Best Practices for Modeling Light Rail at Intersections

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A Report on Research Sponsored by

University Transportation Center for Railway Safety (UTCRS)

University of Nebraska-Lincoln

August 2018

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TECHNICAL REPORT DOCUMENTATION PAGE

<table>
<tr><td>1. Report No.
26-1121-0018-009</td><td>2. Government Accession No.</td><td>3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2">4. Title and Subtitle
Best Practices for Modeling Light Rail at Intersections</td><td>5. Report Date
August 2018
6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Author(s)
M.M. Shakuil Haque, John D. Sangster</td><td>8. Performing Organization Report No.
26-1121-0018-009</td></tr>
<tr><td colspan="2">9. Performing Organization Name and Address
Nebraska Transportation Center
University of Nebraska-Lincoln
Prem S. Paul Research Center at Whittier School
2200 Vine Street
Lincoln, NE 68583-0853</td><td>10. Work Unit No.
11. Contract or Grant No.
DTRT13-G-UTC59</td></tr>
<tr><td colspan="2">12. Sponsoring Agency Name and Address
University Transportation Center for Railway Safety
The University of Texas Rio Grande Valley
1201 W University Drive
Edinburg, Texas 78539</td><td>13. Type of Report and Period Covered
Final Report (June 2017 to August 2018)
14. Sponsoring Agency Code</td></tr>
<tr><td colspan="3">15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.</td></tr>
<tr><td colspan="3">16. Abstract
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<tr><td colspan="2">17. Key Words</td><td>18. Distribution Statement
No restrictions.</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified.</td><td>20. Security Classif. (of this page)
Unclassified.</td><td>21. No. of Pages
36
22. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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Abstract

This research aims to provide guidelines for best practices in modeling urban light rail facilities within transportation simulation software packages, including VISSIM and Aimsun, and improve the understanding of engineers and planners considering light rail facilities.

The case study location of four intersections in Denver, Colorado was analyzed thoroughly to monitor and capture the traffic demand and signal timing plans as a preliminary input for the simulation software environments. The traffic signal patterns of the intersections, including vehicular traffic, light rail, and pedestrian phases has been observed as accurately as possible using both on-site observations and review of video recordings. All the field observations have been documented in this report, and have been implemented faithfully in the simulation environment. Current versions of two of the most widely used simulation software packages were used, VISSIM and Aimsun, attempting to accurately reproduce the traffic conditions observed.

While documenting the modeling steps of the simulation software packages, the authors take for granted that conventional road network modeling is known to the audience, and have instead focused on the modeling techniques specific to the light rail movement. Several screen shots of the functionalities regarding the modeling tools have been included. It is the authors' intention that practitioners and researchers with limited or no prior experience will be able to model the light rail movement based on the documentation herein, and that ultimately, the observations and recommendations of signal timing techniques described in this report will enrich the state of practice for modeling light rail with traffic simulation software.

Chapter 1 Introduction

1.1 Background and Purpose

Light-rail transit is a popular mode of transportation in large cities. The peak demand on urban light rail facilities generally coincides with the peak for motorized vehicles and pedestrian traffic. Such multimodality creates complexity in traffic operations, maximizing the potential for conflict between the various modes. Furthermore, if signal timing plans are not coordinated adequately between light rail and the motorized vehicles, excessive queuing and delays may occur. High levels of congestion have been linked to aggressive driving behaviors, increasing the likelihood of signal violations by drivers, and resulting in adverse safety outcomes for the light rail facility.

1.2 Research Objectives

This research provides guidelines for best practices in modeling urban light rail facilities within transportation simulation software packages, improving the understanding of engineers and planners considering light rail facilities, and increasing the safety of those facilities with optimal signal operations. Furthermore, this research also intends to generate tutorials for light rail modeling in simulation environments, with detailed explanations to help practitioners, researchers, and engineers with limited or no experience to be able to model a light rail facility.

1.3 Methodology

The core research approach proposed herein is the validation of two simulation environments, VISSIM and Aimsun, against field-data recordings of the behavior and interactions between light rail and motor vehicles at signalized intersection facilities. Observations from the video collected include:

1. Light rail observations – the frequency of arrivals, the size and speed of the rail cars, the preemption/prioritization of the signal phasing in the presence of the rail cars, the clear space required as it passes through the intersections, etc.
2. Motor vehicle observations – the turn-movement-counts at the intersection locations, the signal operation in absence of the rail cars, the queues at the start of green, the method of control to prevent motor vehicle violations when the rail cars are passing, any indication of violations against the control, etc.

As part of the calibration and validation of the simulation scenarios in the two software packages, best practices will be identified regarding how to accurately model light rail interactions with motor vehicles, enabling future researchers and practitioners to develop reliable simulations of predicted behavior for potential light rail facilities.

One case study location was used, the square city block defined by Stout St, California St, 18th St, and 19th St in Denver, Colorado. On-site video data was collected and used for validation of simulated facilities within two simulation environments, including VISSIM and Aimsun. Of particular concern are: modeling the scheduled behavior of the light-rail facility; interactions between the light-rail and motor vehicles; signal preemption by the rail; and optimization of the actuated signal systems to minimize motor vehicle delay while prioritizing light-rail movements.

To conduct the data collection, Miovision Scout cameras were set up to record video footage at each intersection. Miovision Scout cameras are a portable video data collection device that is capable of recording video footage from a bird’s eye view. The video data was used to gather the traffic movements for passenger vehicles and light rail trains through each intersection. The video data was also used to identify the type of signal plan that is used at each intersection and the signal splits for each phase.

1.4 Document Layout

The remainder of this report is organized as follows. Chapter 2 includes the literature review on safety concerns, signal preemption and prioritization, and simulation models of light rail. Chapter 3 describes the geometry of the case study location. Chapter 4 contains the data collection and analysis performed to illustrate the traffic demand and signal plans. Chapter 5 discusses the patterns of observed traffic for each intersection studied, including the pedestrian and light rail movements. Chapter 6 describes the best practices for modeling and validation of light rail in two traffic microsimulation software packages, VISSIM and Aimsun. This report concludes with Chapter 7.

Chapter 2 Literature Review

In areas where traffic volumes are growing rapidly and demand is coming up against capacity, cities are examining light-rail transit systems as potential capacity-expanding solutions. Light-rail transit moves a large number of people in high-density areas without adding to oversaturated surface roadway conditions. There is currently a great deal of discussion regarding the benefits and costs associated with light rail facilities. (*1*) The main impediment to adding a light rail transit system to a preexisting traffic network is incorporating light-rail into an adaptive signal that gives the light-rail transit priority, but does not impede vehicular and pedestrian traffic.

2.1 Signal Preemption and Prioritization

There are many case studies available in the literature related to signal preemption and prioritization. The most cited study comes from Skabardonis, who analyzed both passive and active transit priority strategies using a real-life arterial corridor that consisted of 21 signalized intersections and an active transit system. (*2*) From this study, it was found that passive strategies to manage transit movements are effective in simple network configurations. Some of these passive strategies include street designs that are designed to implement transit movements, and weighted signal settings that are geared towards transit priority. However, existing active priority strategies are based for isolated signals, and cannot be actively implemented into a system with fixed-time signals. If these active priority strategies are implemented into a system with mostly fixed-time signals, there can be significant repercussions for the rest of the traffic system. In this study, passive and active priority strategies were developed for the entire system, compared to a single intersection. These strategies were implemented to observe the impacts of transit priority on the rest of the traffic system. (*2*) The best practices for light rail preemption at signalized intersections continues to be an active area of study, such as the recent presentation by Soler on the predictive priority used in Minneapolis. (*3*) Kittleson and Associates is currently working on an NCHRP synthesis addressing traffic signal preemption at intersections near highway-rail grade crossings. (*4*) Furthermore, there are several studies on the signal priority of transit transportation system including multimodal approaches and signal optimization. (*5–9*)

