Light Rail Transit Grade Separation Guidelines

BY ITE TECHNICAL COUNCIL COMMITTEE 6A-42

The joint committees on light rail (6A-42 and 6Y-37) have investigated what is certainly a key design issue facing light rail transit (LRT) planners and engineers in the United States: how to treat light rail roadway crossings. Committee 6A-42 has focused upon the question of when to grade separate, while 6Y-37 has focused upon the issue of how to design for effective at-grade light rail operation.

With the movement toward light rail in many cities, a rapidly increasing base of research, analysis, design, and operational experience is being accumulated. It is clear that for each design situation (isolated crossing, alignment adjacent to an arterial, and alignment in the median of an arterial) there is either no need to grade separate, a need to grade separate if funding will permit, or a situation that requires further analysis to determine whether grade separation is necessary. Since the selection of light rail is so dependent upon its ability to be constructed without incurring the cost of a grade separated (that is, underground or elevated) trackway, these decisions might be critical to the success of a project. This report focuses upon the work that has been done to date and draws conclusions that can be used as guidelines for light rail planning and design.

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The traffic engineering implications of light rail must be clearly understood by traffic engineers, and it is hoped that these guidelines will assist in achieving this level of understanding.

Overall Findings

The committee identified four general situations dealing with light rail grade separation: first, where light rail can usually be operated at-grade with full preemption; second, where full preemption might or might not operate satisfactorily and where site-specific conditions must be taken into account; third, where light rail might be operable only with conditional preemption, signal progression, LRT-only actuated phases, or other solutions involving LRT delays; and fourth, where LRT at-grade operation is likely to be infeasible under any conditions. Results of operational analyses of LRT crossings have been remarkably consistent, thereby suggesting that threshold average daily cross-street traffic (ADT) ranges would serve as useful initial screening criteria to assist in the determination of at-grade operational feasibility.

It is very important to note that local, site-specific policies and priorities can supersede these guidelines. For example, if local decision makers determine that implementation of a light rail line is sufficiently important to the community to grant preferential treatment to light rail vehicles at major intersections, a more permissive set of guidelines would result. It is equally important to note that much of the LRT operational analysis work upon which these recommended guidelines are based was developed under an operating scenario where light rail trains are granted unconditional traffic signal preemption over cross-street traffic. Thus, the guidelines are based upon "worst case" conditions for roadway traffic, which could be partly overcome through traffic-signal progression schemes, or intersection modifications, street widenings, and other geometric design changes. Therefore, the committee emphasizes the need for detailed, site-specific analysis before final grade-separation decisions.

Finally, the guidelines recommended in this report are applicable only at the conceptual design level. As the project moves through the preliminary and final engineering phases, the analysis tools must become more precise, and many factors other than ADT must be considered. These factors are identified in Section B of the full report.

The ADT thresholds described below are based upon a typical six-lane arterial with peak-hour volume equal to 10 percent of daily volume and peak-direction volume equal to 60 percent of total peak-hour volume. For an arterial with different characteristics, these ADT figures obviously would need to be adjusted to reflect the actual characteristics. Actual peak-hour volume per lane is the controlling variable, as described in Section C of the full report.

At-Grade Operation with Preemption Feasibility

Cross-street and turning movement volumes at intersections with light rail often are low enough to easily permit at-grade operation. Parametric analysis and individual design studies for various intersections suggest that at both isolated crossings and in alignments adjacent to arterial streets, if cross-street volumes are lower than the 15,000 to 20,000 ADT range, at-grade light rail operations are usually feasible for even long trains (three to four cars) and short headways (three to six minutes).

If light rail parallels a major arterial street or a railroad, research completed to date suggests that if the light rail tracks are at least 400 feet from the paralleling arterial, the operation of LRT street crossings can be considered independent from the operation of adjacent intersections with the arterial or railroad, again permitting satisfactory at-grade operations.

For alignments in the median of arterial streets, the guideline threshold of 15,000 to 20,000 ADT for cross streets also should hold. However, if the cross street generates a high volume of left turns from the light rail arterial street, special design treatments for those left turns should be considered.

