ANALYSIS OF TRAFFIC IMPACTS AT ISOLATED LIGHT RAIL TRANSIT (LRT) CROSSINGS USING SIMTRAFFIC

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ABSTRACT

As an increasing number of metropolitan areas study the possibility of implementing Light Rail Transit (LRT) as part of their overall transportation system, the need to depict the impacts of LRT to the current or future roadway system must be determined. A recent LRT impact analysis study of offset running LRT was conducted to better understand the impacts to traffic flow when LRT is introduced at an isolated intersection.

Delay and queue impacts were determined using the microscopic traffic engineering software program SimTraffic Version 4.0. Although the program was not explicitly designed to handle transit analysis, recent enhancements have enabled advanced users to program work-arounds to approximate the behavior of the LRT crossing controllers as well as depict the interaction of the LRT and vehicular traffic. Specific programming enhancements include the ability to program the ring and barrier design and the ability to cluster multiple intersection controllers, thereby more accurately representing the interaction of LRT and vehicular traffic.

Analysis output included vehicular delay and queues for LRT and non-LRT scenarios. For the case study presented in this paper and the actual impact study project, the level of service impact to vehicular traffic due to LRT was approximately one increment degradation from non-LRT conditions. All simulation scenarios were run multiple times to achieve statistical confidence. An overview of the major work-arounds is presented in this paper.

Although this paper covers LRT analysis applications, almost any interaction of traffic and headway-based flow can be modeled to develop an understanding of impacts to the traffic stream.

INTRODUCTION

As an increasing number of metropolitan areas study the possibility of implementing Light Rail Transit (LRT) as part of their overall transportation system, the need to depict the impacts of LRT to the current or future roadway system must be determined. This paper covers the analysis methodology that was used in a recent LRT impact analysis study. The purpose of the study was to better understand the impacts to vehicular traffic when LRT is introduced into an existing corridor at isolated intersections. For purposes of this paper an isolated intersection is defined as any intersection that would not be normally considered for coordination. The microsimulation traffic analysis tool, SimTraffic 4.0, was used to determine the impacts of LRT.

Several questions this paper will address are:

- Why study the impacts of LRT on vehicular traffic?
- Is SimTraffic the correct software tool to conduct this analysis?
- How was SimTraffic programmed to conduct this analysis?
- What were the results of the study?

It is worth noting the goal of the study referenced in this paper and the methodology used to conduct the analysis is of an impact perspective, not to generate detailed timing and preemption plans.

BACKGROUND INFORMATION ON LRT OPERATIONS

According to ITE Recommended Practice[1]: Where a signalized highway intersection exists in close proximity to a railroad grade crossing, the railroad signal control equipment and the traffic signal control equipment should be interconnected, and the normal operation of the traffic signals controlling the intersection should be preempted to operate in a special control mode when trains are approaching. A preemption sequence compatible with the railroad grade crossing active warning devices, such as gates and flashing lights, is extremely important to provide safe vehicular, pedestrian, and train movements. Such preemption serves to ensure that the actions of these separate traffic control devices complement rather than conflict with each other.

Given this mandate, traffic engineers may be required to determine the impacts of LRT on the current or proposed transportation systems. For purposes of this paper, the term LRT will be used to describe a transit vehicle facility that operates at a predetermined headway on its own right-of-way in close proximity to roadway infrastructure. Certainly many configurations of LRT interaction with vehicular traffic are in use today, this paper focuses on only the "offset" LRT arrangement depicted in Figure 1.

