Grade Crossing Safety Policy

Adopted: December 18, 2003

Historical Perspective

This policy was amended on October 28, 2010.

In 1984, the Los Angeles City Council adopted recommendations for the Long Beach-Los Angeles Light Rail Project Draft Environmental Impact Report, including a request for the Los Angeles County Transportation Commission to discuss the need for grade separation at Imperial Highway and Wilmington Avenue. In 1985, staff adopted a multi-agency approach and began working with Caltrans, the Public Utilities Commission (PUC), Los Angeles County Department of Public Works, and the City of Los Angeles Bureau of Engineering on grade separation issues. The agency's policy for grade separation was to evaluate each line on its merits as it was planned and designed.

In 1987, the LACTC recommended the study of full grade separation as part of the San Fernando Valley Environmental Impact Report (SFV EIR) based on recommendations made by the San Fernando Valley Citizens Advisory Panel. The 1989 SFV EIR utilized Los Angeles Department of Transportation and CalTrans guidelines for evaluating the need for grade separation. There was also discussion by the Board of adopting a general policy of evaluating the safety of grade separations when designing railways and presenting the costs and benefits with and without grade separation.

In 1991, the Los Angeles County Transportation Commission asked a consultant to study the need for grade separations and overpasses on all surface streets along the Long Beach Blue Line. The Commission also asked the consultant to evaluate the feasibility of constructing grade separations on two major streets each year. The consultant also performed a grade separation study and calculated priority index numbers for certain intersections of the Metro Blue Line. Major factors influencing the index number would be train and vehicle volumes, project costs, and accident data. The findings are contained in the *Metro Blue Line Grade Separations Study* (November 1992).

In February 2000, Board Chair Yvonne Brathwaite Burke made a motion directing staff to:

- Update the grade separation priority index numbers for seven Metro Blue Line intersections included in the 1992 KAKU study;
- Determine whether these intersections may qualify for state or other type of funding;
- Seek Union Pacific's operational and financial participation in the grade separation effort; and;
- Try to expand the PUC's Grade Separation formula to improve light rail grade separation nomination rankings.

Staff reported their findings at the May 2000 Operations meeting. The priority numbers for the Metro Blue Line intersections came in lower than the 1992 study. One of the major factors contributing to the lower index numbers was the high cost associated with grade separation. The low placement on the index list made it an unlikely candidate for funding under the California PUC (CPUC) Grade Separation Program. With regards to the Union Pacific participation, staff was informed that their contribution would not be expected to exceed 10% of the cost.

The CPUC issued a highway-rail grade crossing separation study for Fiscal Year 2000-01 and found 64 candidate intersections statewide. The priority index listing shows a high number for intersections in Northern California, and a low of 11.87 for intersections for Los Angeles County. Because the current PUC priority formula does not include exclusive light rail projects, the PUC informed the agency that they would consider holding workshops to discuss changes to the formula. The PUC ultimately decided not to change their formula.

When staff presented their recommendations for the Locally Preferred Alternative for the Exposition Corridor from downtown Los Angeles to Venice/Robertson at the June 2001 meeting, the Board expressed concerns over the lack of grade separation at congested intersections of the Corridor. This was primarily based on past experiences relating to the Metro Blue Line. The Board ultimately approved the preferred alterative but also approved a motion to include in the subsequent mitigation analysis the need for grade separations at the intersections of Exposition & Vermont, Exposition & Western, and Exposition & La Brea and further analysis on the parallel routes on Jefferson & Adams to the north and Martin Luther King & Vernon to the south. They also asked that bike path projects be adapted to conform to the light rail project as it comes to fruition in those specific areas where bike paths comes into conflict with the proposed rail line.

At the September 2002 meeting, the Board approved the preliminary engineering consultant contract for the Exposition Corridor and amended it to include beginning first with the full evaluation of at-grade segments, at the following locations, and all other intersections in terms of safety in accordance with the PUC process:

- Exposition/Vermont,
- Exposition/ Normandie,
- Exposition/Western,
- Exposition/Crenshaw, and
- Exposition/La Brea.

The motion also requested that safety mitigations be priced, and if determined to be necessary in order to solve a problem at an intersection, then the Board would authorize design. In addition, in order to address the concerns raised by the community east of Figueroa Street, as part of the PE Scope of Work, staff shall study alternative alignments for a non-revenue connector between Hill Street and Long Beach Avenue. The Board also requested that an independent peer review panel assess our design standards and make recommendations to bring the design engineering and construction costs of the Exposition project in line with comparable projects.

In May 2003, the preliminary engineering consultant team prepared a study evaluating the need for grade separations at all 31 intersections that would be crossed by the project. Criteria are being used based on the CPUC, the Institute of Transportation Engineers, and recent experience with the Metro Gold Line project. Staff will report back to the Board with recommendations of any grade separations recommended for inclusion in the Exposition Transit Corridor project.

In June 2003, the peer review panel presented its recommendation to the Board. Their findings were included in the scope of the preliminary engineering and environmental studies. The primary purpose of the analysis was to create system-wide criteria that could be used for future light-rail projects in the County. The secondary purpose was for the criteria to be used to determine for the Exposition corridor the number of at-grade crossings that require grade separation or supplemental grade crossing safety devices.

In September 2003 the Board considered the Grade Crossing Policy for Light Rail Transit, but requested that staff work with the City of Los Angeles and other agencies and jurisdictions to address some policy concerns. The Board directed staff to return the following month with changes to the policy.

Staff made some minor changes to the policy. The most significant change related to the “Initial Screening Graph,” which was adjusted so that more intersections would fall into the “detailed analysis” category, i.e., milestone two. The other changes include more consideration to safety measures and more detail for operation and safety analysis.

In October 2010, Metro Staff revised the policy to include requested edits to the policy by a motion approved from Mark Ridley-Thomas. Changes include:

- The name of the policy shall be changed from the “MTA Grade Crossing Policy for Light Rail Transit” to “Metro Grade Crossing Safety Policy”,
- The narrative of the policy shall be revised to include consideration of public safety and economic development.

MTA Grade Crossing Safety Policy
for
Light Rail Transit

As Revised by Action of the Board of Directors
October 28, 2010

Metropolitan
Transportation
Authority

PURPOSE

The Grade Crossing Safety Policy is intended to provide a structured process for the evaluation of potential grade separation vs. at grade operation along light rail lines. The Policy recognizes the operational and safety issues of at-grade versus grade-separated solutions. It is recognized that local, state and federal government officials are involved in the process as well as the communities along the light rail line and therefore, no rigid MTA policy can dictate the ultimate solution. However, the purpose of the Policy is to provide a process that addresses all of the principal concerns and clarifies the trade-offs involved in grade separation decisions. Furthermore, the policy is intended to minimize the up-front costs associated with consideration of grade separations as well as minimizing the likelihood of unanticipated consequences such as budgeting for an at-grade solution when a grade separation would ultimately be required.

This Policy prescribes both the overall review process as well as the specific technical studies that would be accomplished within the review process. (Refer to the attached Appendix for a list of definitions of traffic engineering technical terms incorporated in the policy as well as the technical support for the policy.)

This Policy does not address conditions at existing crossings; although some of the analytical procedures and indicated treatments have been applied to existing crossings, the intention of the Policy is to develop assessments of conditions at proposed grade crossings before they are constructed.

GRADE CROSSING SAFETY REVIEW PROCESS

Figure 1 illustrates the overall review process. The Policy includes up to three sequential phases of review and three corresponding analytical protocols would take place before arriving at the “Final Decision” on a crossing:

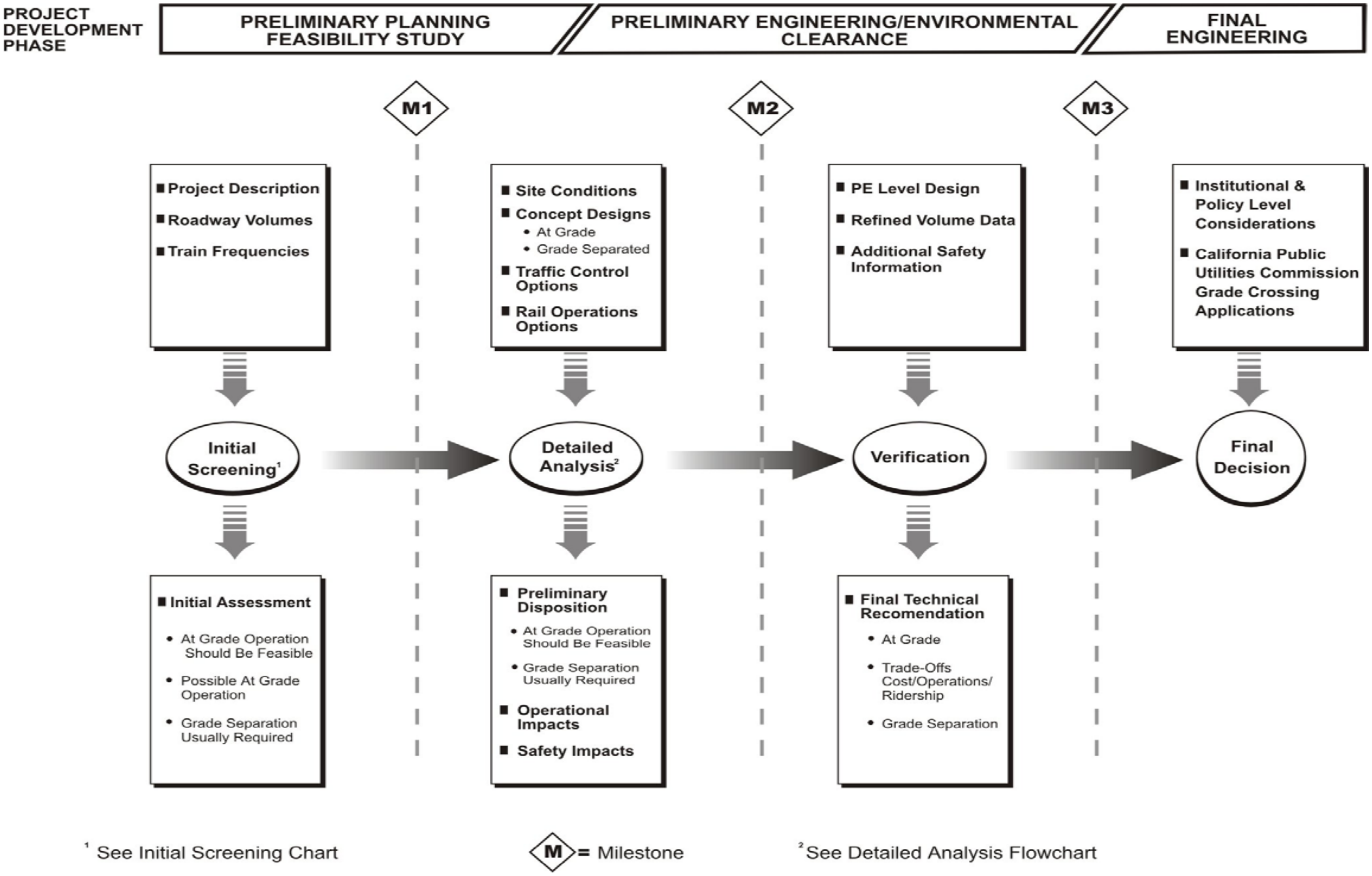
- Analysis Step 1 – Initial Screening – A preliminary, planning level assessment of the roadway crossings based upon readily-available, planning-level data for roadway volumes and train frequencies leading to an initial categorization of roadway crossings into three groups: “At Grade Should be Feasible”, “Possible At Grade Operation”, and “Grade Separation Usually Required”. Results in a preliminary determination of locations that may be operated at-grade versus grade-separated.

- Analysis Step 2 – Detailed Analysis – A detailed operational evaluation taking into account peak period, movement-by-movement analysis of roadway traffic in conjunction with assessment of potential impacts to rail operations and safety. Provides more refined assessment of feasibility of at grade operation and also identifies operational trade-offs between roadway traffic and safety conditions and rail operations. Also includes initial review of safety issues based upon site-specific evaluation of geometric conditions and observed and/or projected usage of the crossing. Results in a preliminary determination of locations that may have safety or rail operations issues that need to be addressed.

