Software-In-The-Loop (SIL) Simulation for Central Mesa Light Rail Transit

1.0 INTRODUCTION

1.1 Background

The Phoenix Metropolitan region commissioned a starter Light Rail Transit (LRT) system in 2008. This 20.5 mile starter line, operating under the brand name METRO, extends from 19th Avenue and Bethany Home Road in north-west Phoenix through the City of Tempe to Main Street and Sycamore in Mesa. The Central Mesa LRT Extension will take this existing METRO line to downtown Mesa. This new 3.1-mile LRT alignment extends the existing system east of Sycamore, crossing the major arterials Alma School Road, Country Club Drive and Mesa Drive, and ends to the east of Hobson. The extension is scheduled to open for service in 2016.

The existing LRT system (starter line) in the Phoenix metropolitan area uses the Predictive Priority logic for controlling vehicular, pedestrian and LRV flow at intersections. The city of Mesa has four intersections that are part of this system. The existing system used Econolite ASC/3 controllers with an add-on 2070-1B central processing unit (CPU) card for implementing this control strategy. The predictive priority control was implemented using the Siemens NextPhase firmware in the CPU card and the native ASC/3 firmware was not utilized. Since these controllers were different from the controllers utilized for managing traffic at other intersection in the City of Mesa, it resulted in operational, management and maintenance difficulties for the City. In order to overcome this and eliminate future issues it was decided to operate LRT intersection in Mesa using the ASC/3 controller running the native firmware. As part of a collaborative development effort between the City of Mesa, Econolite and Parsons Brinckerhoff, the predictive priority signal control was developed and tested using the ASC/3 firmware. The four existing intersection in the City of Mesa are currently using this firmware for signal control.

1.2 Purpose of Study

To develop appropriate signal control strategy and traffic signal timing for each intersection along the Central Mesa LRT Extension, Parsons Brinckerhoff is assisting the City of Mesa and Metro in analyzing the implementation of an advanced transit signal priority control using the ASC/3 firmware. The developed controller timings will be used for opening day traffic signal timings to be implemented at the intersections. This paper will discuss the analysis process, the measures of effectiveness (MOE) and the selected transit signal priority strategy.

2.0 METHODOLOGY

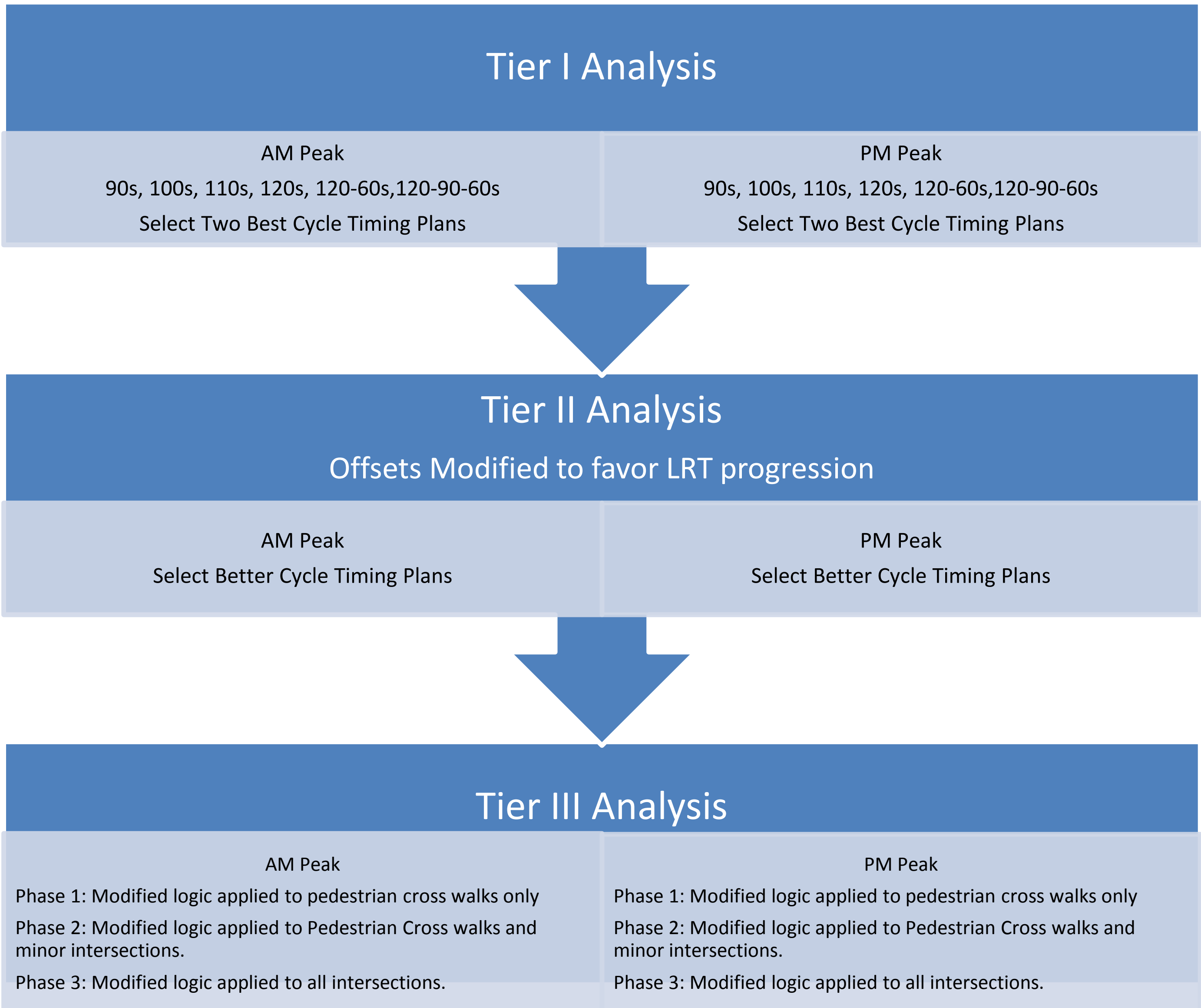
2.1 Analysis Tool - Micro Simulation VISSIM and ASC/3 Software-in-the –Loop (SIL) Package

