Embedded/Networked Final Project – Traffic Light Intersection Modelling

<https://ops.fhwa.dot.gov/trafficanalysistools/tat_vol4/app_f.htm#:~:text=In%20fully%2Dactuated%20mode%2C%20detection,%2C%20left%2Dturn%20movements>).

System Design Description/Requirements

* The traffic intersection is a 4-way intersection
* The intersection supports protected left hand turns, which precede the green light.
* The intersection consists of a 2-way “main” road intersecting a secondary 2-way road with lower priority
* The intersection is situated near a railroad crossing which crosses over the main road.
* Traffic phases should be influenced by railroad interrupts to support the highest traffic throughput.
* The intersection should support interrupts for the detection of emergency vehicles.
* The intersection should switch operating modes at night to accommodate lighter traffic.
* The intersection has adequate visibility and low enough volume to permit left turns on a green light (that is, there is no need to have a “red” left turn arrow to prevent left turns on green).

There are various kinds of traffic light control systems which target specific requirements of intersections. In this case we will consider “fully actuated” control, where sensors are used at every approach to the intersection to determine the phase of traffic. Other systems include fixed time control traffic lights, where traffic phases are on a predetermined cycle length, and semi actuated traffic lights, where sensors are only used to allow cars to pass through the minor road of an intersection.

From “Appendix F: Actuated Signal Control”, US Department of Transportation Federal Highway Administration

A diagram of a barrier and barrier

Description automatically generated

Here, a diagram shows street-movements for a 4-way intersection. The diagram is read left-to-right, with columns of phases happening concurrently. The numbers 1, 2, 5, and 6 denote phases for the “main street”, meaning the road with higher traffic. The numbers 3, 7, 4, and 8 denote phases for the “side street”, or the road with more sparse traffic. This diagram has “leading left turns” for both streets; other configurations for traffic phases are feasible as well.

There are various types of detectors that influence when to move onto the next phase. Extension and count detectors in “presence mode” placed at the stop bar will ask the controller to service their phase. In our case, we may have count detectors on the side roads which ask the controller to move on to the next phase. These same detectors operating in “passage mode” can extend the green phase so that more traffic can be moved during the phase. In our case, we may have passage mode detectors on the main road to extend the green light for the highest volume of traffic.

There are two time-intervals that determine the length of a phase (i.e. green light). The first is the initial interval, which is the minimum time that a green light must be active. This can be a fixed time or can be computed based on the volume of traffic determined by presence mode sensors. The second interval is the extendable interval, which may extend the green light signal if there is demand. The extendable interval also has a maximum length; after the interval times out, the phase must terminate. The extendable interval may terminate early if there is demand for another phase.

**Implementation**

We will have 4 sets of states that denote the main street left turn signal, main street green light, side street left turn signal, and left turn green light.

Each left turn and green light may have one or two states, denoting the initial interval and optionally the extendable interval. Additionally, each will have a yellow light phase and a red turn phase. The red turn phase acts as a waiting period before the next traffic phase can begin.

The stop bar for both directions of the side street will be equipped with two count detectors: one for the left-turn lane and one for the main driving lane. The left-hand turn initial interval will have a variable duration. If there are three or less cars on either left-turn lane on the side street, the initial interval for the left turn signal will be 5 seconds. Each additional car will add an additional 2 seconds to the initial interval, with a maximum duration of 9 seconds. The left turn lane will not have an “extendable” interval; this is usually reserved for light extensions incurred by extension detectors (not predicted by the count of vehicles waiting on a red).

Furthermore, when the side street phase starts, if the count detectors determine that there are no cars waiting at either left turn, the left turn phase will be skipped, and the green light phase will begin. The same is true for the left-turn count detectors on the main street.

For the main driving lane, the count detectors have a similar functionality. If there are five or less cars waiting in either direction, then the initial interval for the green light will be 10 seconds. Each additional waiting car over five cars will add an additional second to the initial interval, with a maximum duration of 15 seconds. Again, there is no notion of an “extendable” interval.

Additionally, the count detectors for either lane (the left-turn lane or the main driving lane) may be used to interrupt the green light for the main street extendable period (which will be described later)

The left turn lane for both directions of the main street will be equipped with count detectors, as in the side street. The minimum initial interval is 5 seconds, and each additional car over two cars will add 2 seconds, for a maximum of 9 seconds.

Both directions of the main street preceding the intersection will be equipped with extension detectors in passage mode. These sensors will detect moving cars before they reach the intersection. In our case, they will signal the green light to remain in the extendable interval.

The main street green light will have an initial interval of 20 seconds. After this period, the green light will enter the extendable interval state. Here, the extension detectors will continuously poll for moving cars. If either sensor detects moving cars, it will signal the green light to remain in the interval state. When it no longer detects moving cars, it will interrupt the extendable state. If the sensor does not detect moving cars, and the side street count detectors indicate that there are side street cars waiting at the red light, the extendable interval state will transition to the yellow light state.

The extendable interval in this case does not have any maximum duration, since we expect most of the traffic to occur on the main street (i.e., many minutes may pass without any cars waiting at the side street red light).