3.2. Cycle Length Requirement

The cycle length was defined in Session 2 as the time required to display a complete sequence of phases. For pretimed control, the cycle time is divided into phases that are displayed sequentially, with the cycle length being the sum of all of the phase times.

There are several considerations that affect the selection of the best cycle length for a specific situation. If the intersection is coordinated with its neighbors, a common system cycle length must be used. At isolated traffic-actuated intersections, the cycle length will vary from cycle to cycle, depending on the instantaneous demand. High volumes will produce longer phases and therefore a longer cycle. At pretimed intersections, the appropriate cycle length must be computed, based on the measured volumes. This section will concentrate on the computation of cycle length for pretimed control.

Continuing the example started in 2.1, we now know that we have a situation that requires 81.9% of the time to be devoted to effective green time, leaving 18.1% available for other purposes. Some of the unneeded time must be devoted to the lost time that is associated with each cycle.

We have assumed that each phase will generate 4 seconds of lost time, and with separate phases for the north-south movements and the east-west movements, this means that each cycle will consume 8 seconds of lost time. So, the more cycles per hour we create, the more lost time will be consumed. If we create too many cycles per hour, we will consume too much lost time, and there will not be enough time left over to move traffic.

Let’s try to identify how much is too much. The total number of seconds in each hour that are not needed for moving traffic may be easily computed as $3600 \times 0.181 = 651.6$. At 8 seconds of lost time per cycle, this means that we could display $651.6 / 8 = 81.45$ cycles per hour. If we display more than that, we will not have enough effective green time available.

By this process, we have just established the minimum cycle length that could be used under these conditions:

$$C_{\text{min}} = \frac{3600 \text{ seconds per hour}}{81.45 \text{ cycles per hour}}$$

$$= 44.2 \text{ seconds per cycle}$$

So, cycle lengths less than 44 sec would not have adequate capacity.
The computation of the minimum cycle length was presented in several steps to help you understand the process. To simplify the procedure, these steps may be combined into a single formula shown in the box at the right. Testing the formula against our multi-step process, we get:

\[ C_{\text{min}} = \frac{L}{1 - Y} = \frac{8}{1 - .819} = 44.2 \]

There are only two ways to spend the unneeded time at a signal. It can be spent as lost time in starting and stopping traffic, or it can be spent by extending each phase beyond its required time. The problem with extending phases unnecessarily is that it makes the whole operation less efficient. The advantage of using the minimum cycle length is that none of the unneeded time is spent as unnecessary green extension time. So, at first glance, it could be argued that the minimum cycle length is the optimum choice.

This would be true if all of the traffic flow was entirely uniform; in other words, if all cycles had exactly the same number of arrivals. We know that this is not a good assumption. Instead there is a random component here that makes for fewer than the average number of arrivals on some cycles and greater than the average on others. So, if we use the minimum cycle length, we will have more vehicles arriving on a significant number of cycles than the signal can accommodate. These vehicles will have to wait until the next cycle to be serviced. Naturally, this will cause unnecessary delay which must be traded off against the delay that will be caused by unnecessary green time extension.

This tradeoff was addressed by Webster, who produced an equation to determine the cycle length that achieves the optimum balance between the two delay-causing factors. See the box at the right. Applying this equation to our example data:

\[ C_{\text{opt}} = \frac{1.5L + 5}{1 - Y} = \frac{17}{1 - .819} = 93.9 \text{ sec} \]

Note that there is a substantial difference between the minimum cycle length and Webster’s optimum cycle length. Webster’s formula was produced by a combination of analytical and simulation techniques. While it provides only an approximation, it is widely used in practice. A more precise estimate of the minimum delay cycle is offered by various signal timing software products that use iterative techniques to minimize the computed delay for each specific set of conditions. Signal timing software will be discussed in Session 5.

The minimum cycle length will operate all of the critical movements at full saturation, i.e., \( X = 1.0 \). Another common approach to cycle length

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**Minimum Cycle Length**

\[ C_{\text{min}} = \frac{L}{1 - Y} \]

**Webster’s Optimal Cycle Length**

\[ C_{\text{opt}} = \frac{1.5L + 5}{1 - Y} \]
computation is to use an extended version of the minimum cycle length formula to determine the cycle length that would produce a target v/c ratio. In this case the critical flow ratio, Y, is divided by the target v/c ratio, X_T, less than 1.0. This formula may be viewed as a more general case of the minimum cycle length formula, with the minimum cycle length determined by setting X_T = 1.0 (i.e., 100% saturation).

Let’s say we want to operate the critical movements at 90% saturation. Applying this to our sample data:

$$C_{90} = \frac{L}{1 - Y/X_T} = \frac{8}{1 - .819/.9} = 88.9 \text{ seconds}$$

This is also substantially greater than the minimum cycle length of 44.2 seconds, and fairly close to the 93.9 seconds produced by Webster’s minimum delay cycle length formula.

We must now decide on a cycle length to use for the remainder of the computations. It appears that a good choice would be a nice round value of 90 seconds. This is the cycle length that will be used for purposes of phase time computation in the next section.