Metropolitan
Transportation
Authority

One Gateway Plaza
Los Angeles, CA
90012-2952

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PLANNING AND PROGRAMMING COMMITTEE
SEPTEMBER 17, 2003

SUBJECT: **GRADE CROSSING POLICY FOR LIGHT RAIL TRANSIT (LRT)**

ACTION: **APPROVAL OF LRT GRADE CROSSING POLICY AND SPECIFIC GRADE SEPARATION AND SAFETY MEASURES FOR THE EXPOSITION LIGHT RAIL TRANSIT CORRIDOR**

RECOMMENDATION

APPROVE:

A) The attached MTA Grade Crossing Policy for Light Rail Transit (Attachment A);

B) Addition of grade separations at the following Exposition Corridor crossings as part of preliminary engineering per the attached Evaluation of Exposition LRT Project With Proposed MTA Grade Crossing Policy (Attachment B):

- La Brea Avenue
- La Cienega Boulevard

C) Per the analysis in Attachment B, consider for inclusion in the Exposition LRT project scope and budget, supplemental grade crossing safety devices for traffic and/or pedestrian safety, at a minimum at the following locations:

- Vermont Avenue (USC/Exposition Park)
- Western Avenue (Foshay Middle School)
- Arlington Avenue (Traffic Safety)
- Gramercy Place/Rodeo Road (Traffic Safety)
- Crenshaw Boulevard (West Angeles Cathedral)
- Farmdale Avenue (Dorsey High School)

ISSUE

In June 2001, the Board approved a Locally Preferred Alternative (LPA) for the Exposition Transit Corridor that defined the project as light rail transit from Downtown Los Angeles to Culver City (9.6 miles). The project was defined to be predominantly at-grade. In a companion motion, however, the Board directed staff to undertake an evaluation of all grade crossings along the Exposition line to determine if grade separations or supplemental safety features would be warranted.

An analysis of potential grade separations was included in the scope of the preliminary engineering and environmental studies that are currently underway. A particular focus of this analysis has been to define systemwide criteria that can be used for future light rail projects in the County. A secondary purpose has been to apply this policy to the Exposition Corridor to determine the number of grade crossings that require grade separation and/or supplemental grade crossing safety devices.

POLICY IMPLICATIONS

The MTA does not currently have a policy on light rail transit grade separations. Approval of a policy would provide a standard by which future corridors will be able to more effectively plan for their projects.

OPTIONS

The Board could choose not to approve the proposed Grade Crossing Policy for LRT. Staff is not recommending this option, because the proposed Policy will provide MTA with good direction in future planning efforts. Also, the sources utilized to develop the proposed policy reflect the current "best practices" and provide a solid foundation for the proposed Policy. The proposed policy, prepared for the MTA by Korve Engineering, is based on guidelines taken from different sources including the Institute of Transportation Engineers, the Dallas Area Rapid Transit system and the California Public Utilities Commission. Specific safety guidelines were adapted from the Transportation Cooperative Research Board (TCRP) and the MTA Risk Management Department.

For the Exposition LRT project, the Board could direct that staff include additional grade separations into the project. Staff is not recommending this option, because there is a good possibility that at-grade operation of the Exposition line will be possible at locations other than La Brea and La Cienega. With the exception of La Brea and La Cienga, the proposed Policy calls for at-grade designs at crossings to proceed at this time. If however, the continuing preliminary engineering work later indicates that at-grade operation is infeasible at any additional location, staff will return to the Board for direction with specific conditions and recommendations at such crossings.

The Board could disagree with staff's conclusion to consider supplemental safety devices at the six listed intersections. This is not recommended because the analysis of grade crossings along the Exposition line identified either particular pedestrian safety needs (such as schools or religious institutions) and/or traffic safety needs that could be addressed by supplemental safety devices.

FINANCIAL IMPACT

Costs for the recommended grade separation at La Cienega have been included in the current Exposition Light Rail Transit cost estimate of $505 million. These costs do not include the proposed grade separation at La Brea. Costs for the proposed addition of a grade separation would be developed as a part of preliminary engineering and added to the project budget.

Costs for the "best practices" safety features as appropriate to each crossing have been included in the current Exposition Light Rail Transit cost estimate of $505 million. These include, where appropriate, quad gates or raised medians at gated crossings, pedestrian gates, special striping, signage, tactile strips and fencing. Current "best practices" do not currently include supplemental safety features such as embedded crosswalk lighting, fiber optic warning signs and photo enforcement camera systems. Costs for the additional safety features would typically range from $85,000 to $235,000 per crossing, depending upon the specific conditions at each location. The specific supplemental safety feature for each of the six intersections and the cost would typically be determined during the later phases of preliminary engineering.

DISCUSSION

Grade Crossing Policy for LRT

The purpose of the proposed Grade Crossing Policy for LRT is to identify and address all of the principle concerns and trade-offs involved in grade separation and safety decision-making. The proposed policy recognizes 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 policy can dictate the ultimate solution. The proposed Policy can, however, prioritize decision-making about grade separations and safety measures so that budget decisions about project cost can be made earlier in the process, when they have less impact on the project funding commitments and construction schedule.

In general, the proposed Policy follows a three-phase process: (1) Initial Screening; (2) Detailed Analysis; and (3) Verification. The Initial Screening relies on traffic volume and train frequency to sort the crossings into at-grade, grade-separated or further analysis required categories. Crossings requiring further analysis move into the detailed analysis phase and are studied for intersection geometry, queuing, intersection level of service and other issues. Based on these studies, these crossings are then given a preliminary disposition of either at-grade or grade separation. In the verification phase, the PE level of design is completed and more detailed traffic volume and safety information may be compiled, in consultation with local jurisdictions, the PUC and local communities. Final determinations can be made at this point.

Exposition LRT Grade Crossing Analysis

Korve Engineering applied the methodology described above through the Initial Screening and Detailed Analysis phases, to the crossings along the Exposition LRT project between Vermont

Avenue and Washington Boulevard (the Downtown to Exposition Park segment is being evaluated separately and this analysis will be provided later as part of the Downtown Branching Analysis).

Korve evaluated the 14 highest-volume crossings and determined, after phase 1 analysis that one would require grade separation based on traffic volumes and train frequencies (La Cienega). Six other locations were taken into the Phase 2 more detailed analysis. Out of this analysis, La Brea was recommended for grade separation based on queuing problems (cars stopped at the traffic light backing up into the right-of-way). For the other five, more detailed analysis indicated that at-grade solutions were possible based on expected train speeds at those locations, acceptable solutions to traffic/traffic safety issues, expected Levels of Service at the intersections and understanding that partial rather than full preemption was acceptable at several intersections.

At several crossings, Korve and the preliminary engineering consultant team identified the need to evaluate incorporation of special safety provisions above and beyond current "best practices". These additional safety provisions could include illuminated pavement lighting, fiber optic warning signs and photo enforcement camera systems and special planning of traffic lights. These would be in addition to the current best practices, which can include quad gates or raised medians at gated crossings, cantilever flashers, pedestrian gates, fencing, and improved streets and sidewalks. The additional safety devices are described more fully in Attachment C.

The reasons that supplemental safety features are being recommended for consideration are as follows:

- **Vermont Avenue**: This crossing has high pedestrian activity because of the close proximity of the University of Southern California and numerous institutional, recreational and religious institutions in the vicinity of Exposition Park.

- **Western Avenue**: This crossing is adjacent to Foshay Middle School.

- **Arlington Avenue**: The safety analysis for this crossing indicated that the Rodeo Road intersection south of the track way should be designed to act as a pre-signal to limit the likelihood that cars would be queued across the tracks.

- **Gramercy Place/Rodeo Road**: The safety analysis for this crossing identified the need for further study of the impact of the angled crossing and complex intersection where Exposition Boulevard branches for Rodeo Road. The selection of appropriate traffic control and traffic safety measures will be required for successful at-grade operation.

- **Crenshaw Boulevard:** This crossing has high pedestrian volumes at certain times due to the close proximity of West Angeles Cathedral.

- **Farmdale Avenue**: This crossing has high pedestrian volumes at certain times due to the close proximity of Dorsey High School.

NEXT STEPS

Staff will incorporate recommendations approved by the Board into preliminary engineering for the project and proceed with validation of these recommendations with the City of Los Angeles, Culver City and the Public Utilities Commission.

ATTACHMENTS

Attachment A	Draft MTA Grade Crossing Policy for Light Rail Transit
Attachment B	Exposition Transit Corridor- Grade Crossing Evaluation in Accordance with Draft MTA Grade Crossing Policy Executive Summary
Attachment C	Exposition Transit Corridor- Review of At-Grade Crossing Safety Devices

Prepared by: David Mieger, Director
Westside Area Planning Team

Steve Brye, Project Manager
Exposition LRT Project

James L. de la Loza, Executive Officer
Countywide Planning and Development

Roger Snoble
Chief Executive Officer

ATTACHMENT A

Grade Crossing Policy for Light Rail Transit

Draft Proposed Policy
September 3, 2003

Metropolitan Transportation Authority

PURPOSE

The Grade Crossing Policy is intended to provide a structured process for the evaluation of potential grade separations vs. at grade operation along light rail lines. The policy recognizes the operational and safety issues of at-grade versus grade-separated solutions as well as the institutional and monetary implications. 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.)

