THE 10 MAJOR PITFALLS OF COORDINATED SIGNAL TIMING

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Over the past four years I have had the good fortune of being personally involved in the retiming of over 250 traffic signals in Northeast Florida covering 18 separate arterial corridors. These corridors, most of which are fully-actuated, range in size from 6 signals to 40 signals and included a wide variety of traffic operating conditions. Ten of these 18 corridors have a freeway interchange with signalized ramps located within the corridor and 9 of these 18 corridors have some form of cross-coordination with other signal systems. The purpose of this article is to describe 10 of the major pitfalls that I have encountered in developing and implementing coordinated signal timings.

The signal retiming work described in this article was the result of a series of contracts between JW Buckholz Traffic Engineering Inc and District 2 of the Florida Department of Transportation. A number of local agencies were also involved in these projects, including: the City of Jacksonville Traffic Engineering Division, the City of Gainesville Traffic Engineering Department, and Clay County Signal Maintenance. FDOT owns the signals while these local agencies maintain the signals.

FDOT provided the funding for the signal timing work and, when needed, also provided new signal controllers and cabinets. FDOT also conducted the initial and final travel time runs along each corridor. The local maintaining agencies provided traffic signal technicians to assist us in the implementation of the timings and to help in the correction of any equipment problems that arose. These agencies also passed along to us any citizen complaints that they received. Bi-weekly meetings were held to discuss progress on the project and to coordinate the retiming effort.

The basic steps used in our timing analysis were those used in most retiming efforts:

1. Collect corridor data, including 8-hour turning movement counts and 7-day machine counts.

2. Run PASSER or TRANSYT.

3. Prepare detailed time-space diagrams.

3. Develop and implement the new timings.

Project results were positive and a favorable public response was received. This response appeared to be most associated with improvements in corridor travel times, reductions in the amount of "stop-and-go" operation, and an overall decrease in the number of cycle failures for both main street and side street traffic. A benefit-to-cost ratio of about 15-to-1 was estimated.

However, to achieve this success, we had to recognize and deal with the following ten coordinated timing pitfalls:

PITFALL #1: The failure to consider "anchor points" early on in the analysis process.
I have coined the term "anchor point" to describe any location that has special characteristics which restrict the size of the cycle length that can be used or that require unique phasing or timing. Five of the most common types of anchor points are described below:

1.) **Freeway Interchanges** - It is very common to have some sort of freeway interchange, often a compressed diamond interchange, located within an arterial corridor. These interchanges usually have limited left turn queue storage along the arterial and may also have limited queue storage on the ramp. The presence of such an interchange may force us to use a smaller cycle length than we would otherwise desire in order to avoid queue overflows that would block arterial thru lanes or back-up onto the freeway. In addition to using smaller cycle lengths, in many cases it is also necessary to "hold" certain minor phases (such as the main street left turn phase) to avoid congestion in the area between the ramps.

    In addition, sizeable "side street platoons" often emanate from freeway off-ramps, platoons which, in many cases, are as large or larger than the main street platoons. The proper progression of these side street platoons needs to be addressed within the timing plan. Unfortunately, many of the computer optimization programs used for arterial signal timing have limited capabilities in dealing with either lane-blockage problems or side street platoon effects.

2.) **Closely Spaced Intersections** - It is not uncommon to have one or more sets of closely spaced signals (less than 0.1 mile apart) within a corridor. This can be especially troublesome in a fully-actuated system where the "early-release" of main street traffic can produce congestion in the area between the signals. Early-release occurs when the amount of side street traffic is not equal at the two signals, causing the main street green indication to begin earlier at one of the signals. The use of non-early-release settings or phase holds may be needed to avoid the complications that can arise. Complicating things further is the fact that these closely spaced intersections are often found in the heavily commercialized area near a freeway interchange. The presence of closely spaced intersections near a freeway interchange almost always necessitates some form of special treatment.