To identify the appropriate controller timings and transit control strategies, a micro-simulation model was developed using PTV VISSIM and Econolite ASC/3 software-in-the-loop (SIL) package. The SIL package emulated the real-world controller functionality of the Econolite ASC/3 controllers that eventually will be installed at intersections along the alignment. To consider the impact from the pedestrian crossings, all the proposed signalized pedestrian cross-walks and assumed pedestrian numbers were added into the VISSIM model.

2.2 Approach

The signal timing alternatives were evaluated and screened using a 3 tiered analysis approach. For each tier of the analysis the Measures of Effectiveness (MOEs) for the alternatives for that tier were documented. The alternatives that met the MOE criteria were carried forward for the next tier analysis. The 3 tiered analysis approach is demonstrated in Figure 2-1.

Figure 2-1: 3-Tiered Analysis Approach



TIER I analysis, involved development and evaluation of signal timing strategies. These strategies included having 90s, 100s, 110s, 120s and combination of these cycle lengths for the on-alignment intersections. Six signal timing strategies each were developed and analyzed for the AM and PM Peak periods. TSP logic was defined for the intersections. Intersection signal timing offsets for each cycle length were optimized using Synchro. All intersections were coordinated for East-West traffic flow except for the intersection of Main Street with Dobson Road, Alma School Road, Country Club Drive and Mesa Drive (four major intersections), which are coordinated for North-South traffic flow. TSP logic included providing LRT phase extension, LRT early green with left turn phase swapping and LRT phase insertion. The analysis helped identify two preferred cycle length strategies for each for the AM and PM Peak periods. These were further evaluated in TIER II.

Offsets for all the on-alignment intersections, except the four major intersections which have North-South coordinated traffic flow, were optimized to improve the light rail train progression, for TIER II analysis. TSP logic was applied to all intersections. The locations for advanced detection of the LRV's were also refined. One alternative each selected for AM and PM peak periods for TIER III analysis.

For TIER III analysis the TSP logic was modified to hold LRT Phase longer than the split time for the phase if the LRT phase is active, and there is an approaching LRV. In the case of pedestrian crosswalks the pedestrian phase was delayed till after the LRV had crossed the intersection. It was understood that violating phase split times would have an adverse impact on signal coordination. Therefore this analysis was done in a phased manner wherein the logic was applied only to certain groups of intersections initially and gradually expanded to encompass all intersections. The analysis was done in three Phases –

Phase 1: Modified logic applied to pedestrian cross walks only.
Phase 2: Modified logic applied to Pedestrian Cross walks and minor intersections.
Phase 3: Modified logic applied to all intersections.