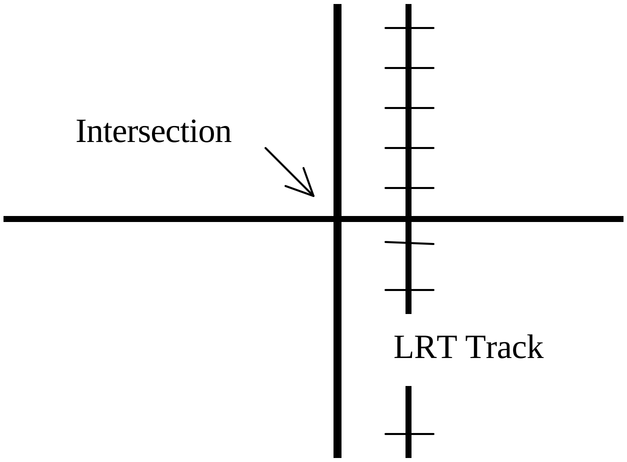


Figure 1: LRT-Intersection Diagram

The main reason, from the point of view of the traffic engineer, for studying the interaction of LRT and vehicular traffic is to understand the delay and queue impacts to the vehicular traffic stream. It is assumed that for purposes of this paper that the LRT will preempt the traffic signal controller in order to transition through the intersection with minimal delay to the LRT vehicle. More detail on the preemption of the traffic signal controller is presented in later sections. Given this assumption, it is clear that any impacts of LRT will be observed on the "traffic side" of the modal system. "How bad will LRT affect traffic?" is the essence of the analysis.

LRT Variables

There are several variables that describe LRT characteristics. A brief discussion of each is presented below.

Headway

An important variable when analyzing LRT is the operating headways. Headway is defined as the time between LRT vehicles operating in the same direction. Headways can vary over the day by demand but for our purposes is considered constant. A 10-minute headway indicates that a LRT vehicle will be generated from each direction approximately every 10 minutes. Since the analysis considers two-way operation of the LRT track, authors assumed the worst case impact to be when the LRT vehicles arrive at the intersection every 5 minutes.

LRT Vehicle Speed and Size

LRT vehicle speed indicates the operating speed of the vehicle on level terrain in a tangent section of track. For purposes of this analysis, a speed of 15 mph was chosen to represent the speed at which the LRT vehicle traverses the intersection. LRT transit vehicles vary in size, capacity, and performance. A LRT vehicle length of 90 feet and a maximum acceleration of 4 feet/sec^2 were chosen. It is worth noting that the goal of the analysis was to determine impacts to traffic based on some general LRT characteristics, not to analyze the LRT mode.

Distance between the tracks and signalized intersection

The distance between the LRT track crossing and the signalized intersection is assumed to be fixed by design standards and right-of-way constraints. The analysis conducted assumed a distance of approximately 200 feet from the center of the intersection to the center of the LRT track. According to the Manual of Uniform Traffic Control Devices[2] (MUTCD) a distance of 200 feet between the grade crossing and the intersection would require the two controllers to operate together. Additional guidance on the interconnection of closely spaced grade crossings and vehicular intersections can is provided in reference three. More information concerning the operation of the LRT track crossing controller and the intersection signal controller is discussed in later sections.

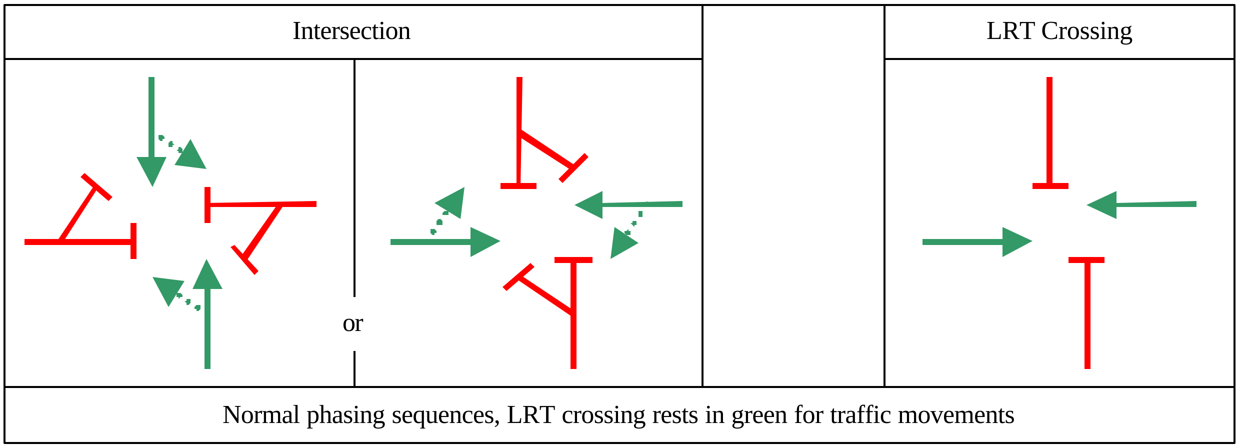
There are many other variables when considering the LRT facility design including but not limited to intersection and crossing geometry:

- crossing angle
- length of crossing
- track clearance distance
- intersection width
- sight distance issues
- approach grades and parallel streets

Clearly, there are many factors that go into the design and operation of a LRT crossing. More detail on all these issues can be found in the references listed at the end of this paper.