- <u>Analysis Step 3 – Verification</u> – This step includes the process of developing consensus regarding the proposed design solution with local constituencies including other involved agencies and the community as appropriate. This step may include preliminary engineering studies and cost estimates for alternative treatments including those directed specifically at addressing safety issues. It may also include refinement of projected traffic volumes and validation of traffic and rail operations using simulation modeling. It may include additional emphasis on safety issues and countermeasures. At the conclusion of this decision point, it is expected that all technical studies will have been completed leading to a final technical staff recommendation for the crossing configuration.

As shown on the flowchart, Analysis Step 1 effort is usually accomplished during a preliminary planning feasibility study, Analysis Step 2 and 3 effort are usually accomplished during preliminary engineering and environmental document preparation, and a final decision should be secured in conjunction with the MTA Board of Directors approving project environmental documents.

Figure 1 – Light Rail Roadway Crossing Review Process



- Final Decision – Final disposition of the crossing configuration based upon all of the preceding technical analyses, engineering studies, and agency consensus building. The MTA staff recommendations should be documented in a Grade Crossing Safety section of the environmental document submitted for MTA board approval for each line. The report should include the results of all technical and quantitative analyses and calculations, any projections made relative to land use, population and traffic and a narrative summarizing the basis for the recommendations. The California Public Utilities Commission must approve of each grade crossing application under the provisions of General Order 75-C. Other third party agreements and requirements must be met.

The boxes across the top of Figure 1 show the required inputs for each of the analysis phases and the boxes across the bottom of the chart indicate the information that results from the analyses.

The Policy presumes that the technical evaluations that are accomplished will be conducted in a cooperative fashion with involved agencies including the local jurisdictions and the California Public Utilities Commission (CPUC). This cooperation would include obtaining available data regarding the proposed crossing locations, reviewing of technical studies, and developing forecasts of land use, demographics and traffic and rail ridership.

In accordance with the degree of project development and the level of detail regarding the proposed LRT project, it is expected that the Initial Assessment (Analysis Step 1) would be prepared in conjunction with a Preliminary Planning Study or Conceptual Design Feasibility Study, and that the Detailed Analysis (Analysis Step 2) and Verification (Analysis Step 3) would be accomplished during the Preliminary Engineering (PE) / Environmental Clearance phase of project development.

In California, formal application under the provisions of General Order 75-C (for grade crossings in general) and in conformity to General Order 143-B (for light rail) needs to be approved prior to construction. This Policy presumes the formal CPUC process constitutes the "Final Decision". Preliminary informal review of the proposed grade crossings with the CPUC staff should take place during Analysis Step 2 and 3 if not earlier. Obtaining a technical consensus with involved third parties during preliminary engineering is important so that a firm construction budget can be developed.

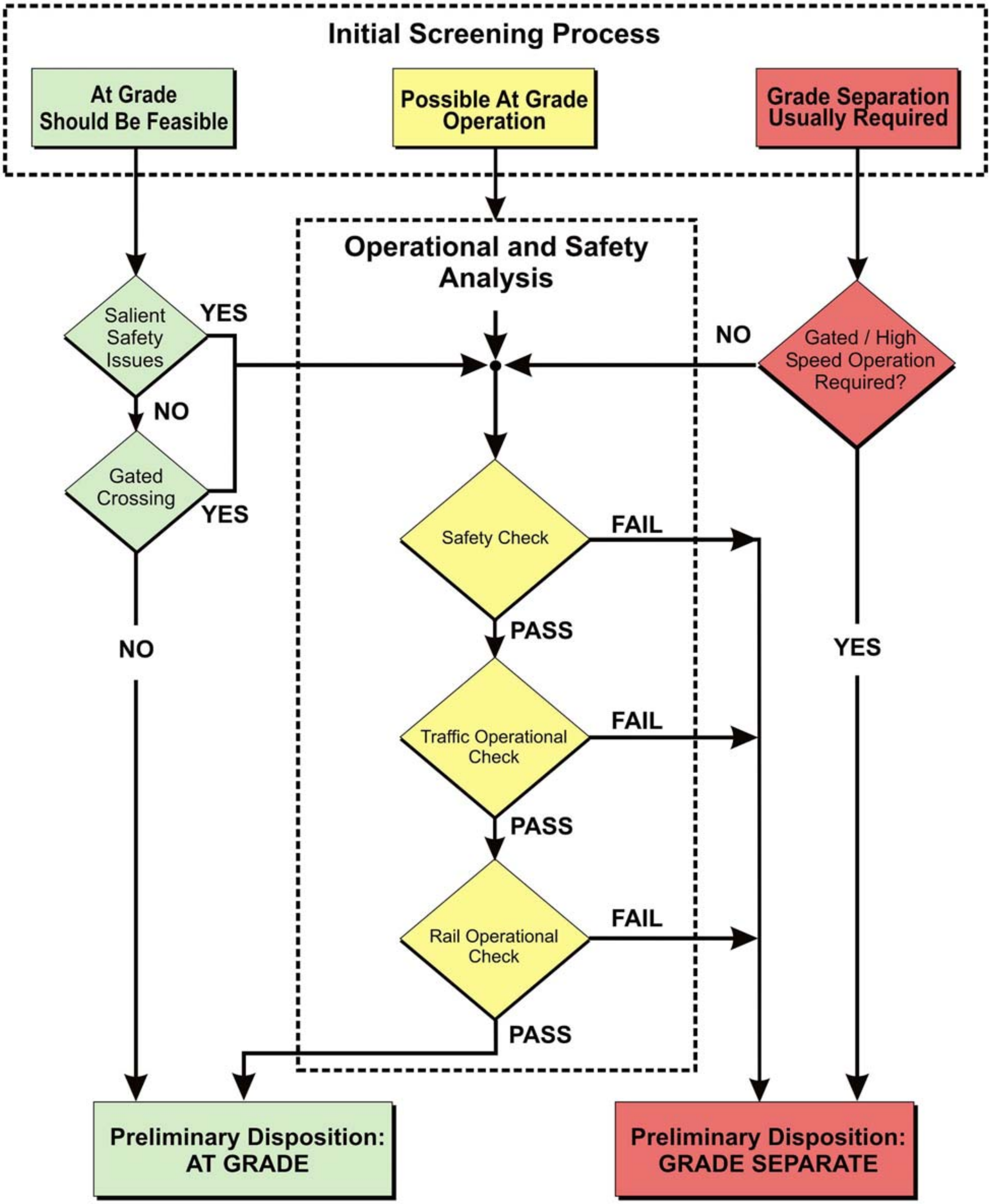
GRADE CROSSING SAFETY REVIEW METHODOLOGY

Figure 2 provides a diagram that depicts the analysis process incorporated in the policy. As indicated at the top of the flowchart, the Initial Screening conducted as part of Analysis Step 1 will result in one of three outcomes. In many instances, the initial determinations for crossings screened as "At Grade Should Be Feasible" or "Grade Separation Usually Required" will be confirmed. However, for all crossings initially screened as "Possible At Grade Operation" as well as for certain conditions as depicted in the flowchart, and engineering study of operational and safety issues needs to be conducted as part of the detailed analysis leading up to Analysis Step 2, and the results of the engineering study may change the resulting outcome. Regardless of the analysis path selected, at the conclusion of the detailed analysis including engineering studies as required, the preliminary disposition of each crossing will be identified as either "At Grade" or "Grade Separate" at the conclusion of Analysis Step 2.

Specific analysis procedures for each step are further described in the text on the following pages.

(Refer to Appendix A for technical support for the methodology.)

Figure 2 – Evaluation Flowchart



ANALYSIS STEP 1 – INITIAL SCREENING

Input Data – Initial Screening:

The initial screening is based upon readily available planning-level information regarding the project description, roadway volumes and number of lanes, as well as train frequencies:

- Project Description Data – As a minimum, identifies all of the potential grade crossings or grade separations. (Conceptual designs are not needed for the Initial Screening).

- Roadway Volumes and Number of Lanes – The Initial Screening is based upon the estimated peak hour per-lane volume of traffic crossing the alignment (highest directional volume). It is preferable to evaluate the year-of-opening volume forecasts as well as 20-year forecast volumes based on the local jurisdiction's land use forecasts. If these are not available, existing volume data factored to a future year may be applied.

- Train Frequencies – The desired headways for train operation need to be identified. If operations' planning has not been completed, train frequencies should be based upon comparable lines, the fallback frequency would be 6- minute headways (10 trains per hour each direction) as a nominal frequency.

Methodology – Initial Screening:

Plot each roadway crossing on the Nomograph for Initial Screening (Figure 3) to determine where on the three zones the crossing would be situated.

In the event a crossing lies very close to one of the two threshold lines, the crossing may be considered in the more restrictive category, i.e., toward at-grade, since existing traffic counts are subject to day-to-day fluctuation and forecasts are estimates only.

Results – Initial Screening:

After the technical analysis has been completed, each crossing should be assigned to one of three categories:

- At Grade Operation Should Be Feasible

- Possible At Grade Operation

- Grade Separation Usually Required

MTA should share the results of the Initial Screening with local jurisdictions and third parties for their review and comments on the preliminary categorization results. Also, MTA should begin to identify and address other issues such as site-specific geometric issues, recurrent traffic queues, accident history, etc., that may indicate safety concerns over and above the traffic operational analysis.

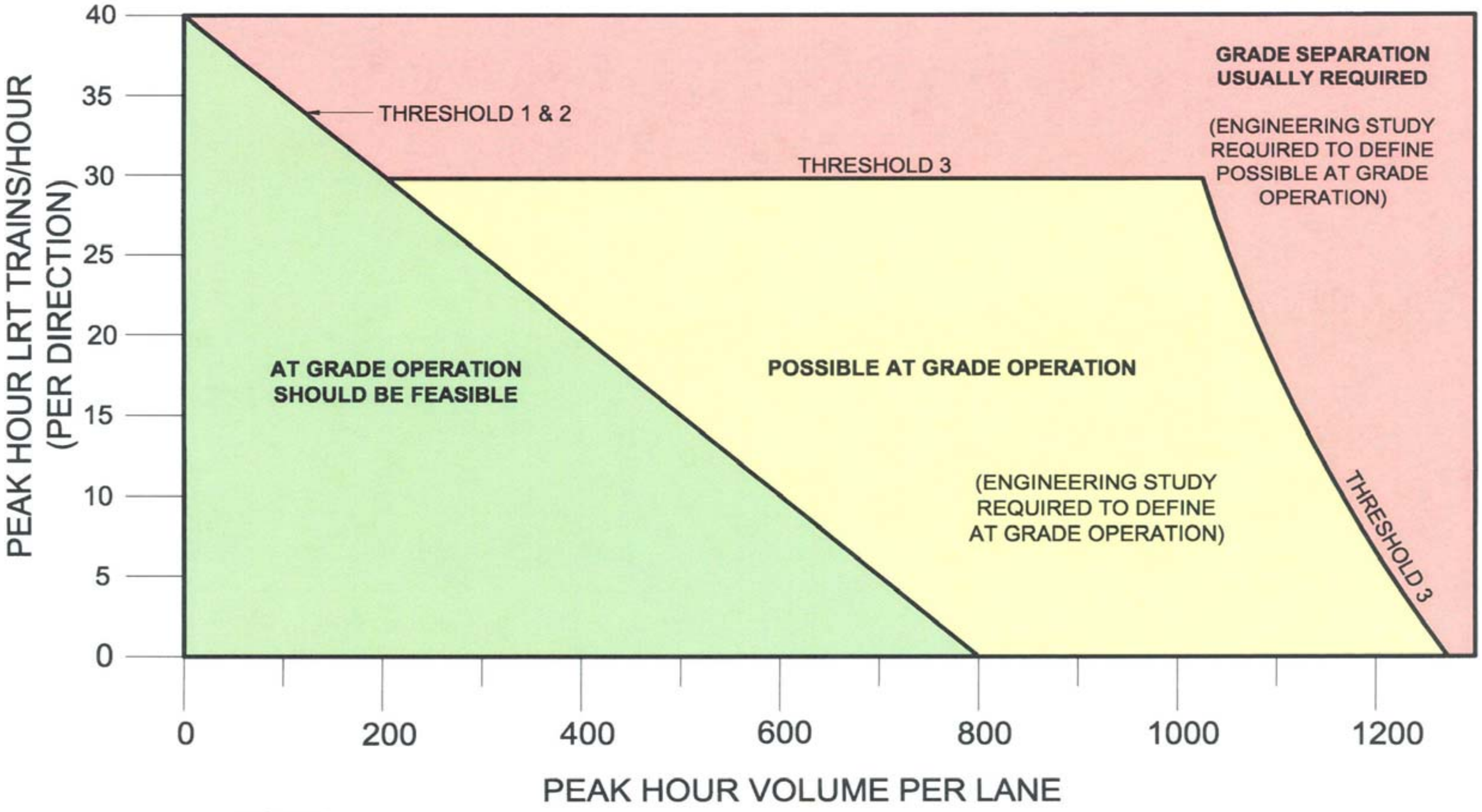
Analysis of Alternative Scenarios

Future year traffic forecasts should be developed for cross streets that reflect these alternative scenarios:

- Traffic levels adjusted to reflect “natural growth” in traffic over 20 years, and
- Traffic levels adjusted to reflect the local jurisdiction’s land use forecasts within a one half mile radius of each crossing over 20 years

These two scenarios along with the use of existing conditions, will estimate impacts on traffic levels that might result from different levels of economic development, and will ensure that grade crossing decisions will accommodate future economic development reflected in the local jurisdiction’s land use forecasts.

