release	Desire to provide high throughput on the mainline. Lower left-turning ramp volumes. **Limited use by WisDOT**.	▪ Provides improved conditions for coordination with adjacent signals	▪ Requires storage of left-turning ramp traffic within the interchange ▪ Left-turns off the mainline *may* be delayed due to phasing sequence
Two Controller Applications (ramp terminal spacing > 500 ft)			
Coordinated Ramps	Desire to provide progression on the mainline & need to provide maximum flexibility for future operational alternatives.	▪ Provides improved conditions for coordination with adjacent signals ▪ Can be made to mimic the phasing alternatives above. ▪ Provides greatest opportunity for operational flexibility	▪ Identifying & implementing maximized operational/timing plan using multiple controllers is more complex than using a single controller ▪ Both controllers must be coordinated ▪ Increased maintenance & capital ▪ *May* require additional detection

VEHICLE DETECTION

In the cases where a single controller is used, large ramp spacing can impact the effectiveness of inductance loops used for vehicle detectors. Refer to TSDM Subject 8-1-1

To operate properly, the differential between the inductance of the loop *should* exceed that of the lead-in cable by a factor of 2:1 (see TSDM Subject 8-1-8 for loop inductance calculations). There are two ways to compensate for the increased spacing.

The first method is to decrease the physical distance between the detection amplifiers that reside in the controller cabinet and the far loops. At diamond interchanges, the preferred location for the controller cabinet is inside the interchange footprint and adjacent to either off-ramp. Placement adjacent to either off-ramp is acceptable if sight-distance from the controlled approach is not impeded.

The second method is to increase inductance within the loop relative to the lead-in cable. This is done by using a larger number of turns within the loop. In general, that maximum number of turns a loop can contain is six.

RAMP METERING CONSIDERATIONS

In highly urbanized locations, future or pending ramp metering capabilities *may* need to be considered. Such considerations can include the need for interconnection to the traffic signal control cabinet and additional geometric capacity. Additional capacity treatments *may* include extension of right- and left-turn lanes used to access metered on-ramps, and additional lanes (at appropriate length) on the ramp itself to store vehicles.

OTHER ELECTRICAL FACILITIES

As stated in TSDM Subject 6-1-4, other facilities for continuous roadway lighting or ITS elements (such as ramp meters and VMS), **shall** be contained within their own systems for maintenance and operational reasons.

SINGLE POINT URBAN INTERCHANGES

Single Point Urban Interchanges (SPUI's) consist of a distinct geometric design, such that all interchange movements converge at a single point within the interchange and left-turns phases are eliminated. SPUI's are also a proper application for single controllers and will typically use 3-phase operation.

In the illustration on the right, vehicular movements served by individual phases are distinguished by color.

Figure 2. Single Point Urban Interchanges