Seattle Central Link Light Rail: Enhanced Transit Priority and Public Perception

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ABSTRACT

The Seattle Central Link light rail began final design in 2000 and started revenue service in July 2009. When the project began, the City of Seattle and Sound Transit felt that the typical priority or preempt features available in the marketplace at the time would not satisfy the operational needs of the Martin Luther King Jr. Way S. corridor. Through the development of a VISSIM model of the Light Rail Transit (LRT) corridor and multiple needs evaluation sessions with the stakeholders, a new traffic signal controller software approach was born.

The controller software started development in late 2005 and first hit the street for testing in the summer of 2008. The software includes multiple levels of priority and varying methods of recovery following an LRT priority event. Many of the features developed for this corridor have not been used on any other LRT system in the nation.

The intent of the system was to have the least amount of impact on general purpose traffic and pedestrians; while progressing trains between stations without stopping. Despite all the flexibility and control developed in the system, in the end, the comments and concerns raised by the traveling public ultimately dictated how the corridor was operated.

This paper will present the new and innovative forms of priority developed for this corridor and how they originated through the initial VISSIM analysis. This will be followed by a discussion of the publics’ reaction to the system and the ultimate changes in operation that were accepted.

1 INTRODUCTION

When operational planning for the Central Link light rail began in 2000, there were mature light rail systems operating on the west coast in Portland, Sacramento, San Jose, San Francisco and Los Angeles. While much was learned from these systems, Seattle and Sound Transit knew they had to develop a unique system to exactly fit the needs of the heavily congested conditions in the Rainier Valley of Seattle.

This paper will describe the process that was used to develop the operational characteristics of the Central Link system and briefly describe the new controller features that were developed for Seattle. In addition, this paper will describe how input from the public, through observations and direct comments, helped shape the final system.

The following section will provide some background information on the Central Link light rail transit (LRT) system.

1.1 Project Background

In 1996, Seattle area voters approved a regional high capacity transit initiative, which included express buses, commuter rail, and funding for the Central Link light rail. Preliminary engineering began almost immediately, with final engineering beginning in 2000.

The Central Link System was initially scheduled to run from the University of Washington to south of SeaTac airport. It was scaled back after the preliminary engineering stage to include the area from the north end of the existing Downtown Seattle Transit Tunnel (Westlake Station) to the Tukwila International Boulevard Station. The Airport Link segment was completed within six months of the initial segment and the University Link segment is currently under construction. The segment noted in the map above as the “initial segment” was completed for $2.3 billion. This was $136 million under the estimated budget.

This paper addresses the portion of the Central Link system that runs at-grade through the Rainier Valley along Martin Luther King Jr. Way S. The at-grade section is 4.5 miles and stretches roughly from the Mount Baker station to just south of the Rainier Beach Station. The original roadway was a five lane arterial which cut through single family residential, commercial and light industrial areas. . The final alignment provided two lanes in each direction with the light rail tracks down the center of the roadway. The original roadway had 11 traffic signals and carried 28,000 vehicles per day (2004). The final alignment has 28 at-grade crossings.

There are a total of 12 stations along the initial segement; three in the at-grade portion. During peak periods, the trains operate at 7.5 minute headways in both directions and scale back to 10 and 15 minute headways off-peak. Currently, the system is running two car trains, but is designed for four car trains to accommodate increased ridership with expansion of the system.

2 PLANNING FOR PRIORITY OPERATIONS

Light rail trains began running on the corridor in the summer of 2009, but planning for the LRT operations started in 2000. There were two studies performed from 2000 to 2002 that helped shape the priority features for the Central Link corridor: 1) an evaluation of LRT operation technology used with other systems along the west coast; and 2) a model of the corridor in VISSIM. The following two subsections provide more detail on the information gathered out of these two studies.

