**OPERATIONAL SCENARIOS**

These operational scenarios have been extracted from a Concept of Operations prepared for a real project. The street names and place names have been changed.

**INITIAL CORRIDOR**

This section describes operational scenarios envisioned for the pilot deployment in the Broadway Avenue corridor. The wider deployment of the adaptive system will involve some additional operational characteristics that will not be applicable to the pilot project. Several extended scenarios are described in a later section. Although the term "cycle length" is used in the following descriptions, this should not necessarily be interpreted to mean a constant, repeating cycle length. It may represent a variable length of time between the start of a phase sequence, using a fixed sequence, or also the length of time between the start of a particular phase (say a nominated coordinated phase) with a variable sequence of phases occurring between consecutive occurrences of the reference point.

**PEAK PERIODS – UNSATURATED CONDITIONS**

During typical peak periods (and other periods when traffic volumes are high), the system will select a cycle length that accommodates all movements at all intersections. The primary determinant of the cycle length will be to ensure that there are no phase failures on critical movements that would adversely affect the operation of other intersections or the progress in the peak direction. It is expected that the cycle length will vary according to the traffic conditions, increasing as the peak period begins and decreasing as it dies down.

The system will compare the volumes traveling in each direction, and provide coordination in the dominant direction. Should the volumes be balanced, the coordination will be implemented in a manner that provides balanced progression as far as possible in the two directions.

Where leading and lagging left turn phases are used, the system will determine the optimal phase sequence in order to provide the best coordination. This would be linked to the direction of offset, such as providing a lagging left turn in the heavy, coordinated direction. If the green time required for a left turn phase is longer the time required to service a queue fully occupying the left turn bay, and the queue would overflow and block the adjacent lane, the operator will be able to specify the phase to operate twice per cycle in order to avoid queue overflow.

The entire corridor may be set by the operator to operate as one coordinated group, or the system may have the freedom to operate it as one group subject to user-specified criteria, such as similar required cycle lengths in different parts of the corridor are similar or the volume of traffic in the peak direction exceeds a threshold.

**PEAK PERIODS – OVERSATURATED CONDITIONS**

During peak periods when one or more intersections are oversaturated, the primary objective of the system will be to maximize the throughput along the corridor in the peak direction. The cycle length chosen by the system will be the maximum permitted by the operator, or determined by a user-specified maximum duration between successively servicing a phase with demand present. The system will determine the direction with peak flow and provide the maximum bandwidth possible within the selected cycle length. This will be subject to user-specified constraints, such as allowable phase sequences, and minimum and maximum phase times.

As described in the unsaturated peak description, phase sequence of lead-lag phases, and the operation of left turn phases twice per cycle, will be determined by the system. The entire corridor may be set by the operator to operate as one coordinated group, or the system may have the freedom to operate it as one group subject to user-specified criteria, such as similar required cycle lengths in different parts of the corridor are similar or the volume of traffic in the peak direction exceeds a threshold.

**BUSINESS HOURS**

During business hours, there will be two separate but complementary objectives: select a cycle length that ensures all movements at all intersections are accommodated equitably, while providing reasonable coordination in one or both directions. Because of the block spacing on Broadway Avenue and the associated travel times between the key intersections, there are several cycle lengths that provide good coordination in both directions. Provided a cycle length that provides good coordination exceeds the minimum cycle length needed to serve all movements at all intersections, the system will pick that cycle length. During this period, there are sufficient pedestrians present at the key intersections that the cycle length will need to accommodate pedestrians on most phases in almost every cycle. If the demand peaks (as sometimes happens during lunchtime), the system will increase the cycle length and select the appropriate progression in the same manner as during unsaturated peak conditions.

The entire corridor may be set by the operator to operate as one or more coordinated groups under this condition, or the system may have the freedom to operate it as one or more groups subject to user-specified criteria, such as similar required cycle lengths in different parts of the corridor are similar or the volume of traffic at key locations exceeds a threshold.