3.) **Cross Coordination** - It is also common to have one or more of the signals in a corridor be part of another "cross coordinated" system. Unless the decision is made to retime the two systems concurrently, the cycle lengths which are selected will need to match those of the crossing arterial.

4.) **Over-Capacity Intersections** - It is often the case that one or two critical intersections along a corridor will become over-capacity (LOS F) during the peak hour, resulting in recurring cycle failures that cannot be eliminated through retiming. These intersections essentially become a "wall" in the coordinated scheme, producing an unavoidable stop for any platoon that arrives there. Although the cycle failures cannot be eliminated, measures can be taken to ensure that no time is needlessly wasted at these intersections and to ensure that queues emanating from downstream signals do not interfere with their operation.

The important thing to keep in mind with anchor points is that they need to be recognized early in the analysis process and appropriately treated. An efficient system cannot be obtained unless these critical locations function properly, and field experimentation is often needed at these locations to ensure that a given set of timings will work. Ignore these anchor points and the system that is developed will be doomed from the start.

PITFALL #2: The failure to watch the corridor prior to the analysis.
A great deal of important information can be obtained by simply watching the corridor under the existing timings, and doing so for each important time period (AM peak, PM peak, etc.) This will give the analyst a grass-roots feel for appropriate cycle lengths, the location of potential queuing problems, and required green split times. In addition, during the initial observation period, case-specific values can be obtained for important modelling parameters, such as saturation flow. Not watching the corridor prior to analysis is a pitfall that can be easily avoided, but often isn't.

PITFALL #3: Selection of the wrong cycle length.
The old saying goes in real estate that three things are important: location, location, and location. The same is true in coordinated signal timing, only the three important things are: cycle length, cycle length, and cycle length. If you select the proper cycle length for a given period then workable solutions will be obtainable along the corridor. If the wrong cycle length is chosen then you will have considerable difficulty in achieving suitable traffic operation, regardless of how well your green splits and offsets are chosen. Selection of a cycle length that is too short for a given time period will result in cycle failures and poor progression while the selection of too long of a cycle length will result in queue blockage problems and "running of the red" (or subsequent irate phone calls) by impatient side street motorists.

Our experience has shown that the computer optimization programs commonly used for arterial signal timing are not very good at picking the best cycle length. We have discovered that, in general, PASSER will recommend a cycle length that is too long whereas TRANSYT will recommend a cycle length that is too short. This is not surprising given the nature of their respective optimization algorithms. Therefore, it becomes necessary for the analyst to severely constrain the range of cycle lengths over which these programs can search in order to produce usable results. This is best done be observing the busiest intersections in the corridor and, for the critical movements, noting either the extent of the cycle failures if the current cycle is too short (and adding 2 seconds for every car that doesn't clear), or noting the amount of wasted green time if the current cycle is too long. Our experience has shown that this sort of empirical approach is the best method for determining a suitable range of cycle lengths to be used in the analysis. You can go to all kinds of trouble trying to calculate the best cycle length with any number of available computer programs, however, the simplest and most accurate way is to just observe it.

One last item regarding cycle length. In many areas of the country, including Florida, the nature of the urban arterial has changed dramatically over the years. With increasing suburbanization has come wider arterials with more lanes, more traffic, and more phases. In the past we might have been dealing with four lane arterials having single left turn lanes on the main street, two phase signals, and carrying 40,000 vehicles per day. But these days it is not uncommon to have a six lane arterial with dual left turn lanes and exclusive left turn phasing on all four approaches - an arterial which may carry more than 60,000 vehicles per day. Our experience has clearly shown that this type of an arterial cannot accommodate rush hour traffic without using cycle lengths of between 150 and 180 seconds. The old 120 second cycle length ceiling no longer applies for many arterials.