Figure 3 – Nomograph for Initial Screening



NOTES:

- ROADWAY VOLUME IS PEAK HOUR, HIGHEST PER LANE FLOW RATE
- ADAPTED FROM INSTITUTE OF TRANSPORTATION ENGINEERS INFORMATIONAL REPORT, LIGHT RAIL TRANSIT GRADE SEPARATION GUIDELINES, 1992, THRESHOLD 1 AND THRESHOLD 2 COMBINED.

ANALYSIS STEP 2 – DETAILED ANALYSIS

Input Data – Detailed Analysis:

The Detailed Analysis phase utilizes all available planning information and includes conceptual design plans for the crossings. The following inputs are required:

- Site Conditions – Geometric and traffic operational conditions at the grade crossings should be identified. Geometric conditions include: the lane configuration of the crossing roadway back to and including the nearest signalized intersection or major intersection on either side of the crossing as well as driveways, curb delineation, channelization, or other features which could affect traffic operation in the vicinity of the crossing. Of particular interest are any substandard geometric conditions that are potential safety hazards.

  From an operations' perspective, considerations include: the approach speeds of trains and roadway vehicles, accident history and observed unsafe behavior, recurrent queuing in the vicinity of the crossing, whether there is a background traffic signal progression along the cross street, pedestrian activity, or other unique operational conditions. The current use of the roadway including: whether it is a school bus route or along a pedestrian route to school, if used by a high percentage of heavy vehicles or vehicles carrying hazardous substances, or if the crossing is required to be used frequently by emergency response units should be identified.

  Other existing conditions to remain that could affect operations should be noted such as parallel freight rail lines that are to remain in operation with LRT.

- Concept Designs – The crossing geometry needs to be conceptually defined. This will include whether the crossing will be a "mid block" crossing or whether the LRT line will be median or side-running along an existing roadway intersecting with the cross street at the crossing. The number of tracks and the approximate track alignment is key. The concept design should also identify the proposed method of traffic control (e.g., gates or traffic signal including the location of key channelization features such as stop bars).

  The location of the trackway and the roadway configuration, including any changes proposed in conjunction with provision of a grade crossing should be identified. This should include consideration of stop bar locations, and bicycle and pedestrian accommodations including the provision of appropriate "refuge zones" between roadway lanes and the trackway.

  The conceptual design plans should identify lane geometrics that can provide suitable operation with the LRT grade crossing. For example, for on-street alignments at intersections with traffic signal control, turn bays should be provided to hold traffic turning across the trackway. Left turn bays should also be provided where feasible on street running alignments at intersections on the cross street to accommodate track clearance for gated crossings and to preclude opposing left turns from "interlocking" in the LRT median.

  In accordance with General Order 143-B of the CPUC, the allowable alignment speed will depend upon the degree of separation between a parallel roadway and the track alignment.

- Traffic Control Options (Including Safety Devices) – The detailed analysis will identify traffic control options, for which there are two principal choices under current regulations of the California Public Utilities Commission: (1) greater than 35 mph with traffic control using automatic crossing gates or (2) lower speed (35 mph- or less) operation with a traffic signal used as the primary traffic control device. In most instances, gated crossings will also require pre-emption of traffic signals within the influence zone.[1] In addition to the primary means of traffic control, known supplemental traffic control, warning or safety devices that are proposed should be identified.

  If the crossing is signalized, the proposed signal phasing should be identified including necessary slot clearance provisions such as green extensions for downstream signal heads. In some cases, a range of alternative timing plans, including variations in cycle length may need to be reviewed to determine which provides the best operation. In addition, there are a number of possible traffic control strategies including "full priority", "partial priority", "green band", or "pre-emption". One or more options may be under consideration, which would lead to a number of possible grade crossing solutions, each with different traffic and rail operational results.

- Rail Operations Options – In addition to the intended train frequencies, the rail operations information should include the speed profile through the crossing, station dwell if there is an adjacent platform, and the proposed location of "hold points" if one of the operational considerations to obtain at-grade operation is accepting train delays.

Methodology – Detailed Analysis:

The flowchart previously shown in Figure 2 depicts the analysis process.

In many instances, an immediate assessment of the Preliminary Disposition of the crossing can be made (as indicated in the tracks to the extreme left and right hand sides of the flowchart:

- At Grade – If the Initial Screening is *"At Grade Should Be Feasible"*, and the crossing is proposed as a traffic signal controlled, "low speed" crossing, and there are no salient safety issues, then the result of the Detailed Analysis phase is "*Preliminary Disposition At Grade"*. Note that two additional decision points may trigger the operational and safety analysis shown in the middle track of the flow chart: 1) gated crossings, for which a queuing analysis needs to be performed to determine the need for traffic signal pre-emption or other queuing control techniques, and 2) locations where the site conditions or crossing usage indicates the need for safety review at this stage of the process.

- Grade Separation – If the Initial Screening indicated *"Grade Separation Usually Required"* and the crossing is proposed as a gated, crossing with pre-emption of adjacent traffic signal (if present) or unimpeded, "high speed" rail operations are required, then the result of the Detailed Analysis is *"Preliminary Disposition Grade Separated."* If, on the other hand, lower speed operation through the crossing with use

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[1] Per the current requirements of the Manual of Uniform Traffic Control Devices (MUTCD) the influence zone is a minimum of 200 feet (60 m) but could be greater, depending upon engineering study of likely recurrent queuing into the grade crossing.

of a traffic signal to control the crossing is acceptable, then as shown in the decision point, additional operational and safety analysis can be done for this alternate approach.

All other conditions, including all of the locations that are initially screened as “Possible At Grade Operation”, will require “Engineering Study” consisting of an operational and safety analysis as described immediately below to be accomplished in order to make a determination as to whether the crossing could be operated at grade.

Traffic Operational and Safety Engineering Study Procedure:

The engineering study is a multi-step manual evaluation of the Level of Service of adjacent or included traffic signal controlled intersections, queuing and other safety factors along with identification of impacts to rail operations including delays and patronage. Queuing analyses should take into account various operational scenarios including evaluation of the range of queuing anticipated given likely operational conditions, e.g., crossing gate blockage times may be longer with near-side stations. (Refer to Appendix A for a more detailed description of the process.) It should be noted that the 7 steps discussed below must be conducted sequentially since analysis of some of the subsequent steps requires results from the previous steps to complete. Therefore, the sequence of the multiple steps does not imply any priority but is based on protocol.

1. Identify Operational Volumes – Review the traffic volume assumptions and make adjustments if appropriate.

2. Compute Influence Zone Queue – The influence zone queue is the queue which builds from an adjacent signalized intersection along the cross street towards the grade crossing (see Figure 4).

3. Compute Crossing Spillback Queue – The crossing spillback queue is the queue that builds from the grade crossing back towards an adjacent roadway-roadway intersection (see Figure 4).

4. Evaluate Cross Street Queues vs. Available Storage – The extent of queuing along the cross street should be compared to the roadway geometry to determine whether either the crossing spillback queue is impacting an adjacent major intersection or if an adjacent major intersection is generating an influence zone queue which would impact the grade crossing. Queuing can be determined by computation or, for existing conditions, by observation. In the event crossing queues are spilling back, mitigation measures are required. (Refer to Appendix A for specifics).

5. Evaluate Impact of Pre-Emption – In the event the crossing will be pre-empted, an evaluation of the impact on cross street vehicle platoons should be accomplished to verify the ability of the roadway to “recover” from pre-emption events.

   The analysis methodology requires four steps:

   - Step 1 – Identify Useable Green Ratio for Non-Compatible Phase
   - Step 2 – Adjust Useable Green Ratio to Reflect Train Frequency
   - Step 3 – Evaluate Base Case Volume/Capacity of Controlling Intersection

- Step 4 – Apply V/C Adjustment

The results of the numeric analysis (refer to Appendix for details) should be evaluated as shown in Table 1:

Table 1 – Criteria for Evaluating Impact of Pre-Emption on Cross-Street Progression

Adjusted Volume/Capacity Ratio Of Controlling Intersection (1)	Quality of Cross Street Progression (2)		
	Little or No	Moderate	High
V/C < 0.85	OK	OK	OK
0.85 <= V/C <= 0.95	OK	Marginal (3)	Fail (4)
V/C > 0.95	Marginal (3)	Fail (4)	Fail (4)

<u>Notes:</u>

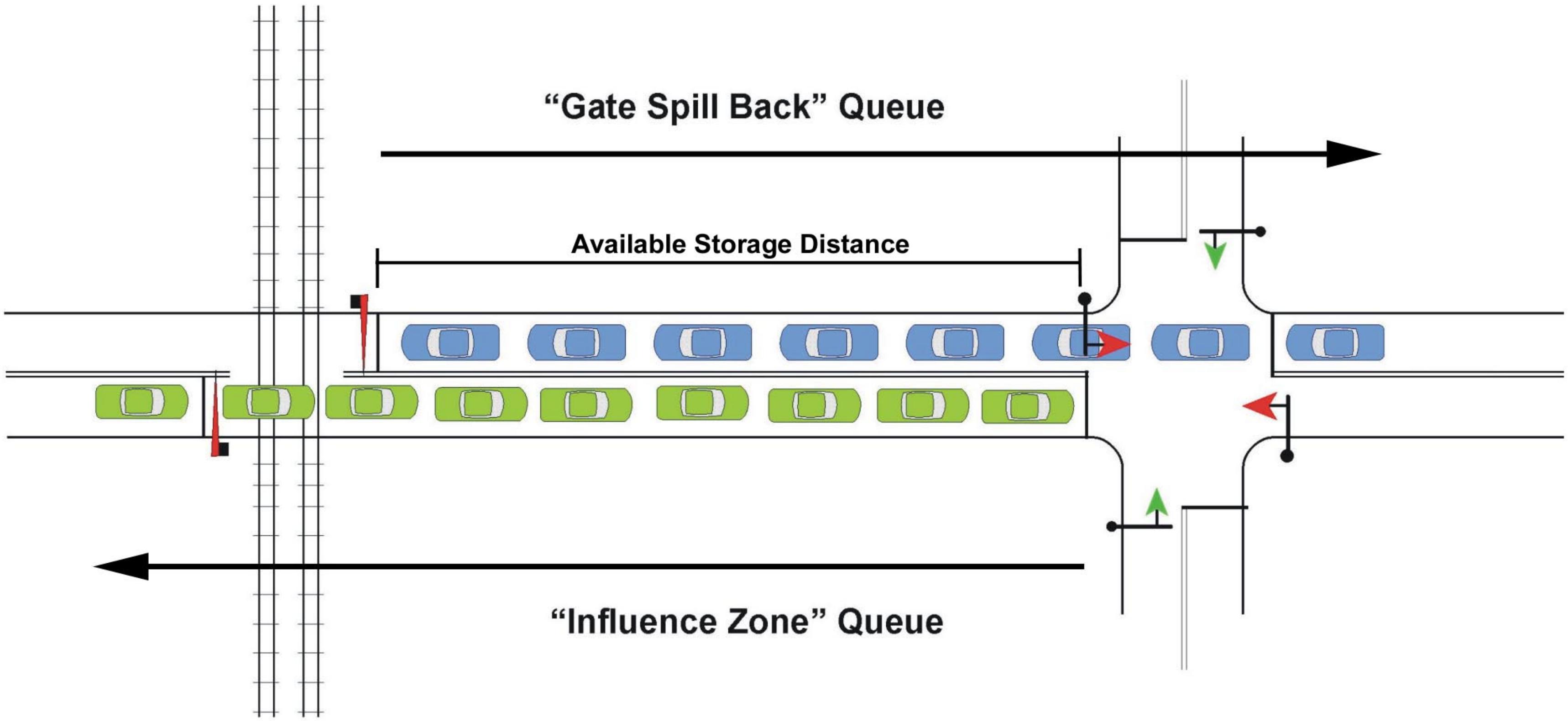
(1) “Controlling Intersection” is the cross street intersection within ½ mile proximity to the LRT grade crossing (including the LRT intersection for median-running conditions) which has the highest degree of saturation; the V/C of the controlling intersection should be adjusted for impact to non-compatible phase (see text for analysis procedure).