2.2 At-Grade Light Rail Systems

2.2.1 Safety Concerns with Light Rail

Along with the difficulties of implementing light-rail transit into an adaptive signal, there are also multiple safety issues that arise with light-rail transit. Meadow published findings related to Los Angeles light rail safety issues, and cites an ITE survey of 17 operating light-rail transit systems. (*10*) Issues identified by survey participants that are pertinent to the current research effort include:

- Motorist disobedience of traffic laws
- Traffic queues blocking crossings
- Vehicles exiting driveways stopping on tracks
- Vehicles turning from streets running parallel to the tracks
- Motorists running around closed crossing gates
- Pedestrian conflicts at station areas and crossings
- Light rail vehicles blocking street and pedestrian crosswalk areas
- Motorist confusion over traffic signals, light rail transit signals, and signage at intersections, and
- Unusual crossing configurations

The advent of the Highway Safety Manual has caused the embrace of crash modification factors throughout our industry. (*11*) A recent study by Fischaber and Jason applied the empirical Bayes method to light rail crossings of roadways developing safety performance functions that compared favorably against the U.S. DOT crash prediction models for at-grade crossings. (*12*) This type of crash prediction modeling can be used in conjunction with the simulation modeling proposed herein. A summary of related research can be found in TRB's Research in Progress (RIP) database, where Lu et al provide a fairly thorough literature review within their abstract for their ongoing research project titled "Highway-Rail Grade Crossing Traffic Hazard Forecasting Model." (*13*)

2.2.2 Modeling of Light Rail in Traffic Simulation Software

One of the problems with light-rail transit is modeling an entire system. Traffic simulating software that have been used so far to model light-rail transit systems are Vissim and Paramics. Vissim is capable of modeling typical passenger vehicles, trucks, and modes of public transport such as buses, heavy rail, and light-rail transit. Vissim also has the capability of modeling complex traffic systems that include preemption for buses and light-rail transit. (*14*) One study modeled the San Diego trolley system to minimize intersection delays for trolley, vehicles, and pedestrians by providing signal priority to the trolley. The following parameters were used: total travel time, aggregate travel speed, non-stop movement speed, and intersection delays. PARAMICS used the proposed signal control algorithm, trolley movement predictor, dwelling time predictor, and data collection and analysis tools that were programmed into PARAMICS. The results from PARAMICS validated signal priority for light-rail transit and reduced delays for the trolley and mixed traffic. (*15*) The focus of these prior studies is more on the case study location itself, and less about the best practices for modeling the location using the software.

Chapter 3 Denver Light Rail

The case study area selected for this project is located in the central business district of Denver, Colorado, as shown in **Figure 3.1**, below. California and Stout streets runs through the south and north directions, respectively, and 18th and 19th Street traverse through the west and east direction, respectively. Together, these four one-way streets create a city block defined by four intersections. Due to the roadway grid in Denver being set up in alternating direction one way roads the vehicle traffic (i.e., passenger cars, heavy vehicles, and buses) flows in a clockwise manner within the rectangular block study area. The light rail travels through the four intersections in the opposite direction compared to the vehicular traffic, i.e., counterclockwise.

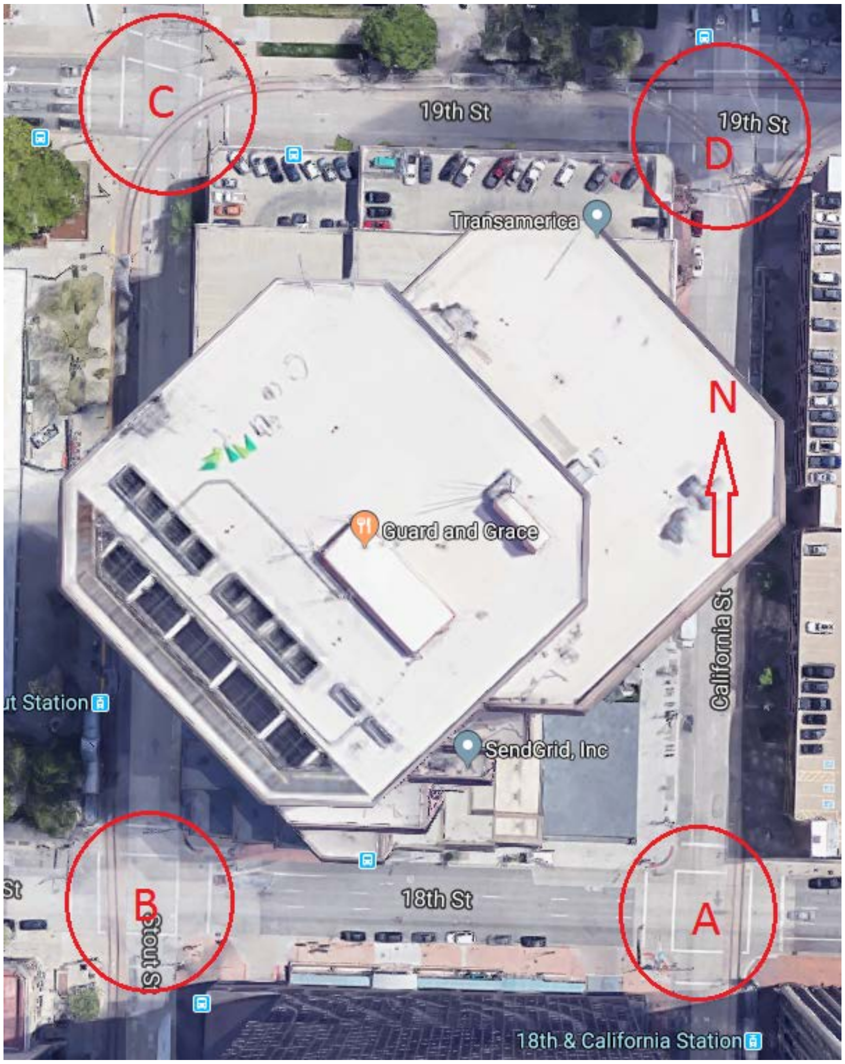


Figure 3.1 Case study location of four intersections in Denver, Colorado.

Figure 3.1 depicts the four intersections of the case study location. The intersection of 18th Street and California Street is denoted as location A. Location B is the crossing of 18th Street and Stout Street. The intersection of 19th Street and Stout Street forms location C. Location D is located at the crossing of 19th Street and California Street. Along 18th street between locations A and B, there are three through lanes and one right-turn pocket lane approaching Stout St. Along Stout Street from location B to C there are two through lanes, and along 19th Street from C to D, there are three through lanes. California Street between locations

D and A includes two lanes for the through movements and one pocket right turn lane near 18th Street. The lane widths were measured as being effectively the standard 12 feet.

Between several of the intersections, there are parking decks that impact the traffic flow as traffic origins/destinations. Each intersection has its own pedestrian crossing for four directions. For the case study location, the posted speed limit is 25 miles per hour, throughout.

Chapter 4 Data Collection and Analysis

Data was collected at the case study location utilizing video data from cameras attached to utility poles at high elevation (20ft +/-). The video data recorded the peak-hour behavior of pedestrians, motor vehicles, light rail, and the infrastructure itself. Raising the cameras prevented occlusion of the data by trucks and other large objects. The video data of the case study location used for analysis in this report was collected on June 7, 2017. The following two subsections describe the traffic demand and signal timing plans observed from the video data.

4.1 Traffic Demand

The turning movement counts for the four intersections were collected from the video data. Furthermore, a manual count was performed to carefully and accurately capture the field conditions. An evening peak hour period from 3:00 pm to 4:00 pm was chosen for this location, due to gridlock traffic conditions causing a reduction in observed demand flowrates, in spite of constant queues between 4:00 and 6:00. **Tables 4.1, 4.2, 4.3** and **4.4** show the 15-minute interval turning movement counts for the peak hour period for the vehicular traffic for locations A, B, C, and D, respectively. The manual counts for the various movements are shown, including right, left, and through turn movement counts. It should be noted that due to the presence of the parking facilities between the adjacent intersections, the outflow from an intersection and the inflow to the adjoining intersection does not match in every case. Such disparity has been considered and carefully modeled within the simulation environment to capture the accurate field conditions, described later in this report. It is the authors' opinion that such adjustments might take a significant amount of time regarding the balancing of traffic flow to simulate the network into the traffic simulation package accordingly.