GRADE CROSSING REVIEW PROCESS

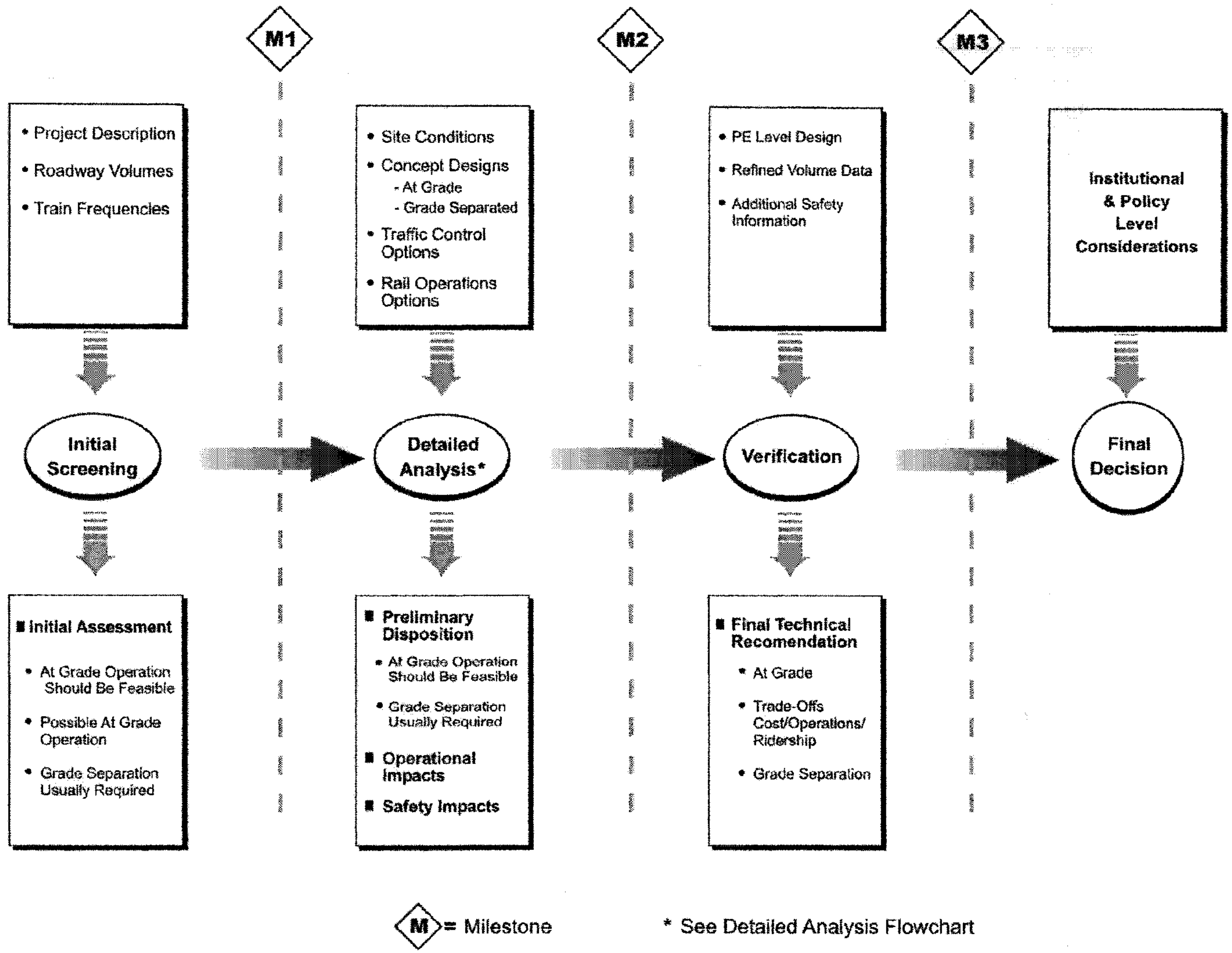
Figure 1 illustrates the overall review process. The policy includes up to three sequential phases of review and three corresponding Milestones would take place before arriving at the "Final Decision" on a crossing:

- Milestone 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".

- Milestone 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 due to priority control. Provides more refined assessment of feasibility of at grade operation and also identifies operational trade-offs between roadway traffic 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 be operated at grade versus grade-separated.

- Milestone 3 – Verification – 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. It may also include refinement of projected traffic volumes and validation of traffic and rail operations using simulation modeling. Finally, it may include additional effort on safety issues and countermeasures. At the conclusion of this milestone, it is expected that all technical studies will have been completed leading to a final recommendation by MTA for the crossing configuration.

Figure 1 – Light Rail Roadway Crossing Review Process



- Final Decision – Final disposition of the crossing configuration based upon all of the preceding technical analysis, engineering studies, and agency consensus building. Third party requirements may dictate the requirements for the crossing configuration.

The boxes across the top of Figure 1 shows the required inputs for each of the analysis phases and the boxes across the bottom of the chart indicate the information which is available following each step in the process.

After the technical studies within each of the three phases have progressed to a point where the draft results can be shared, MTA should brief stakeholders (e.g., local government representatives and the California Public Utilities Commission staff) on the tentative conclusions. It is expected that, to the greatest degree possible, MTA would incorporate review comments with an objective to arrive at a technical consensus on the analysis as early as possible in the process to minimize the total effort and cost of determining the configuration of the crossings as appropriate given the trade-offs of the cost of the alternatives (e.g., additional study may be appropriate if a costly grade separation can be avoided with an acceptable at grade design.)

In particular, it is expected that the grade crossing review process will have accomplished Milestone 2 or Milestone 3 (if required) prior to the conclusion of preliminary engineering and establishment of a firm construction budget for an LRT project.

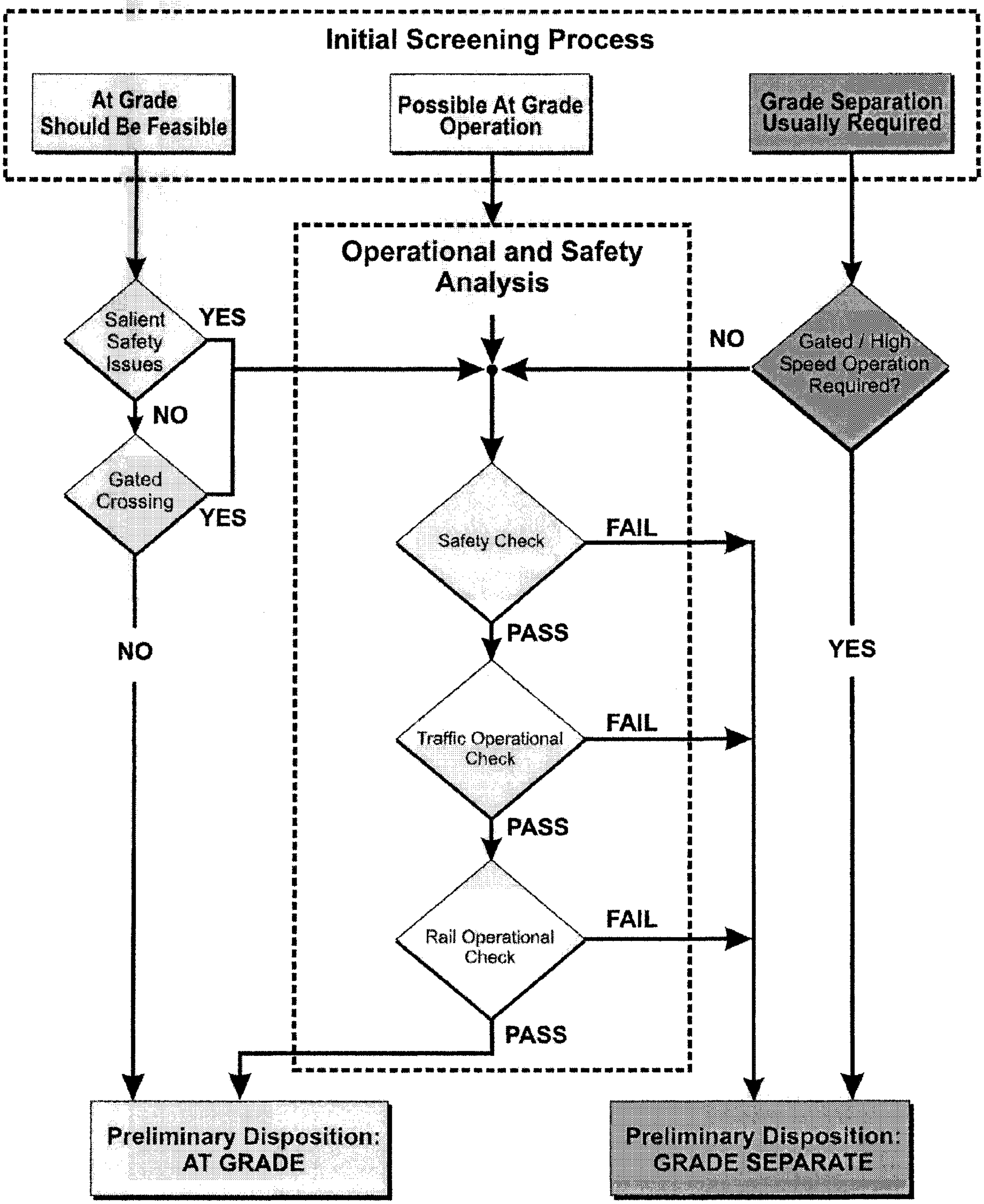
GRADE CROSSING REVIEW METHODOLOGY

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 Milestone 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 Milestone 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 Milestone 2.

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

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

Figure 2 – Evaluation Flowchart



MILESTONE 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 volumes and the 20-year forecast volumes, if available. If these are not available, existing volume data factored to a future year may be used.
- Train Frequencies – The desired headways for train operation need to be identified. If operations planning has not been accomplished, train frequencies should be based upon comparable lines, or 6- minute headways (10 trains per hour each direction) can be assumed as a nominal frequency.

Methodology – Initial Screening:

Plot each roadway crossing on the Initial Screening Chart (Figure 3) to determine which of the three zones the crossing lies within. (Refer to the "Notes on Traffic Turning Data" in Appendix A for recommended handling of left-turn movements, if available.).

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, since existing traffic counts are subject to day-to-day fluctuation and forecasts are estimates only.

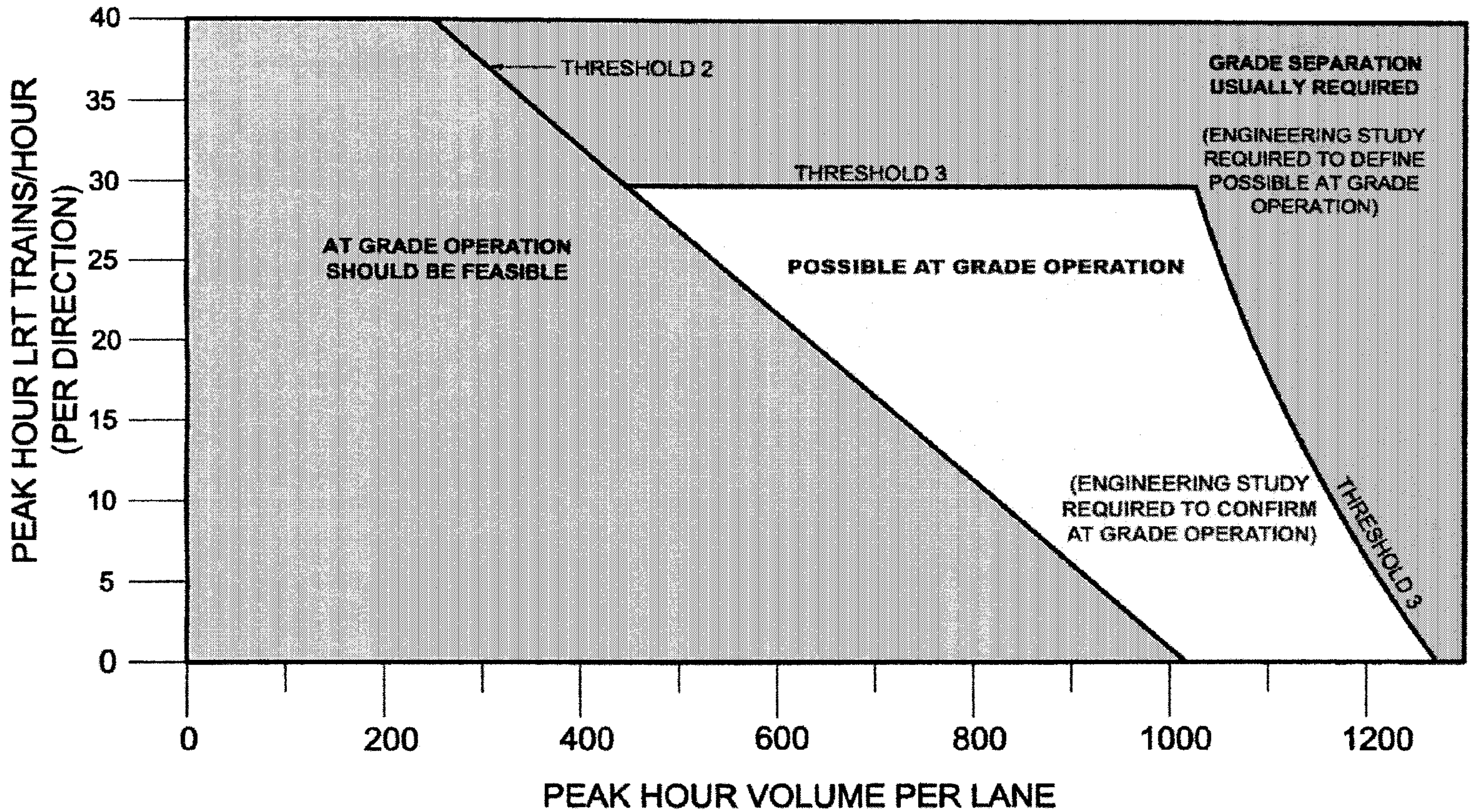
Results – Initial Screening:

