ON USING PERFECT SIGNAL PROGRESSION AS THE BASIS FOR ARTERIAL DESIGN: A NEW PERSPECTIVE

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ABSTRACT

Many roadway agencies are interested in maximizing the throughput of existing roadways through the use of access management. Part of access management involves spacing intersections effectively so as to attempt to provide the maximum progression and bandwidth. However, an arterial often has intersections that are irregularly spaced, thereby not allowing for the maximum progression through traditional means. This paper proposes a new method of achieving perfect progression in both directions of an arterial roadway, by using signal progression itself as the design criterion for the arterial and its signalized intersections. First the green bands are established, and then the intersections are designed around them. What is important in the design of signal progression is to ensure that enough bandwidth is provided to handle the arterial’s through movements effectively. However, the most important parameter is a new parameter defined herein as the “bandwidth offset”, which is a measure of the amount of time in the cycle between the green bands in the two opposing directions of travel in a given location. Based upon these parameters, several principles for the design of intersections can be established. The hope with this theory is to be able to not just design a new corridor, but also to be able to retrofit an existing corridor, in order to guarantee perfect progression in both directions, minimizing the travel times along the corridor while also minimizing the long-term impacts on the surrounding community.
INTRODUCTION

Many roadway agencies wish to maximize the use of the existing road system as much as possible. One way of achieving this is through the use of access management techniques to control the location, spacing, and design of the median openings, access points, and intersections along an arterial corridor. One very important part of access management concerns the location and the design of the signalized intersections in order to promote good signal progression.

In Virginia, the Road Design Manual (1) contains some very explicit standards for the spacing of the signalized intersections on principal and minor arterial roadways, and on collector roads. In theory, the signalized intersections should be evenly spaced, and they should be spaced according to the signal spacing guidelines presented therein. However, there are a few flaws with that approach: First, many arterials do not have signalized intersections that can be evenly spaced. Second, it is often not possible to meet the signal spacing standards in many cases. Finally, there may be some cases where the intersections meet or exceed the spacing standards and are still not evenly spaced.

Indiana’s access management standards (2) take a different approach: Desirably, signals should be spaced one half-mile apart. If this is not possible, there is a definite bandwidth requirement that must be met, that provides a “window of green” in which traffic is able to proceed on an arterial roadway without stopping. This allows more design flexibility, but may be more technically challenging to enforce using the current design methodologies and tools currently in use.

Currently, in intersection design, designers focus simply on the performance of each individual intersection, to ensure that each intersection has enough capacity to handle the various turning volumes of traffic at each intersection, and can handle this traffic at acceptable levels of service (LOS) which is based on vehicle delay. Currently, optimization methods for a system of signals focus on minimizing the total network delay of a system of intersections, regardless of how many stops one may have to make on the arterial. These methodologies, however, have weaknesses. Synchro’s system optimization tools do not allow one to enforce a bandwidth requirement, and they do not take into account many other important factors.

On a principal arterial roadway, however, the design emphasis should be on moving large amounts of through traffic. How can delay be minimized if this through traffic has to stop at every other signalized intersection on an arterial roadway? This is frustrating to many drivers and can cause safety concerns, especially with heavy truck traffic.

This paper presents a new design methodology that overcomes these limitations, and uses perfect signal progression as a criterion for the design of an arterial roadway and its intersections. It is a system approach, where the design and operational characteristics of the arterial roadway system are determined first, and the design and operational characteristics of each intersection are determined based on where they are located within the system.

Unlike the superstreet intersection (3) in which the arterial corridor is essentially split into two one-way roadways, this design methodology is intended to be used on a two-way roadway. On a superstreet corridor, where each signalized intersection only controls one side of the arterial, a direct left turn or through movement on the minor road cannot be made without some type of
grade separation (4); this design theory eliminates that limitation, and in many cases will allow
the minor road’s left turns and/or through movements to be made at grade.

BACKGROUND

Perfect signal progression on a one-way street is possible regardless of the cycle length, the
design speed, or the distance between intersections. However, on a two-way arterial roadway,
maintaining perfect signal progression in both directions is more difficult.