(2) Based upon “Arrival Type” definitions as provided in Highway Capacity Manual 2000: “High” is arrival type 5 or 6, “Moderate” is arrival type 4, and “Little or No” is arrival types 1 – 3.

(3) Indicates pre-emption results in measurable impact to cross street. Operation with pre-emption subject to engineering review of need for traffic progression and impact to LRT if pre-emption not provided. Alternative at-grade operation with green band or priority control should be feasible provided there are traffic signal phases that are compatible with the LRT movement at this location.

(4) Indicates pre-emption results in significant adverse impact to cross street; extenuating circumstances needed to justify use of pre-emption provided traffic progression is needed on cross street. Alternative at-grade operation with green band or priority control may be feasible provided there are traffic signal phases that are compatible with the LRT movement at this location.

Figure 4 – Grade Crossing Queues Illustrating Queue Overflow Beyond Capacity



6. Compute Controlling Intersection Level of Service (LOS) – The controlling intersection is the signalized intersection at the grade crossing or along the cross street within the influence zone (as identified in Step 2) which is the most congested during the peak period. The LOS of the controlling intersection provides an indication of the feasibility of transit priority solutions with traffic signal control at the grade crossing and whether the impact of operation as a gated crossing is feasible. (Refer to Appendix A for discussion of service levels.)

7. Safety Analyses

   As a standard practice, a safety review should be conducted for all grade crossings as part of the design of the project. However, for the purpose of determining the need for a grade separation, a safety analysis should be conducted for grade crossings where the decision to grade separate is not conclusive in order to determine whether adverse safety conditions, in conjunction with adverse operational conditions, would suggest/support a grade-separated solution.

   Given that there are a wide range of safety mitigations and design features which can be incorporated into the design of an LRT alignment; substantial experience has been gained with treatments over the past decade; and, substantial documentation of available measures and design treatments is readily available to designers. Saying this, it is difficult to identify specific numeric thresholds for grade separation based purely on safety concerns without consideration for the effect of safety provisions proposed in conjunction with the at-grade design.[2]

   The factors presented in Table 2 should be considered in a preliminary safety review. Table 2 indicates potential mitigation for each identified safety concern. An Engineering Study should be performed to determine which of the factors is a concern at the crossing, possible countermeasures, potential applicability, and effectiveness of potential mitigations.

   The recommended approach for conducting the safety review is to assemble a "diagnostic team" to field review the proposed crossing. The diagnostic team should include representation from MTA operations, MTA rail construction, MTA planning, the responsible local highway authority, and the CPUC. Procedures for conducting the field diagnostic review are provided in the federal Highway Grade Crossing Handbook.

   The Engineering Study of safety features should determine whether effective mitigations are available to address identified safety concerns. If mitigation is not possible, then a grade separation should be considered.

   (Refer to Appendix A for more discussion of the safety review and analysis.)

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[2] Excepting recurrent queuing across the tracks that cannot be managed or eliminated with traffic control techniques.

Table 2 – Safety Concerns and Potential Mitigation

Safety Concern	**Mitigation**
Traffic Queuing	Anti-Queuing Traffic Control Measures; Grade Separation if None Feasible
Approach and Corner Sight Distance	Supplemental Active Warning Devices Reduce Allowable Train Speed
Visual Confusion/Sign or Signal Clutter	Removal of Unnecessary Signs/Signals
Prevailing Traffic Speed	Control Traffic Speed with Traffic Signal Control or Reduced Speed Limit
Large Truck Percentage	Restrict Truck Traffic. Improve Signing or Traffic Signal Timing to Keep Trucks of Tracks
Heavy Pedestrian Volumes	Channelization, Active Warning Devices and Pedestrian Control Devices, Traffic Control Officers for Events
School Access Route	Channelization, Active Warning Devices and Pedestrian Control Devices, Education, and Crossing Guards
Emergency Vehicle Route	Identify and/or Provide Alternative Route Provide Remote Notification of Crossing Status
Accident History	Remedy Specific to the Accident Cause
Gate Drive Around Potential	Photo Enforcement, Medians, Four Quadrant Gates
Delineation and Roadway Marking	Increase Contrast at Crossing or Improve Delineation
Traffic Control Observance	Install Active Signs. Increase Enforcement

Preliminary Disposition

After the operational analysis data is developed, crossings are assigned a Preliminary Disposition as either at grade or grade separated based upon consideration of the Detailed Analysis data and further consideration of possible priority strategies.

There are three basic “tests” that the engineering study ultimately addresses. If the grade crossing passes all three tests, a preliminary disposition of at-grade can be assigned. If the grade crossing fails any of the three tests, then a preliminary disposition of grade separate should be assigned. The tests are as follows:

- Safety Check

  Pass**-** Safety concerns are minor and/or can be mitigated.

  Fail**-** Engineering study determines that mitigation is not available to address safety concerns to adequate level.

- Traffic Operations Check

  Pass**-** No operational factors are found that would result in unacceptable traffic impacts due to the proposed grade crossing.

  Fail- Unacceptable conditions predicted based upon the traffic operational analysis, as further noted below.

  It should be noted that most grade crossings would be operated using either crossing gates or traffic signals to provide traffic control. In the event crossing gates are provided, pre-emption of traffic signals that are within the influence zone of the crossing (as determined by engineering study) is ordinarily required by the Manual of Uniform Traffic Control Devices. In the event traffic signals are provided, the signals may be pre-empted or priority control may be utilized. With priority control, either “full” or “partial” priority can be provided. In addition, rail operation could be accommodated by providing a “green band” type of operation in which the signals operate on a fixed time pattern with slots for LRT movements provided as part of the timing plan.

  In performing the traffic operations check, the analyst must determine whether the proposed type of traffic control as described above can be accommodated based upon the geometry, volumes, and rail operations projected for the grade crossing. In the event the controlling intersection is operating at or close to capacity (e.g., LOS E-F), it may not be possible to provide pre-emption or high priority for LRT movements, but delays under partial priority or green band type of operation may be acceptable from an LRT operations perspective. Conversely, even with LOS C or D, if pre-emption is required for rail operations, unacceptable impacts to cross street traffic signal progressions may result.

  Examples of failure of the traffic operations check include, but are not limited to: (1) Pre-emption of traffic signal required at the crossing for rail operations purposes, but pre-emption results in unacceptable impact to progressive traffic flows along the cross street. (2) High priority over street traffic required at the crossings for rail operations purposes, but there is inadequate slack time for adjusting the controlling traffic signal and the controlling traffic signal must remain in coordination with other signals along the cross street. (3) At a street-running location there are no LRT-compatible movements so the LRT would need to have a separate phase, but the intersection is already operating at capacity due to vehicular movements and no mitigation can be identified. (4) At a location proposed for "green band" type of operation, no acceptable traffic signal timing plan can be identified to provide the required "slots" for LRT movements which is also workable vehicular traffic.

At locations where the Traffic Operations Check fails, the result of the Detailed Analysis phase is *Preliminary Disposition Grade Separate*. It is still possible to further test these conditions for at grade operation during the Verification Phase, but the expectation is that grade separation will be necessary.

- Rail Operations Check

  Pass**-** Impact of the speed and signal control assumptions used in the traffic check are acceptable to the rail operating plan and patronage assumptions (e.g., does not cause unacceptable levels of delay to the overall run time). This would include the proposed speed profile through the crossings, taking into account the presence of adjacent stations or other factors affecting speeds. In addition, for options with traffic signal control, there should be an evaluation of possible train delays associated with the crossing based upon the identified priority control strategy.

  Fail**-** If the speed and signal control assumptions used in the traffic check are unacceptable (e.g., cause unacceptable levels of delay).

Results – Detailed Analysis

At the conclusion of the Detailed Analysis phase, the following information and conclusions will be available:

- Preliminary Disposition – At grade or grade separated

- Concept Designs – All options, at grade and/or grade separated; concept designs should address "other issues" such as complex or unusual geometry, heavy pedestrian traffic or school routes, etc.

- Traffic Operations Analysis – Identification of controlling intersection, Level of Service, projected queuing vs. available storage

- Priority Control Options – For at grade alternatives, traffic signal or gates with proposed stop lines; conceptual definition of proposed method of traffic control (e.g., green band, full priority, or partial priority) with timing considerations

- Train Operational Impacts – Rail operating speed profile through grade crossings with assessment of possible train delays at traffic signal controlled locations

- Special Studies (Optional) – Any supplemental studies required as a result of site-specific considerations which could affect the crossing disposition

In the event MTA staff is able to develop in concept an agreement from CPUC staff and other involved responsible agencies and parties including the local highway authority, no further analysis is required to determine whether a crossing will be at-grade or grade-separated. MTA staff should proceed with filing of grade crossing applications and final design of the crossings when project funding is assured and a firm construction schedule can be established.

ANALYSIS STEP **3 – VERIFICATION PHASE**

The Verification Phase includes any additional efforts that are necessary to arrive at a Final Technical Recommendation of the crossing status with regard to an at-grade or grade-separated operation. As noted under Analysis Step 2, this effort is only required if MTA staff cannot obtain agreement on the crossing status based upon the Detailed Analysis conducted as part of Analysis Step 2.

It is anticipated that efforts performed as part of Analysis Step 3 will be specifically tailored to resolve outstanding issues. The scope of these efforts should be established in cooperation with involved local jurisdictions. As such, the Verification Phase may include the following types of studies:

- Preliminary Engineering – Especially for grade separated options, feasibility studies to develop the cost of grade separation may need to be performed to provide an understanding of the trade-offs involved.

- Traffic Simulation Modeling – In the event the results of the manual Detailed Analysis process are not conclusive, simulation modeling may need to be accomplished to demonstrate how the crossings will operate at grade and to verify the predicted traffic and train operations impacts.

- Detailed Safety Studies – To the extent that outstanding safety issues remain after consideration of the initial review conducted as part of the detailed analysis, additional Engineering Study of remaining safety issues may be required. The scope of these studies should be defined based upon the safety concerns, which are outstanding.

Input Data – Verification Phase:

The verification phase should be done with assistance and input from the local jurisdiction, so as to build consensus towards the result. The following input data is required, in accordance with the anticipated geometric design and/or traffic modeling process:

- Engineering Design – Key feasibility issues including configuration (over vs. under), impact adjacent stations (if present) need to be identified for consideration in the preliminary engineering effort.

- Refined Traffic Volumes – In the event traffic simulation will be accomplished, the boundary for the simulation model will need to be established and detailed traffic volume data at the turning movement level of detail that reflects upstream constraints in the roadway network capacity and is internally consistent (upstream to downstream) from intersection to intersection is needed.

- Safety Studies – As required to evaluate safety concerns and mitigations.

Methodology – Verification Phase:

- Preliminary Engineering – If provided, the preliminary engineering should demonstrate the configuration of a feasible solution including the proposed design, required right-of-way, cost, and secondary impacts (e.g., noise and visual, sight distance, etc.)