Table 4.1 Turn movement counts at 15 minute intervals at location A (18th and California)

Start Time	California St. Southbound			18th St. Westbound		
	Left	Thru	Right	Left	Thru	Right
3:00	0	50	35	31	168	0
3:15	0	60	23	39	150	0
3:30	0	76	33	22	187	0
3:45	0	66	29	33	182	0
Total Volume	0	252	120	125	687	0

Table 4.2 Turn movement counts at 15 minute intervals at location B (18th and Stout)

Start Time	Stout St. Northbound			18th St. Westbound		
	Left	Thru	Right	Left	Thru	Right
3:00	27	99	0	0	168	38
3:15	28	85	0	0	165	39
3:30	21	90	0	0	198	38
3:45	30	103	0	0	203	46
Total Volume	106	377	0	0	734	161

Table 4.3 Turn movement counts at 15 minute intervals at location C (19th and Stout)

Start Time	Stout St. Northbound			19th St. Eastbound		
	Left	Thru	Right	Left	Thru	Right
3:00	0	124	20	19	60	0
3:15	0	121	18	25	87	0
3:30	0	129	18	19	75	0
3:45	0	126	22	22	100	0
Total Volume	0	500	78	85	322	0

Table 4.4 Turn movement counts at 15 minute intervals at location D (19th and California)

Start Time	California St. Southbound			19th St. Eastbound		
	Left	Thru	Right	Left	Thru	Right
3:00	9	56	0	0	92	16
3:15	6	43	0	0	96	18
3:30	6	45	0	0	106	12
3:45	10	61	0	0	117	14
Total Volume	31	205	0	0	411	60

4.2 Signal Timing Plans

The traffic signal plans were determined using manual observation of the video data from the case study location. The signal plans contain actuated timing parameters including, but not limited to, the minimum green time, maximum green time, vehicle extension time, yellow time, red clearance time for the vehicular traffic, pedestrian, and light rail. The maximum and minimum and no recall (components of the actuated signal control system) have also been investigated to code the signal timing into the simulation software to capture a close pattern found from field condition. The sequences of phase operation were also determined, and included as the observed traffic pattern in chapter 5 of this report.

For all four intersections, an actuated signal control system is being applied to control the traffic approaching the intersections. **Tables 4.5, 4.6, 4.7** and **4.8** include the quantitative measurements of the timing plans for locations A, B, C, and D, respectively. It is observed that throughout the four intersections, both the vehicle extension and yellow time are 3 seconds and the red clearance time is 1 second, for all the phases.

Table 4.5 Observed Signal Timing Plan at location A (18th and California)

Phase	California	Pedestrian	18th	Light Rail
Minimum Green Time	27	19	24	16
Maximum Green Time	37	24	35	30
Vehicle Extension Time	3	3	3	3
Yellow Time	3	3	3	3
Red Clearance Time	1	1	1	1

Table 4.6 Observed Signal Timing Plan at location B (18th and Stout)

Phase	18th	Pedestrian	Stout	Light Rail
Minimum Green Time	21	13	28	20
Maximum Green Time	41	21	32	26
Vehicle Extension Time	3	3	3	3
Yellow Time	3	3	3	3
Red Clearance Time	1	1	1	1

Table 4.7 Observed Signal Timing Plan at location C (19th and Stout)

Phase	19th	Stout	Light Rail	Pedestrian
Minimum Green Time	21	13	28	20
Maximum Green Time	41	21	32	26
Vehicle Extension Time	3	3	3	3
Yellow Time	3	3	3	3
Red Clearance Time	1	1	1	1

Table 4.8 Observed Signal Timing Plan at location D (19th and California)

Phase	19th	Light Rail (California)	California	Light Rail (19th)	Pedestrian
Minimum Green Time	16	35	9	35	35
Maximum Green Time	33	45	36	45	45
Vehicle Extension Time	3	3	3	3	3
Yellow Time	3	3	3	3	3
Red Clearance Time	1	1	1	1	1

For all the intersections, the minimum green time for the vehicular traffic was observed to be between 9 and 35 seconds, and the maximum green time was observed to be between 21 and 41 seconds. In the case of light rail traffic, the minimum green time was observed to be between 16 and 35 seconds, and the maximum green time was observed to be between 26 and 45 seconds. Throughout all the intersections, the maximum green time for the exclusive pedestrian phase was observed to be between 21 and 45 seconds. Due to the high demand flowrate for pedestrians within the Denver central business district, most of the pedestrian phases of different intersections runs up to the maximum allowable green time.

Chapter 5 Observation of Traffic Patterns

From the video data, the traffic patterns have been identified to simulate in the software packages including VISSIM and Aimsun. The sequences of the phases for the vehicular traffic, light rail, and pedestrians have been observed for all four intersections.

5.1 Intersection Specific Observations

Location A is the intersection of 18th Street and California Street. Comprised of one-way streets, vehicular traffic traverses this intersection toward the south and west. The light rail passes north, parallel to the southbound traffic. This study observed that during peak hour conditions, pedestrians were serviced with an exclusive phase at the end of the vehicular traffic phases. The sequence of the traffic and pedestrian movements is as follows: westbound vehicular traffic, southbound vehicular traffic with northbound light rail, and finally the exclusive pedestrian phases. The corresponding timing parameters are shown in the previous section of this report, in **Table 4.5.**

The intersection of 18th Street and Stout Street is identified as location B. Similar to location A, the one-way street configuration allows northbound and westbound vehicular traffic through the intersection. The light rail traverses in the southbound direction parallel to the vehicular northbound traffic. This intersection also has a dedicated phase for pedestrians. The sequence of the phases are as follows: northbound vehicular traffic along with southbound light rail traffic, westbound vehicular traffic, and an exclusive pedestrian phase. The corresponding timing plan is shown in **Table 4.6.**

The intersection of 19th Street and Stout Street has been identified as location C. The vehicular traffic flows in the eastbound and northbound directions, and light rail crosses the intersection as a westbound left-turn movement. Consequently, all movements operate as dedicated phases to ensure safe intersection operation. The phases appear sequentially as follows: eastbound vehicular traffic, southbound vehicular traffic, light rail movement (westbound left), and pedestrian movement. It was observed that after the two vehicular traffic phases, if the light rail has queued approaching the intersection, the light rail phase gets priority over the pedestrian phase. The corresponding timing plan is described in **Table 4.7**.

Location D is the intersection of 19th Street and California Street. The light rail has three separate movements at this location including, northbound left-turn, northbound right-turn, and westbound through. The vehicular traffic operates with southbound and eastbound approaches. The following phase sequence patterns have been observed: southbound vehicular traffic, eastbound vehicular traffic with westbound light rail, northbound light rail, and pedestrian phase. Northbound light rail movement (based upon the arrival) is prioritized over the exclusive pedestrian phase. The timing plan of location D is shown in **Table 4.8**.

5.2 Frequency of Light Rail Movement

The vehicular traffic counts for the four intersections of the case study location are included above in **Tables 4.1-4.4**. To model the light rail into the microsimulation package accurately, the frequency of the appearance of the light rail into the network was carefully observed. Although the light rail enters into the network in locations A and D, the arrival pattern for different sets of origin and destination vary. The light rail originating from location A (18th St. and California St.) has two types of destinations, northbound right and left movements through location D (19th St. and California St.). The northbound right light rail arrives at a fifteen-minute interval, whereas the northbound left approaches arrive around six and half minutes apart and then leave the network. The light rail originating from location D and arriving at location B (18^{th} St. and Stout St.) arrives every fifteen minutes.