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

At this point in time MTA should share the results of the Initial Screening with third parties that may have comments on the data and 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.

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 2 AND THRESHOLD 3 ONLY.

MILESTONE 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 includes 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.

  From an operations perspective, considerations include the approach speeds of trains and roadway vehicles, accident history and observed risky 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.

- 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 concept design should identify the proposed method of traffic control (e.g., gates or traffic signal with stop bars located).

- Traffic Control Options – 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 / 56 kph operation with traffic control using automatic crossing gates or (2) lower speed (35 mph / 56 kph 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]

  If the crossing is signalized, 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:

[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.

- At Grade – If the Initial Screening was *"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, "high speed" crossing with pre-emption of adjacent traffic signal (if present), 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 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 were 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 co-incident traffic signal controlled intersections, queuing and other safety factors along with identification of impacts to rail operations including delays and patronage. (Refer to Appendix A for a more detailed description of the process.)

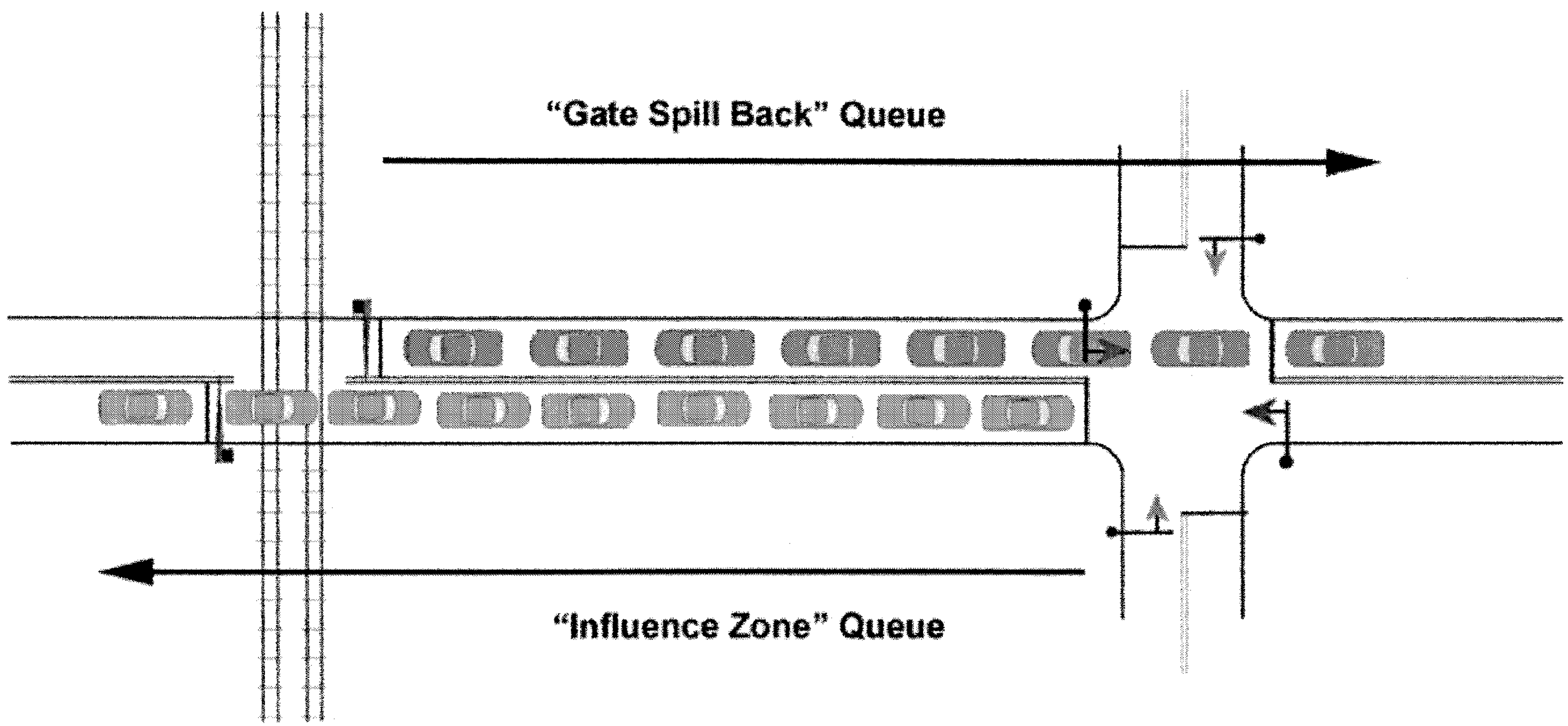
1. Identify Operational Volumes – Review the traffic volume assumptions and make adjustments if appropriate.

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 back from the grade crossing 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).

Figure 4 – Grade Crossing Queues



5. 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.)

6. Safety Analysis

   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 questionable in order to determine whether adverse safety conditions, in conjunction with adverse operational conditions, would suggest 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, 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.[1]

   The factors presented in Table 1 should be considered in a preliminary safety review. Table 1 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.

   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.)

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

Table 1 – 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
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 mitigations are not available to address safety concerns to adequate level.

- **Traffic Operations Check**

  Pass- (1) Intersection is at a level of service (LOS) A-D; or (2) Intersection is a LOS E-F but signalized crossing with Green Band Operation (little or no transit Priority) is acceptable.

  Fail – Intersection is at LOS E-F with gates/pre-emption or traffic signal with Priority (e.g., green band operation with little or no priority is unacceptable).

  The following is a fuller explanation of the Traffic Operations Check:

  Gated Crossings / Level of Service A-D – At locations which are proposed as gated, if the LOS of the controlling intersection is A, B, C, or D (e.g., acceptable operations), then the roadway network should be able to absorb the impact of crossing gate operation and pre-emption of adjacent traffic signals within the influence zone (if present).

  Signalized Crossings / Priority Strategy / Level of Service A-D – At locations which are proposed as traffic signal controlled, and the LOS of the controlling intersection is A, B, C or D (e.g., acceptable operations), then a priority strategy should be identified and the crossings should be able to operate at grade.[1]

  Signalized Crossings / Green Band Operation Acceptable – In the event a timing plan compatible with roadway traffic patterns can be identified that provides a means to progress trains through a number of intersections without stopping (or if the delay impact at an isolated intersection is small enough to allow LRV operation with little or no transit priority), then operation within a fixed background timing plan and little or no transit priority may be acceptable. [2]

[1] The priority strategy may be "partial priority" providing an early green or holding a green phase (up to a specified number of seconds) for the LRT train, or it may be "full priority" allowing additional techniques such as greater split modification with the "early green" and "green hold" techniques as well as other methods such as omitting conflicting phases or serving the LRT phase out of the normal sequence.

[2] Evaluation of the feasibility of green band operation should include identifying all of the traffic signals which would operate as a "group", the approximate "splits" between north-south and east-west timing, the basic concept of the "offsets" provided in the plan, and the points where the LRT train may need to "hold" to wait for the "green band".

At locations where the Detailed Analysis indicates LOS E-F for the controlling intersection (and green band operation is not desirable), or for gated locations where the Initial Screening indicated grade separation would be likely, 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., do 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

When the Detailed Analysis has progressed to a point where the results can be shared, it is appropriate to provide the draft findings to third parties that may have comments on the data and findings. At this point in time, the scope of further efforts under the Verification Phase should be addressed.

MILESTONE 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 at grade or grade-separated operation. In particular, the Verification Phase may include either or both of the following:

- 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 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.

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 the 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.

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

The final decision on the crossings will be based upon all of the technical input into the process including the Final Technical Recommendation; however, the policy recognizes that the ultimate decision will involve institutional consideration of the proposed crossing treatments and may require third party approvals or agreements from involved cities and state-level agencies such as the California Public Utilities Commission and Caltrans.

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)[1] 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.[2] 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.[3]

In addition to the research, Korve Engineering, Inc. staff experience in LRT and grade crossing safety and operational studies [4, 5] 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
- Operations and Safety Engineering Study – More detailed discussion of selected key topics including traffic volumes, queuing analysis, level of service, and safety studies

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[1] Mid-City/Westside Transit Corridor Draft EIS/EIR. SCH No. 2000051058. Los Angeles County Metropolitan Transportation Authority. Los Angeles, CA. April 6, 2001.
[2] ITE Technical Committee 6A-42. Light Rail Transit Grade Separation Guidelines. Institute of Transportation Engineers, Washington, D.C., March 1992.
[3] 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.
[4] 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.
[5] 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.

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 through a signalized intersection.

- 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.

- 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.

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

- Pre-emption – 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 mass 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.

- Priority or Priority Control – 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:

  - Full Priority – 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.

  - Partial Priority – 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.