- Simulation Modeling – If provided, traffic simulation studies should test alternative methods of traffic signal timing and identify travel times, delay, and queuing that could affect traffic and train operations.

- Rail Operations – The results of the simulation modeling may be used to revise the estimate of traffic signal delay and of overall travel time for the rail line. If at grade operation through a number of crossings would result in substantially different end-to-end travel times, it may be appropriate to assess possible impact upon the projected patronage of the facility and the resulting cost-effectiveness (cost per new rider).

- Safety Studies – Further Engineering Study to be accomplished in accordance with the outstanding safety issues.

- Other Considerations- Quantitative assessments of other considerations identified above.

Results – Verification Phase:

At the conclusion of the Verification Phase, the results from the supplemental studies should be considered and the Preliminary Disposition of the grade crossings reviewed in light of the additional information. The trade-offs between the cost and benefits of at-grade and grade-separated options should be reviewed and a *Final Technical Recommendation* for at-grade or grade-separation operation should be made. The results should be documented in the project environmental documents in a section on Grade Crossing Safety for each of the rail crossings in the study area. The report should include all quantitative analyses including calculations, any other technical analyses that are limited to a narrative discussion, and descriptions of input data including forecasts and other modeling.

When the results of the Verification Phase have progressed to the point that draft findings can be shared, third party input should be obtained.

FINAL DECISION

Final determination of each project's grade crossings configuration will be made by the MTA Board of Directors in conjunction with approving project environmental documents. Each decision will be based on analysis consistent with current technical standards and methodologies, including consideration of public safety and economic development as reflected in local jurisdictions' land use forecasts. However, the policy recognizes that the ultimate decision will involve institutional consideration of the proposed crossing treatments and will require third party approvals, primarily consisting of approval of the crossings by the California Public Utilities Commission under the provisions of General Order 75-C (for grade crossings) and consistent with General Order 143-B (for light rail transit). Additional agreements including those to obtain necessary right-of-way, and for identifying any sharing of construction and/or maintenance costs would need to be addressed as part of the Final Decision.

Appendix A
Policy Support

BACKGROUND

The Grade Crossing Policy and the methodologies recommended to apply the policy were developed as a response to an MTA Board Action requesting that the Exposition LRT Project grade crossings identified in the Draft Environmental Impact Statement/Report (DEIS/R)[3] be re-evaluated to determine which crossings will operate at grade and which ones will be grade separated – MTA does not currently have a set policy or procedure for determining whether to provide grade separations at roadway crossings.

Research was conducted to identify existing grade separation warrants or criteria in use by regulatory agencies and transit operators. The research identified a grade separation policy developed by the Dallas Area Rapid Transit dating from studies conducted in 1987. The research also identified an “Informational Report” prepared by the Institute of Transportation Engineers (ITE) in 1992.[4] The research also included an evaluation of the grade separation index utilized by the California Public Utilities Commission (CPUC) for prioritizing funding requests for grade separations (primarily for mainline railroads). The research identified one additional methodology by Rex Nichelson – this approach is an economics-based methodology that does not specifically consider LRT operations.[5]

In addition to the research, Korve Engineering, Inc. staff experience in LRT and grade crossing safety and operational studies [6, 7] was brought to bear on the problem. Finally, consideration was given for advances in traffic signal “priority control” for transit that have occurred since the ITE report was written.

CONTENTS

This appendix provides technical support for the MTA Grade Crossings Policy in the following areas:

- Definitions – A list of definitions of key technical terms used in the policy
- Initial Screening – The technical basis for the recommended nomograph and recommended procedures for incorporating grade crossing intersection turning movements in the analysis, if available

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[3] Mid-City/Westside Transit Corridor Draft EIS/EIR. SCH No. 2000051058. Los Angeles County Metropolitan Transportation Authority. Los Angeles, CA. April 6, 2001.

[4] ITE Technical Committee 6A-42. Light Rail Transit Grade Separation Guidelines. Institute of Transportation Engineers, Washington, D.C., March 1992.

[5] G. Rex Nichelson, Jr. & George L. Reed. Grade Separations – When Do We Separate. 1999 Highway-Rail Grade Crossing Conference. Texas Transportation Institute. College Station, TX, October, 1999.

[6] Korve, H., Farran, J., Mansel, D. TCRP Report 17: Integration of Light Rail transit Into City Streets. Transportation Research Board, National Research Council, Washington D.C., 1996.

[7] Korve, H., Ogden, B., Siques, J. TCRP Report 69: Light Rail Service: Vehicular and Pedestrian Safety. Transportation Research Board, National Research Council, Washington D.C., 2001.

- Engineering Study of Operations and Safety– More detailed discussion of selected key topics including traffic volumes, queuing analysis, level of service, safety studies, and impact of pre-emption on progressive traffic movements

DEFINITIONS

For the purpose of the MTA Grade Crossings Policy, the following definitions are presented to clarify the terms discussed.

- Compatible Phase – The traffic signal roadway phase that controls roadway movements that are not in conflict with concurrent transit movements.

- Controlling Intersection – The cross street intersection within ½ mile proximity to the LRT grade crossing (including the LRT intersection for median-running conditions) which has the highest degree of saturation.

- Early Green – A strategy that foreshortens phases ahead of the transit compatible phase so that the transit compatible roadway phase and transit phase can be brought up upon arrival of a transit consist at an intersection.

- Green Band Operation (Passive Priority) – A fixed timing plan which provides a coordinated sequence of phases across a group of traffic signals so that the transit compatible phase occurs at successive traffic signals to facilitate movement of transit vehicles. (The transit compatible phase will be brought up regardless of the presence of a transit consist, although the transit phase may optionally be displayed in response to the detected arrival of a transit vehicle.)

- Green Extend – A priority strategy that lengthens the duration of the green portion of the transit compatible phase so that the transit phase can be displayed and the transit vehicle can be served upon arrival within a specified time at a signalized intersection.

- Green Hold – A priority strategy that holds the green portion of the transit compatible phase so that the transit phase can be displayed and the transit consist can be served upon arrival at a signalized intersection. If provided with a “timeout”, the hold will expire after a designated time; otherwise the phase will be held until the transit vehicle is served and “checks out” of the intersection.

- Group – A set of traffic signals that are all operated on a common time reference so that the first phase at each signal in the group has the same offset.

- Mid-Block Crossing – A rail-only crossing in between roadway intersections where the transit mode crosses the roadway.

- Non-Compatible Phase – The traffic signal roadway phase that controls roadway movements that conflict with concurrent transit movements.

- Offset – The variance in time for the initiation of the cycle at an individual traffic signal with respect to the time reference for a group of signals.

- <u>Phase Omit</u> – A strategy that skips over a traffic signal phase so that a subsequent phase can be displayed.

- <u>Pre-emption</u> – Defined by the MUTCD as “The transfer of normal operation of traffic signals to a special control mode (MUTCD, 2000, Section 8A.01).” Pre-emption is usually accomplished to provide a track clearance phase at a highway-rail grade crossing or to allow for expedited movement of emergency vehicles through a signalized intersection. Pre-emption can be used to grant the right-of-way to a transit vehicle at a signalized intersection by interrupting the normal signal cycle sequence and substituting an alternative sequence of phases. Use of pre-emption is disruptive to normal signal operations such as progressions because the signal is pulled off the background cycle and it may take two or more cycles for the signal to “recover”. For this reason, the current practice is to provide “priority” to facilitate transit movements through intersections.

- <u>Priority or Priority Control</u> – A range of techniques that can be used to provide a transit phase on demand without use of the pre-emption logic of the traffic signal controller. For this reason, priority control strategies are less disruptive to traffic patterns and most implementations of priority maintain coordination over one or two signal cycles. Examples of priority techniques include strategies to shorten or skip phases ahead of the arrival of the transit vehicle, as well as strategies to extend or hold the transit phase or the phase that is compatible with the transit phase. Within the context of transit priority, two additional terms are in common use:

    - <u>Full Priority</u> – While maintaining overall coordination with the background cycle, additional techniques such as skipping a phase, or swapping the sequence of phases (“phase rotation”) within a cycle is allowed. The most common example is skipping conflicting left-turns. Full priority provides additional benefits for transit operation but the downside is possible driver confusion. Full priority may also refer to more aggressive changes to the signal cycle using the “early green” or “green extend” techniques. For example, a signal may be put in “green hold” which is simply a “green extend” that maintains the transit phase until the transit vehicle “checks out” or until the phase times out.

    - <u>Partial Priority</u> – This term is usually used to refer to priority techniques that are the least disruptive to normal signal operation. Examples include advancing the start of the transit and/or transit compatible phase (“early green”), as well as holding the transit and compatible phase (“green extend”). Partial Priority does not skip any vehicle phase to extend or bring up early the transit phase and the degree to which phases may be shortened is limited.

- <u>Queue Jump</u> – A strategy that inserts or activates the transit phase before the compatible roadway phase upon demand based upon the detection of a transit consist.

- <u>Split</u> – A portion of a traffic signal cycle that is assigned to a specified phase

INITIAL SCREENING

The Initial Screening is adapted from procedures contained in the Informational Report (IR) “Light Rail Transit Grade Separation Guidelines” published in 1992 by the Institute of Transportation Engineers (ITE).

The chart presented in the 1992 ITE IR (see Figure A-1) stipulates three assumptions:

- Double Track LRT with Equal Frequencies in Each Direction
- Conflicting Traffic Intersection Level of Service LOS D or Better
- At Grade Thresholds Assume Gated Crossing with Traffic Signal Pre-Emption

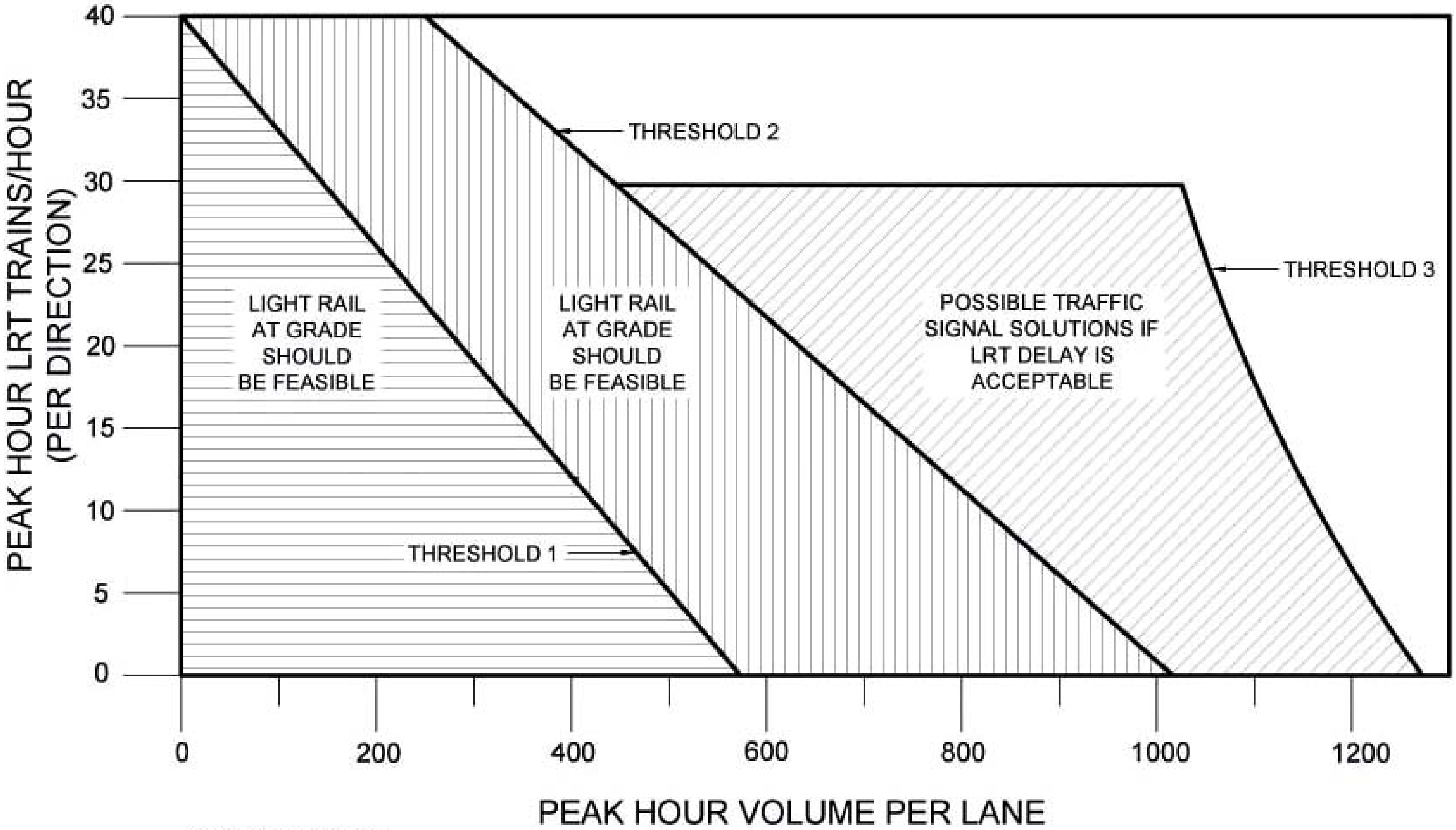
As stated in the Guidelines, Threshold Line 1 is drawn using the most conservative assessments and operational assumptions in estimating intersection LOS. Threshold Line 2 is drawn using less conservative assumptions and analytical techniques. The areas below and to the left of Line 1 are the combinations where at-grade LRT operation should be feasible. The area between Lines 1 and 2 represent situations where at-grade operation with pre-emption may be feasible, depending on 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 non-linear form reflects the ability of fixed signal timing to “collect” LRV’s delayed in both directions and move them on a single phase. Any grade crossing that lies below Threshold Lines1 or 2 should be feasible at grade. If the crossing lies beyond Threshold Line 2 and below Threshold Line 3, at-grade operation is also feasible if the LRT operator is willing to accept some delays for the LRV at the grade crossing to accommodate cross street traffic (e.g. the LRV may not have full priority at the grade crossing). If the grade crossing lies beyond Threshold Line 3, then at-grade operation is not feasible without significant delays to LRV’s and/or cross street traffic.