PITFALL #4: Ignoring the effects of pedestrian timings
At the risk of sounding unsympathetic to our friends on foot, let me say that pedestrians can truly "eat your lunch" when it comes to coordinated signal timing. The combination of wider arterials and an aging

population (especially here in Florida) results in pedestrian crossing times that can be very long. In many instances the time required by pedestrians to cross the main street is considerably longer than the time required by the side street vehicles that are moving concurrent with the pedestrians.

The negative effect of long pedestrian crossing times is twofold: 1.) it requires more time to be allocated to the side street thru phase, thus decreasing the amount of time available for main street progression; 2.) it requires the use of higher cycle lengths, even during low volume periods, to ensure that the sum of all phase times is less than the cycle length. If the sum of the phase times exceeds the cycle length then the signal controller may exhibit intermittent unpredictable and undesirable behavior, such as hanging-up in a phase or reverting to free (non-coordinated) operation. If the timings which are developed do not properly accommodate the required pedestrian times then these types of serious operational problems can, and will, occur.

This discussion underscores the critical need for the development of a reasonable pedestrian crossing policy, one that provides safe, but not excessive, crossing times. Using the nationally accepted guidelines contained in the FHWA's <u>Traffic Control Devices Handbook</u> (1) is a good starting point. Policies which arbitrarily use excessive pedestrian times or which treat every crossing the same, regardless of the type of pedestrian that frequents the crossing, should be discouraged.

PITFALL #5: An unreasonable fear of lead/lag operation (lago phobia)

Under the right circumstances, the use of lead/lag operation can be extremely beneficial in facilitating coordinated flow. We have successfully utilized it on many of our corridors with excellent results. However, many traffic engineers are still scared to death of it, envisioning all kinds of resulting catastrophes with it's use. Their complaint is that it violates "driver expectation" and will lead to increased accidents. We have found this to not be the case, even at locations where we switch the direction of the lead/lag by time of day. It is true that it takes a while for motorists to realize that the phasing is different (which is the case for any phasing change), however, they seem to adapt quite well once they become accustomed to it.

Keep in mind that, at fully-actuated intersections, even with lead/lead operation specified, signal operation that is quite similar to lagging left's may occur during low volume periods if there is no side street traffic and the side street phase is skipped. Consequently, lagging left's are not a totally unfamiliar phenomenon, even in areas that lead/lag operation is not used.

One note of caution. Lead/lag operation cannot be used unless the leading left turn is protected-only. Otherwise, motorists turning left during the permissive period may encounter a phenomenon called the "left turn trap". This occurs when a motorist turning left during the permissive green period sees all the thru movement signals on his side of the intersection turn yellow and thinks that the opposing thru traffic is also stopping whereas, in reality, the opposing thru traffic still has the green ball which is running concurrently with the lag left phase. This set of circumstances could trick the motorist into turning left into an oncoming vehicle. For this reason, lead/lag phasing cannot be safely used if the lead left turn phase has a permissive interval.

Consideration of lead/lag operation leads to the discovery of one of the major drawbacks of the TRANSYT computer program, it's inability to optimize main street left turn phasing. The interaction between cycle length and phasing is an intimate one and it is just not possible to select the best main street phasing without simultaneously considering the cycle length, and vice versa.

PITFALL #6: Ignorance of controller restrictions and capabilities
No matter how good your timing plan is, if it cannot be installed on the available equipment (or if it is not properly installed) the expected results will not be achieved. For example, it you develop a set of timings that require 5 cycle lengths throughout the week, yet the available controllers will only handle 4 cycle lengths, then you have a problem. Or, let's say you want to install lead/lag operation and switch it's orientation by time of day, but the available controller does not have this capability, then you've got another problem. If you don't understand the limitations of the available controllers beforehand, you may very well design something that either cannot be implemented or will require controller upgrades prior to installation.

Another aspect of this pitfall is the general ignorance of most traffic engineers with respect to the capabilities of modern signal controllers. Modern signal controllers are very sophisticated microprocessors with capabilities that are often fully understood only by those who either design or sell them. Such advanced features as detector switching, conditional service, shortway offset seeking, dual entry, and simultaneous gap out are not well understood by many traffic engineers and, consequently, are not used.