2.1 Technology Evaluation

Although Sound Transit was nearing completion of the Tacoma Link streetcar system in downtown Tacoma when the Central Link design began, Sound Transit and the City of Seattle chose to start from scratch in defining the operational characteristics of the Central Link alignment. The evaluation began with a series of phone interviews with LRT operators in the western United States. The evaluated systems included: Long Beach-Los Angeles LRT; Tri-County Metropolitan Transportation District (Tri-Met) MAX LRT system in the Portland area; Sacramento’s Regional Transit District LRT; San Francisco’s Municipal Railway; Valley Transit Authority LRT in Santa Clara County, CA; and the Utah Transit Authority LRT in the Salt Lake City area. Through these interviews the design team gathered information about the following:

- Type of LRT detection
- Traffic signal controller and software types
- Specialized LRT traffic signals and signing
- Priority/Preemption features used to progress trains

A survey was also conducted of all the traffic signal controller vendors to see which ones were capable of operating traffic signals with LRT movements and what type of functionality was available for progressing the trains without stopping. The surveys of operators and vendors culminated in a peer panel workshop where many of the operators and all the vendors were invited to come present their systems and answer questions about their experiences (operators) and their capabilities (vendors).

2.2 VISSIM Evaluation

Development of a VISSIM simulation of the Central Link corridor was one of the first tasks in the final design. There was significant concern about the ability to operate LRT on a corridor that was near capacity and was going to have double the number of traffic signals when the system was complete. The City of Seattle and Sound Transit were very anxious to see what this combination would look like in the future. Everyone was confident that the system would work, but knew that it would require the use of controller features that may not currently exist.

The operational goals of the system were simple: trains must travel station to station without stopping; and Martin Luther King Jr. Way S must be able to maintain coordination.

The City of Seattle and King County Metro had recently spent two years developing and testing new controller software for transit signal priority using the “Low Priority” features of traffic signal controllers. The goal of the Low Priority was to always stay in coordination by balancing the cycle when phases are cut short or extended to facilitate a bus. Seattle was interested in seeing if this same approach would work with the trains. They also entertained the idea of preemption, which was one of the primary forms of train control used on the west coast at the time. A few significant issues were identified when testing these forms of signal control:

1. Partial priority helped maintain the mainline motor vehicle progression, but it eventually would breakdown due to heavy left turns spilling out of their pockets and eventually hindering coordination.
2. Preemption was great for the train and coordination wasn’t quite as bad as expected since motor vehicles could follow the green band created by the train, but the skipping of phases resulted in a high number of cross street pedestrian calls being skipped. Over 5% of pedestrians were predicted to wait more than the cycle length to be served, which was deemed unacceptable.
3. Left turn queuing was identified as a significant issue with both partial priority and preemption. Five intersections had left turn movements that became level-of-service F as a result of the train operations.

The results of the VISSIM analysis provided valuable input into the operational needs for the corridor. The following section describes some of the priority features that were developed as a result of this analysis.

3 PRIORITY FUNCTIONS

The City of Seattle determined from the VISSIM analysis that one form of traffic signal control was not the best solution for their corridor. They wanted to find a way to have the best of both worlds. Ideally, they only wanted phases skipped when it was absolutely necessary to get the train through a traffic signal, but if there was a way to just shorten phases, as is done with Low Priority, they wanted the ability for the traffic signal controller to be intelligent enough to select this functionality. Knowing that queuing and pedestrian phase skipping were a significant issue, they felt they also needed a means of addressing these issues in the future controller software.

The City of Seattle, Sound Transit and DKS Associates worked together to develop a complete list of all the LRT functions that would be needed for the Martin Luther King Jr. Way S corridor. This list was compared against all the traffic signal controllers on the market and it was found that none could meet the City's needs without significant development work. The City and Sound Transit met with multiple vendors to discuss the potential software development and ultimately chose Siemens and the SEPAC software as the starting point for the LRT traffic signal controller software. The City already had SEPAC running in EPAC controllers at about 1/3 of the City's traffic signals.

The following sections describe some of the unique features developed into SEPAC software.