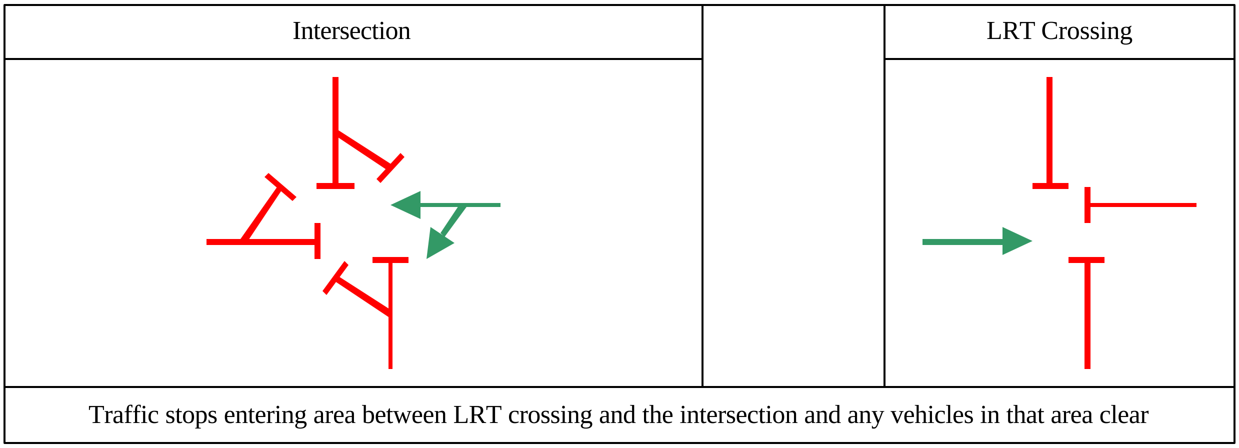
Sequence of Controller Operation

Given that two closely spaced intersections, one LRT crossing and one signalized for traffic, are required to operate as a system an understanding of the operation of these controllers is needed. Figures 2 through 4 illustrate the phasing sequence of operations prior to and while a LRT vehicle approaches the grade crossing.



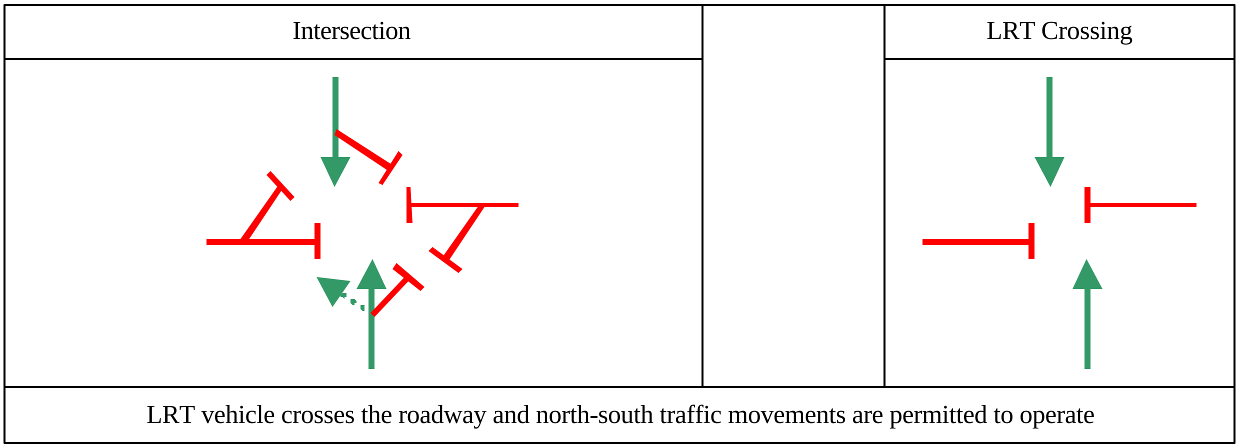
Normal phasing sequences, LRT crossing rests in green for traffic movements