3.0 RESULTS

Table 3-1 and Table 3-2 summarized the AM and PM Peak travel time measurements for all the VISSIM simulation scenarios. As indicated in the tables, LRT travel time would decrease from 12-15 minutes to 8-9 minutes when modified priority control is applied to more intersections. The travel time for vehicular traffic on Main Street increases by 1-2 minutes. The travel time for most north-south major arterials are similar except Mesa Drive northbound during AM Peak. The travel time would increase to 5 minutes.

Table 3-1: AM Peak Travel Time Outputs Summary

AM Peak	LRT		Main St.		Dobson Rd.		Alma School Rd.		Country Club Dr.		Mesa Dr.	
	EB (min)	WB (min)	EB (min)	WB (min)	SB (min)	NB (min)	SB (min)	NB (min)	SB (min)	NB (min)	SB (min)	NB (min)
Tier I	14.8	13.8	12.7	13.4	2.3	2.2	2.4	2.5	2.5	2.6	2.7	3.1
Tier II	12.7	13.1	13.1	13.5	2.3	2.2	2.5	2.5	2.5	2.6	2.7	3.1
Tier III-Phase1	11.5	11.1	16.4	16.0	2.3	2.2	2.5	2.4	2.6	2.5	2.8	3.1
Tier III-Phase2	10.2	9.8	13.2	13.2	2.3	2.2	2.4	2.3	2.6	2.4	2.8	2.9
Tier III-Phase3	8.1	8.3	12.9	15.1	2.7	2.6	2.7	2.7	2.7	2.6	3.0	5.5

Table 3-2: PM Peak Travel Time Outputs Summary

M Peak	LRT		Main St.		Dobson Rd.		Alma School Rd.		Country Club Dr.		Mesa Dr.	
	EB (min)	WB (min)	EB (min)	WB (min)	SB (min)	NB (min)	SB (min)	NB (min)	SB (min)	NB (min)	SB (min)	NB (min)
Tier I	12.3	13.4	14.8	14.1	2.4	2.3	2.4	2.4	2.5	3.3	5.0	2.8
Tier II	11.9	12.7	17.4	14.1	2.3	2.3	2.5	2.4	2.1	3.2	4.9	3.0
Tier III-Phase1	9.5	11.7	19.1	15.7	2.3	2.3	2.5	2.5	2.2	3.2	4.9	3.1
Tier III-Phase2	10.4	11.2	16.2	15.4	2.3	2.3	2.4	2.4	2.2	3.1	5.0	3.1
Tier III-Phase3	8.4	8.3	16.5	15.4	2.8	2.8	2.5	2.4	2.3	3.4	5.5	3.5

AM and PM peak hour overall intersection Level of Service (LOS) for all on-alignment intersections show that intersections of Main Street at Extension Road and Mesa Dr would be expected LOS E during AM peak hour if extra holding for phase 2 and phase 6 was set up. The traffic on Extension Road and Mesa Drive would not be fully serviced. During PM Peak, the intersection of Main Street and Mesa Drive would be operating between LOS D and LOS E.
It should be mentioned that LOS E would be expected for most left turn movements on Main Street, the overall intersection would still operate at LOS D or better.

Figure 3-1 through Figure 3-2 show the LRT stop probability at each signalized intersection for cycle lengths of 100 seconds for AM peak and 120-60 seconds for PM Peak. These figures also indicated the LRT progression improved gradually and significantly with the modified priority logic being applied to more intersections.

Figure 3-1: LRT Stop Probability at Signalized Intersection-AM Peak B1 (100 seconds) Tier I vs. Tier III