3.1 Full and Partial Priority

"Low Priority" and "Preemption" were common terms used in Seattle for bus operations and emergency vehicle/heavy rail operations respectively; however they did not seem quite appropriate for what was being developed for light rail. It was determined through the VISSIM analysis that Low Priority was not going to work well enough. Preemption was the next option, but no one wanted the light rail operations to be labeled as "Preemption" due to the somewhat negative perception of that operation. Preemption is associated with shortening or skipping pedestrian movements and severely shortening and skipping vehicle movements, it was felt the ultimate operations would have a softer impact. As a result of these discussions, the terms "Full Priority" and "Partial Priority" were introduced.

3.1.1 Full Priority

The software developed for Seattle created Full Priority as a separate entity from Preemption. Although they had some similar characteristics, such as phase skipping, there were significantly different controls associated with light rail operations. Preemption would allow a flashing Don't Walk interval to be shortened or eliminated and it could reduce a vehicle movement below its minimum green, but Full Priority would not allow the Flashing Don't Walk interval to be impacted and cannot violate minimum green times. Full Priority was also developed to work from a preempt input or up to nine detector inputs from the light rail system.

3.1.2 Partial Priority

The typical definition of low priority is the ability to extend a green indication associated with the direction of travel of a transit vehicle and shorten conflicting greens to return to a transit movement more quickly. The operation of “Partial Priority” for Central Link is exactly the same just with a different name. The word “Partial” was used instead of “Low” to better fit with the new term developed for the more aggressive form of Priority (Full Priority).

When a light rail vehicle call is received, the controller will first look to see if it can provide an LRT green for enough time to clear the train by extending the companion motor vehicle green to the LRT movement (co-phase) or shorten other conflicting greens to get back to the companion phase in time for the train. If the controller determines that it cannot use green extension or phase shorting to serve the train, it will then switch into Full Priority mode and skip phases as needed to get the train through without stopping.

3.2 Recovery

Multiple options for recovering from a Full Priority event were developed to counterbalance the effects of skipping phases and losing coordination. The controller has the following three recovery options:

3.2.1 Normal

With “Normal” selected the controller has the option to get back into coordination through the typical offset seeking method used when a preempt occurs, or it can jump directly into the correct location in the background cycle. For example, with a standard eight phase intersection, if the train runs with phases 2 and 6 and clears during 4 and 8, the controller will immediately clear 2 and 6 and jump into 4 and 8 if there is enough time to serve the minimum green or pedestrians. Offset seeking would require the controller to serve phases 3 and 7 first and may take multiple cycles before it the intersection is back in step.

3.2.2 Wait

The controller has the ability to determine the recovery phase based on movements with the most significant delay. The default operation is to return to the vehicle phase that has waited the longest. This is an easy way to quickly clear a vehicle phase that was skipped during Full Priority timing. The vehicle delay can be overridden by a delayed pedestrian movement if the delay reaches a programmable time threshold. Lastly, through the use of queue detectors, the controller can also return to any vehicle movement that has met the occupancy and delay time associated with a queue on a particular conflicting movement.

The wait timers were developed specifically to address the pedestrian delay and queuing issues identified in the VISSIM model.

Following service of a movement that met the Wait conditions, the controller can return to coordination through offset seeking or jumping into the background cycle.

3.2.3 Defined Phase

The user has the option to force the controller to return to the same phase following every light rail event. This is a very aggressive means of addressing a movement that experiences significant delay. The user has the option to have the controller get back into coordination following the defined phase through offset seeking or jumping into the background cycle.