Figure 2: Sequence of Controller Operation, No LRT



Traffic stops entering area between LRT crossing and the intersection and any vehicles in that area clear

Figure 3: Sequence of Controller Operation, LRT Approaching



LRT vehicle crosses the roadway and north-south traffic movements are permitted to operate

Figure 4: Sequence of Controller Operation, LRT Crossing

Prior to and after a LRT vehicle has been serviced the traffic controller will operate normally, servicing phases based on detection calls from traffic flow and showing green for the traffic movements at the grade crossing. This operation is illustrated in Figure 2.

Once a LRT vehicle has placed a request for service the controller terminates the current phases, providing the proper change intervals and without violating local standards for pedestrian timing. The traffic signal controller then provides a "clearance" phase and services the traffic between the intersection and the LRT grade crossing. This is accomplished by terminating westbound traffic movements across the grade crossing and providing an exclusive westbound phase for traffic at the signalized intersection. These two operations prevent additional traffic from entering the area between the intersection and the LRT crossing and clear out any vehicles from this area. This operation is illustrated in Figure 3. The required clearance time can be calculated by using the following formula:

$$t(\text{sec}) = 4 + 2(n)$$

where n = the number of vehicles that queue between the intersection and the LRT crossing[3]

Once the proper clearance phase has terminated the LRT movement phase is serviced. It is allowable to provide green time to non-conflicting traffic movements while servicing the LRT. In the case of our example, the north and south movements can be serviced, however, northbound right turns are not allowed. This operation is illustrated in Figure 4. Once the LRT has cleared the crossing, normal operation can be resumed.

ANALYSIS METHODS

Given the complexities of the phasing sequence and variables involved, a macroscopic analysis tool does not provide for the most accurate analysis. A microscopic analysis tool would provide for the complex interaction of individual vehicles operating under the phase scheme described previously. The traffic engineering software package SimTraffic was chosen as the traffic analysis tool.

SimTraffic

SimTraffic is not an explicit analysis tool for transit applications. In fact, the developers of SimTraffic have cautioned users from attempting this analysis unless they have advanced knowledge of the program. However, given the ability to program the ring and barrier designer and the ability to cluster two or more intersections, the authors felt this was a reasonable tool to approximate the LRT interaction. Additionally, at the time of development of this methodology, LRT operations were being analyzed with the CORSIM package. The authors felt that the SimTraffic option was far superior to the CORSIM program for the ability to approximate the interaction of LRT and vehicular traffic. It is also acknowledged that there are transit software packages available that conduct this analysis without the need for "work-arounds". The specific work-arounds will be described in later sections of this paper.

SimTraffic is a microscopic, stochastic model that provides the ability to test alternatives based on input variables such as traffic volumes, traffic signal control schemes, geometric conditions, and a host of other variables. The input processor for the SimTraffic model is Synchro. The package version that was used for this analysis was 4.0.

CASE STUDY

The inspiration for this paper comes from a recent project in Union County, New Jersey. The objectives of that project were to determine the impacts to traffic at an existing isolated intersection once LRT operations were introduced. The actual project included an analysis of four peak periods over three volume horizon years. To better illustrate the concepts presented in this paper, the intersection geometry and traffic volumes used for the analysis were simplified. The traffic volumes and geometry used for this paper's analysis are illustrated in Figure 5.