At-Grade Operation with LRT Delays Feasibility

For the second category, research completed to date suggests that, in many cases, light rail should be grade separated from crossing arterials with volumes greater than 30,000 to 40,000 ADT, for LRT headways of three to six minutes, respectively. For relatively low-frequency operation involving relatively short trains, for cases where future funding sources will be called upon to construct future grade separations, and for times when some delay to LRT can be accepted and traffic-signal progression or conditional preemption schemes are feasible, exceptions could and should be made to this guideline.

Solutions in this range would not rely on full preemption; rather, they would rely either on conditional preemption or on techniques originally developed for streetcar operations, such as traffic-signal progression and LRT-only actuated phases.

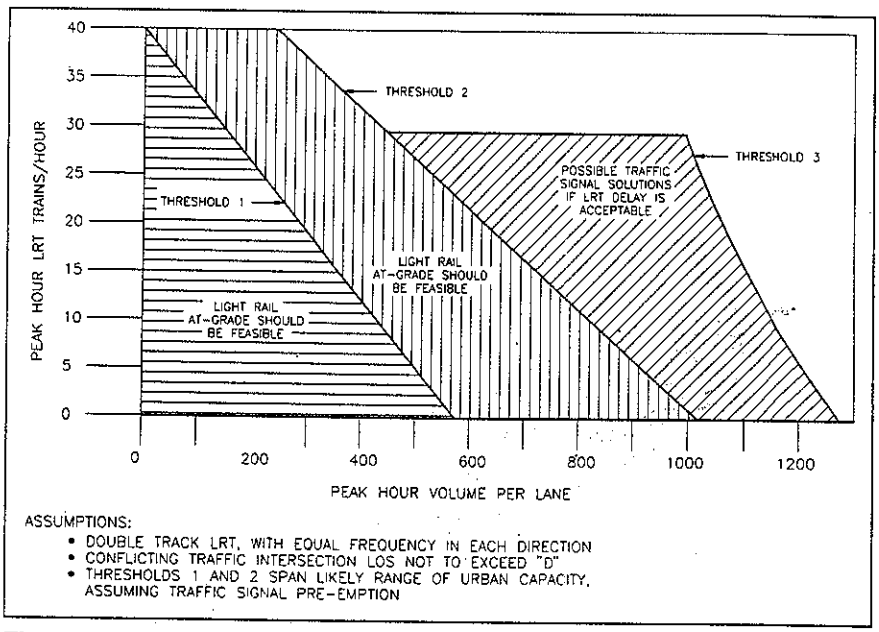

Figure 1. Potential threshold levels for at-grade operation (varying traffic volume and LRT frequency.

At-Grade Operation with Preemption Feasibility

The "gray area" between these two thresholds (preemptions and delays between 15,000 to 30,000 ADT, or 20,000 to 40,000 ADT, depending upon light rail vehicle headway) is where site-specific detailed analysis is needed to determine if grade separation will be desired. In many instances, the question is one of selecting the proper design year. For example, in many fast-growing Sunbelt and western cities, projected population growth rates are so high that many arterials, which today could easily be crossed at-grade, are projected to have future traffic volumes much greater than 30,000 ADT. In this case, it is very important to examine the funds available for the project to determine if the construction of the grade separation can be deferred until, and if, the higher crossing-traffic volumes actually materialize. In the interim, local officials should attempt to reserve the right-of-way that would be required for the grade separation and make planning, zoning, local access, and development-approval decisions accordingly.

If existing traffic volumes for the cross street are within this so called gray area, other factors need to be examined to determine if preemption is feasible. For example, the impact upon adjacent intersections on the cross street and upon signal progressions should be examined.

For cases in which the light rail tracks parallel an arterial or a railroad route, detailed queue length studies should be performed to ensure that queues will block neither the light rail tracks nor the adjacent roadway or railroad tracks.

At-Grade Operation Feasibility

Beyond a certain volume, even the more restrictive LRT grade-crossing solutions likely will not be feasible, or accepted. ADT thresholds for this limit are in the vicinity of 50,000 to 55,000 for LRT headways of three and six minutes, respectively.