Figure 1 is a time-space diagram which illustrates the difference between signal progression on
one-way streets and two-way streets. The yellow highlighted areas in these time/space diagrams
illustrate the green bands. The center side of the time/space illustrates signal progression on a
two-way street; the left and the right sides of the time/space diagram illustrate two different one-
way streets, flowing in opposite directions, both operating using timing plans that feature perfect
signal progression on a one-way street.

The center portion of Figure 1 illustrates the two directions of flow superimposed over each
other. This is representative of perfect signal progression on a two-way street. Some observations
must be noted:

• Both directions of flow on the two-way street will operate using the same signal cycle
  length.
• There will be points on the two-way street where the green bands will coincide with each
  other perfectly. These points will be evenly spaced, and will be known throughout this
  paper as “Point A”. At these “Point A” locations, the bandwidth offset (defined later) will
  be equal to zero.
• The points where the green bands coincide are given by an equation known as the
  resonant cycle length equation (5).
• There will be some other points on the two-way street where the green bands will pass
  through each point at completely different points in the cycle.
In traditional practice, it is assumed that perfect progression requires all of the intersections on a two-way street to be evenly spaced and located at the “Point A” locations on the time/space diagram where the green bands on both directions of the two-way street coincide. This, however, will not always be true. There are intersections that run on “lead/lag” left turn phasing on the arterial (with leading left turns in one direction and lagging left turns in the other direction) where the green bands on the arterial pass through the intersection at somewhat different points in the signal cycle length. There are now other intersection designs, such as the diverging diamond interchange, where the two sides of the arterial must cross each other at a signalized intersection, where the two green bands on the arterial must pass through the intersection at completely different times within the signal cycle. It can then be seen that different intersection types and operational strategies will work best in different locations on the two-way street.

It can therefore be postulated that it is possible to achieve perfect progression on a two-way street, regardless of the intersection spacing and even with irregular intersection spacing. This will require designing all of the arterial’s signalized intersections to fit within the requirements of progression, while still handling the minor road’s turning and crossing volumes effectively. Figure 2 illustrates a time/space diagram of an arterial system operating in perfect progression in both directions, with each of the irregularly spaced intersections functioning under a different set of design criteria, based upon a set of five different design inputs.
Figure 2. Intersections need not be evenly spaced. However, the design requirements of each one will depend on the turning volumes, the amount of bandwidth needed, and its position in the time/space diagram (e.g. the offset between the arrival of the platoons in both directions). Intersections, represented by the vertical lines in the time/space diagram, will therefore require different design and operational strategies.

Figure 3.
DESIGN INPUTS

In designing a corridor for perfect signal progression in both directions, each intersection will have different design requirements based upon five different design inputs. The system will require one common cycle length, determined by the resonant cycle length. Once this resonant system cycle length is established, there are four other inputs that will influence the design of each intersection: the bandwidth offset, the amount of bandwidth required for the arterial, the turning movement volumes, and the signal cycle length.

Resonant Cycle Length/Distance/Speed Relationship

The time/space diagrams on the Figures 1, 2, and 3 show that, on a two-way arterial roadway where there is perfect progression, there are points along the arterial where the green bands of both directions of the arterial pass through simultaneously (herein called “Point A”, and is labeled as point “A: in Figures 1 and 3). These points are given by:

\[ C = \frac{2L_a}{S} \]  

(1)

Where:

- \( C \): signal cycle length (seconds),
- \( L_a \): the distance between each Point A (feet)
- \( S \): the speed limit of the arterial (ft/s)

Traditionally, this equation is used as the basis for the intersection spacing on an arterial. However, it is not necessary to locate all of the intersections at the Point A locations. Intersections can in fact be located anywhere, and the Point A locations can be completely arbitrary. The Point A locations will always be evenly spaced, even if the intersections are not evenly spaced.

In a design for perfect progression, the locations of each Point A, even though they are arbitrary, must be pre-determined in advance of any design activities, because the bandwidth offset of each intersection will depend upon its location relative to each Point A.

Bandwidth Offset

Normally, in a coordinated signal system, the offset of each intersection is defined as the number of seconds (or percent of the cycle length), relative to the master intersection, of the beginning of green of the coordinated phase of the intersection.

Here, a new variable called the bandwidth offset is defined. The bandwidth offset of each intersection is defined as the amount of time in the cycle length between the onsets of green of the two opposing directions of travel on the arterial.