Chapter 6 Modeling of Light Rail in the Simulation Environment

A key goal of this report is to identify best practices for modeling light rail movements in microsimulation software packages. VISSIM version 10.00-02 and Aimsun Next version 8.2.2 have been used to model the light rail movement in the case study location, representing two popular and current traffic microsimulation software packages in use today by both researchers and consultants. [16, 17]

The authors are aware that the traffic microsimulation software packages are flexible enough to model the same facility in different ways. However, the authors intend to present a simplified way of modeling to provide a reference or starting place for practitioners or researchers with limited or no experience in modeling such a facility. Primarily, this report intends to describe the procedure to include light rail in microsimulation environments for analysis. Therefore, this report does not include a detailed description of the modeling of the vehicular traffic, and researchers or practitioners seeking information on base model creation should refer to the user manuals and tutorials for the respective software packages. Similar to the modeling of the vehicular traffic, however, the most critical input parameters for modeling light rail are the demand flow rates and signal timing. This report includes the procedure to model light rail volume and signal timing for two microsimulation software packages, VISSIM and Aimsun, and include validation of the model.

6.1 VISSIM

The modeling of the vehicular traffic including the volume and signal settings are done conventionally in VISSIM. The network objects of VISSIM microsimulation, such as links, desired speed decisions, conflict areas, stop signs, signal heads, detectors, vehicle inputs, vehicle routes, etcetera, are used to build the simulated network for the vehicular traffic operation. In addition to these network building objects, the “Public Transport Line”, in particular, has been used to build the operation of the light rail portion of the entire network. In the following two subsections, the modeling details of the light rail volume set up and signal settings are described. A screenshot of a completed model of the Denver case study location in VISSIM is shown in **Figure 6.1**.

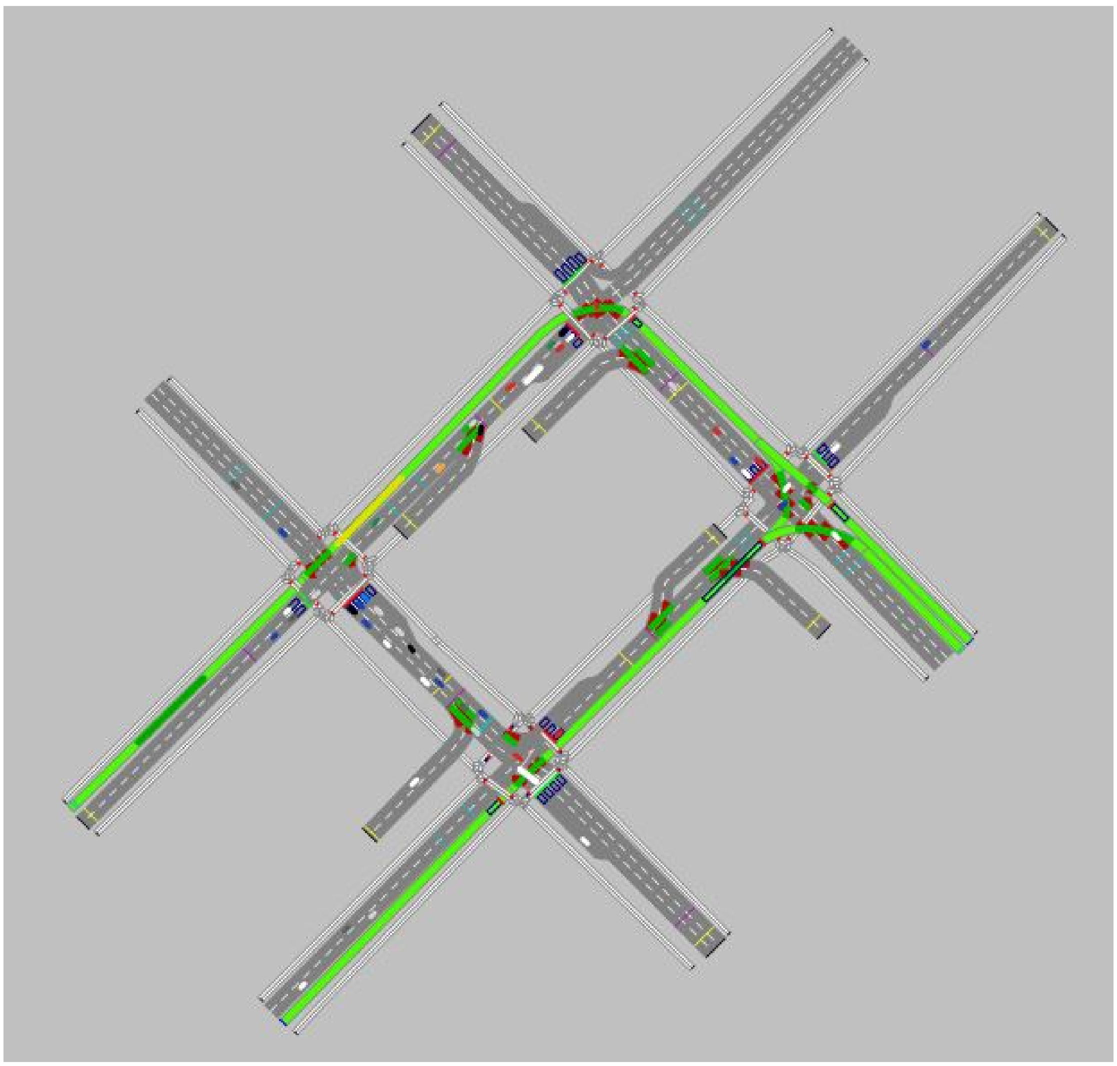


Figure 6.1 Multimodal traffic including light rail simulated for case study in Denver, CO.

6.1.1 Modeling the Light Rail Volume in VISSIM

Light Rail Links: The link properties for the light rail (indicated in **Figure 6.2**) can be modified as follows: behavior type is Urban (motorized), Display type is Rail (road), and Level is Base.