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

- Split – 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 nomograph 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

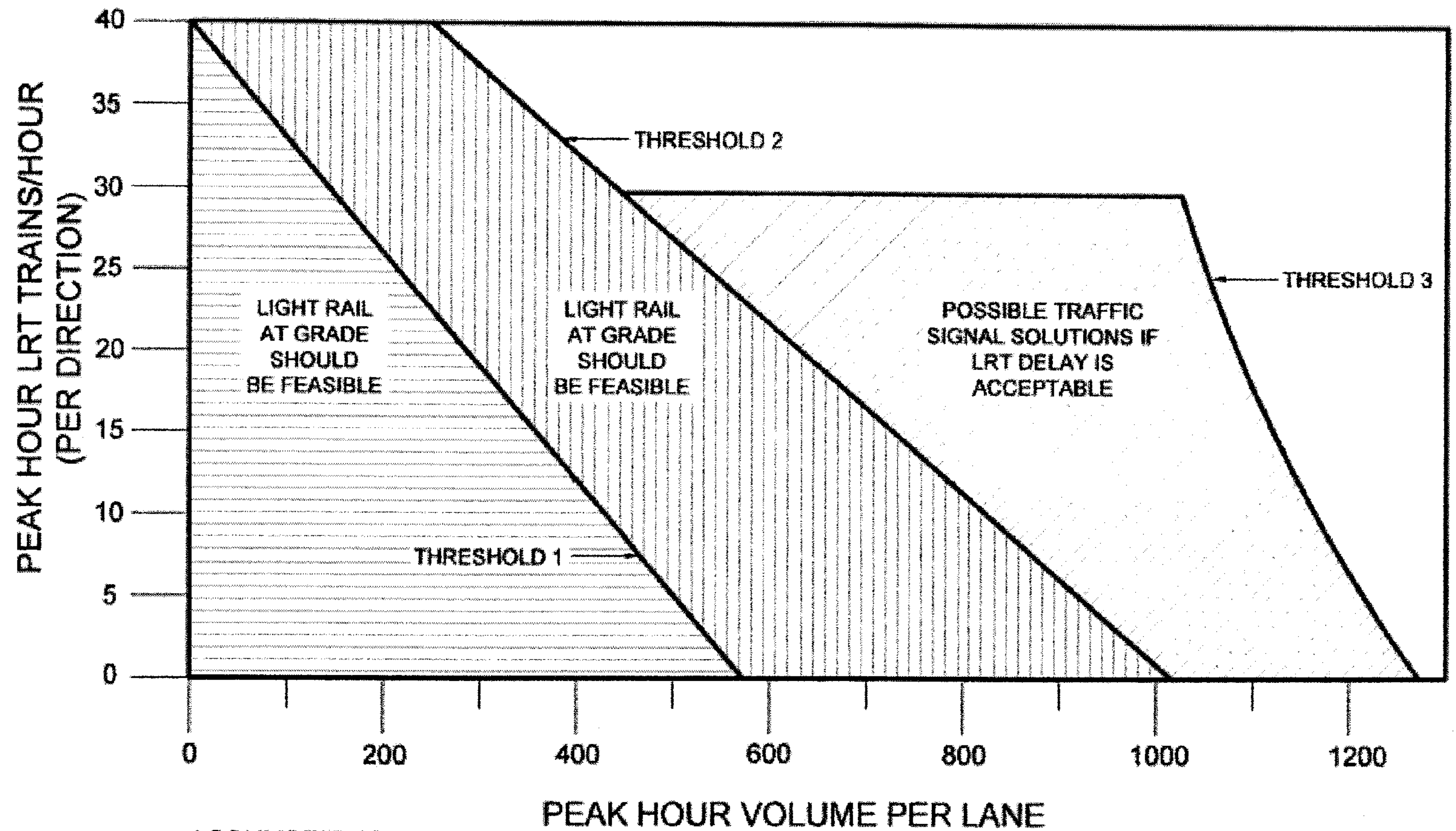
As stated in the Guidelines, Threshold Line 1 is drawn using the most conservative assessments and operational assumptions in estimating intersection LOS. Threshold Line 2 is drawn using less conservative assumptions and analytical techniques. The areas below and to the left of Line 1 are the combinations 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, "Threshold 2" 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:

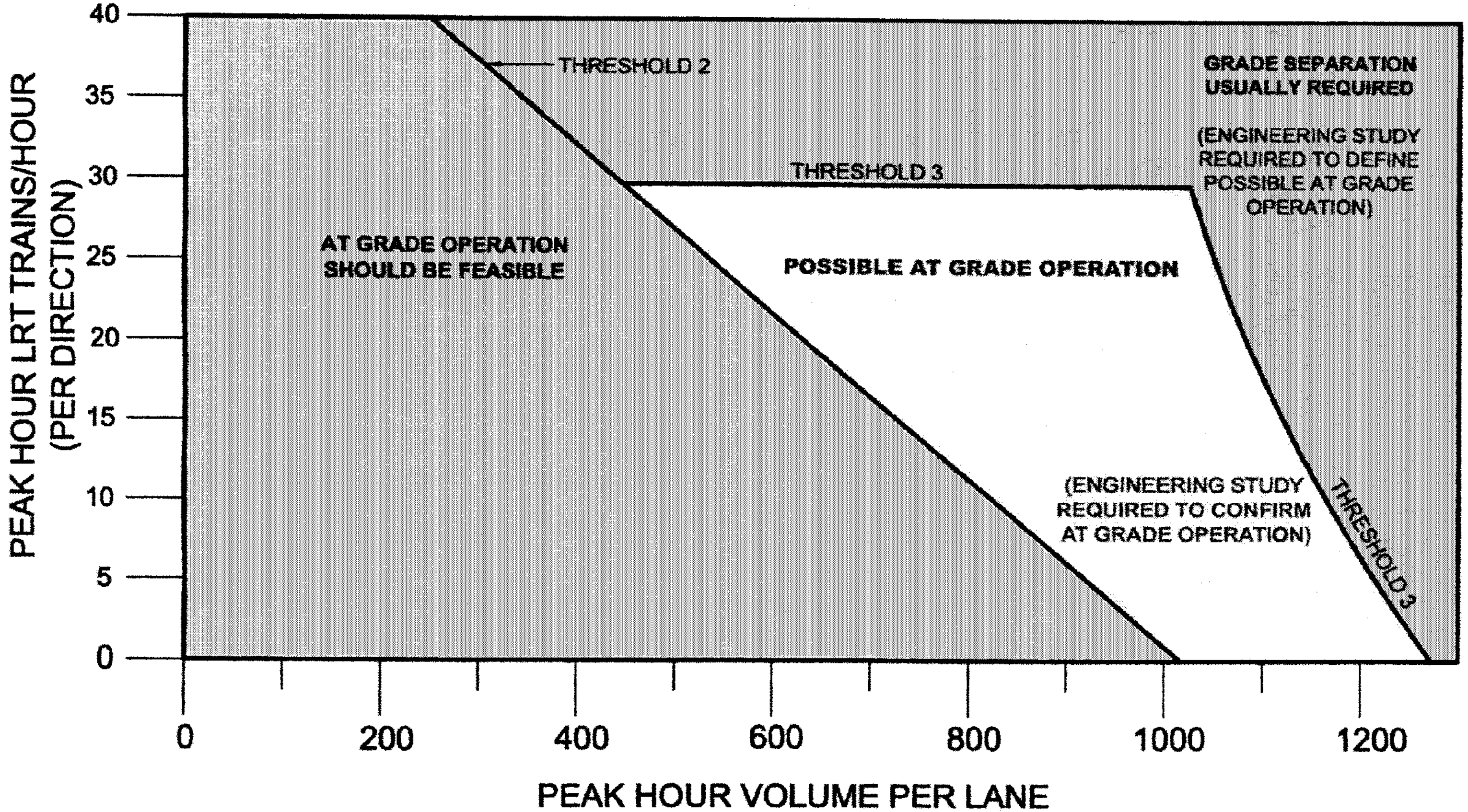
- Threshold 2 Utilized in Lieu of Threshold 1 – Threshold 2 is a linear equation which varies from about 1,000 vehicles per hour with no trains to 250 vehicles per hour per lane with 40 trains per hour each direction (90-second headways); for typical LRT operation of 10 trains per hour, the corresponding roadway volume limit is approximately 800 vehicles per hour per lane (peak flow direction).

- Gated, Higher Speed Operation (Greater Than 35 mph / 55 kph) – 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 / 55 kph 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-2 should be used for Initial Screening as part of this policy.

Figure A-2 – Recommended Initial Screening Evaluation Matrix



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 2 AND THRESHOLD 3 ONLY.

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 then add the greater per-lane left-turn volume from the parallel roadway. If there are dedicated lanes for left turns made from the cross street, then use the greatest per lane volume of either the through movement or left turn movement from either side of the trackway for cross street traffic.
- 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).

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

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, am and pm peak periods. 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) [1]
  d = Average delay (seconds) [2]

  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.

[1] 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.
[2] Delay is indicated by the level of service – for LOS D the delay ranges from 35 to 55 seconds.

- Computation of Crossing Spillback Queue – 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. [1]

- Evaluation of 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. In the event crossing queues are spilling back, mitigation measures may be appropriate.[2] 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.

[1] Typical crossing gate blockage time will be 35 seconds (20 seconds advance warning time plus 7.5 seconds for 3-car train passage at 20 mph plus 7.5 seconds crossing gate recovery).
[2] 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, substantial documentation of available measures and design treatments is readily available to designers, therefore it is difficult to identify specific numeric thresholds for grade separation based purely on safety concerns.[1] Therefore, each safety issue needs to be identified and reviewed in the context of the potential effectiveness of available mitigation.

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.

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

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 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
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

ATTACHMENT B

Evaluation of
Exposition Light Rail Transit Project
with
Proposed MTA Grade Crossing Policy

Prepared by:

Korve Engineering
September 2003

Executive Summary

OVERVIEW

This report summarizes the initial screening and preliminary analysis of road crossings along the Exposition Light Rail Transit Project (Expo LRT) and provides initial recommendations regarding which LRT road crossings may be operated at grade versus those crossings for which grade separations are recommended.

The findings in this report were developed using methodologies in the proposed "Road Crossing Policy for Light Rail Transit" which was prepared in order to provide MTA with a structured analysis process for determining the feasibility of at grade LRT operation.

This report addresses the roadway crossings along the Exposition Corridor only and does not include evaluations for crossings of Figueroa, Flower, or any of the roadways associated with the alternatives being considered for connecting the Exposition Corridor with the existing Metro Blue Line and service to and through downtown Los Angeles – as the feasibility of at grade operation at Figueroa and Flower depends upon the alignment option, evaluation of these roadway crossings has been included in a separate Exposition Branching Study report which specifically addresses the downtown connection alternatives.

The analysis has been prepared using revised traffic projections which have been prepared based upon a more recent run of the MTA travel forecast model than was originally used to develop the Draft Environmental Impact Statement/Report (DEIS/R). The new model runs and intersection volume forecasts were prepared to address comments received from the Los Angeles Department of Transportation (LADOT) as well as Culver City regarding the traffic forecasts shown in the draft environmental document. MTA is in the process of reviewing and presenting the revised forecasts and it is possible than some adjustments could be required. As the estimated traffic volume crossing the LRT trackway is a principal factor in the analysis, these results should be considered preliminary until the forecasts are finalized.