**OFF-PEAK PERIODS**

During early mornings, evenings and parts of the weekends when traffic is lighter than during the business hours, the coordination objectives will be similar to the business hours, although a lower cycle length may be applicable. If there is a cycle length that would provide good two-way progression and accommodate all movements at all intersections equitably, but cannot accommodate all pedestrian movements on all phases and stay in coordination, the system will allow the lower cycle length through the following actions. If protected/permitted left turn phasing is in operation, the protected phase can be omitted under user-specified conditions, such as very light volume or short queue lengths (determined by detector logic). The maximum green time may be set lower than the sum of pedestrian walk and clearance times, and still allow the pedestrian phase to operate by extending the green time when necessary without throwing the system out of coordination.

During normal weekend traffic conditions, the system may operate in the same manner as the business hours or as the off-peak periods.

The entire corridor may be set by the operator to operate as one or more coordinated groups under this condition, or the system may have the freedom to operate it as one or more groups subject to user-specified criteria, such as similar required cycle lengths in different parts of the corridor are similar or the volume of traffic at key locations exceeds a threshold.

**LRT PREEMPTION**

LRT operation is an extremely important part of the corridor operation. There are gated grade crossings of the light rail line on several of the east-west routes that cross Broadway Avenue, namely Northern, E. Central Blvd and E. Southern St. The light rail line is approximately 600ft. to the east of Broadway, and there is a signalized intersection with S. Telegraph Avenue approximately 400ft. east of Broadway. The light rail preempts the signals at S. Telegraph Avenue and also preempts the S. Arroyo Parkway signals (operated by State DOT) to the east of the light rail line. The light rail currently provides advance warning of an approaching train 72 seconds before its expected arrival at the crossing. This provides time for the controller to cycle through appropriate clearance phases (such as eastbound through and left turn phases at Arroyo) before entering the preemption operation (either flashing red or limited service, depending on the location).

There are times when the westbound queuing is sufficiently heavy that preemption of the Broadway signals may be necessary in order to clear the tracks safely. A preemption call received at S. Telegraph will be transmitted to the controller at S. Broadway, and logic applied so that a preemption phase will be able to be initiated if there is insufficient queuing space available in the block between S. Telegraph and S. Broadway to store vehicles that clear the block between S. Telegraph and the light rail line. This logic will be determined by a queue detector west of S. Telegraph in the westbound lanes. This is expected to result in preemption generally not being required outside the peak periods, and only being required within the peak periods when queuing is present on the westbound approach to Broadway.

The existing arrangement of inhibiting the eastbound through phase at S. Broadway during a preemption if the eastbound block is full will be continued. A queue detector east of S. Broadway in the eastbound direction detects the presence of a queue. If the gates are down, the eastbound detectors are suppressed, and the eastbound through phase does not run.

Once the gates are raised, the signals enter a post-preemption sequence. Typically this involves serving the east-west phases first to clear or reduce the queues on those movements that built up during the preemption.

**BUS PRIORITY**

Bus priority will be provided at each intersection. The input requesting priority will come either from the centralized METRO priority system or directly from the approaching bus, depending on location and bus route. The system will have the capability to extend the existing green if that will serve the bust, introduce an early green by shortening or skipping other phases, or run a phase called exclusively by the bus. The decision to provide priority will be determined within the local controller, based on user-definable and settable rules. These rules will include such items as: length of time or number of cycles since last priority was provided, and priority level if there are competing requests. It is anticipated that the various bus priority systems that will be in place will have their own logic to determine whether a priority request for an approaching bus will be transmitted to the signal controller, based on such parameters as schedule adherence, route number, in-service or out-of-service and passenger loading. This logic will not reside within the adaptive system.