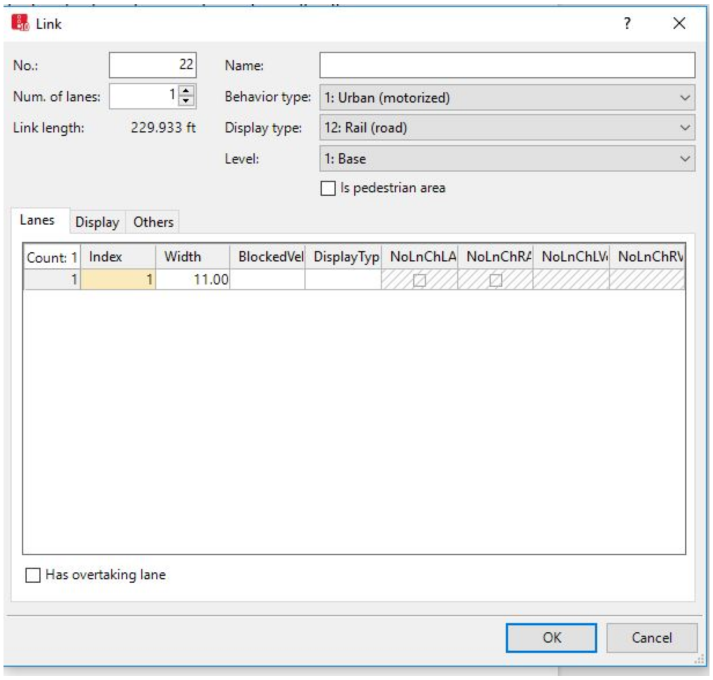
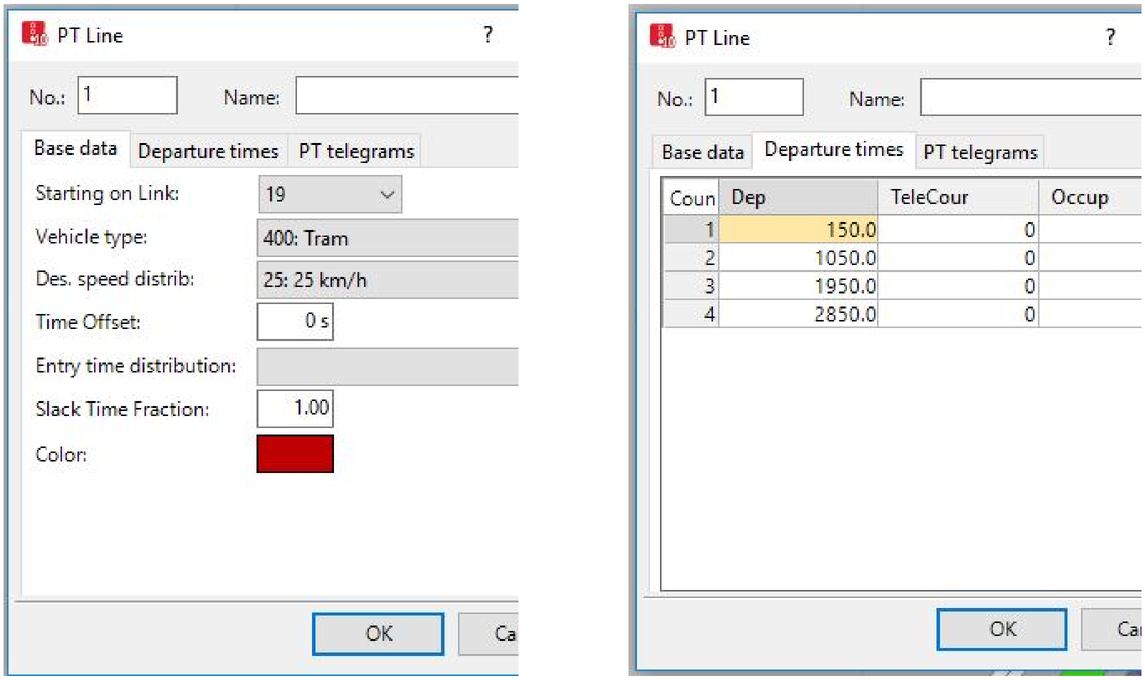


Figure 6.2 Link properties for light rail in VISSIM.

Light Rail Input: Similar to the "Vehicle Inputs" for the vehicular traffic, the volume of the light rail can be set up through the "Public Transport Line", as shown in **Figure 6.3**. The public transport line should be set up based on the origin and destination of the light rail observed in the field. In this case study, as mentioned earlier, there are three sets of origins and destinations of the light rail within the four selected intersections of the network: from location A to the northbound right-turn approach of location D, from location A to location B, and from location D to location B.



a) Base data b) Departure times

Figure 6.3 Public Transport Line for light rail modeling in VISSIM.

For each set of origin and destination, the base data and volume (i.e. departure times) should be defined. The main base data includes defining the starting link, vehicle type, and desired speed distribution. The volume of the light rail, in terms of arrival rate based on field observation, can be defined through the departure times, as shown in **Figure 6.3 (a)** and **Figure 6.3 (b)**.

For this case study location, the vehicle type “400” is the appropriate choice, and the posted speed limit for the light rail has been used for the desired speed distribution. For the light rail volume through the three routes, the observed light rail’s frequency of appearance has been used. For the transit line from location A to the northbound right approach of location D, a fifteen-minute field-observed value has been defined. A similar value for the arrival rate has been used for the transit line originating from location D to location B. A six-and-a-half-minute arrival rate was found for the transit line traveling between location A and location B and modeled accordingly into VISSIM. It should be mentioned that this strategy for setting light rail demand flow-rates may vary from case to case or even from user to user based on the field conditions and expected level of accuracy in modeling.

6.1.2 Modeling the Signal Timing Plan of Light Rail in VISSIM

This report includes the detailed quantitative analysis of the signal timing within **Table 4.5 to Table 4.8** including the sequence of the phases of traffic movements in the intersection described in Chapter 5. As previously mentioned, an actuated signal control system is used for the safe operation of the traffic in the intersection. A pretimed-equivalent signal timing can be modeled with Ring Barrier Controller (often know as RBC control) in VISSIM. A preview is shown in **Figure 6.4**.

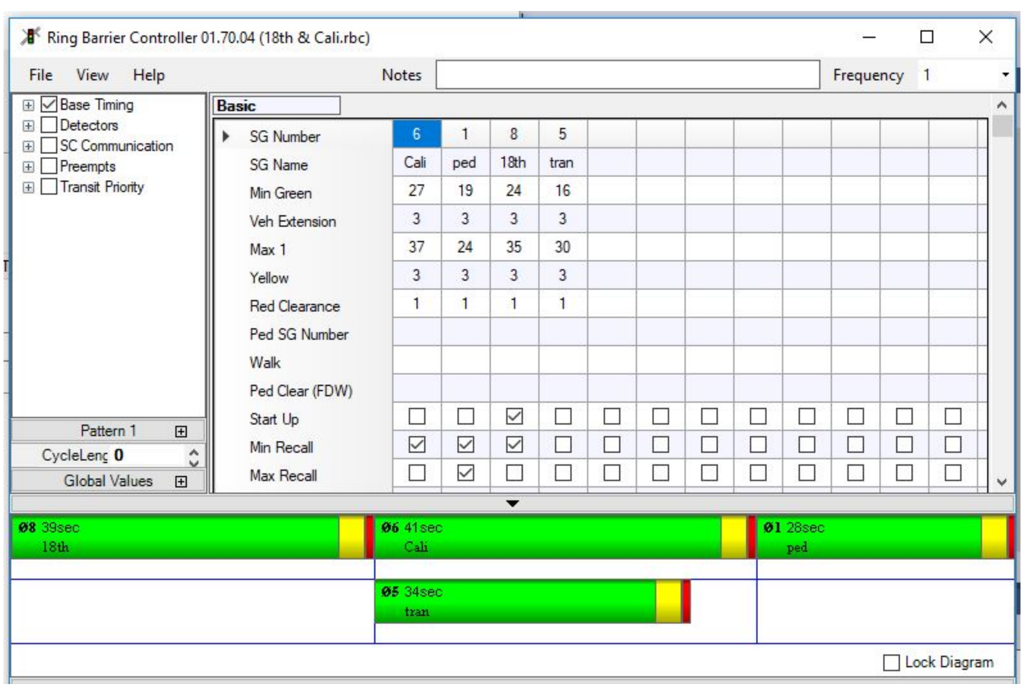


Figure 6.4 Actuated signal control simulated by Ring Barrier Controller in VISSIM.

The actuated signal timing parameters for the light rail movements of the four intersections were previously shown in **Table 4.5 to Table 4.8**. As this report intends to document the light rail modeling strategies, the following observations and recommendations for light rail signalization have been drawn from the field observation and the model creation and validation process in VISSIM.

- In the Ring Barrier Controller, no recall should be selected for the light rail phase. Such operation selection will switch the phase into the next phase if no light rail approaches the intersection. This procedure has been followed to model all the intersections through VISSIM. It also prevents unnecessary operational delay at the intersection.
- When the light rail and vehicular traffic moves parallel to each other (within the same or opposite direction), an identical phase can be set for such movements to minimize the cycle length and delay. Such a pattern has been observed in the Denver case study for locations A, D, and B. In the case of location A with northbound right rail, location D with westbound right rail, and location B with southbound light rail, their corresponding phases are shared with the parallel movement of the vehicular traffic toward the southbound, eastbound, and northbound directions, respectively.
- When the light rail moves across the intersection (not a parallel movement, but instead a diagonal movement through the intersection), a dedicated phase must be used to ensure safe traffic operation. In the case study network, the light rail originating from location A to the northbound left direction across location D, and the light rail from location D crossing location C have exclusive light rail phases dedicated to their respective movements.