3.3 Queue and Pedestrian Protection

The software was designed with a few other features that would help address queuing and delayed pedestrian and vehicle movements as described below:

1. Clear Out Conflicting Phase: When a train is detected and the controller determines it must use full priority to serve the train, the controller can have as much as 50 seconds of cycle time to use before the train arrives. The operator can use this time to serve specified phases that typically have long queues. The controller will jump to these phases and cycle through the ones with demand until it is time to be in the light rail co-phases.
2. Conflicting Phase Extension: This feature was also developed for use during the time between when the first LRT call is received and when the traffic signal has to be in the co-phases. If the controller is in a phase that conflicts with the train when the LRT call is received, the controller can serve this phase beyond its normal split to allow extra time to clear queued vehicles. The controller will only extend the conflicting phase if there is demand. Once the phase gaps out the controller can go to another conflicting phase if time allows, otherwise it will go straight to the co-phases.
3. Pedestrian Skip Frequency: The controller has a timer that can track how long a pedestrian call has waited to be served. The controller can potentially block a Full Priority event from occurring if the pedestrian skip frequency timer reaches a user defined threshold. The user can tell the controller to either use a Partial Priority call to get to the LRT co-phases or cycle through the phases using the normal splits.
4. Frequency Timers: The controller has two frequency timers that can potentially block priority calls if used. One timer focuses on trains traveling the same direction. The purpose of this timer is to keep the trains from bunching on the corridor by slowing the second train requesting a priority call in the same direction. The user can allow the second train to get a Partial Priority call, but a second Full Priority call cannot be obtained until the timer expires. The second timer will block a second priority call regardless of direction.

3.4 System Components

The light rail system at signalized intersections has two primary components for controlling the intersection; the train to wayside controller (TWC) cabinet, and the traffic signal controller cabinet. The train to wayside controller cabinet houses all the communication hardware for the detection system on the corridor. The LRT system uses VETAG (Vehicle Tagging) detectors. The TWC cabinets use a fiber optic cable to communicate between TWC cabinets and then a conversion to copper cable for the connection between the TWC and traffic signal controller cabinets. The connection between TWC cabinets allows train calls to be cascaded down the corridor to provide multiple time point inputs on the arrival of a train at each intersection. On average, each intersection receives a call from an approaching train three intersections in advance, with a maximum of six advanced calls. With each new call, the traffic signal controller can update the arrival time to account for any variation in the train speed.

If the train is stopped for some reason after the first advanced call, the backup call at the stop location will cancel the priority call at all downstream intersections until the train starts moving again. This operation helps reduce the number of false calls on the corridor.

The new SEPAC software is running on a 2070 traffic signal controller. The 2070 is housed in an "ITS cabinet". The cabinet has the foot print of a standard 332 cabinet but is six inches taller. The cabinet can handle up to 64 detector inputs and 14 load switches. All the controller cabinets are interconnected on fiber optic cable using Ethernet switches. The City is using TACTICS for their central system.

4 PUBLIC INPUT TO OPERATIONAL CHANGES

Although trains did not start revenue service until July of 2009, the track way and roadway construction was complete in 2007. Operational issues were discovered almost immediately after the full four lane alignment was opened. The trains started running consistently on the corridor in early 2009 and this operation triggered the discovery of more issues. Most operational issues were found through observations on the corridor by the City, Sound Transit and DKS staff, but others were identified by motorists and called into the City. The following is a description of some of the issues found after construction was complete.

1. North-South Concurrent Left Turns:

The geometrics of the intersections were laid out so northbound and southbound left turns could occur concurrently, but it required drivers to flatten the turn slightly instead of allowing for a rounded arch through the center of the intersection. The flattened turns allowed for plenty of clearance between passing vehicles. Unfortunately, with the new extra width in the median caused by two sets of tracks, and in some locations stations, drivers were becoming a bit lost in the wide open median. Drivers were observed not always following the most direct path through the intersection, which could have led to collisions, so most signals were immediately configured to prohibit concurrent lefts.

The inability to run concurrent lefts creates a condition that is not as efficient for the trains. This issue was solved by painting tracking lines through the intersection aligned with the turn pocket approach strip. This tracking provided guidance to the driver on the outside of the vehicle. This simple modification was an instant success. Now all the intersections are able to run concurrent lefts.