The bandwidth offset required of any intersection is directly related to its distance between each Point A is defined as follows:

\[ F = \frac{D_a}{L_a} \times 100\% \]  

(2)
Where:

F: bandwidth offset (percentage of cycle length)

D_a: distance from the intersection to the nearest Point A (feet)

L_a: distance between each Point A (feet)

Figure 2 shows an example of randomly-spaced intersections, each one with a different bandwidth offset; Figure 4 shows the impact of the bandwidth offset (which will be discussed later). At each Point A on the time/space diagram, the bandwidth offset is zero. At the midpoint of the links between each Point A (called Point C), the bandwidth offset is 50%. For all other locations, the bandwidth offset is as defined above.

FIGURE 4. Illustration of varying bandwidth offsets in a time/space diagram.

The bandwidth offset will directly affect the design and operational strategy needed for each intersection: The greater the bandwidth offset, the lesser the amount of green time there is available to the minor road’s movements. An intersection with a higher bandwidth offset is more likely to require lead/lag phasing (or split-phasing) on the major road, as opposed to an intersection with lower bandwidth offset that will require simultaneous left-turn phasing (or redirected left turns) on the major road. This is explained in further detail below.

Bandwidth Amount Needed

The INDOT Access Management Guide (2) defines bandwidth as a “window of green” along an arterial where drivers can traverse its length without having to stop at any of its signals. For example, an arterial that has a 50% bandwidth, if it were to have a 100-second cycle length,
would have a 50-second window of green during which traffic can traverse the length of an arterial without having to stop at any of the signals.

Recall that the saturation flow rate for any given movement at a signalized intersection can be determined from the following formula from the Highway Capacity Manual (6):

\[ c = sN \frac{g}{C} \]  

(3)

Where:
- \( c \): capacity for movement at intersection (vehicles per hour)
- \( s \): saturation flow rate (vehicles per hour per lane)
- \( N \): number of lanes
- \( g \): effective green time in the signal cycle (seconds)
- \( C \): signal cycle length (seconds)

The ratio \( g/C \) represents the percentage of green time given to that particular movement.

When designing an arterial roadway to provide for perfect signal progression in both directions, there needs to be enough bandwidth provided along an arterial so that the through traffic volumes can be adequately progressed without having to stop at the signals. Therefore, the amount of bandwidth required is a function of the through volumes of traffic and the number of lanes provided. The equation above should then be recast in favor of the proportion of green time given to the major road’s through movements:

\[ \frac{g}{C} = \frac{c}{sN} \]  

(4)

Here, all terms are as defined previously. Let \( B \) be defined as the bandwidth required for the major road’s through movements, expressed as percentage of signal cycle length:

\[ B = \frac{g}{C} = \frac{c}{sN} \]  

(5)

Where:
- \( B \): arterial bandwidth required (percentage of cycle length)
- \( g \): effective green time in the signal cycle (seconds)
- \( C \): signal cycle length (seconds)
- \( c \): capacity at intersection (also the design flow rate) (vehicles per hour)
- \( s \): saturation flow rate (vehicles per hour per lane)
- \( N \): number of lanes on the arterial

Note that the bandwidth amount required on the arterial is independent of the system cycle length selected. This is illustrated by Figure 5; the figure illustrates 25% bandwidth, 50% bandwidth, and 75% bandwidth, using the same cycle length and progression speed.
FIGURE 5. Bandwidth amount is independent of any other factors for a perfect progression signal system. The amount of bandwidth needed is one of the inputs for the design of such a system.

Turning Volumes

One very important point to be made is that, even when perfect progression is implemented along an arterial roadway, there is still a need to maintain acceptable levels of service (LOS) on the minor roadway. Therefore, the turning movement volumes must also be considered, so that an intersection can be designed to still handle the minor road and left-turning traffic while still fitting into a perfect progression system.

Design strategies for intersections with varying amounts of bandwidth offset and turning volumes are discussed later in this paper; however, each intersection must be tested to ensure that it will work efficiently with the bandwidth offset at that location and that it will provide adequate operations for the left-turning and crossing movements.

Intersection Cycle Length

The final input in the intersection design is the system cycle length itself, which sets a practical limit on the number of phases that an intersection can have (based on the lost time due to the clearance intervals).