6.2 AIMSUN

The vehicular traffic in this case study is modeled in Aimsun using conventional network tools including but not limited to: section, node, control plan, traffic demand (state), traffic state, detector, dynamic scenario, and so on. These tools have been used to model the links and the signal settings for the vehicular traffic. In addition to these steps, the light rail has been included into the network using the “Transit Lines” and “Transit Plans” functions. As mentioned earlier, this report aims to codify a simplified way to model light rail in Aimsun, keeping in mind that such procedures may vary from users to users and case to case. A screenshot of the Denver network modeled in Aimsun is shown in **Figure 6.5**. The volume and signal setup of light rail in Aimsun are described in the following two subsections.

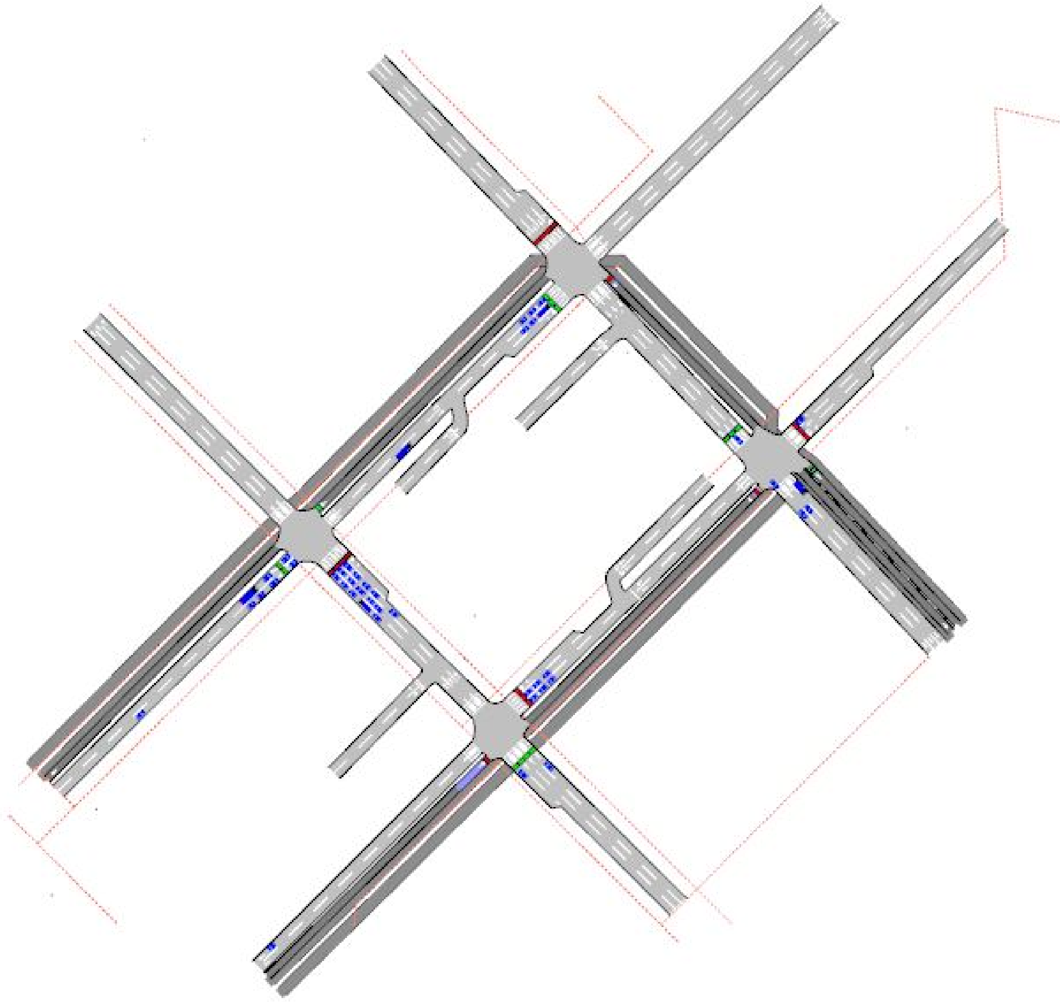


Figure 6.5 Multimodal traffic including light rail simulated in Aimsun.

6.2.1 Modeling the Light Rail Volume in Aimsun

Transit Lines: Similar to the of “Public Transport Line” functionality in VISSIM, the “Transit Lines” function in Aimsun (shown in **Figure 6.6**) can help define the light rail operation in the network.

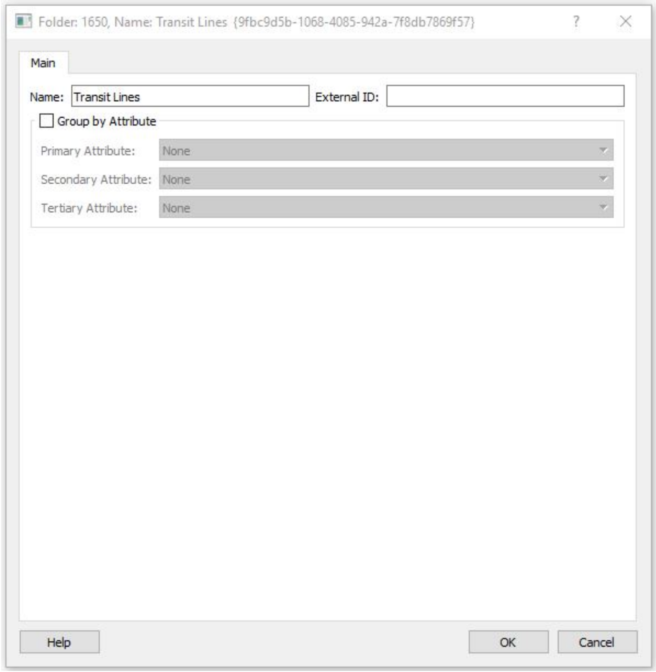
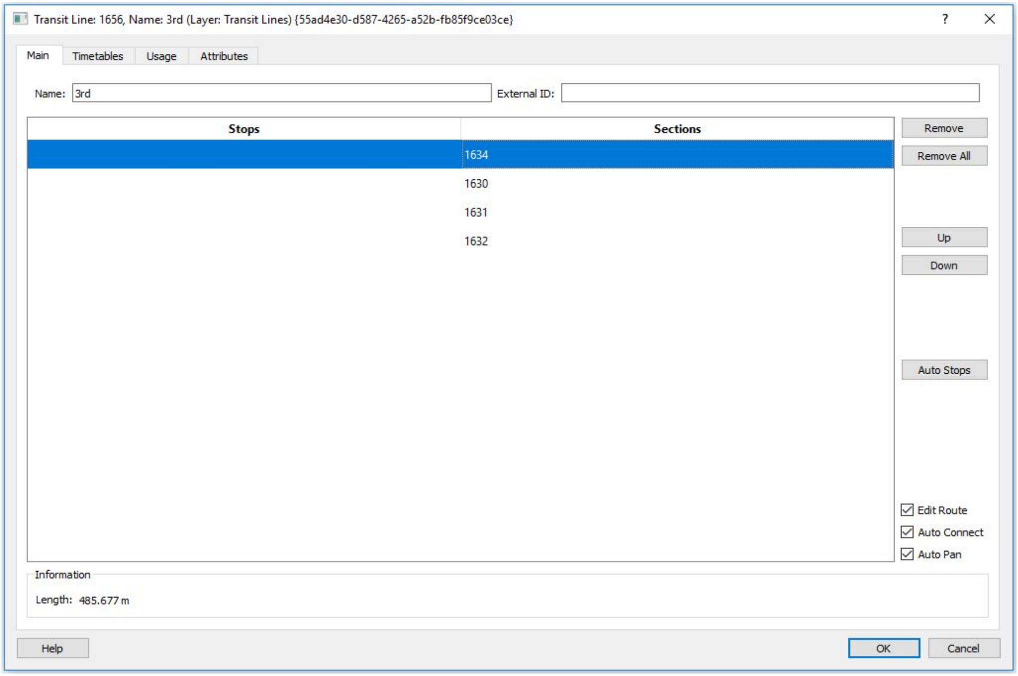