Thresholds 1 and 2 are based upon granting unconditional pre-emption to light rail trains at normal operating speed, with railroad type crossing protection features (e.g., automatic crossing gates with flashing lights and bells). For all points between Threshold Line 2 and Threshold Line 3 at grade operation may be feasible with advanced traffic signal coordination, conditional train pre-emption, and partial priority (as opposed to full pre-emption).

The thresholds are based upon “worst case” conditions for roadway traffic which could be partly overcome through traffic signal progression schemes, and/or intersection modifications, street widenings, and other geometric design changes.

It is important to recognize that the ITE IR was published in 1992; more importantly, the references cited are primarily dated from the mid-1980’s – which means the ITE IR pre-dates most of the traffic signal software currently in use in the United States to provide transit priority (as opposed to pre-emption): The most recent transit priority software includes a number of features such as the ability to track the background cycle and re-allocate green time over more than one cycle in order to provide transit phases with a minimum of disruption to the roadway network which makes at-grade operation feasible in a wider range of contexts than would have been possible at the time the ITE IR was developed.

Figure A-1 – Potential Threshold Levels for At-Grade Operation for Varying Traffic Volume and LRT Frequency



ASSUMPTIONS:

- DOUBLE TRACK LRT, WITH EQUAL FREQUENCY IN EACH DIRECTION
- CONFLICTING TRAFFIC INTERSECTION LOS NOT TO EXCEED "D"
- THRESHOLDS 1 AND 2 SPAN LIKELY RANGE OF URBAN CAPACITY, ASSUMING TRAFFIC SIGNAL PRE-EMPTION

SOURCE: ITE (IR) "LIGHT RAIL TRANSIT GRADE SEPARATION GUIDELINES", 1992

In addition the “Threshold 3” limit of acceptable at-grade LRT operation identified in the ITE IR is based upon an assumed maximum tolerable delay to the train operations. However, there may be circumstances in which this threshold does not apply or would not be considered to be a limiting factor, for example:

- Green Band Operation – If the LRT trains operate within a window provided by a fixed background signal cycle, the LRT movements can be made at the same time as compatible traffic phases (e.g., parallel roadway traffic through phase). For a segment of line, there may be an initial delay for an LRT to wait for the first green, but the train may be able to continue through a number of crossings before encountering a red signal, thereby significantly reducing the average delay per crossing for the signal group.

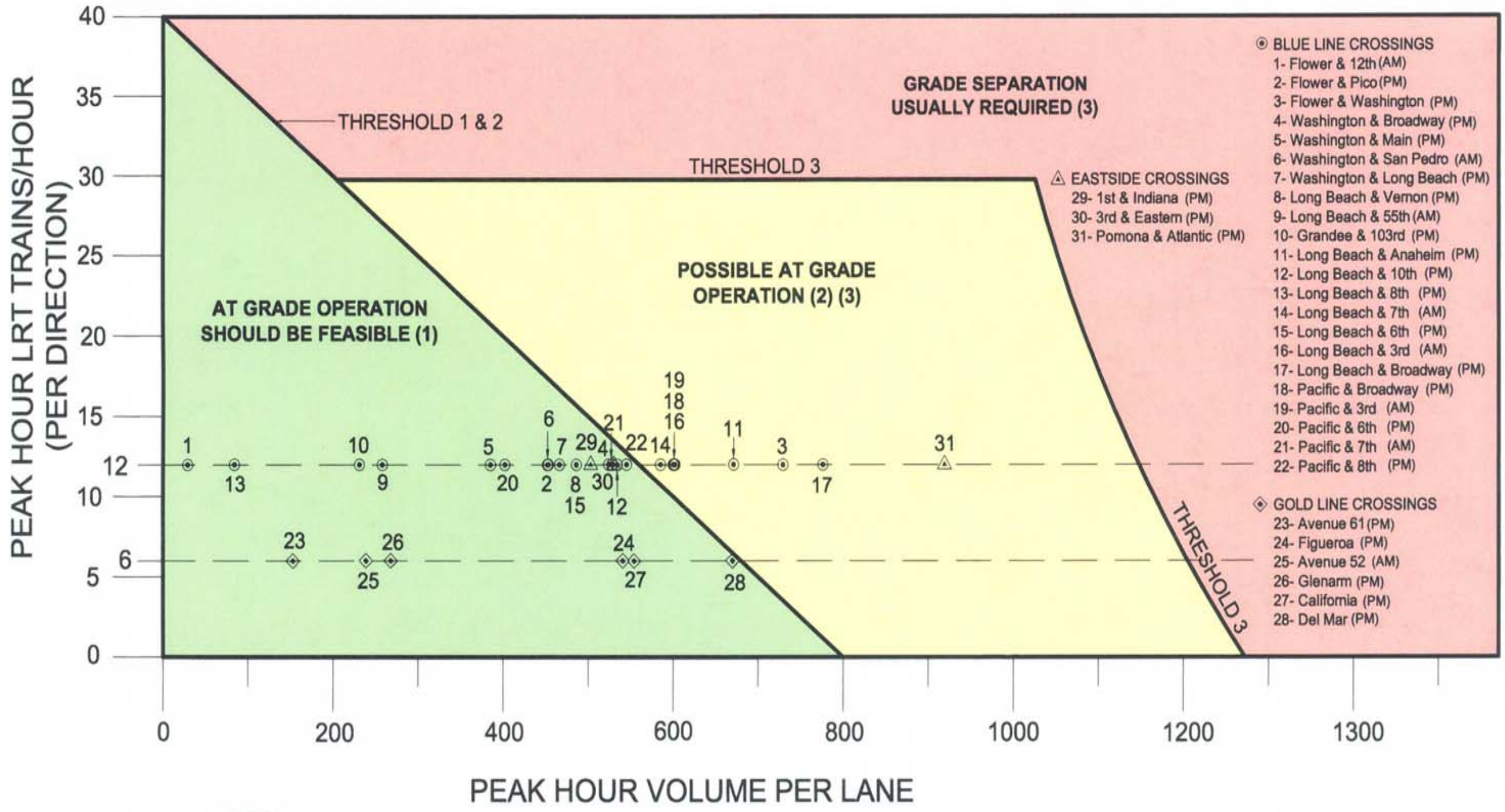
- Extraordinary Circumstances – Financial or physical constraints may dictate the need to provide an at-grade solution, even if there are significant delays to the LRT trains. The MTA may decide to defer construction of costly grade separations, or current roadway traffic levels may not be high enough to justify grade separations. Also, the agency may be willing to accept higher levels of delay in order to avoid grade separations.

Finally, it should be noted that the ITE IR indicated two thresholds (“Threshold 1” and “Threshold 2”) for the likely range of at-grade operation – this was based upon differing methodologies for computing intersection levels of service – based upon high levels of observed saturation flow, shorter than average vehicular headways, and high rates of green time utilization in the Los Angeles metropolitan area, a line approximately mid-way between “Threshold 1” and “Threshold 2” (intercepting the “zero trains per hour” axis at 800 vehicles per hour per lane correlates more closely with observed intersection capacities in Southern California as reflected in “saturation flow rates” (e.g., absolute maximum traffic levels) commonly used to compute intersection capacities for local conditions.

In summary, it is recommended that the ITE nomograph published in the 1992 ITE IR should be utilized with the following stipulations:

Use Blend of Threshold 1 and Threshold 2 – The threshold which represents the nominal limit for operation with pre-emption should use a blend of the two ITE thresholds resulting in a line that intercepts the horizontal axis (capacity with no trains in operation) at 800 vehicles per hour. The recommended threshold indicates a limit of 600 vehicles per hour with 10 trains per hour corresponding to 12-minute headways in each direction. This threshold is supported by empirical data from the Los Angeles area – As shown in Figure A-2, the gated crossings at Del Mar on the Gold Line and at Long Beach / Vernon on the Blue Line fall approximately along this threshold line.

Figure A-2 – Existing Grade Crossing on Initial Screening Chart



NOTES:

(1) WITH CROSSING GATES AND PRE-EMPTION OR TRAFFIC SIGNAL PRIORITY
(2) WITH TRAFFIC SIGNAL PRIORITY AND SOME LRT DELAY
(3) ENGINEERING STUDY REQUIRED TO DEFINE OR CONFIRM AT GRADE OPERATION

- Gated, Higher Speed Operation (Greater Than 35 mph) – Assume at-grade operation for conditions which are below Threshold 2; Assume grade-separated operation for conditions which exceed Threshold 3; Locations which lie between Threshold 2 and Threshold 3 require Further Study to confirm at-grade operation.

- Signalized, Lower Speed Operation (35 mph or Less) – Assume at-grade operation for conditions which are below Threshold 2; Locations which lie between Threshold 2 and Threshold 3 require Further Study to Verify At-Grade Feasibility; Locations which exceed Threshold 3 may require grade separation but further study may be accomplished to determine if there is a possible feasible at-grade solution.

In recognition of these points, we are recommending that the simplified nomograph presented in Figure A-3 should be used for Initial Screening as part of this policy.

