COMPARISON OF ALTERNATIVE METHODOLOGIES TO DETERMINE BREAKPOINTS IN SIGNAL PROGRESSION.

David Hook, P.E.
Allen Albers, P.E.

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Introduction

Signal timing a city is a big task. Tremendous amounts of data need to be collected, processed, evaluated and implemented. One of the most critical issues in developing signal timing for a city is to determine where breakpoints in cycle length must occur.

A common cycle length allows signals to be progressed. The best cycle length is the one that provides for a minimum amount of delay at each intersection but provides also provides for adequate progression along the corridor. The minimum delay cycle length produces the overall minimum delay for each approach to the signal. At busy arterial-arterial intersections, the minimum delay may be very close to the progression cycle. At minor intersections, the minimum delay may be much smaller than the progression cycle length.

The best cycle length for progression is a function of spacing of the signals and speeds along the roadway. Be careful about collecting progression speed as it is a critical element to the process. The best way to collect the progression speed is to drive the roadway during the time period that the timing plan is being developed. During peak periods, the progression speed can be much lower than the free flow speed.

Coordinatability Factors

Several attempts have been made over the years to develop a factor to determine where signal progression breaks should occur. Three different methodologies are presented here.

Coupling Index

The Coupling Index is the simplest of the three methodologies. The theory is based upon Newton's law of gravitation which states that the attraction between two bodies is proportional to the size of the two bodies and inversely proportional to the distance squared. The formula is shown here.

$CI = V/D^2$

CI	=	*Coupling Index (unitless)*
V	=	*traffic volume for the time period analyzed (1000 vehicles/hour)*
D	=	*link distance (miles)*

These values are created between every signalized intersection in the system. A map can then be produced showing these values graphically. The higher the number, the higher the need to coordinate adjacent signals. A good rule of thumb is to always coordinate signals with a Coupling Index greater than 50. A value between 1 and 50 indicates coordination is desirable. A Coupling Index less than 1 does not require coordination.

Strength of Attraction

In the Strength of Attraction, the desirability of coordinating two adjacent intersections is based on the intersection spacing (link distance), link traffic volume, link travel speeds, and platoon interference (i.e., on-street parking maneuvers, driveways, etc.). The strength of attraction between intersections, for a given time period, is calculated from the following formula.

$AF = I * V * (S/D)^2$

AF	=	*strength of attraction (unitless)*
I	=	*platoon interference (unitless)*
V	=	*traffic volume for the time period analyzed (vehicles/hour)*
S	=	*link travel speed (miles/hour)*
D	=	*link distance (feet)*

Platoon interference is a unitless value describing interference of the platoon as it progresses down the street. For simplicity, a platoon interference factor of 2.0 can be used for roadways without parking, 1.5 for roadways with parallel parking, and 1.0 for roadways with angled parking.

The relative values between intersections should be considered in determining optimum signal groupings. There is no absolute strength of attraction at which coordination should or should not occur, however a natural breakpoint of approximately “1” appears to exist.

Coordinatability Factor

Synchro, a popular signal timing and intersection analysis program, has an internal methodology to calculate coordinatability. The Synchro3 program calculates a coordinatability factor considering travel time, volume, distance, vehicle platooning, vehicle queuing, and natural cycle lengths. The coordinatability is similar to the strength of attraction but also considers the natural cycle length and vehicle queuing. The natural cycle length is defined as the cycle at which the intersection would run in an isolated mode or the minimum delay cycle length. The potential for vehicle queues exceeding the available storage is also considered in determining the desirability of coordination.

A summary of the various coordinatability is given below in Table 1.

Table 1. Coordinability Methodologies and Recommended Breakpoints

Methodology	Coordination not desirable	Coordination Desirable	Coordination Critical
Coupling Index	<1	1 to 50	>50
Strength of Attraction	<.5	.5 to 2	>2
Synchro	<20	20 to 80	>80

To determine the methodology that produced the best result, five links were randomly chosen in the City of Fort Collins. For the five links, the three coordinatability factors were calculated. The results are shown in Table 2.