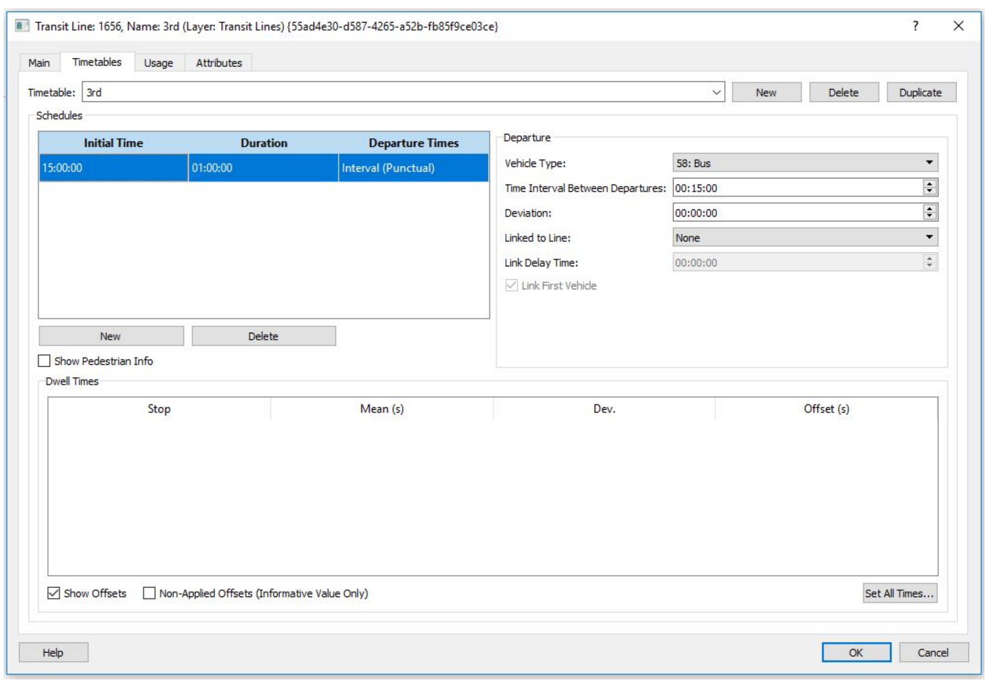
Figure 6.6 Transit Lines tab for modeling light rail in Aimsun.

The “Main” tab of the Transit Lines function is used to define the sections by selecting the links where the light rail would travel. It is also used to define any stops through the movements, as shown in **Figure 6.7 (a)**. Therefore, three transit lines have been created through the Aimsun network: from location A to the northbound right approach of location D, from location A to location B, and from location D to location B.

The “Timetables” function, as shown in **Figure 6.7 (b)**, helps to code the arrival rate (the volume setup) and the vehicle type. The choice of vehicle type can be restricted by the default setup of the simulation software. For the timetables, the initial time is selected as the initiation of the simulation time (for example, 3 pm as shown in the field condition). The duration is set as 1 hour to simulate the field scenario. There are three types of departure times available in the system: Interval (Punctual), Fixed, and Interval Cumulative. In this case study, Interval (Punctual) has been used and the time interval between departures has been set based on the field observations for the three different light rail routes. For the transit lines from location A to the northbound right approach of location D, and from location D to location B, a fifteen-minute value for the interval between the departures (the field observed value) have been defined into Aimsun. A six-and-a-half-minute value is used for the transit lines from location A to location B. Again, it should be mentioned that different users will set the volume demand flow-rates according to their field observed conditions.



a) Transit Lines: Main- Choice of Routes



b) Transit Lines: Timetables- Light Rail Volume Setup

Figure 6.7 Functionalities of Transit Lines in Aimsun: Main and Timetables.

Transit Plans: After outlining all the routes and the arrival information for the light rail, the transit plans should be defined. In this study, all of the three available transit lines and timetables have been included in the transit plan lists, as shown in **Figure 6.8**. As per the strategy or requirement of the model, the inclusion of the transit lines to the transit plans may vary.

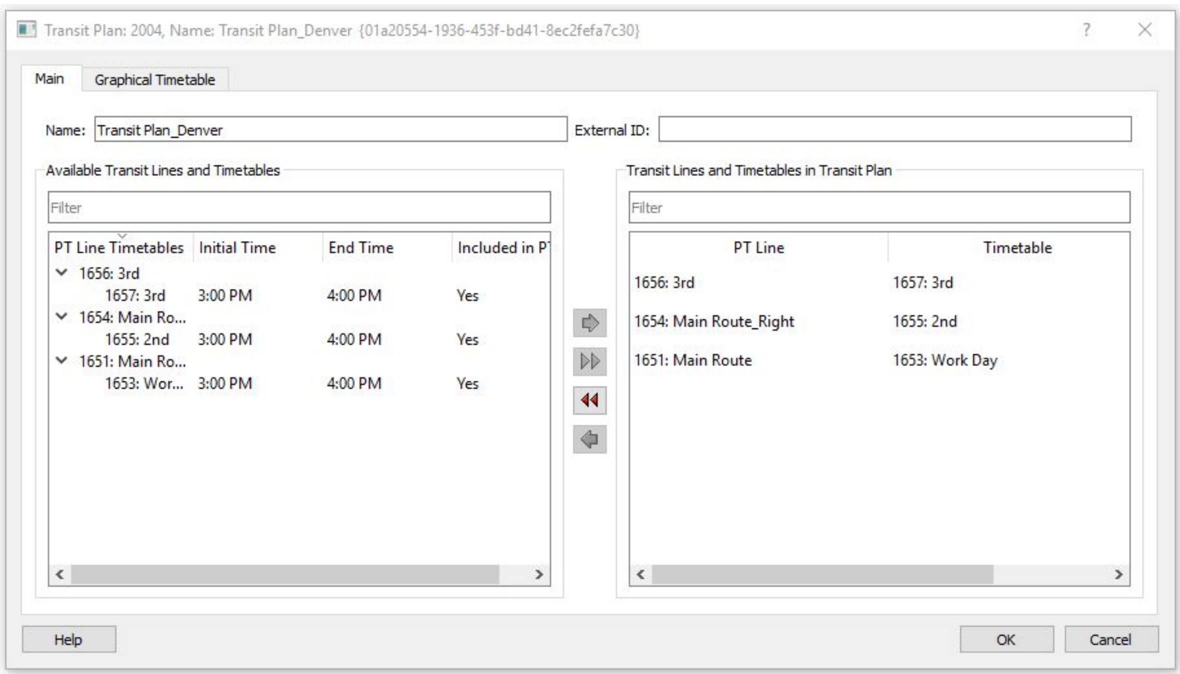


Figure 6.8 Functionality of Transit Plan in Aimsun.

It should be noted that the Transit Plan must be included into the dynamic scenario, as shown in **Figure 6.9**, to be able to run the simulation of the light rail into the network.