In a perfect progression system, all intersections in the system MUST be designed to operate efficiently within the cycle length selected for the system. That is to say, the natural cycle length of each intersection cannot be greater than the system cycle length. For example, if the signal
system needs to run on an 80-second cycle length to achieve perfect progression, then each and
every intersection will need to have a natural cycle length of no greater than 80 seconds.

There are methods in place (Webster’s Equation, HCM, macroscopic models, and
microsimulation) that can be used to determine the natural cycle length of an intersection. (This
is the cycle length that can produce the lowest delay for the intersection if it were to run as an
isolated intersection.) If one particular design for an intersection will require a natural cycle
length of greater than the system cycle length, then that design is inadequate and other
intersection designs will need to be considered.

HOW THE DESIGN WILL VARY BASED UPON THESE INPUTS

The first observation to be made is regarding the various cycle lengths selected for the system.
Table 1, taken from (I) and (6), shows a relationship between the cycle length, speed, and the
distance between each Point A in the time/space diagrams illustrated herein. This has been
calculated using the resonant cycle length equation above.

**TABLE 1** Progression Speed based on Spacing and Cycle Length

<table>
<thead>
<tr>
<th>Progression Speed (MPH)</th>
<th>Spacing (between Points A with zero bandwidth offset)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/8 mile (600 ft)</td>
</tr>
<tr>
<td>60</td>
<td>15</td>
</tr>
<tr>
<td>70</td>
<td>13</td>
</tr>
<tr>
<td>80</td>
<td>11</td>
</tr>
<tr>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>100</td>
<td>9</td>
</tr>
<tr>
<td>110</td>
<td>8</td>
</tr>
<tr>
<td>120</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Table 2 illustrates the results of the resonant cycle length equation recast in terms of having
progression speed as the independent variable.

**TABLE 2** Cycle Length based on Spacing and Progression Speed

<table>
<thead>
<tr>
<th>Progression Speed (MPH)</th>
<th>Spacing (between Points A with zero bandwidth offset)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/8 mile (600 ft)</td>
</tr>
<tr>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>35</td>
<td>26</td>
</tr>
<tr>
<td>40</td>
<td>23</td>
</tr>
<tr>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>50</td>
<td>18</td>
</tr>
<tr>
<td>55</td>
<td>16</td>
</tr>
</tbody>
</table>

Note that, in order to achieve an acceptable operating speed (30-55 MPH) on a signalized
arterial, and to have closely-spaced Point A locations, some of these cycle lengths are extremely
short! In some cases, in order for two different Point A locations (with zero bandwidth offset) to
be located within even a half mile of each other, the signals will need to operate with a cycle length of no greater than 65 to 90 seconds for an arterial speed of 40-55 MPH. (Contrast this with some at-grade intersections using an eight-phase, quad-left, dual-ring controller that often require cycle lengths of 120 seconds or longer to operate efficiently.)

This puts a constraint on what types of intersections will be feasible for a signalized corridor, especially at higher-volume intersections that will require shorter cycle lengths in order to be able to fit within the signalized system. Often it will be necessary to consider intersection types that will have no more than two or three phases (three phases per ring in a dual-ring controller). At extremely short cycle lengths, even a three-phase signal may not work effectively, and the intersections will need to be designed in order to operate with two-phase signals only.

In many cases, this can only be achieved using innovative intersection designs that are capable of reducing the number of signal phases required at the intersection, while still moving traffic efficiently on all of the movements, not just on the major road.

However, in determining a design and operational strategy for any given intersection, the bandwidth offset must also be considered. Although intersections can theoretically be located at any point, with a varying amount of bandwidth offset, the bandwidth offset directly impacts the green time available on the minor road for a direct through movement on the minor road across the major road. This is also a function of the bandwidth provided on the arterial.

The total amount of effective green time available (including the yellow change and all-red clearance intervals) for the minor road phases (where both sides of the arterial roadway are stopped) is given by the following:

\[ G = 100\% - B - F \]  

Where:

- \( G \): green time available on the minor road (percentage of cycle length)
- \( B \): bandwidth provided on the major road (percentage of cycle length)
- \( F \): bandwidth offset (percentage of cycle length)

This green time can also be expressed in terms of number of seconds:

\[ T_G = T_C - T_B - T_F \]  

Where:

- \( T_G \): green time available on the minor road (seconds)
- \( T_C \): signal cycle length (seconds)
- \( T_B \): bandwidth provided on the major road (seconds)
- \( T_F \): bandwidth offset (seconds)

To illustrate this, consider a signalized intersection system with a cycle length of 100 seconds and a 40% bandwidth (\( B = 40\% \)) on the arterial in both directions.
The green time available on the minor road is maximized when the bandwidth offset is zero (F = 0), assuming that there is not a separate phase given for a concurrent pair of major road left turns (which will take green time away from the minor road).