2. North-South Left Turn Signal Confusion:

The large median area created by the track way also caused some confusion for drivers who observed east-west signal heads as they passed through the intersection. On multiple occasions, motorists were found stopped on the tracks with a green arrow still on for their turning movement because when they entered the middle of the intersection, they thought the red ball for the eastbound or westbound traffic was intended for them. Motorists are not accustomed to seeing these indications from inside the intersection.

This issue was also quickly rectified with the installation of a louver insert in the east-west signal heads. The louver unit could be modified to cut off the view of the signal once a driver reached the edge of the track way. By the time a left turning vehicle was starting their turn toward the east or west, the eastbound and westbound signal would no longer be visible.

3. Pedestrian Crossing Time:

Martin Luther King Jr. Way S was approximately 55’ wide prior to construction of the light rail. After construction, some crossings became 130’ wide, which resulted in Flashing Don’t Walk times as high as 31 seconds. A refuge area with a pedestrian push button was installed on every crossing between the tracks, but this was not an area that Seattle or Sound Transit wanted to store people. All street crossings were designed for the pedestrian to cross in one phase. However, multiple complaints were received from pedestrians that felt they couldn’t make it all the way across.

This issue was addressed by adding countdown pedestrian signal heads on all east-west crossings. Pedestrians on the corridor were pleased with the additional information regarding the time available to complete their crossing.

4. Full Priority Recovery Perception

When programming of the priority features began for the corridor, an aggressive approach was taken in an attempt to maintain motor vehicle progression. Each intersection was initially programmed to jump directly into the background cycle so that green bands could be maintained when possible. North-south progression seemed to work well with this configuration, but the motoring public on other movements were very disturbed with the perceived erratic behavior of the traffic signal. Drivers waiting on conflicting movements did not like not knowing where the traffic signal was going after the train cleared the intersection. Consequently, the City chose to force the traffic signal to recover to the same phase following every Full Priority event.

About eight months after revenue service began, a new version of controller software was released that improved the recovery operations so the “Wait” feature was implemented at most intersections. This recovery will also cause the signal to frequently jump to unexpected phases following a train crossing, but the public was much more receptive. The use of wait was showing great improvements with queuing issues on the corridor and drivers seemed to be more comfortable with dynamic changes to the signal operations after spending almost a year with the train on the corridor.

5. Station Dwell

Sound Transit was very concerned about keeping the station dwell time consist and as efficient as possible so the public did not perceive any wasted time on the corridor. Sound Transit had determined that they could comfortably leave a station 25 seconds after arriving. However, to clear the worst case condition of the downstream intersection just ending the co-phases and starting an east-west pedestrian movement, some intersections needed as much as 44 seconds of time. Sound Transit chose 28 seconds as the programmed arrival time at the first intersection and banked on missing the worst case condition with most trains. Over time it was found the worst case conditions were hit much more frequently than expected and train drivers and passengers were growing frustrated with the resultant delays caused by the train not getting through the first downstream traffic signal at a station.

After eight months of revenue service, Seattle increased the station dwell to 38 seconds and it reduced the number of train delay issues by as much as 10%. The 38 second dwell at the station almost completely eliminated random stops at intersections between stations. The best part of this modification is that Sound Transit did not receive a single complaint about longer dwell times at the stations.

5 CONCLUSION

At the beginning of this project, Sound Transit did their best to learn from other light rail operators to ensure the Central Link project. Many of the operators surveyed at the start of the signal operations project were brought in for a peer panel workshop to discuss some of the lessons they learned over the years of operating their systems. The biggest lesson learned on this project is that drivers in different parts of the country, and in some cases, different parts of the same city, can have significantly different behavior. Conditions on Martin Luther King Jr. Way S were not necessarily better or worse than other locations, but they created new challenges that had not been identified in other areas.

Fortunately, Sound Transit and the City of Seattle developed a very strong partnership from the beginning of this project that allowed them to effectively work together to quickly resolve issues identified as operation of the new corridor began. The trust and support provided by each agency was invaluable.

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