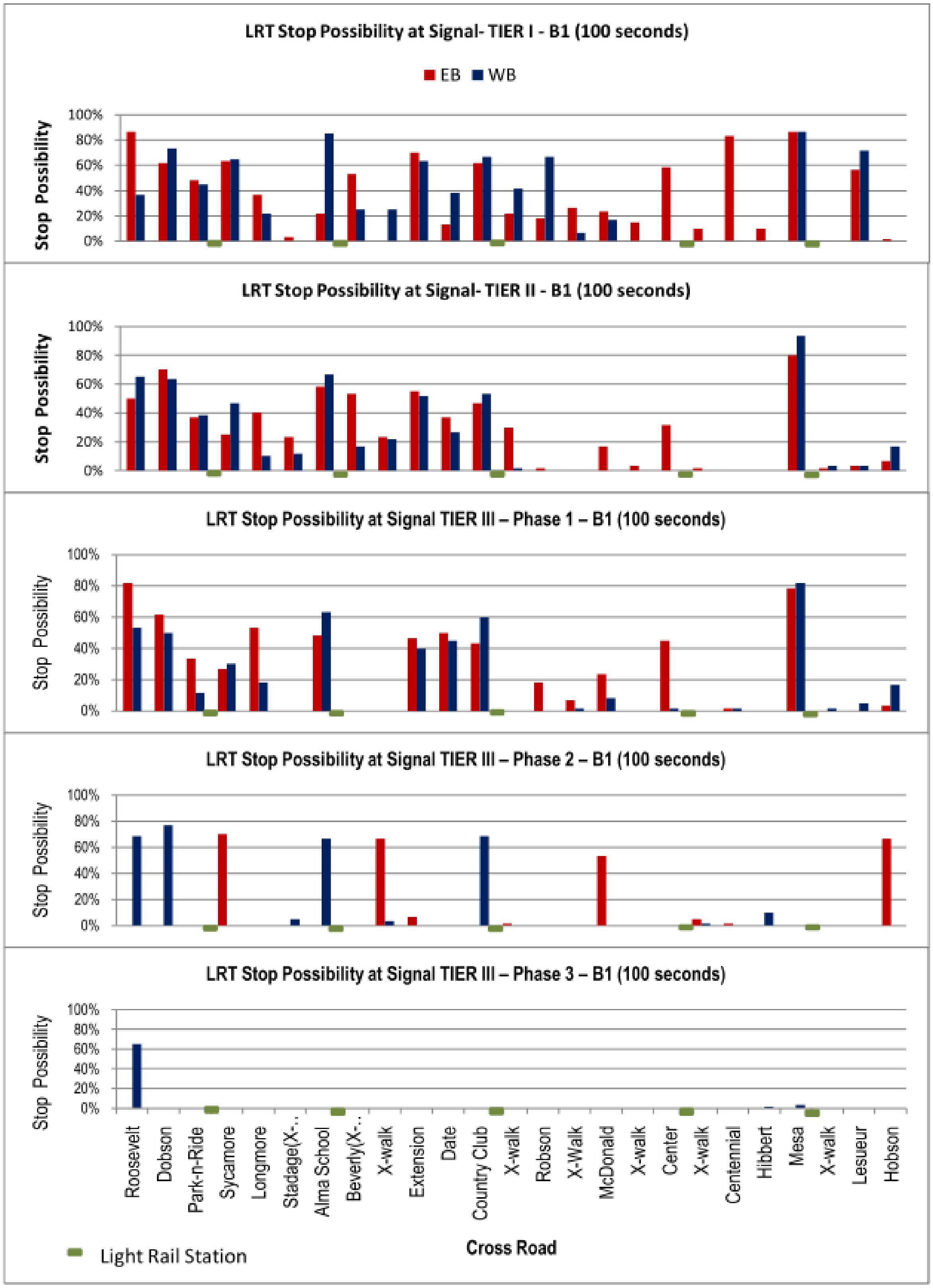
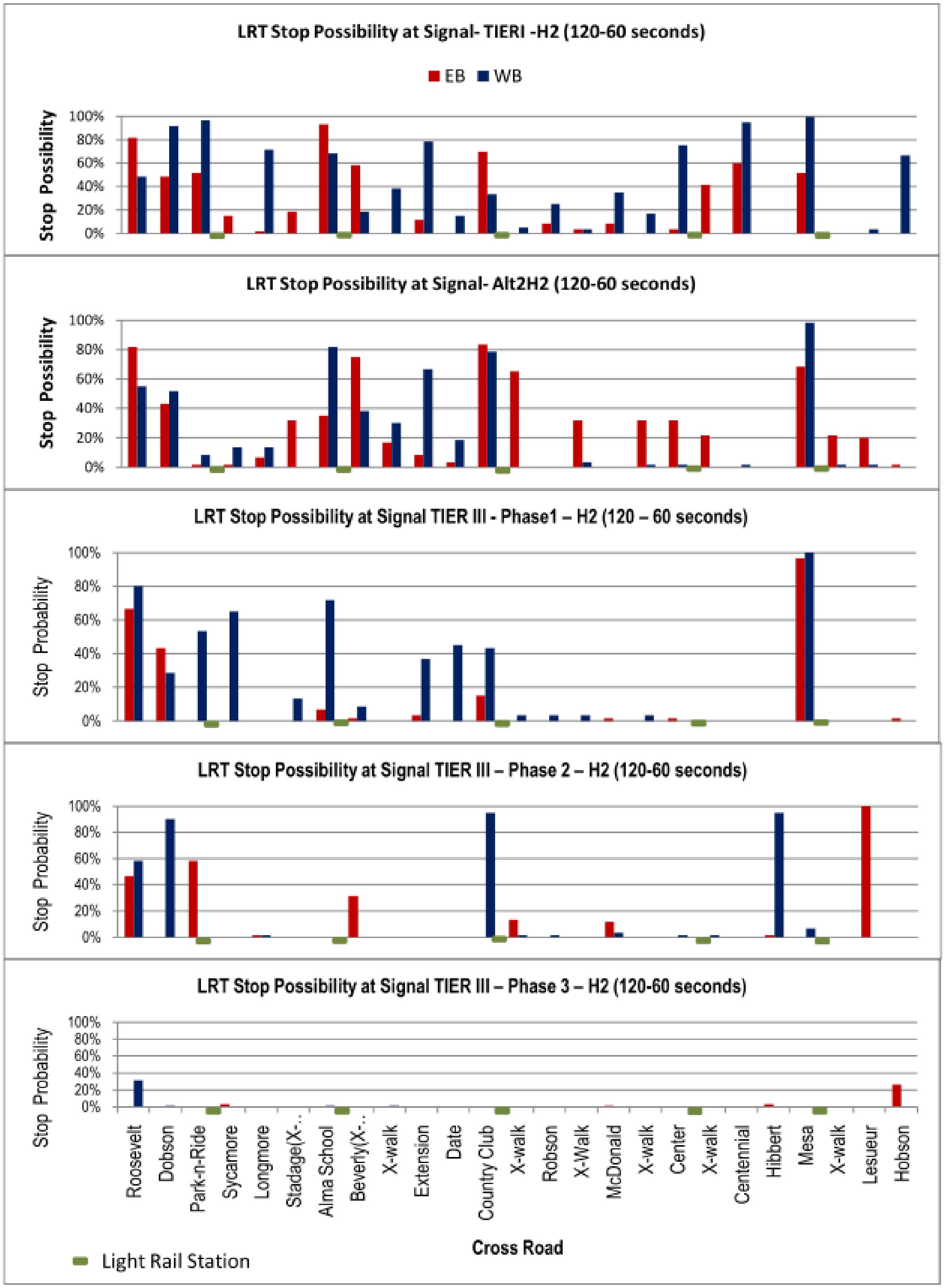