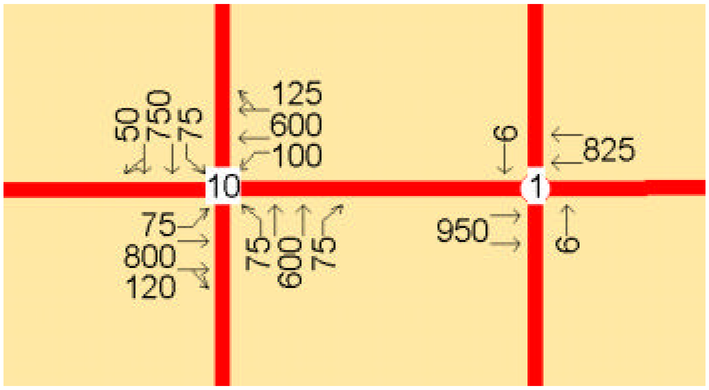


Figure 5: Case Study Hourly Traffic Volumes and Geometry

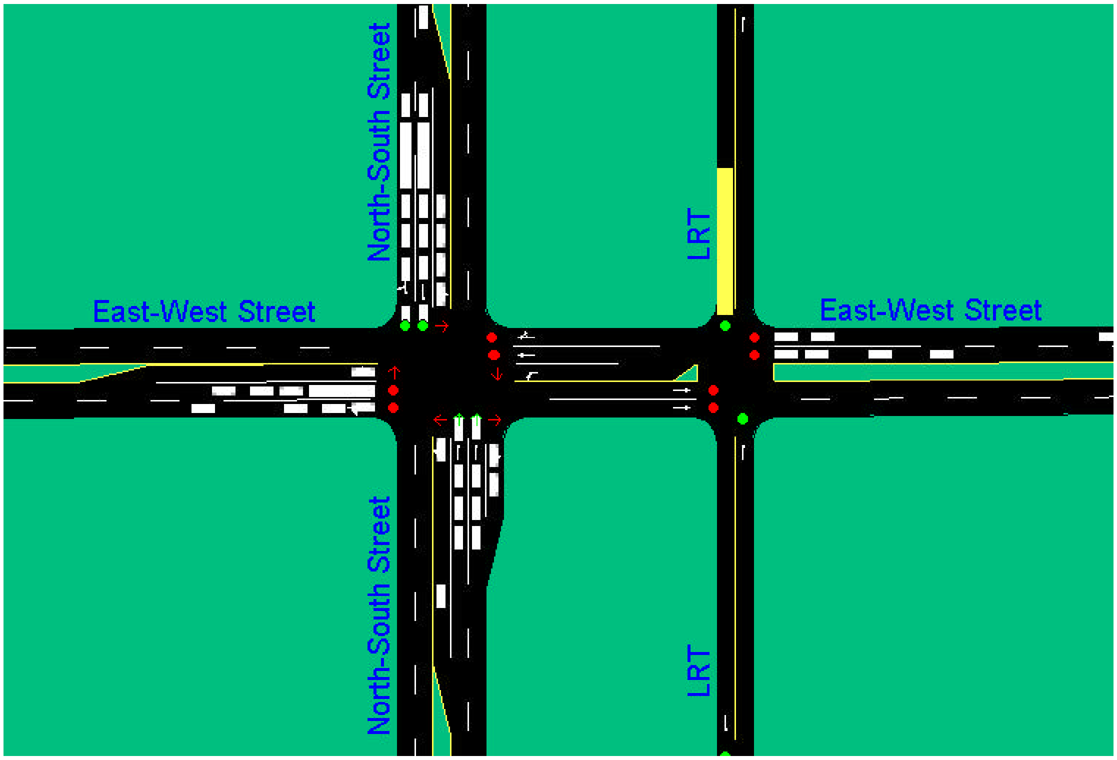


Figure 6: Image of the SimTraffic Animation (LRT moving southbound)

Coding Issues

To ensure proper evaluation of the intersection impacts several assumptions were made concerning intersection operations and SimTraffic coding. Specific SimTraffic coding issues follow:

1. Simulation of the LRT vehicles.

Simulation of the LRT vehicle was achieved by coding another "roadway" link within close proximity to the standard traffic roadway links. The LRT roadway volumes were coded to only contain 100 percent heavy vehicles. To ensure trucks were evaluated within the traffic stream, a vehicle type in SimTraffic was altered to have the same size and performance characteristics as standard trucks. The LRT vehicles were coded to replicate the size and acceleration parameters desired.

2. Operation of the complex phasing arrangement and timing.

Programming the ring and barrier designer in Synchro allowed for the complex phasing arrangement needed. The traffic signal phases were coded in rings A and B, and the LRT phases were coded using ring C.

3. Operation of the clearance phases.

The clearance phase was programmed using the ring and barrier designer and the ability to code movements under several phases. The specific time of the clearance phase was determined by using the equation presented in earlier sections.