Thresholds for At-Grade Operation

Figure 1 combines the results of several different LRT intersection-capacity analyses, which the committee collected from various sources. It is based upon plots of the predicted LRT intersection level of service (LOS) for a range of crossing-traffic volumes (measured in terms of hourly traffic volume per lane) as a function of light rail train frequency (measured in trains per hour per direction, assuming two tracks carrying trains at the same frequency in opposite direc-

tions). The data upon which the figure is based cover a broad range of analytical techniques, different assumptions on LRT clearance times, and differing traffic characteristics. The threshold lines shown have been graphically fitted to the data at 80 percent of LOS E-volumes, assuming that LOS E or worse clearly would be unacceptable to most traffic jurisdictions. Threshold Line 1 is drawn using the most conservative assessments and operational assumptions in estimating intersection LOS. Line 2 is drawn using less conservative assumptions and analytical techniques. The areas below and to the left of Line 1 are the combinations where at-grade LRT operation should be feasible. The area between Lines 1 and 2 represent situations where at-grade operation with preemption might be feasible, depending upon the assumptions used in the analysis. Line 3 represents the boundary of possible solutions for acceptable LRT delays (15 seconds per crossing), using the absolute minimum crossing time for a single-unit light rail vehicle (LRV). Its nonlinear form reflects the ability of fixed signal timing to "collect" LRVs delayed in both directions and move them on a single phase.

If Line 1 is used as a threshold value, for LRT frequencies of up to 10 trains per hour (six-minute headways), up to 430 crossing vehicles per lane per hour would be accommodated at an LOS at or above level E.

If less conservatively derived Line 2 is used as a threshold value, for LRT frequency of up to 10 trains per hour, a maximum crossing volume of up to 800 vehicles per hour per lane could be accommodated at or above LOS E.

These values correspond to crossing ADTs of about 21,500 for Line 1 and 40,000 for Line 2, respectively, assuming a six-lane major arterial crossing with total peak hourly volume equal to 10 percent of ADT and peak direction volume of 60 percent of total peak-hour volume. Curve 3 would correspond to an ADT of 58,000 under these assumptions.

For higher-frequency, closer-headway light rail operation, crossing ADTs at these thresholds would be correspondingly lower, just as they would be higher for lower-frequency operation. This can be estimated by moving upward to the left on the threshold line or downward to the right, respectively.

Thresholds 1 and 2 are based upon granting unconditional preemption to light rail trains at normal operating speed, with railroad-type protection features. For all points to the left of Threshold 3, alternative solutions might be possible when local conditions permit. When the full preemption treatment is feasible (that is, in most cases within Threshold 1, and many cases inside Threshold 2), it is generally a preferred solution, because it involves no delay to the light rail operation.

In cases where full preemption is not feasible, but grade separation is not appropriate for cost or other reasons, conditional preemption or traffic-signal solutions might be appropriate. Solutions in this category would eliminate the time required for advance-warning devices and gate operation by using traffic signals or similar indications. These typically are accompanied by LRT delays, speed restrictions, and other compromises. Although solutions of this type might be feasible over the entire range considered by the committee (that is, up to 40 trains per hour per direction), there is evidence that the variable LRT delays caused by the traffic-signal solutions will contribute to schedule adherence problems and "bunching" of trains. Beyond 30 trains per hour per direction, LRT operations including crossings of this type will tend to resemble on-street local bus or streetcar service in this respect. Even at longer headways, consideration should be made of the possible effects of this class of solutions on schedule adherence.

Application of Threshold Criteria

This report demonstrates that many factors enter into the analysis of at-grade operations—not simply ADT. These factors include: physical configuration, intersection traffic-control characteristics, traffic-flow conditions, pedestrian-flow conditions, and LRT operational characteristics. Thus, the final decision on whether to grade separate is one that must be made on a site-specific, crossing-by-crossing basis. Therefore, these general threshold ADT values should be used only as initial guidelines for determining surface operational feasibility. ▮

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This report is a summary of an informational report of the Institute of Transportation Engineers. The report was prepared by Technical Council Committee 6A-42. The information in this report has been obtained from experiences of transportation engineering professionals and research. ITE informational reports are prepared for informational purposes only and do not include Institute recommendations on the best course of action or the preferred application of data. The complete report can be obtained upon request from the ITE Bookstore at ITE Headquarters.

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