Figure 3-2: LRT Stop Probability at Signalized Intersection-PM Peak H2 (120 60 seconds) Tier I vs. Tier III



4.0 Recommendation and Discussion

Based on the simulation analysis, the cycle length of 100 seconds is recommended for AM peak. The signal timing strategy with 120 seconds on major and minor intersections and 60 seconds for all the pedestrian crossing intersections is recommended for PM peak. As seen from the three tiered analysis, the modified predictive priority applied for all on-alignment intersections was able to provide the best LRT good progression. For each cycle length, the associated splits and offsets can be used as the starting point for the field testing.

The following assumptions were made for the analysis. It is recommended that these be verified and adjusted as necessary during the field or shop and after the initial implementation.

LRT Travel Speed

The LRT travel speed is assumed as to be 35 MPH through the entire study area. Any changes to this will be addressed during the testing/integration period.

LRT Dwelling Time

LRT Dwelling time for all the stations within the study area is assumed as 15 seconds. This should be verified prior to operation to accurately set up advanced call settings.

Vehicular Traffic Volumes

Although traffic diversion was assumed because of the lane reduction on Main Street, the actual traffic volumes will need to be verified after the extension is open for service. The timing plan splits will need to be adjusted accordingly.

Pedestrian Crossing Time

Pedestrian crossing time is calculated based on City guidelines with the assumption of crossing the entire cross road. It is most likely the pedestrians near the LRT stations will only cross half way of the Main Street. Hence, the split for pedestrian phase can be reduced.

Advanced Check-in Detectors

These detectors were placed half-mile upstream for minor intersections and pedestrian crossing intersections while for major intersections the distance is around three-quarter mile upstream. In the field implementation, the actual delay time should be adjusted according to the updated timing plans.

Intersections of Main Street at Extension Road and Mesa Drive

With the unsatisfactory LOS observed in the simulation analysis, these two locations may need to be revisited during the subsequent testing.