The green time available on the minor road is minimized when the bandwidth offset is greater than or equal to the bandwidth provided (F=40% when B=40%). Where the bandwidth offset is greater than or equal to the bandwidth provided, then the major road will operate on a split-phase operation, and the minor road green time will be a mere 20% of the system cycle length (G = 100% - 40% - 40% = 100% - 80% = 20%). This is illustrated in Figure 4.

For bandwidth offset, F, between 0% and 40%, the minor road green time will vary, and the major road will possibly require lead/lag left-turn phasing. This is illustrated both in Table 3 and Figure 4.

### Table 3. Minor Road Total Split Time based on Bandwidth Offset (100 second cycle)

<table>
<thead>
<tr>
<th>Cycle Length (s)</th>
<th>Bandwidth (s)</th>
<th>Bandwidth offset (s)</th>
<th>Minor Road Total Split Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>40</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>100</td>
<td>40</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>100</td>
<td>40</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>100</td>
<td>40</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>100</td>
<td>40</td>
<td>40</td>
<td>20</td>
</tr>
</tbody>
</table>

For lead/lag left-turn phasing, the amount of green time available for the major road left turns will be equal to the bandwidth offset. The test to determine whether it will be viable for a design and operational strategy is to determine whether the bandwidth offset time provides enough green time for that left-turn movement to operate efficiently.

When the bandwidth offset exceeds the bandwidth provided (in this case, when F > 40%) and as F approaches 50%, something interesting happens: Not only will the green time on the minor road be only 20 seconds, that 20 seconds will be divided up into two smaller green intervals on the minor road.

Consider another case where the bandwidth provided for the signal system is 50% or greater (F ≥ 50%). As an example, consider an arterial with a 100-second cycle length and 60% bandwidth. Again, the green time for the minor road will be maximized where the bandwidth offset is zero. However, for a bandwidth offset equal to 40 seconds (F = 100% - B), there will be zero green time available on the minor road, except for a mandatory right turn. This is illustrated in Figure 6.

Using this information based on the cycle length, number of phases feasible, and the bandwidth offset, several intersection design and operation strategies can be developed to handle the crossing and turning traffic volumes at any given intersection.

### DESIGN AND OPERATIONAL STRATEGIES FOR INTERSECTIONS

Several intersection design and operational strategies are available for various combinations of bandwidth amounts, bandwidth offset, and cycle length, while providing enough capacity for various combinations of turning volumes. There are several phasing strategies that can be used at
conventional four-phase intersections (using 8-phase dual-ring controllers), and there are several
design strategies that can be used to develop higher-capacity signalized intersections that have
fewer signal phases.

FIGURE 6. A progression system with more than 50% bandwidth (here showing 60% bandwidth) will have some intersections unable to provide direct crossing or left-turn movements.

Conventional 4-phase Intersections

Even though conventional intersections are the at-grade intersection type with the lowest amount of available capacity for all of the turning movements, they are the most versatile, with five different operating strategies from the major road’s perspective, depending upon the bandwidth offset. These are illustrated in Figure 7.
At zero bandwidth offset, the conventional intersection will require simultaneous left-turn phasing, either dual leading or dual lagging. The major road through movements at the intersection will both begin and terminate together.

At a higher bandwidth offset (which is less than the amount of bandwidth required for the system), if the bandwidth offset provides enough green time for the left-turn movements, then the intersection will utilize lead/lag phasing on the major road, where the left turn in one direction of the major road proceeds at the beginning of the cycle, and the left turn in the other direction of the major road proceeds at the end of the signal cycle.

If the bandwidth offset does not provide enough green time for the major road’s left turns, and yet is not equal to zero, one possibility is to have a hybrid of the two phasing strategies mentioned above: One of the left turns can be either a leading left turn or a lagging left turn, and the other left turn can be a twice per cycle left turn, where the green arrow appears both at the beginning and the end of the signal cycle. An example of this operation is described in (7).