**EMERGENCY VEHICLE PREEMPTION**

When a fire call is received, a request for a preemption route will be placed from the fire house. This will be achieved by either activating a switch inside the fire house or by placing a preemption call to the first intersection from the fire truck. If there are multiple routes from which the fireman must choose one, there would generally by multiple switches inside the fire house. Preemptions will be placed at the appropriate intersections along the route. If travel time to an intersection is longer than required for any clearance period, the introduction of the preemption will be delayed until it is required, and any potentially conflicting vehicle or pedestrian phases that would delay the preemption will be suppressed.

At other intersections beyond the pre-set routes, emergency vehicle preemption will occur in the normal fashion when requested by an approaching emergency vehicle.

**MAJOR EVENTS**

During major events, the traffic characteristics are often similar to the peak periods, either oversaturated or unsaturated. The system will behave in a similar fashion to those periods, and the detection system will determine whether unsaturated or oversaturated conditions prevail. If there is heavily directional traffic before or after an event, the system will determine the predominant direction and coordinate accordingly, with an appropriate cycle length and offset. If the event traffic is not as heavy as peak hours, but the traffic on the corridor is still highly directional, then the system will recognize this provide coordination predominantly in the heaviest direction, even though the cycle length may be similar to business hours (with balanced flows) cycle lengths.

The entire corridor may be set by the operator to operate as one or more coordinated groups under this condition, or the system may have the freedom to operate it as one or more groups subject to user-specified criteria, such as similar required cycle lengths in different parts of the corridor are similar or the volume of traffic at key locations exceeds a threshold.

**MAJOR INCIDENTS**

When a major incident occurs on one of the freeways, or at a location within Central City, the traffic on Broadway Avenue will change in a manner that is difficult to predict, and the response required of the system will vary depending on the time of day, day of week and the current traffic conditions at the time the incident occurs. The system will detect any increase in traffic volume and take the following action. If the increased volume needs a higher cycle length in order to continue to accommodate all movements at all intersections, it will increase the cycle length, but only up to the maximum permitted by the operator. If the diverted traffic results in a change in the balance of the direction of the traffic on the corridor, the progression will be changed to match the traffic. Typically the result of these actions will be to increase the cycle length and provide a wide progression bandwidth in the direction of the diverted traffic. However, if the incident occurs at times of lower overall traffic volumes, and it does not result in oversaturated conditions on the corridor, the result may be that the system mimics a typical peak pattern or business hours pattern.

This type of incident will typically not result in a uniform increase in traffic in one direction for the entire length of the corridor. If traffic diverts from one of the freeways to the north or south of this corridor, it often will turn onto one or more of the important east-west corridors. Therefore, it is expected that the response of the system will be different in the northern and southern parts of the corridor, depending on the location, nature and time of day of the incident. The architecture of the system will allow the northern, central and southern portions of the system to respond independently but in a consistent manner during incidents.

**DETECTOR FAILURE**

Detector reliability is a very important part of successful adaptive operation. The system will recognize a detector failure and take appropriate action to accommodate the missing data. For a local detector failure, the local controller will place a soft recall or maximum recall (to be user-specified) on the appropriate phase, and issue an alarm. For a detector that influences the adaptive operation (e.g., a system detector), the system will use data from an alternate (user-specified) detector, such as in an adjacent lane or at an appropriate upstream or downstream location. If the number of detector failures within a specified group exceeds a user-specified threshold, the system will cease adaptive operation and go to a fallback mode of time-of-day operation or free operation. The fallback mode will be specified by the user based on location and time of day.

All detector failure alarms will be automatically transmitted to maintenance and operations staff for appropriate attention.

**COMMUNICATION FAILURE**

Depending on the architecture of the system, communications failures will have varying effects on the operation. If a communication failure prevents the adaptive system from continuing to control one or more intersections within a defined group, all signals within the group will revert to an appropriate, user-specified fallback mode of operation, either time-of-day operation or free operation. The fallback mode will be specified by the user based on location and time of day.