4. Operation of the intersection and LRT crossing as one controller.

The cluster editor feature in Synchro was used to operate both the traffic intersection and the LRT crossing intersection as one controller. Figure 7 illustrates the final timing and phasing sequence for the signal controller. The traffic intersection movements are indicated with the shaded arrows and the non-shaded arrows indicate the LRT crossing phases. As illustrated in Figure 5, the traffic intersection was coded with a node number of 10 and the grade crossing was coded as a node number of 1.

5. Preempting the traffic signal controllers.

Preempting the traffic signal controller is not within the capability of the Synchro or SimTraffic programs. To approximate the preemption, advance detectors were placed upstream of the LRT crossing. As a LRT vehicle approaches the grade crossing a call is placed to the controller so that the intersection would conduct the clearance phase and be operating in the LRT movement phase when the LRT arrived. The operating phase is not terminated by an LRT call. This is a deviation from the actual operating parameters that would be observed in the field. To better replicate the LRT interruption, a second set of LRT clearance and LRT crossing phases was introduced after each barrier point. This is illustrated in Figure 7. It is worth noting that in some instances the LRT vehicle does get delayed prior to crossing. Keeping in mind that impacts to the traffic stream were the main concern, these minor LRT delays were not considered to affect the results of the study.

6. Metering the LRT vehicle headways.

Since the LRT track is simply another roadway link, an inlet meter was developed to control the arrival rate of the LRT vehicles. The original LRT headways were at 10-minute intervals. The limit of Synchro's cycle length is 360 seconds. Using the Universal Traffic Data Formatting (UTDF) features of Synchro a separate database file was created to allow for long cycle lengths at the inlet meters.

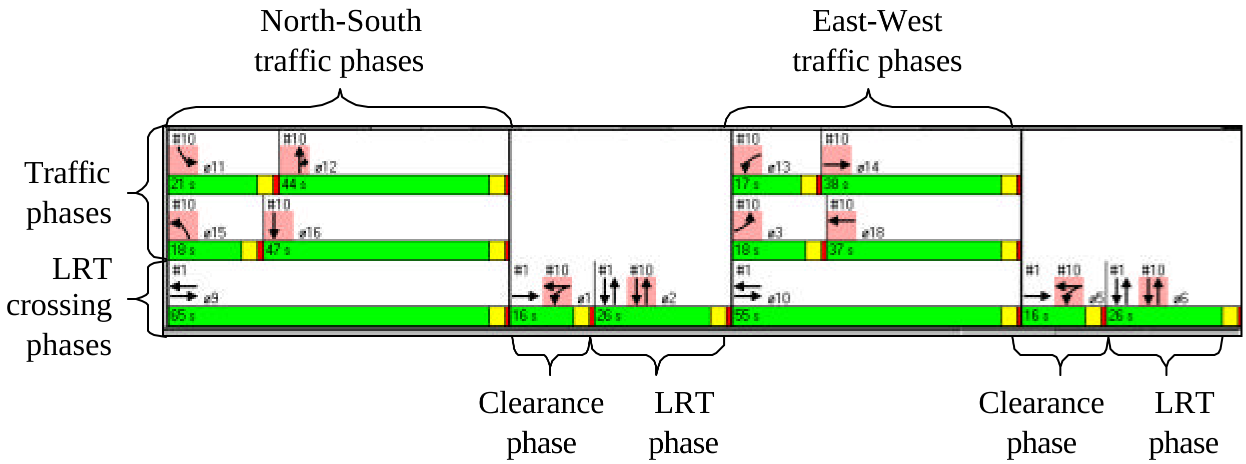


Figure 7: Timing and Phasing Operation

FINDINGS

Output Measures of Effectiveness

The output summarized in this section was developed from three 60-minute runs of the SimTraffic program. The random seed number was changed for each run to develop the stochastic robustness of the simulation. Each individual vehicle's statistics are tracked throughout the simulation period, providing measures of effectiveness (MOEs) that otherwise would be difficult to obtain. The output measures of delay and queue lengths were determined to be of most interest. The comparisons presented in this section are between No-LRT and the 10-minute headway operation of LRT. The only difference between the two models was that under the No-LRT scenario the clearance and LRT phases were never called.

The overall Level of Service for the intersection went from C (33.3 seconds of delay per vehicle) to D (39.9 seconds of delay per vehicle), an approximately 12 percent increase in delay. Given that the north-south movements were provided green time during the LRT crossings, this result is well within what was expected. Although the specific input variables of traffic volume and intersection geometry were altered for this paper, a one-increment LOS degradation was generally observed for all peak periods for the actual project variables.