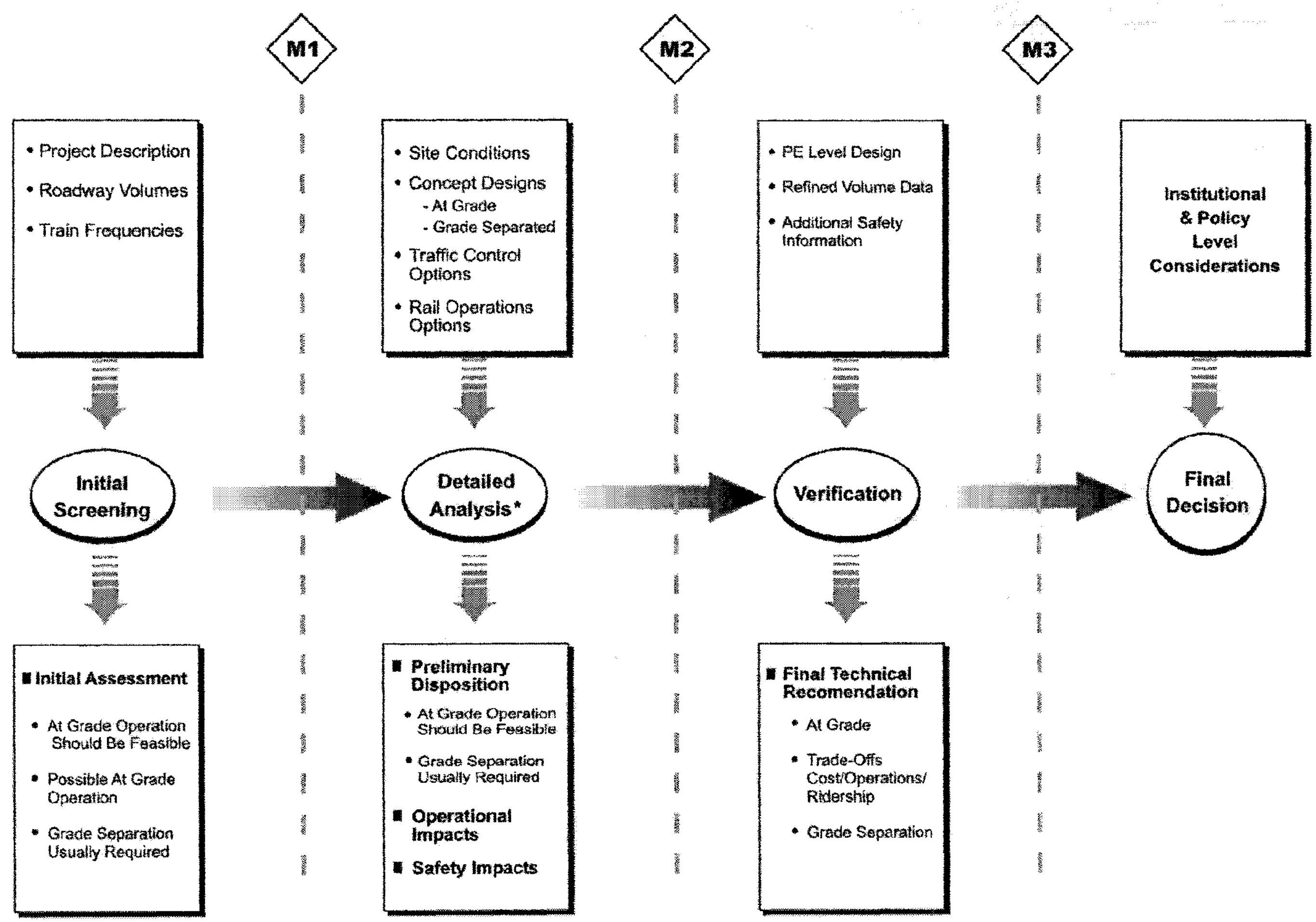
This report includes a first look at safety issues associated with the crossings that may be operated at grade along with identification of potential mitigation of noted safety concerns. As design development of the Expo LRT project proceeds and greater detail is available regarding the specific configuration of each crossing, the proposed design should incorporate appropriate provisions to enhance safe operation. Additional safety analysis may be required to establish the specific design features.

GRADE CROSSING POLICY

The Proposed Grade Crossing Policy for Light Rail Transit (see Figure 1) was developed to provide a standard methodology for evaluating the feasibility of at grade LRT operations. The recommended policy provides for three phases of review before arriving at the "Final Decision" on a crossing:

- Milestone 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".

Figure 1 – Light Rail Grade Crossing Review Process



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M = Milestone

* See Detailed Analysis Flowchart

- Milestone 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 due to priority control. Provides more refined assessment of feasibility of at grade operation and also identifies operational trade-offs between roadway traffic 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 be operated at grade versus grade-separated.

- Milestone 3 – Verification – The process of developing consensus regarding the proposed design solution with involved constituencies including other involved agencies and the community as appropriate. May include preliminary engineering studies and cost estimates for alternative treatments. May include refinement of projected traffic volumes and validation of traffic and rail operations using simulation modeling. May include additional effort on safety issues and countermeasures. At the conclusion of this milestone, it is expected that all technical studies will have been completed leading to a final recommendation for the crossing configuration.

- Final Decision – Final disposition of the crossing configuration based upon all of the preceding technical analysis, engineering studies, and agency consensus building. Third party requirements may dictate the requirements for the crossing configuration.

FINDINGS

At the time this report was prepared, the technical analysis for Milestones 1 and 2 has been accomplished for the Expo LRT using the DEIR traffic forecasts and a "preliminary disposition" of each crossing (at grade vs. grade-separated) has been identified. The preliminary evaluations are being presented to and discussed with other involved agencies and jurisdictions.

Fourteen roadway crossings have been evaluated. The westernmost crossing is Washington Boulevard in Culver City and the easternmost crossing is Vermont Avenue in the City of Los Angeles.

Initial Screening

Figure 1 indicates the Preliminary Screening results for the fourteen locations where traffic volume forecasts are available. (Lower levels of activity occur at 7th Avenue and 11th Avenue and these locations were not analyzed. In addition, Hayden Road is proposed to be closed to vehicles and was not reviewed). For four additional crossings (Denker, Buckingham, Grammercy and Farmdale, modeled projections show traffic volumes well within the threshold for at-grade operation. Therefore, intersection traffic counts were not taken for these intersections and they do not appear in Figure 1.

The Preliminary Screening indicates that one crossing (La Cienega) warrants grade separation and seven other locations are within or nearly within the "possible at grade operation" band that requires more detailed analysis using the Policy.[1]

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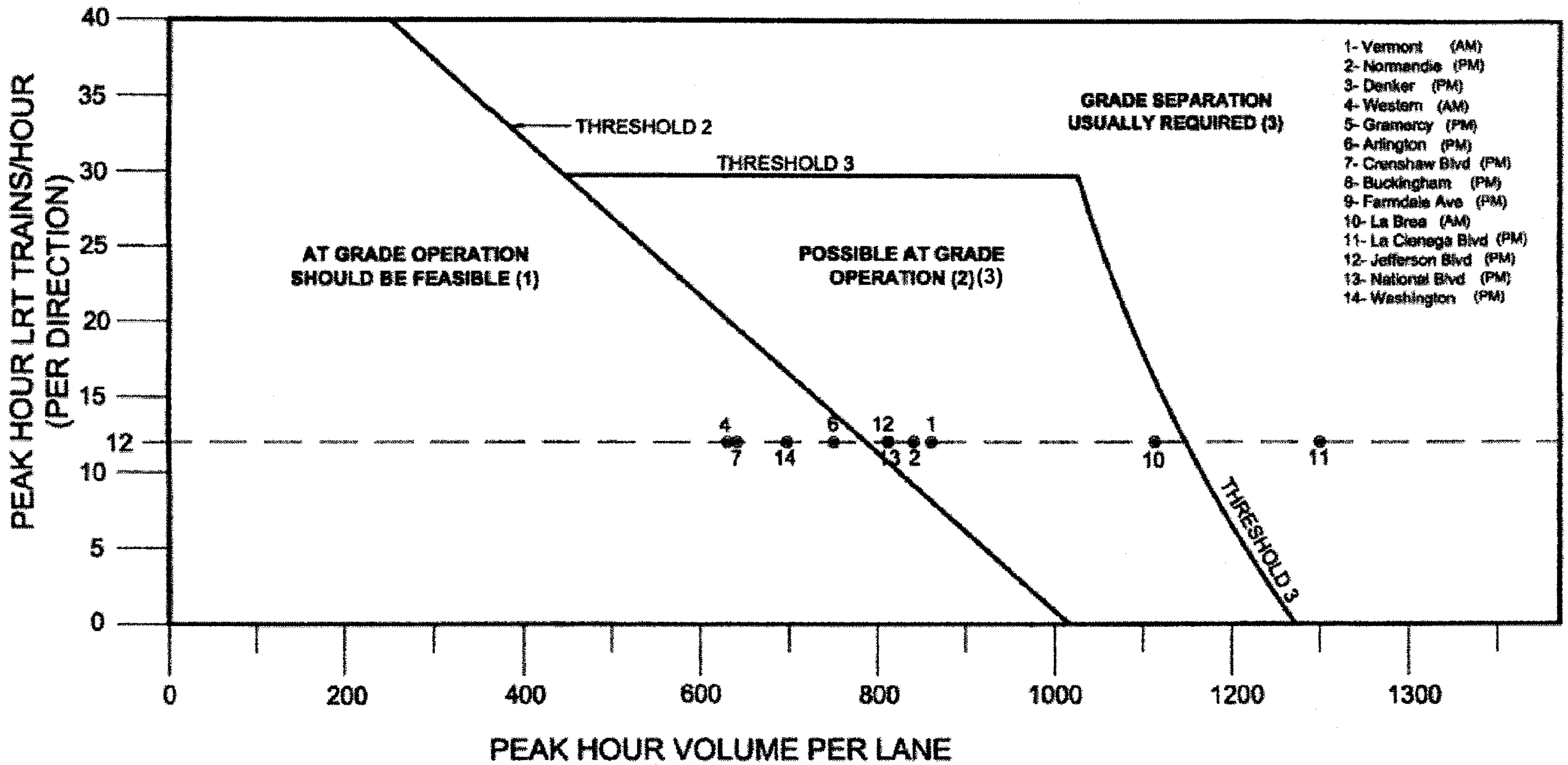
[1] For the purpose of the analysis, Washington and National in Culver City are treated as a combined location due to their close proximity – although Washington is below Threshold 2, National exceeds it and therefore both locations were included in the Detailed Analysis.