Table 2. Comparison of Coordinatability Factors

Link	Coupling Index	Strength of Attraction	Synchro Coordinatability Factor	Agree?
Minor Arterial on street parking 500' link	212 Critical	9.3 Critical	114 Critical	Yes
Slow Speed Collector 1300' link	22 Desirable	1.4 Desirable	75 Desirable	Yes
High Speed Major Arterial 2640' link	10 Desirable	.9 Desirable	80 Desirable	Yes
Minor Arterial low volume 2640' link	6 Desirable	.3 Not desirable	51 Desirable	No
Minor Arterial Low Volume 5280' link	2 Not Desirable	.1 Not Desirable	5 Not Desirable	Yes
Major Arterial High volume 1400' link	51 Critical	1.6 Desirable	73 Desirable	No

As can be seen by the table, the results from the various methodologies differ only slightly. If a computer program is available to automatically produce the number, then it is probably worth the time and effort. If a program is not available, a simple coupling index seems to produce the same results.

Lessons learned

1. Develop timing for corridors

Rather than evaluate regions of a city, it is sometimes useful to look at the corridors. For example, most cities have major north-south and east-west corridors. Instead of breaking apart a city into groups, each corridor can be evaluated separately for optimum cycle length. These cycle lengths can then be compared to see if corridors should be linked together.

If two crossing corridors have nearly the same cycle length, it is likely that a common cycle length to both could be found that produces good progression.

2. Oversaturated Intersections

Often times the perfect progression cycle length is lower than the cycle length needed for capacity. One example is when the cycle length for perfect progression is 100 seconds but one intersection along the corridor needs to operate at 150 seconds for capacity. In this instance, it is better to allow the intersection to run actuated (free) and not try to progress through the signal. If it runs at 100 second cycle length, there will not be progression through the signal anyway because traffic will back up. Most motorists think of capacity first and progression second. If they can get through a very congested signal "on one cycle" they tend to be satisfied. Most motorists do not expect to progress through congested locations.

3. Using raw turning movement counts

Raw turning movement counts can provide a problem for signal timing. Turning movement counts usually measure flow through the intersection, but not necessarily demand. If the queue is backing up half a mile, then running capacity analysis from turning movement counts will not get you the true picture of the situation.

There are two ways to handle this situation. The first is to have the data collector measure queue at the end of each 15 minute period. This is the new recommendation from the Highway Capacity and Quality of Service Committee. If the number of vehicles in the queue at the beginning and the end of each 15 minute period is collected, it is straight-forward to calculate the demand that was added during each 15 minute period.

Another method is to use a machine traffic counter mid-block upstream from the signal. There should not be any major traffic generators between the machine counter and the intersection, or the results will be skewed.

There can also be a problem with raw turning movement counts. It is very easy to get incorrect turning movement count data. Standing at an intersection for two hours collecting vehicles can be a tedious task and even the best data collectors can make mistakes. Turning movement counts are also only a spot estimate on the roadway. Traffic can be significantly different from one day to the next.

4. School Zones

It is difficult to progress through a school zone. An optimum progression speed can be calculated including the school zone but this produces little success. School zones are usually placed where there is large pedestrian traffic. The randomness of the length of delay through a school zone makes it difficult to predict a reliable average speed. It is best not to try to progress through a school zone. It is also useful to keep the length of time that the school zones operate to a minimum.

5. Fire Station Signals

Fire station signals typically do not cause much of a problem. The frequency of the signal being activated is usually very low. When they are activated, progression along the corridor is typically adversely affected.

Conclusion

From the research into various coordinatablity factors, the following conclusions can be drawn:

1. There is no absolute best factor for determining where progression breaks should occur. Evaluate the input data that you have and compare this to each method. Since each method gives about the same result, the simpler methods are just as valid as the complicated ones.
2. School zones affect progression so they make logical breaks. Fire stations signals do not effect progression that much.
3. Be careful in using raw traffic data. Turning movement counts only measure flow through the intersection. Be aware of existing queues in the system. Be aware that turning movement counts are only a spot estimate and volumes can be much different than those collected.
4. As in every aspect of engineering, judgement and experience are the best tools.