Queue lengths for the east and west approaches were expected to increase; however the north and south approach queue lengths were not expected to degrade with any significance. The eastbound queue (maximum observed queue) went from 245 feet to 308 feet, an approximate 26 percent increase. The westbound approach queue length went from 207 feet to 259 feet, an approximate 25 percent increase. The westbound approach queue accounted for the queues at both the intersection and the LRT crossing.

Sensitivity Analysis

In an effort to determine the impacts of varying the LRT headways, a sensitivity analysis was conducted at 5-minute and 20-minute headways. The same coding parameters were utilized as with the 10-minute headway LRT scenarios, with the minor exception of changes in the LRT meter cycle length to achieve the desired headways.

Table 1 summarizes the average delay for the No-LRT and the three LRT headway scenarios studied. As would be expected, delay increases once LRT is introduced into the system for the eastbound and westbound approaches. However, the northbound and southbound approaches do not incur any significant delay, and in some cases delay decreases, due to the fact that these phases receive green time when the LRT crossing is in operation.

Table 1 LRT Headway Sensitivity Analysis, Average Delay

Scenario	Average Delay/Vehicle (sec)			
	Eastbound	Westbound	Northbound	Southbound
No LRT	36.4	35.8	29.2	30.9
LRT (5 Minute Headways)	66.1	51.8	30.9	29.1
LRT (10 Minute Headways)	46.4	41.1	30.2	28.7
LRT (20 Minute Headways)	42.1	39.4	29.7	29.8

Table 2 summarizes the average queue lengths for the No-LRT and the three LRT headway scenarios studied. As with the delay MOEs, queues increase once LRT is introduced into the system at the eastbound and westbound approaches. The northbound and southbound queue lengths did not increase under any of the LRT scenarios.

Table 2 LRT Headway Sensitivity Analysis, Queue Lengths

Scenario	Average Queue Lengths (feet/percent increase)			
	Eastbound	Eastbound	Westbound	Westbound
No LRT	245	----	207	----
LRT (5 Minute Headways)	387	58%	322	56%
LRT (10 Minute Headways)	308	26%	259	25%
LRT (20 Minute Headways)	282	15%	232	12%

CONCLUSIONS

As more municipalities study the possibility of introducing LRT into the existing traffic infrastructure the analysis methods need to provide accurate impact measures of effectiveness. This paper reviewed the analysis of the impacts to vehicular traffic at an offset-running LRT crossing using the simulation package SimTraffic 4.0.

The LOS impacts of introducing offset-running LRT appear to be approximately a one LOS degradation, with the conflicting approaches absorbing nearly all of the delay. Depending on the LRT headways, queue lengths on the conflicting approaches can increase dramatically. Of course, inputs such as signal timing, traffic volumes, and LRT headways will have a major impact on the results of any particular analysis.

SimTraffic does not explicitly model transit operations. However, given the recent enhancements to the program and the ability of the traffic engineer to provide clever work-arounds, the resulting output can be very helpful in determining the impacts of LRT on the current traffic network. It is worth noting that other “off-the-shelf” programs are available to model transit operations and should be evaluated at the onset of a project to determine the best program to meet your project goals.

Two final comments. It is not the intention of the authors to either endorse or discourage the use of any traffic software analysis package. The SimTraffic program was used to conduct this analysis because it offered several enhancements over the current methodology and it was readily available to the analysts. Finally, the coding procedures used to study the LRT impacts could easily be applied to any headway-based or reoccurring interruption to a traffic stream. Other applications could be drawbridge operations, heavy-rail applications, or special incidents to name a few.

ACKNOWLEDGEMENTS

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REFERENCES

1. *Preemption of Traffic Signals At or Near Railroad Grade Crossings with Active Warning Devices*, Institute of Transportation Engineers. Washington, DC, 1997.
2. *Manual on Uniform Traffic Control Devices for Street and Highways*, Federal Highway Administration, Washington, DC, 1988
3. *Program of Instruction for the Highway-Grade Crossing Workshop*, The Traffic Institute Northwestern University. Evanston, IL, 1999.

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