Even if the traffic engineer is familiar with the limitations and capabilities of the equipment, it is still important to have a knowledgeable signal technician involved in the timing project. We have discovered many curious controller "glitches" while implementing coordinated timings, especially when using equipment that is greater than 5 years old. Some of these operational problems were encountered at very inopportune times (such as during the afternoon rush hour). Having a knowledgeable technician available has helped us avoid disaster on more than one occasion.

PITFALL #7: Incomplete time-of-day and day-of-week plans
A successful set of timing plans will efficiently handle traffic at all times of the day, for all days of the week, and over all weeks of the year. It is not uncommon for a complete set of timing plans along a major urban arterial to include, for an average weekday, an AM peak plan, a PM peak plan, a noon peak plan, an other-than-noon midday plan, and an evening plan, along with free and flash operation late at night. It is also not uncommon to have special Friday, Saturday, Sunday, and Holiday plans and to have special plans during the Christmas shopping season or when school is out. Depending on the corridor, the amount of time-of-day and day-of-week variation can become quite complex.

It is not an easy task to decide which periods to develop plans for and when to start and stop these plans, especially when one considers that our timing analyses are usually based on a very small sample of traffic volumes (typically one day's worth of turning movement counts and a week's worth of 15-minute machine counts). Since it would be much too expensive to collect an exhaustive set of count data for all time periods of the day, all days of the week, and all weeks of the year, we are forced to use some common sense in both developing the various timing plans and deciding during which times to place the plans into effect. A frequent pitfall is to spend all of one's time and resources developing the timing plans while expending little effort deciding when to use them.

PITFALL #8: Not recognizing the need for special split plans
It is often the case that there will be one or more signals along a corridor that experience intense side street demand during a brief portion of the day. It may also be the case that this surge in side street demand will go undetected when the turning movement counts are performed because it does not occur during the peak

hours. The end result is the inadequate provision of side street green time during these periods and associated cycle failures. Examples of land uses which can cause such off-peak traffic surges are schools, churches, factories, and shopping centers. Although isolated in nature, the failure to accommodate these surges can lead to a bevy of irate phone calls.

PITFALL #9: Lack of in-the-field timing adjustments

No matter how good your counts, no matter how successful your computer runs, and now matter how well thought out your time/space diagrams, unless you are dealing with a very simple corridor, the new timing plan that you install will undoubtedly need some form of adjustment in the field. And it may be that considerable adjustment will be needed, not just fine-tuning. If you are persistent, and if the controlling agencies are far-sighted enough to realize that things sometimes must get worse before they get better, substantial improvement in corridor operation is typically obtainable. However, if success is expected without field adjustment, then failure can be pretty much guaranteed. This point cannot be overemphasized.

PITFALL # 10: Ignoring the need for timing maintenance

A system for periodically reviewing signal timings should be developed to make sure that the benefits of signal coordination are maintained. This review would include such items as checking yellow offsets against the appropriate time-space diagram to make sure that no signal has drifted out of step, and looking for locations where traffic volumes have increased and timing modifications are needed. It has been our experience that timings get inadvertently changed, clocks drift or are incorrectly set, and holiday implementation schedules are not updated. Without some form of periodic monitoring (at least once a year and preferably twice a year) the operation of the system will deteriorate over time. This monitoring becomes even more critical with time-based signal systems. One cannot simply "set it and forget it" and expect to maintain the benefits of signal coordination.

CONCLUSION

The benefits of coordinated signal timing are well known. Also well known and well documented are the various computer programs used to develop coordinated timings. What is not well understood are the many pitfalls that must be avoided if improved timings are to be properly developed and successfully implemented. Hopefully, this article sheds some light in that direction.

References

1. U.S. Department of Transportation, Federal Highway Administration, *Traffic Control Devices Handbook*, Washington, DC, FHWA, 1983