Figure 1 – Initial Screening Results



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 POSSIBLE AT GRADE SOLUTION

Detailed Analysis

In accordance with the provisions of the Roadway Crossing Policy, Detailed Analysis was accomplished for the seven locations identified in the Preliminary Screening as "Possible At Grade Operation".

As a result of the Detailed Analysis which considers operational and safety issues, it was determined that one additional location – La Brea Avenue in Los Angeles – is recommended for grade separation.

Table 1 shown on the following page incorporates the results of the Detailed Analysis step and summarizes all of the analysis to date. The table indicates the preliminary disposition of all fourteen locations with two recommended grade separations and twelve locations to be operated at grade. The columns on Table 1 indicate, from left to right: proposed traffic control (signal and/or gates); initial screening results (three possible outcomes); detailed analysis results (operations and safety); and preliminary disposition (at grade or grade separated); plus comments.

A crossing-by-crossing summary of the findings and key issues follows. The crossings are addressed from high to low relative to the traffic conflict levels identified in the preliminary screening.

Preliminary Disposition Grade Separated

- La Cienega Boulevard (Los Angeles) – This location was identified for grade separation in the conceptual engineering drawings for the Locally Preferred Alternative (LPA) designated in the DEIS/R). The initial screening indicated that grade separation is usually required. This location has the highest level of conflicting traffic with the LRT trackway and the roadway is highly congested. In accordance with the Policy, since the proposed operation at this location is greater than 35 mph, the recommendation is to proceed with design development of a grade separation as shown in the conceptual engineering drawings.

- La Brea Boulevard (Los Angeles) – In the initial screening, this location fell just below the grade separation threshold in the road crossing policy. Detailed analysis indicates that crossing gates would be required to meet the proposed rail operating speed that exceeds 35 mph in this segment (although speeds may be slower due to stops at the La Brea station), however, this would require pre-emption of the Jefferson / La Brea traffic signal which presently generates queues of vehicles backing up across the trackway. Control of the queuing would require installation of a traffic signal at the crossing and use of priority control in lieu of pre-emption to avoid excessive traffic impacts. However, there is a concern that the "readability" of the crossing is not adequate with traffic signal control alone (e.g., without gates). Due to these factors, both the "operations" and "safety" criteria were judged as "fail" in the detailed analysis. Therefore, the recommendation is that MTA proceed with preliminary engineering of a grade separation at this location.

Table 1 – Roadway Crossing Recommendations Summary Table

Roadway Crossing	Proposed Traffic Control		Initial Screening	Detailed Analysis		Preliminary Disposition	Comments
	Signal	Gates		Operations	Safety		
1 – Vermont	X		◎	◎	◎	O	Pedestrian safety enhancements
2 – Normandie	X		◎	O	O	O	
3 – Denker	X		O	-	O	O	
4 – Western	X		O	-	◎	O	Provide pedestrian safety enhancements
5 – Gramercy	X	X	O	-	◎	O	Select devices to address complex geometry
6 – Arlington		X	O / ◎	O	◎	O	Use Rodeo intersection as pre-signal
7 – Crenshaw		X	O	-	◎	O	Provide ped safety enhancements & pre signal
8 – Buckingham		X	O	-	O	O	
9 – Farmdale		X	O	-	◎	O	Provide pedestrian safety enhancements
10 – La Brea		X	◎ / ③	③	③	③	Recommended for grade separation
11 – La Cienega	-	-	③	-	-	③	Recommended for grade separation
12 – Jefferson	X	X	O / ◎	O	O	O	
13 – National	X	X	O / ◎	◎	◎	O	Possible long term grade separation
14 – Washington	X	X	O / ◎	◎	◎	O	Possible long term grade separation

Legend

Symbol	Initial Screening	Detailed Analysis	Preliminary Disposition
O	At grade should be feasible	OK, acceptable	At grade
◎	Possible at grade operation	OK with mitigation	-
③	Grade separation usually required	Fails, unacceptable	Grade separate

Preliminary Disposition At Grade

The assessment of the remaining twelve locations is all at grade. The Detailed Analysis described in the Policy procedures was carried out for six of these locations. The other six locations were identified as feasible under the Initial Screening and no further analysis was performed. The results by location are described below, listed in order of decreasing levels of traffic:

Detailed Analysis Performed

- Vermont Avenue (Los Angeles) – The initial screening for this location using the recommended Policy was "Possible At Grade Operation". Detailed operational analysis was accomplished and the results indicated at grade operation would be potentially feasible, however, there may be little or no transit priority available due to the level of projected future roadway congestion at the intersection, with or without Expo LRT. Given the fact that the first station along Exposition Boulevard is located adjacent to Vermont, it is reasonable to assume that the station could serve as a "time point" for westbound trains and that a count-down timer could be provided so that trains would depart to receive clearance through the grade crossing with minimal traffic signal delay. Eastbound trains would potentially experience delays due to the fact that the "slack time" in the traffic signal cycle available for priority treatment of the LRT would be affected by the degree of congestion along Vermont.

- Normandie Avenue (Los Angeles) – The initial screening for this location using the recommended Policy was "Possible At Grade Operation". Detailed operational analysis was accomplished which confirmed the viability of at grade operation using traffic signals to control traffic at the crossing with transit priority to minimize LRT delays. This analysis identified that roadway congestion levels were low enough to accommodate transit priority and the safety review did not identify any extraordinary safety issues.

- Washington & National Boulevards (Culver City) – These two roadway crossings comprise two corners of a triangle with the Washington/National intersection as the third corner. The National crossing exceeds Threshold 2, so Detailed Analysis was performed. A queuing check performed as part of this analysis confirmed that the common intersection of Washington / National is within the influence zone of both crossings. Therefore all three locations (two grade crossings and common roadway intersection) must be operated as a unit. For this to happen, all three locations must be operated with traffic signals to manage the traffic queues. In addition, the safety review indicated crossing gates would be needed to enforce compliance with stop bars as well as to address the sight distance restrictions associated with the angled crossings. Despite these complications, at grade operation should be feasible as long as LRT speeds through the crossings are below 35 mph and trains are run through both locations based upon a "green band" type of operation with little or no priority should be feasible. A count-down timer could be used at the Venice station to indicate an appropriate departure time so that no additional delay would occur for eastbound trains. (A count down timer for westbound trains could be provided at the La Cienega station as well.) In the long term, a grade separation may be appropriate to reduce delays, especially in the event the line were extended further west.

- Jefferson / National (Culver City / Los Angeles) – Designated as a grade separated crossing in the conceptual engineering drawings for the LPA, this location is proposed as an at grade crossing using a design concept which emerged from the Value Engineering session for the project. In applying the Policy to the proposed crossing, and assuming the roadway configuration is sized to meet the roadway Level of Service requirements for good traffic operation, this location was evaluated as just above the threshold of "At Grade Operation Should Be Feasible" vs. "Possible At Grade Operation" in the Initial Screening. Detailed operational analysis indicates a combination of crossing gates and traffic signal controls would be desirable to operate the crossing. Since this intersection acts as an "isolated" location, and roadway capacity to provide for a good Level of Service is available, priority control or pre-emption should be feasible.

- Arlington Avenue (Los Angeles) – This location was evaluated at below Threshold 2 in the Preliminary Screening which would ordinarily require no further analysis for at grade operational feasibility, however, since it was very close to the threshold, detailed analysis was performed to confirm the feasibility of at grade operation. The Detailed Analysis indicated adequate roadway capacity exists to provide a high degree of transit priority, so adequate operations should result even with crossing gates and pre-emption. The safety review indicated that the Rodeo intersection south of the trackway should be designed to act as a pre-signal to limit the likelihood that cars would be queued on the tracks.

Initial Screening At Grade (No Detailed Analysis Required)

- Crenshaw Boulevard (Los Angeles) – This location was identified as acceptable for at grade operation based upon the Initial Screening. The safety review identified the need for further study of the pedestrian activity levels at the crossing and incorporation of appropriate safety provisions. In addition, the safety review identified the need to develop a pre-signal for the frontage roadway immediately south of the LRT trackway to reduce the possibility of queuing across the tracks.

- Western Avenue (Los Angeles) – The Initial Screening indicated at grade operation would be acceptable. The safety review identified the need for further study of the pedestrian activity levels at the crossing and incorporation of appropriate safety provisions.

- Buckingham Road (Los Angeles) – At grade operation should be feasible according to the Initial Screening. No further issues were identified as a result of the safety screening. The ultimate design should incorporate standard safety features.

- Gramercy Place (Los Angeles) – The Initial Screening indicated at grade operation would be acceptable. The safety review identified the need for further study of the impact of the angled crossing and complex intersection geometry and the selection of appropriate traffic control and traffic safety measures for successful at grade operation.

- Denker Avenue (Los Angeles) – At grade operation should be feasible according to the Initial Screening. No further issues were identified as a result of the safety screening. The ultimate design should incorporate standard safety features.

- Farmdale Avenue (Los Angeles) – The Initial Screening indicated at grade operation would be acceptable. The safety review identified the need for further study of the pedestrian activity levels at the crossing and incorporation of appropriate safety provisions.

Safety Review

The proposed Roadway Crossing Framework includes provisions for initial safety reviews of the roadway crossings that are considered for "Possible At Grade Operation". In addition, the MTA Board specifically requested a review of operations and safety for five mid-corridor roadway crossings in the City of Los Angeles Mid Cities area:

- Crenshaw Boulevard
- Arlington Avenue
- Gramercy Place
- Western Avenue
- Vermont Avenue

Consideration was therefore given to potential safety concerns at the five crossings as well as all of the other locations where feasibility of at grade operation was in question under the Framework. The specific safety concerns that were reviewed, subject to available data included:

- Traffic Queuing
- Approach and Corner Sight Distance
- Visual Confusion/Sign or Signal Clutter
- Prevailing Traffic Speed
- Large Truck Percentage
- Heavy Pedestrian Volumes
- School Access Route
- Accident History
- Gate Drive Around Potential
- Delineation and Roadway Marking
- Traffic Control Observance

As a result, a number of initial recommendations for safety treatments are included in the report. It is important to recognize that, as the level of design development proceeds, on-going review of safety concerns and design provisions should be incorporated in the project development process for proposed traffic and pedestrian crossings.