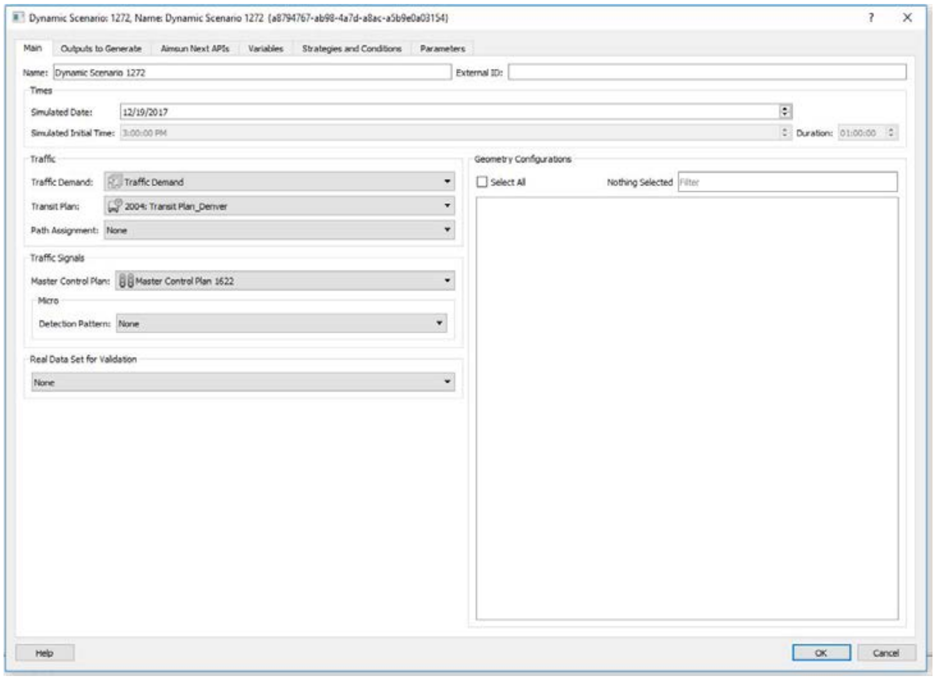


Figure 6.9 Inclusion of Transit Plans into the Dynamic Scenario in Aimsun.

6.2.2 Modeling the Signal Timing Plan in Aimsun

In the VISSIM simulation section, this report listed some observations and recommendations for the signal setting strategies for light rail based on field observation and modeling in the software, which are also applicable for the Aimsun simulation software package. However, it is the authors' observation and opinion that unlike the Ring Barrier Controller of VISSIM, the setting of actuated signal control into Aimsun might seem complicated to many users. Therefore, the aim of this section is to clarify some signal simulation tools within Aimsun to ease the codification of the observed field signal timing plan. From the control plan, the type of signal timing is selected as "Actuated." A preview of the actuated signal timing tab of Aimsun is included in **Figure 6.10**.

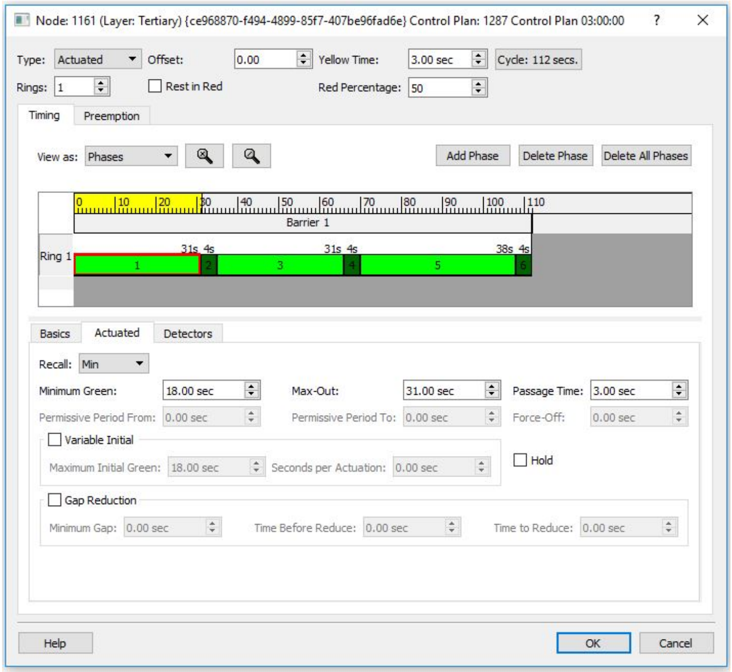


Figure 6.10 Actuated signal time plan modeling in Aimsun.

Subsequently, different phases are added into the signal system to replicate the observed field conditions. In Aimsun the "Red Percentage" should not be confused with the "All Red" or "Red Clearance Time," and is additionally not associated with the percentage of vehicles arriving on red. The red percentage instead indicates the percentage of yellow time a vehicle will consider as red. For example, if a red percentage is set at 50, out of the 3 seconds of yellow time, the vehicle will consider the first 1.5 seconds as green time. It should be noted that in this model, the red percentage is set as 50. The all red or red clearance time (1 second in this case study) can be included in "Interphase." The interphase represents the time of switching from one phase to another. A total of 4 seconds is defined as the interphase time to include the 3 seconds of yellow and 1 second of all red. In Aimsun's actuated interface, the vehicle extension time (3 seconds for our case study) is included as the passage time. Furthermore, the maximum green time can be coded as the "Max-out." It should be noted that such functionalities are not only applicable for light rail signal timing, but also for the modeling of the vehicular traffic in Aimsun. It is the authors' opinion that a thorough knowledge of the ring barrier concept would ease the signal timing setting strategies to offset the potential added difficulties of Aimsun compared to that of VISSIM. It should be further mentioned that based on the authors' experience the license type of the traffic simulation software might limit the signal controller types available. In many cases, a different signal controller may come up as an "add-on" feature for the simulation software, which would incur additional expense to the design phase of the project.

6.3 Model Validation

Both the VISSIM and Aimsun microsimulation software packages have been modeled based on the field observation values of vehicular traffic, including light rail flow and signal timing plans. The field-observed travel times come from the MioVision Scout equipment, which has the ability to "sniff" for Bluetooth devices, recording mac addresses as the devices pass by, then correlating the collected mac address for multiple locations to generate travel time estimates. The mean travel time observed in the field between location A and location C was found to be 60 seconds. A travel time section from location A to C was created for VISSIM, with the average simulated travel time found to be 64 seconds. A similar approach was taken with Aimsun, with very similar results as those from VISSIM. These results serve to validate the basic parameters used for the simulation models, but a great deal of additional validation is necessary for most applications. When modeling a potential light rail scenario where light rail currently does not exist, the authors recommend calibration for the vehicular traffic as would normally be conducted, further adjusting the model to accommodate the signal timing of the light rail in order to determine anticipated operational performance of the design.

Chapter 7 Conclusion

With the ever-increasing demand for traffic and limited scope to build a new or extended road network, light rail transit systems are a potential solution to mitigate oversaturated conditions that is being embraced by urban centers with increasing frequency. However, the incorporation of light rail with the vehicular traffic and pedestrians significantly increases the vulnerability of safe and efficient traffic operation through the intersection. Traffic microsimulation software is a platform where planners and engineers can test a model before implementing into the real field.

This research aims to provide guidelines for best practices in modeling urban light rail facilities within transportation simulation software packages, including VISSIM and Aimsun, improving the understanding of engineers and planners considering light rail facilities.

The case study location of Denver, Colorado was analyzed thoroughly to monitor and capture the traffic demand and signal timing plans as a preliminary input for the simulation software environments. The traffic signal patterns of the intersections, including vehicular traffic, light rail, and pedestrian phases has been observed as accurately as possible using both on-site observations and review of video recordings. All the field observations have been documented in this report, and have been implemented faithfully in the simulation environment. Current versions of two of the most widely used simulation software packages were used, VISSIM and Aimsun, attempting to accurately reproduce the traffic conditions observed.

While documenting the modeling steps of the simulation software packages, the authors take for granted that conventional road network modeling is known to the audience, and have instead focused on the modeling techniques specific to the light rail movement. Several screen shots of the functionalities regarding the modeling tools have been included. It is the authors' intention that practitioners and researchers with limited or no prior experience will be able to model the light rail movement based on the documentation herein, and that ultimately, the observations and recommendations of signal timing techniques described in this report will enrich the state of practice for modeling light rail with traffic simulation software.

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