Notes on Traffic Turning Data:

The Initial Screening is accomplished using “readily available” traffic volume data (existing and/or projected future). The analysis method specifies that the “highest per lane flow rate” should be used in applying the nomograph. The methodology does not address the issue of turning movements, especially left turns made from the parallel roadway with median running conditions which certainly conflict with LRT movements as do cross-street through traffic movements. In the event turning movement data is available to be incorporated into the analysis, the following methods are recommended for consistency:

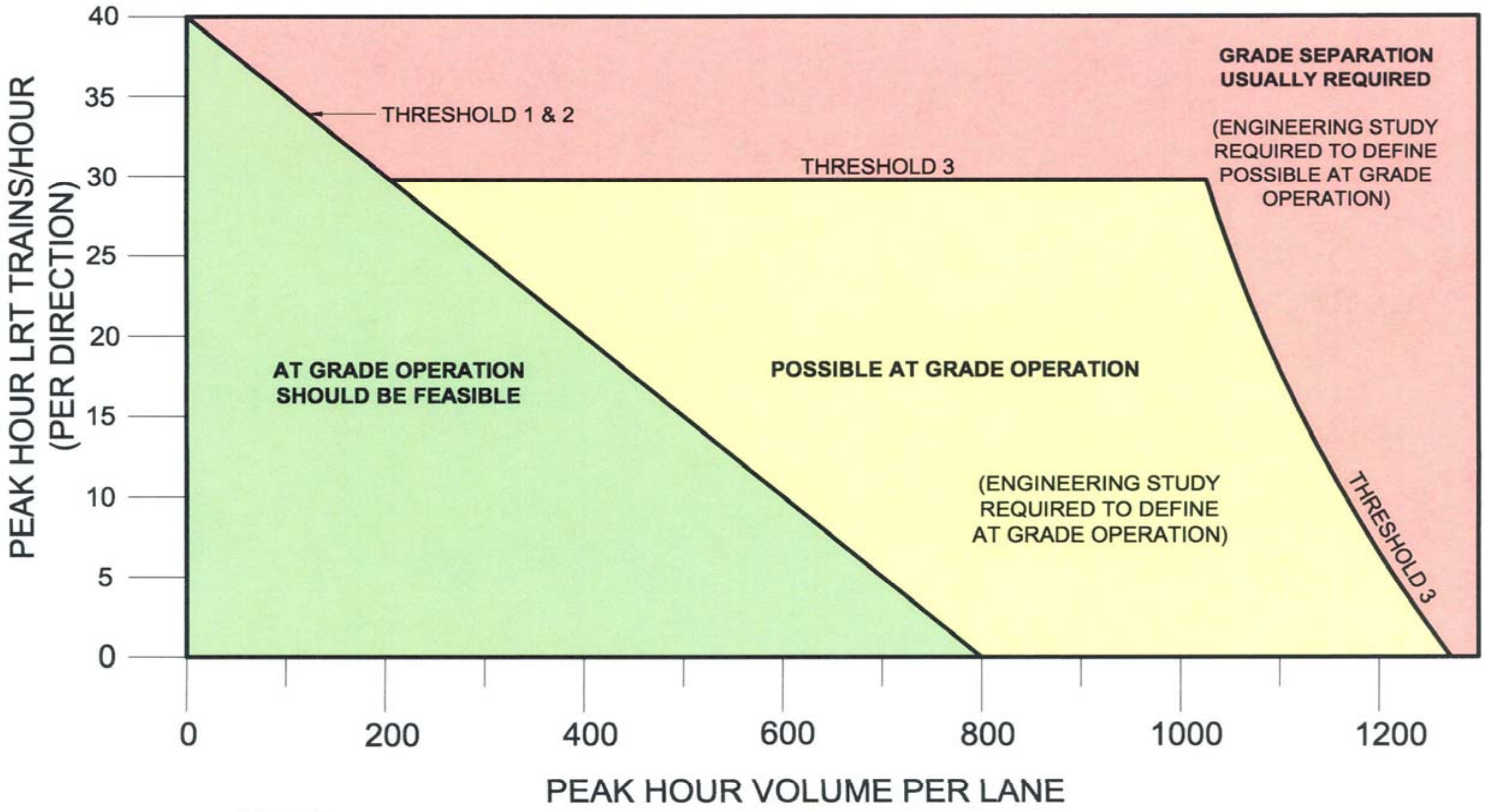
- Mid Block Crossing – LRT trackway crosses roadway between roadway intersections with no parallel traffic lanes – Use highest one-way hourly per lane flow rate for traffic crossing the tracks, as stated in the ITE IR.

- Side Running Crossing – LRT trackway runs parallel to roadway and crosses one leg of an intersection – Consider the maximum per-lane volume of either the approach flow or the departure flow on the leg containing the grade crossing.

- Median Running Crossing – LRT trackway runs within median of one roadway and the grade crossing occurs at an intersection with a cross street to that road – Identify the greater sum of through plus left-turn traffic on a per-lane basis coming from either of the two cross street approach legs lanes. In the event the left-turn from the parallel roadway is the principal movement, this volume may be considered in the analysis.

- Special Conditions – Multi-Leg Intersections with LRT crossing – Use the sum of the highest per lane traffic volumes for all movements that cross the LRT trackway independently (e.g., on separate traffic signal phases).

Figure A-3 – Recommended Initial Screening Evaluation Chart



NOTES:

- ROADWAY VOLUME IS PEAK HOUR, HIGHEST PER LANE FLOW RATE
- ADAPTED FROM INSTITUTE OF TRANSPORTATION ENGINEERS INFORMATIONAL REPORT, LIGHT RAIL TRANSIT GRADE SEPARATION GUIDELINES, 1992, THRESHOLD 1 AND THRESHOLD 2 COMBINED.

DETAILED DESCRIPTION OF ENGINEERING STUDY OF OPERATIONS AND SAFETY

The Operational Analysis is a six-step manual evaluation of the Level of Service of adjacent or co-incident traffic signal controlled intersections, queuing and other safety factors along with identification of impacts to rail operations including delays and patronage.

Selected topics of the analysis are addressed in more detail for the following points:

- Traffic Volumes Used for Analysis
- Queuing Analysis
- Controlling Intersection Level of Service
- Safety Analysis
- Evaluation of Impact of Pre-Emption on Progressive Traffic Movements

Traffic Volumes Used for Analysis

As noted in the Initial Screening methodology, the grade crossings would typically be checked for Opening Year and 20 Year Future traffic levels, during the am and pm peak periods or the period of highest traffic under the typical daily. For the Operational Analysis in the Detailed Analysis phase, the traffic volume assumptions should be reviewed and adjustments made if appropriate. For example, if the projected future year volumes are higher than the roadway capacity, they should be adjusted downwards to reflect network constraints.

Queuing Analysis

The following procedures are provided for the analysis of queuing:

- Computation of Influence Zone Queue – The influence zone queue is the queue which builds from an adjacent signalized intersection along the cross street towards the grade crossing. For isolated intersections, the average queue can be computed using the Webster formula:

  $N = q \times R/2$ OR $N = q \times (R/2 + d)$ (Use greater result)

  Where:

  N = Average number of vehicles in queue
  q = Peak period vehicle arrival rate (vehicles / second)
  R = Red time (seconds) [8]
  d = Average delay (seconds) [9]

  A peaking factor of 1.5 to 2.0 should be included to identify the maximum design queue that could occur during the peak period due to cycle-to-cycle variations in arrival rate.

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[8] Red time is determined by signal timing; typical values range from 40 to 60 seconds depending upon the total cycle length and amount of green time allocated to the cross street.

[9] Delay is indicated by the level of service – for LOS D the delay ranges from 35 to 55 seconds.

- <u>Computation of Crossing Spillback Queue</u> – The crossing spillback queue is the queue that builds back from the grade crossing towards an adjacent roadway-roadway intersection. The Webster formula can be used; for a gated crossing, the gate down time should be considered in lieu of the traffic signal red time. [10]

- <u>Evaluation of Cross Street Queues vs. Available Storage</u> – The extent of queuing along the cross street should be compared to the roadway geometry to determine whether either the crossing spillback queue is impacting an adjacent major intersection or if an adjacent major intersection is generating an influence zone queue which would impact the grade crossing. In the event crossing queues are spilling back, mitigation measures may be appropriate.[11] In the event the crossing is in the influence zone, queuing mitigation measures such as warning signs, pre-signals or signal progressions should be considered and, if the crossing is gated, the adjacent traffic signal should be pre-empted.

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[10] Typical crossing gate blockage time will be 34 to 45 seconds (refer to the guidance on evaluating *Impact of Pre-Emption on Progressive Traffic Movements* for a breakdown of typical times).

[11] E.g., provision of turn bays for movements approaching the grade crossing to allow parallel through traffic to continue unimpeded by traffic backing up from the grade crossing.

Controlling Intersection Level of Service

The controlling intersection is the signalized intersection at the grade crossing or along the cross street within the influence zone (as identified in Step 2) which is the most congested during the peak period. The Level of Service (LOS) of the controlling intersection provides an indication of the feasibility of transit priority solutions with traffic signal control at the grade crossing and whether the impact of operation as a gated crossing is feasible.

The ability of a roadway or intersection to accommodate vehicular traffic can be measured by calculating its LOS. LOS is a measure that describes traffic conditions at intersections, ranging from LOS "A" for free-flow or excellent conditions, to LOS "F" for roadways or intersections that are overloaded or operating above capacity. This measure is based upon the amount of stopped delay, measured in seconds per vehicle, a driver experiences within an intersection due to traffic congestion. This ratio can be determined for daily and peak periods. Peak hour delay calculations give the most accurate picture of the level of service of congestion experienced by a motorist. A complete description of the LOS designations is provided in Table A-1.

Table A-1 – Level of Service Criteria for Signalized Intersections

Level of Service	**Delay per Vehicle (secs)**	**Description of Traffic Conditions**	
A	≤ 10.0	Excellent	No vehicle waits longer than one red light and no approach phase is fully used.
B	> 10.0 and ≤ 20.0	Very Good	An occasional approach phase is fully utilized; many drivers begin to feel somewhat restricted within groups of vehicles.
C	> 20.0 and ≤ 35.0	Good	Occasionally, drivers may have to wait through more than one red light; backups may develop behind turning vehicles.
D	> 35.0 and ≤ 55.0	Fair	Delays may be substantial during portions of the rush hours, but enough lower volume periods occur to permit clearing of developing lines, preventing excessive backups.
E	> 55.0 and ≤ 80.0	Poor	Represents the most vehicles that intersection approaches can accommodate; may be long lines of waiting vehicles through several signal cycles.
F	> 80.0	Failure	Backups from nearby intersections or on cross streets may restrict or prevent movement of vehicles out of the intersection approaches. Tremendous delays with continuously increasing queue lengths.

Safety Analysis

Two recent studies of light rail grade crossing safety have been conducted by the United States Department of Transportation, Transit Cooperative Research Project (TCRP):

- Report 17, “Integration of Light Rail Transit Into City Streets,” 1996
- Report 69, “Light Rail Service: Pedestrian and Vehicular Safety,” 2001

Report 17 presents research and guidelines developed for lower-speed crossings not protected by automatic crossing gates, through a review of 10 LRT systems within North America. Report 69 provides research and guidelines for gated crossings and also has additional pedestrian crossing findings, through a review of 11 LRT systems through North America. Report 17 notes that locations with crossing gates have generally lower accident rates per mile compared to the low-speed on-street alignments. While the accident rate for gated, high-speed crossings is lower than the rate for lower speed signalized crossings, the percentage of collisions resulting in fatalities is greater for gated operation where the train operating speed exceeds 35 mph.

As part of the research presented in TCRP Report 17, the report identified and ranked 14 of the most common causes for collisions involving LRT trains at grade crossings where the LRV maximum operating speed was less than 35 mph. None of the top four highest ranked issues involved the choice of traffic signals or gates. The top four reasons were, in decreasing importance:

1. Pedestrians trespassing on side-aligned LRT rights-of-way where there are no sidewalks
2. Pedestrians jaywalking across LRT/transit mall rights-of-way after receiving unclear messages about crossing legality
3. Inadequate pedestrian queuing areas and safety zones
4. Two-way or contra-flow side-aligned LRT operations

Of the remaining 10 issues in the list of 14 highest concerns, some were attributed to the traffic signal operation at the intersection. However, mitigation for these issues can be provided by current LRT design practices.

For example, consider concerns ranked 5 and 6:

5. Motorists making illegal left turns across the LRT right-of-way immediately after termination of their protected left-turn phase,

   And,

6. Motorists violating red left-turn arrow indications when the leading left-turn signals phase is preempted by an approaching LRV

Both of these problems can be avoided if the left turn phase always comes up after the through phase (“lagging left turn”) so that the LRT always proceeds through the intersection on the through movement phase preceding the left turn arrow.

TCRP Report 69 presents a list of issues that contribute to collisions at grade crossings, where the crossings are controlled with gates. One of the major causes for collisions at gated crossings is that motorists drive around the lowered automatic gates. A variety of strategies including photo enforcement, education, four quadrant gates, and raised medians have been demonstrated to be effective at reducing accidents along gated crossings. Examples of effective treatments include photo enforcement and four quadrant gates along the MTA Metro Blue Line, where collisions have reduced dramatically since they have been installed. As described in TCRP Report 69, photo enforcement has reduced crossing gate violations by 92% and LRT-motorist collisions by 70% along the Blue Line. In addition, the installation of four-quadrant gates has reduced the number of motorists driving around or under the lowered gates by 94%.