NEXT STEPS

In accordance with the proposed Roadway Crossing Policy, the following "Next Steps" are recommended:

Technical Studies

- Develop Grade Separation Concepts and Costs for La Brea Avenue
- Finalize Updated Traffic Forecasts Reflecting New Travel Model Results
- Conduct Detailed Safety Review of At Grade Crossings
- Validate Feasibility of Proposed At Grade Operation As Required To Satisfy Third Parties

Agency Coordination

- Develop Consensus on Revised Traffic Forecasts
- Review Candidate Traffic Control Strategies
- Develop Consensus on Configuration of At Grade Crossing at Jefferson / National Intersection
- Address Traffic Controls for Washington/National Crossings At Grade
- Address Traffic Impacts of Interim Terminal Station at Venice
- Coordinate with California Public Utilities Commission and Caltrans

ATTACHMENT C

Los Angeles County Metropolitan Transportation Authority

Exposition Light Rail Transit Project

Preliminary Engineering Services

SUMMARY OF

LRT GRADE CROSSING SAFETY DEVICES

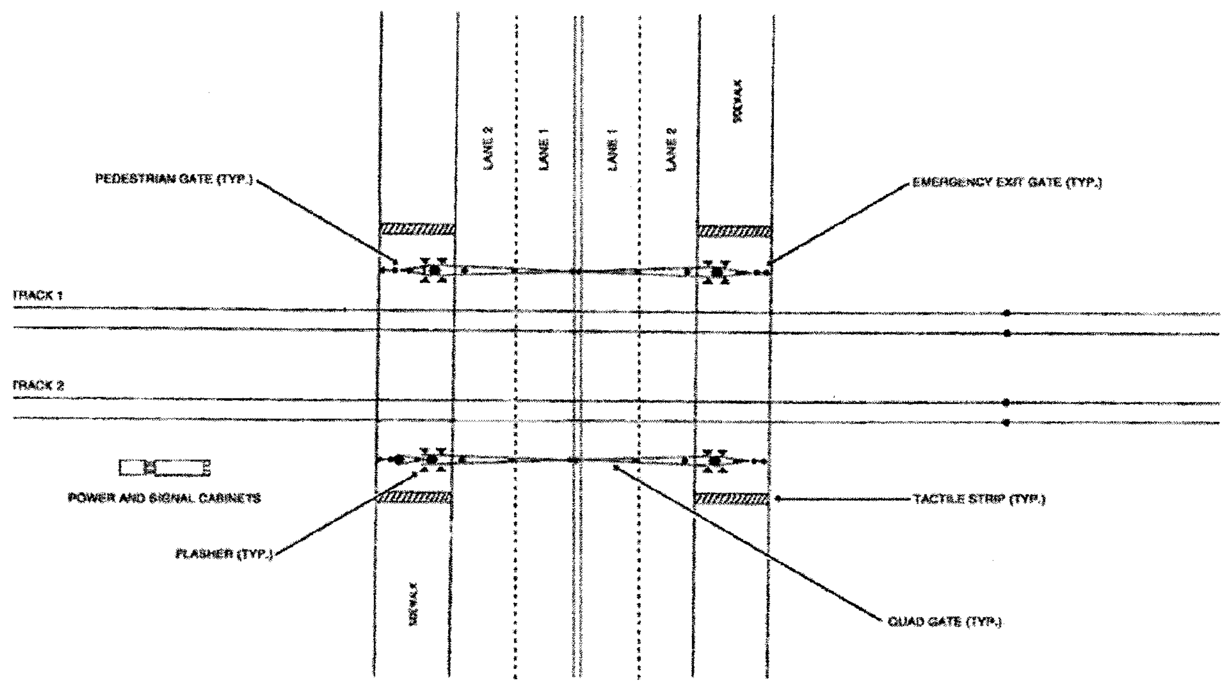
DMJM HARRIS
Booz Allen Hamilton Inc.
Corrpro Companies, Inc.
Diaz Yourman & Associates
Egis-Semaly Inc.
Gateway Science & Engineering
Harris Miller Miller & Hanson Inc.
Jackie Patterson & Associates
KAKU Associates, Inc.
Kal Krishnan Consulting Services, Inc.
Meléndrez Design Partners
Myra L. Frank & Associates, Inc.
Psomas
The Robert Group
Zimmer Gunsul Frasca Partnership

1.0 SUMMARY

The following report provides information concerning the proposed at-grade crossing safety devices for the Mid-City/Exposition Light Rail Project (Expo Line). The proposed safety devices and general configuration are in accordance with the California Public Utility Commission (CPUC) General Orders but will require final design specific to each crossing and CPUC final approval. This paper is not intended to be a Hazard Analysis of the crossings and is not to replace the official CPUC application process, which will begin at a later date. This analysis was prepared is support of the Draft LRT Grade Crossing Policy and Evaluation of Exposition LRT Project with Propsoed MTA Grade Crossing Policy, prepared by Korve Engineering, Inc.

2.0 APPROACH

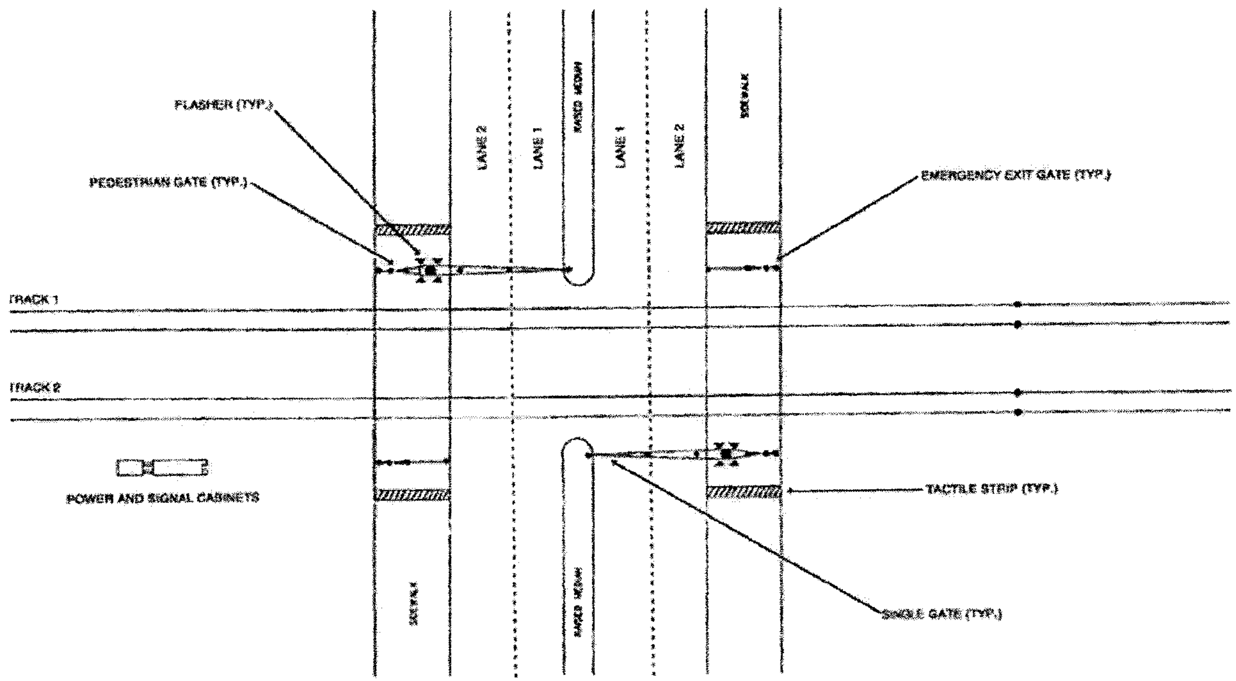
The Exposition Light Rail Transit Project Line Preliminary Engineering Team (PE Team) compiled technical data concerning existing at-grade crossing safety devices from the Metro Gold Line, the Metro Blue Line, and innovative/pioneering at-grade crossing safety technology not widely used in existing MTA lines. Using the proposed Expo Line alignment, the PE Team designated each of the Expo Line at-grade crossings into one of four general types of at-grade crossings: three small options and one large option. The small at-grade crossings are defined as typical residential street or private driveway with one or two lanes in each direction (Diagrams 1-3). A large at-grade crossing is defined as a typical thoroughfare with three or four lanes in each direction (Diagram 4).