If the bandwidth offset is equal to the bandwidth provided for the system, then the major road will operate using split phasing. Here, the protected left turn for the major road will always begin and terminate together with the associated through movement (both the green arrow and the circular green on the major road will always start and end together). One side of the major road will proceed, and then the other side of the major road will proceed; then, there will be two phases that will handle the minor road’s through movements and left turns.

Finally, in the case where the bandwidth offset is greater than the arterial bandwidth provided, and as the bandwidth offset reaches the upper limit of 50%, then there will still be a split-phase
operation, but it will take the form of separated phasing or a rotating split-phase operation.

Here, one side of the major road will have its left turn and through movement; then, one pair of
minor road phases will get the green light; then, the other side of the major road will have its left
turn and through movement; and finally, the other pair of the minor road phases will get the
green light.

Sometimes, the conventional intersection with a 4-phase signal (or 8-phase dual-ring controller)
will be unacceptable, and alternative intersection designs will be needed.

Three-Phase Intersections

A three-phase intersection will either have one signal phase for the major road and two phases
for the minor road, or it will have two signal phases for the major road and one signal phase for
the minor road.

If there is one signal phase for the major road and if the major road’s left turns are diverted or
made indirectly, then the intersection will need to be located at a point of zero bandwidth offset.

However, a three-phase intersection with a non-zero bandwidth offset will instead require that
the minor road have only one signal phase, so that the major road can have two signal phases.
This is necessary so that the major road left turns can use lead-lag phasing or any of the other
phasing strategies described above for four-phase intersections (twice-per-cycle left turns, split-
phasing, etc.).

Some possible design treatments for a 3-phase intersection involve combining some of the minor
road’s movements into some of the other signal phases that are used for other movements. For
instance, the minor road’s left turns can, with a design such as a continuous-flow intersection
(CFI) on the minor road, occur on the same phase as the minor road’s through movements.

Another design treatment for a 3-phase intersection involves diverting a pair of movements from
the minor road such that those movements are made with an indirect movement. Either the minor
road’s left turns can be made with an indirect movement (such as with a Michigan Left), or the
minor road’s through movements can be made with an indirect maneuver if the minor road’s left
turns have a heavier volume than the through movements.

Two-Phase Intersections

If a two-phase signal is used, then the design strategies become even more restrictive and the
intersection designs become even more specialized. Figure 8 illustrates these design strategies.

Any two-phase intersection that simultaneously stops both sides of the major road so as to allow
for the minor road’s left turns and/or crossing movements, such as the full CFI, the traditional
Michigan Left, or the Center-Turn Overpass, requires zero bandwidth offset.
FIGURE 8. Examples of two-phase intersection design based on bandwidth offset.

Any two-phase intersection that has a non-zero bandwidth offset will require that the signals on both sides of the arterial operate independently from each other. This will require the use of the Superstreet design, where all minor road movements are made via an indirect maneuver (3), or an intersection featuring some form of grade separation. Some intersection designs featuring grade separations that are applicable include the Echelon Interchange (8) and the Windmill B.

DESIGN PROCEDURE FOR PERFECT PROGRESSION ON AN ARTERIAL

Based on the discussion presented herein, a procedure can be developed to design an arterial that has perfect signal progression in both directions:

1. Determine the amount of bandwidth required on the major road based on the number of lanes and traffic volumes.

2. Use the resonant cycle relationship to analyze different scenarios of cycle length and distances between each “Point A” (points with zero bandwidth offset).
3. Set the system cycle length and the locations of each “Point A” with zero bandwidth offset.

4. Determine the bandwidth offset at each intersection location.

5. Determine the turning volumes at each intersection location.

6. Design the intersections accordingly.

7. Check to confirm that each intersection will operate efficiently within the system’s cycle length, and make adjustments to the design as needed.

In the project development process, it may be necessary to consider several alternative scenarios of perfect progression design based upon the number of lanes, different cycle lengths, different bandwidth offsets, and the different means available to handle the turning movements at each intersection. These different scenarios will then need to be analyzed to determine the benefits, costs, and impacts of each alternative.

REFERENCES