Given that there are a wide range of safety mitigations and design features that can be incorporated into the design of an LRT alignment; substantial experience has been gained with treatments over the past decade; and, documentation of available measures and design treatments is readily available to designers. Although there are various methods for prioritizing grade separations that take safety factors such as exposure and site specific conditions into account, there are no quantitative safety evaluation methodologies in general use that incorporate warrants for LRT grade separations. Therefore each safety issue needs to be identified and reviewed in the context of the potential effectiveness of available mitigation. One notable exception is recurrent queuing across the tracks that cannot be managed or eliminated with traffic control techniques – in the event this condition is observed or predicted, then grade separation should be considered.

There may be additional site-specific conditions that warrant additional studies (e.g., heavy pedestrian movements, unusual geometries, etc.) If so, these studies should be accomplished in conjunction with the Detailed Analysis so the results can be considered in establishing the preliminary disposition as at grade or grade separated. For this reason, the safety analysis is included in this “detailed analysis” phase of study as part of the recommended policy procedure where site-specific considerations (including the conceptual design), as well as site-specific operational conditions (e.g., pedestrian volumes, queuing, etc.) are considered.

The factors presented in Table A-2 should be considered in a preliminary safety review. Table A-2 indicates potential mitigation for each identified safety concern. Engineering Study should be accomplished to determine which of the factors is a concern at the crossing, possible countermeasures, potential applicability, and effectiveness of potential mitigations.

An assessment of queuing can be accomplished either by observation of existing conditions and/or by computation of predicted queues using procedures defined in the operational analysis section.

The Engineering Study of safety features should determine whether effective mitigations are available to address identified safety concerns. If mitigation is not possible, then a grade separation should be considered.

Table A-2 – Safety Concerns and Potential Mitigation

Safety Concern	**Mitigation**
Traffic Queuing	Anti-Queuing Traffic Control Measures; Grade Separation if None Feasible
Approach and Corner Sight Distance	Supplemental Active Warning Devices Reduce Allowable Train Speed
Visual Confusion/Sign or Signal Clutter	Removal of Unnecessary Signs/Signals
Prevailing High Traffic Speed	Control Traffic Speed with Traffic Signal Control or Enforcement
Large Truck Percentage	Restrict Truck Traffic. Improve Signing or Traffic Signal Timing to Keep Trucks Off Tracks
Heavy Pedestrian Volumes	Channelization, Active Warning Devices and Pedestrian Control Devices, Traffic Control Officers for Events
School Access Route	Channelization, Active Warning Devices and Pedestrian Control Devices, Education, and Crossing Guards
Emergency Vehicle Route	Identify and/or Provide Alternative Route Provide Remote Notification of Crossing Status
Accident History	Remedy Specific to the Accident Cause
Gate Drive Around Potential	Photo Enforcement, Medians, Four Quadrant Gates
Delineation and Roadway Marking	Increase Contrast at Crossing or Improve Delineation
Traffic Control Observance	Install Active Signs. Increase Enforcement

Impact of Pre-Emption on Progressive Traffic Movements

Table A-3 indicates an evaluation chart to be used to evaluate the potential impact of traffic signal pre-emption on progressive traffic movements. The evaluation is based upon the degree of cross street traffic progression required to be present and the adjusted volume/capacity (V/C) ratio of the controlling intersection, as further explained in the table notes. On the following page, the analysis procedure for determining the adjusted V/C is provided. An alternative approach would be to develop a micro-simulation model, however, the policy suggests that such modeling would only be accomplished as part of Milestone 3, verification effort.

Table A-3 – Evaluation Chart

Adjusted Volume/Capacity Ratio Of Controlling Intersection (1)	Quality of Cross Street Progression (2)		
	Little or No	Moderate	High
V/C < 0.85	OK	OK	Marginal (3)
0.85 <= V/C <= 0.95	OK	Marginal (3)	Fail (4)
V/C > 0.95	Marginal (3)	Fail (4)	Fail (4)

Notes:

(1) “Controlling Intersection” is the cross street intersection within ½ mile proximity to the LRT grade crossing (including the LRT intersection for median-running conditions) which has the highest degree of saturation; the V/C of the controlling intersection should be adjusted for impact to non-compatible phase (see text for analysis procedure).

(2) Based upon “Arrival Type” definitions as provided in Highway Capacity Manual 2000: “High” is arrival type 5 or 6, “Moderate” is arrival type 4, and “Little or No” is arrival types 1 – 3.

(3) Indicates pre-emption results in measurable impact to cross street. Operation with pre-emption subject to engineering review of need for traffic progression and impact to LRT if pre-emption not provided. Alternative at-grade operation with green band or priority control should be feasible provided there are traffic signal phases that are compatible with the LRT movement at this location.

(4) Indicates pre-emption results in significant adverse impact to cross street; extenuating circumstances needed to justify use of pre-emption provided traffic progression is needed on cross street. Alternative at-grade operation with green band or priority control may be feasible provided there are traffic signal phases that are compatible with the LRT movement at this location.

Four analysis steps are required:

Step 1 – Identify Useable Green Ratio for Non-Compatible Phase
Step 2 – Adjust Useable Green Ratio to Reflect Train Frequency
Step 3 – Evaluate Base Case Volume/Capacity of Controlling Intersection
Step 4 – Apply V/C Adjustment

Required input data includes:

- Geometry and projected traffic volumes at controlling intersection
- Likely signal timing plan at controlling intersection with LRT
- Train frequencies based upon proposed or potential rail operating plan
- Likely rail operating speeds through the grade crossing
- Likely rail consist length based upon number of cars and car type
- Roadway width at grade crossing

Step-by-step procedure (refer to derivations in technical support following procedure):

Step 1: Identify Useable Green Ratio for Non-Compatible Phase

Useable Green Ratio: GC_{NC} (Represents proportion of signal cycle at controlling Intersection that is useable for non-compatible roadway movements when grade crossing is blocked by gates)

Computed by averaging "Worst Case" condition (e.g., gate blockage during non-compatible signal phases) and "Best Case" condition (e.g., gate blockage during compatible signal phases)

Where:

GC_{NC}: Green + Yellow time / Cycle time for non-LRT compatible movements at controlling intersection

GC_C: GC for compatible movements; $GC_C = 1.0 - GC_{NC}$

GC_T: Gate Down time / Cycle time representing proportion of cycle that crossing gates will block the cross street

Note: Computation of GC_T – Gate Down Time / Total Cycle Time:

This factor should be computed by dividing total estimated gate down time at grade crossing by typical signal cycle time at controlling intersection in seconds, with the gate down time including all of the following:

- 20 seconds minimum warning time (including activation of flashing lights and lowering of crossing gate)

- 5 – 7 seconds (typical) train passage time (computed using typical train length and average speed through grade crossing)
- 2 – 3 seconds (typical) train clearance time (computed based upon street width and average speed through grade crossing)
- 2 – 3 seconds (typical) allowance for lag in detection of train "checkout" after grade crossing is cleared
- 5 – 7 seconds (typical) lag time for gates to start up and cars to enter crossing area
- Added allowance of 5 seconds (specific number to be based upon anticipated conditions at specified crossing) additional gate down time for random delay in arrival of train at crossing after activation of gates due to factors such as upstream operational conditions, departure from near-side station at reduced speed, etc.

"Best Case" GC_1 – Condition When Crossing Gates Down During LRT Compatible Phase

If $GC_T > GC_C$ then GC_{NC} is reduced by the amount to which GC_T exceeds GC_C and the resulting capacity factor is:

$$GC_1 = GC_{NC} - (GC_T - GC_C)$$

Otherwise, if $GC_C > GC_T$ then there is no impact to GC_{NC} since the gate blockage occurs during the compatible phase and the resulting capacity factor is:

$$GC_1 = GC_{NC}$$

"Worst Case" GC_2 – Condition When Crossing Gates Down During Non-LRT Compatible Phase

If $GC_{NC} > GC_T$ then the remaining amount of GC_{NC} is the difference between GC_{NC} and GC_T and the resulting capacity factor is:

$$GC_2 = GC_{NC} – GC_T$$

If $GC_{NC} < GC_T$ then the entire phase is blocked by the crossing gates; therefore

$$GC_2 = 0$$

“Average Case”

Assuming train arrivals are random with respect to the traffic signal, the average available signal split to serve the non-compatible traffic is approximately the average of the two conditions as noted above, e.g.,

$GC_{NC} = (GC_1 + GC_2) / 2$

Step 2: Adjust Useable Green Ratio to Reflect Train Frequency

When no train is present, there is no capacity impact; the likelihood of this is 1.0 minus the likelihood of a train being present during a given cycle. Therefore, the weighted capacity factor can be computed by adding the two impacts with the likelihood weights, e.g., if

L_T: Likelihood of train impact in signal cycle computed as trains / hour (both ways) divided by number of traffic signal cycles per hour at controlling intersection

And,

GC_{NC}: Average Capacity Factor on non-compatible green proportion with gates blocking crossing, computed as described in Step 1.

Then the weighted average is computed as the sum of the following conditions:

No Train	1.0 (no impact) x (1 - L_T)
Plus Train:	GC_{NC} (train impact) x L_T

E.g.,

$F_T = 1.0 - L_T + (F_{NC} \times L_T)$

Step 3: Evaluate Base Case Volume/Capacity of Controlling Intersection

Controlling Intersection Volume/Capacity Ratio, Without Impact of Grade Crossing:

Volume/Capacity Ratio = V/C_0

This ratio should be computed using industry-accepted practice or software (e.g., Highway Capacity Manual or “Synchro” software). The evaluation should be performed using projected volumes with LRT and base case geometry but no adjustment to the computed V/C should be made for the “with LRT” condition since this procedure defines the adjustment.

Step 4: Apply V/C Adjustment

Adjusted V/C of Controlling Intersection with grade crossing:

$V/C_{ADJ} = V/C_0 / F_T$

HYPOTHETICAL EXAMPLE SHOWING USE OF FORMULAS

Assume the following conditions:

Gate Down Time

20 seconds warning time
07 seconds passage time
03 seconds clearance time
02 seconds checkout time
05 seconds gate up / car startup
05 seconds random arrival delay

42 seconds effective gate blockage time

Train Frequency

24 trains/hour

Signal Cycle

100 seconds

Volume to Capacity

0.60

Non-Compatible Green Time

55 seconds

Then

$GC_T = 0.42$

$GC_{NC} = 0.55$; $GC_C = 0.45$

"Best Case" Useable Green Ratio

Since $GC_T < GC_C$ then $GC_1 = 0.55$

"Worst Case" Useable Green Ratio

Since $GC_{NC} > GC_T$ then $GC_2 = GC_{NC} – GC_T = 0.55 - 0.42 = 0.13$

"Average Case" Capacity Factor

$GC_{NC} = (0.55 + 0.13) / 2 = 0.34$

Train Weighted Capacity Factor

L_T = 24 trains/hour / 36 cycles/hr = 0.67

$F_T = 1.0 - L_T + (GC_{NC} \times L_T) = (1.0 – 0.67) + (0.34 \times 0.67) = 0.56$

Adjusted V/C

$V/C_{ADJ} = \quad V/C_0 / F_T = 0.60 / 0.56 = 1.07$

Comment:

This example shows that the impact of 24 pre-emptions per hour is sufficient to raise the V/C at the controlling intersection from 0.60 to 1.07 (e.g., elevating LOS B to LOS F) with nominal cycle length and splits. Using the methodology, traffic operational performance would be considered "FAIL" if a moderate or high degree of progression is present, or required to be maintained, on the cross street.

Therefore, under the proposed methodology, extenuating factors would need to be considered in order to accept pre-emption at this location.

An alternative at-grade treatment involving operation of the train through the crossing using green band type of operation may be feasible provided there are intersection phases that are compatible with the LRT movement.

Given the favorable base (unadjusted) LOS of the intersection, it may be possible to operate under traffic signal control with priority as well (with or without use of a background green band).