All communication failure alarms will be automatically transmitted to maintenance and operations staff for appropriate attention.

**ADAPTIVE SYSTEM FAILURE**

There are two types of adaptive system failures: failure of the server or equipment that operates the adaptive algorithms; and inability of the adaptive algorithms to accommodate current traffic conditions.

If the equipment that operates the adaptive algorithms fails, the system will recognize the failure and place the operation in an appropriate, user-specified fallback mode, either time-of-day operation or free operation. The fallback mode will be specified by the user based and time of day.

The adaptive system makes its decisions based largely on detector information. Occasionally, as the result of an incident or other event outside the control of the system and outside the area covered by the system, congestion will propagate back into the adaptive control area and the measured traffic conditions will be outside the range of data that can be processed by the system. In locations where this is likely to occur, the intersection detectors, or queue detectors installed specifically for this purpose, will measure increased occupancy. In such cases, when user-specified signal timing and detector occupancy conditions are met, the system will recognize that the its response to the input data may not be appropriate, and it will revert to an appropriate, user-specified fallback mode, either time-of-day operation or free operation. The fallback mode will be specified by the user based and time of day.

All adaptive system failure alarms will be automatically and immediately transmitted to maintenance and operations staff for appropriate attention.

**ULTIMATE DEPLOYMENT**

This section describes several additional operational scenarios that will not occur on the S. Broadway Avenue corridor, but are situations that will need to be covered by the adaptive system elsewhere in Central City.

**ISOLATED CRITICAL INTERSECTION**

At an isolated intersection that is not part of a coordinated arterial, but cannot operate efficiently as a vehicle-actuated intersection in free mode at all times, the system will determine the appropriate cycle length, phase sequence and split times. User-specified limits will be applied to key parameters such as cycle length and duration between successive displays of a phase. Upon detection of phase failure (through high occupancy of detection zones) or overflow of storage bays (through queue detection), the system will introduce the appropriate phase twice per cycle until the condition is cleared. The system will also have the ability to select different phase sequences to efficiently accommodate different balances of traffic volumes.

**CROSSING ARTERIALS**

Where crossing arterials are coordinated by the system, the system will determine the appropriate cycle length and direction of coordination independently on each arterial. If the critical intersection requires significantly different operation than the other arterial intersections on all approaches, the system will operate this intersection in the manner described in section 0 for an isolated critical intersection. If the desired operation on both arterials requires a similar cycle length, then both arterials will be coordinated in a consistent manner. Although all intersections may operate at the same cycle length, the system will still independently select the mode and direction of coordination to suit each arterial (e.g., maximum throughput on one arterial and balanced coordination bands on the crossing arterial, even though they are operating with a common cycle length).

If the operation on one arterial requires a different cycle length or other characteristics than are appropriate for the crossing arterial, the intersections on the crossing arterial will operate with a separate coordination pattern and the crossing arterial approaches to the critical intersection will not be coordinated.

**CROSS-JURISDICTION OPERATION**

At freeway interchanges on some arterials, the signals are owned and/or operated by State DOT. In the future, if these signals are included in the adaptive system, State DOT operators will be able to log on to the adaptive system to monitor and control those intersections, and monitor other elements of the system. This will allow them to set the parameters under which these signals will be coordinated with other (Central City) signals on the arterials, and override the adaptive operation at those intersections should conditions require it (such as presence of an incident and unacceptable queuing on the freeway off-ramps).

**CLOSELY SPACED INTERSECTIONS**

For successful operation at the interchanges and other locations with closely spaced intersections, the system will operate within user-specified cycle length and coordination limits that are appropriate for closely spaced intersections. This will include: control of maximum cycle lengths to prevent excessive queuing on internal approaches between intersections; use of trailing offsets to clear blocks at the end of certain phases; and the ability to operate one intersection as a slave to another, so its phase endings clear the block between them, and phase start can be held until the block ahead is guaranteed to be clear.