ION

TYPICAL FOUR-LANE GRADE CROSSING CONCEPTUAL
SMALL OPTION: QUAD GATES

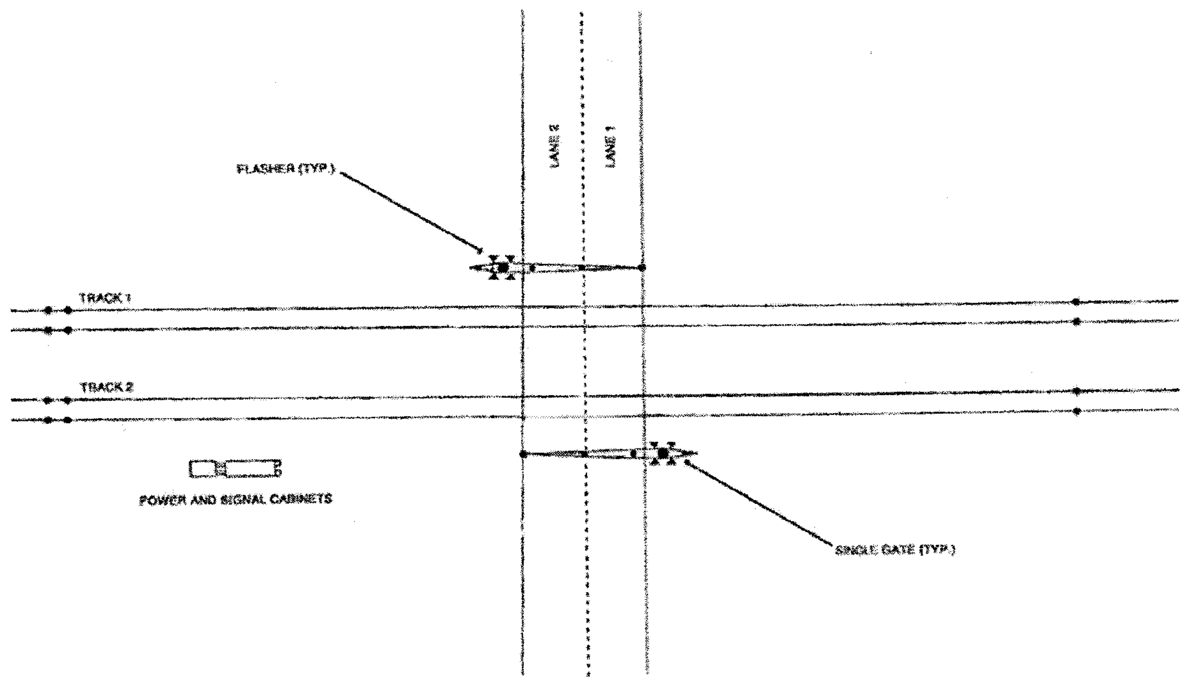
DIAGRAM 1



TION

TYPICAL FOUR-LANE GRADE CROSSING CONCEPTUAL
SMALL OPTION: RAISED MEDIAN

DIAGRAM 2



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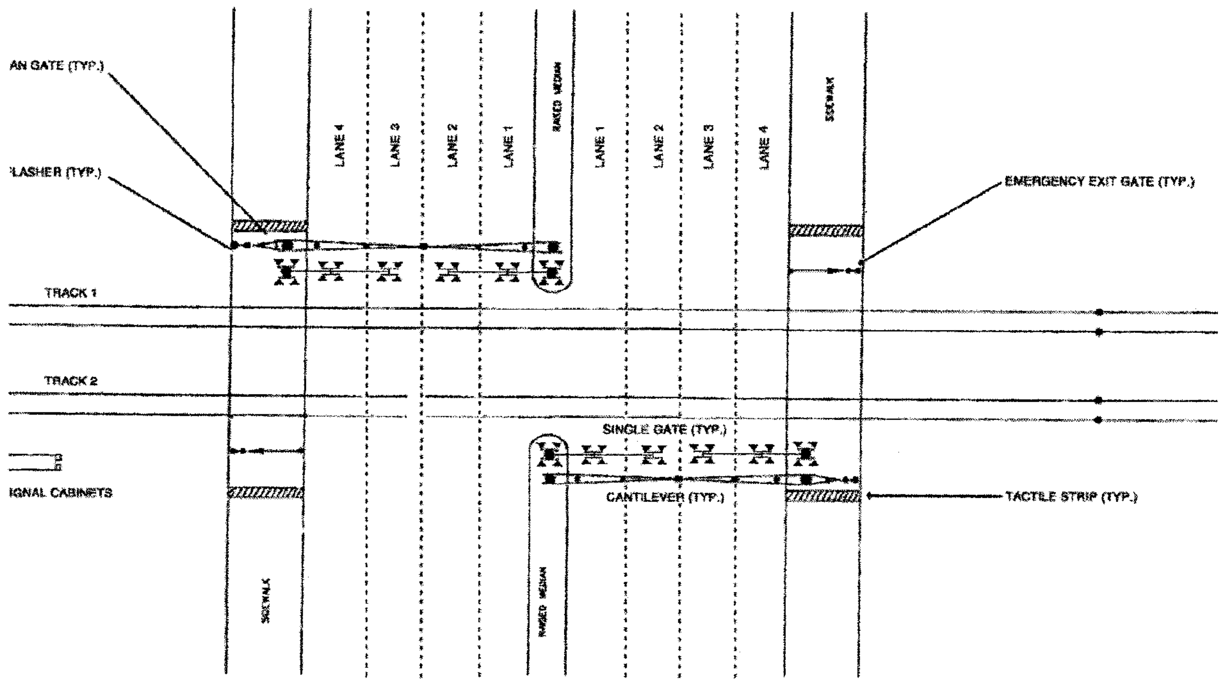
TYPICAL TWO-LANE GRADE CROSSING CONCEPTUAL
SMALL OPTION: PRIVATE DRIVEWAY

DIAGRAM 3



TYPICAL EIGHT-LANE GRADE CROSSING CONCEPTUAL
LARGE OPTION

DIAGRAM 4

3.0 BEST AND CURRENT AT-GRADE CROSSING SAFETY DEVICES

Best and current at-grade crossing safety devices include the following:

- Standard grade crossing gates with flashing lights
- Quadrant gates with flashing lights
- Cantilever flashers
- Pedestrian and emergency exit gates
- Bells and horns
- Power and signal cabinets
- Upgrades to street and sidewalks
  - Medians
  - Fencing
  - Signs
  - Striping

3.1 Quadrant Gates

Quadrant gates, more commonly called quad gates, are a relatively new grade crossing technology first demonstrated in the United States by the MTA in 1998. The quad gate system provides crossing gates on all four corners of an at-grade crossing to fully secure the crossing from automobile gate running. This system is generally installed where there is not a raised center median to prevent vehicles from running the gates. See Exhibit 1. Safety features of quad gates include:

Exhibit 1
Typical quad gate at-grade crossing

- Closure of at-grade crossing in all directions to automobile traffic
- Exit gate (i.e., gates installed on the exit side of the crossing) fail in up position to eliminate the potential to trap an auto in grade crossing
- Exit gate operation to down position is delayed in order to allow automobile traffic to clear crossing
- Exit gates are held in the up position if an automobile is detected in the crossing track area
- Rail Operations Center receives an alarm if gates are held in up position.

Small flashers are directly mounted on to the quad gates in addition to the larger flashers mounted to poles at each of the four corners of the at-grade crossing to visually alert the drivers. See Exhibit 2. The final locations and configurations of quad gates along the Expo Line alignment will not be completed until after preliminary engineering design.

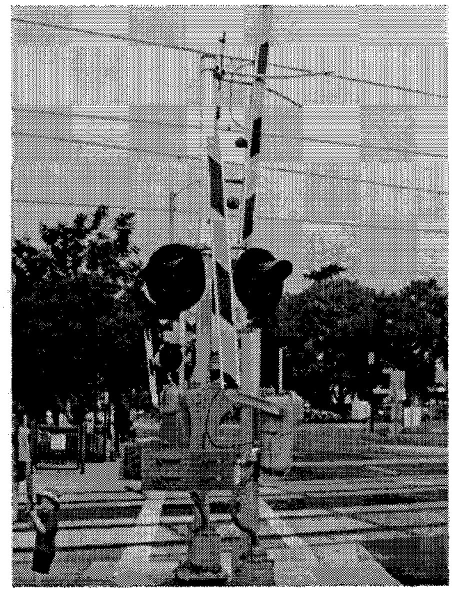


Exhibit 2
Large flasher mounted to pole adjacent to quad gate

Another option to the quad gate is the use of single gates installed in the on-coming traffic lanes only along with a raised center median to prevent drivers from gate running. See Diagram 2 from previous section. A center median is necessary to limit the length of the gate. Current standards do not allow the use of a single gate to cover more than two lanes. The disadvantage to this option is the possible need to acquire additional right-of-way in order to construct the center median in order to keep the original number of traffic lanes.

3.2 Cantilever Flashers

Cantilever flashers are used at locations where it is necessary to cover an inside lane with a flashing light. See Exhibit 3.

Current standards require each traffic lane to be covered by a flashing light and a gate. In cases where the traffic lane is adjacent to the curb, the light on the signal mast is sufficient. However, in cases where there are three or more traffic lanes in either direction, a center median is necessary to limit the gate length. The outside two lanes would be covered by a gate and cantilever installed on the sidewalk while the inside lane would be covered by a gate and a signal mounted on the gate mast. In these cases a raised median is necessary to install the inside gate and flashing light.

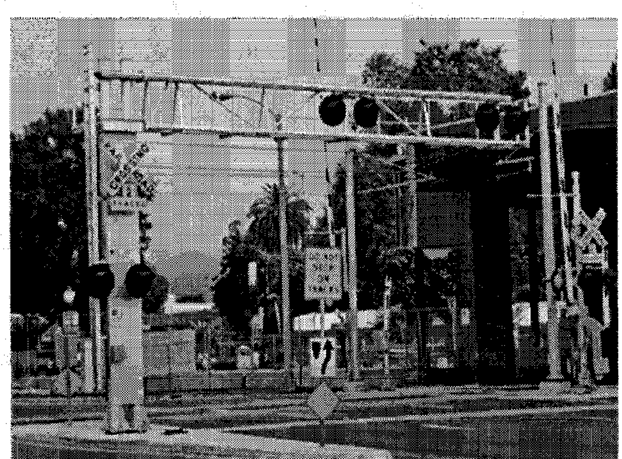


Exhibit 3
View of cantilever flasher from front

3.3 Pedestrian Gates and Emergency Exit Pedestrian Gates

Pedestrian gates are safety devices that act similar to the vehicular gates but are smaller and are situated on the sidewalks for the pedestrians. In addition, flashers are mounted to the pedestrian gates to visually alert the pedestrians. Adjacent to the pedestrian gates are emergency exit pedestrian gates so that pedestrians who are crossing the tracks when a train approaches can safely exit the grade crossing. Each gate has a tactile strip located directly in front to alert the visually impaired. See Exhibits 4, 5, and 6.

Exhibit 4
Emergency exit and pedestrian gate in down position. The yellow tactile strip alerts the visually impaired.

Exhibit 5
Emergency exit gate

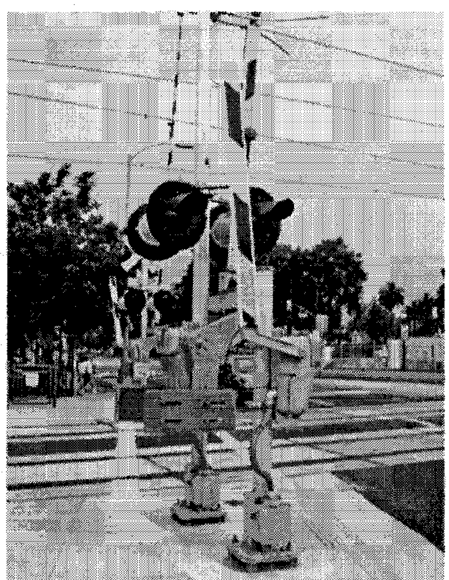


Exhibit 6
Pedestrian gate in upright position

3.4 Bells and Horns

As an extra precaution, some grade crossings may require bells located on the flashers and/or require a horn to be blown located on the trains to audibly alert vehicles and/or pedestrians.

3.5 Power and Signal Cabinets

Power and signal controls for the quad and pedestrian gates are stored in electrical equipment cabinets located usually adjacent to the grade crossing. See Exhibit 7.

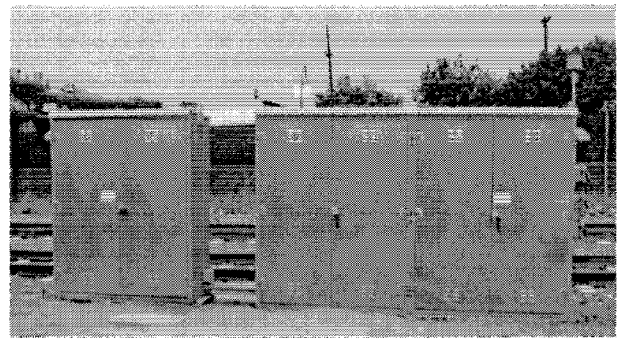


Exhibit 7
Typical power and signal cabinets

3.6 Upgrades in street and sidewalks

Most at-grade crossings will require upgrades to the existing street and sidewalk in order to accommodate the various safety devices. Such upgrades include:

- Raised median to allow gates and cantilever flashers for large at-grade crossings. See Exhibit 8.
- Enlarge sidewalks to allow pedestrian and emergency exit gate installations.
- Fencing adjacent to pedestrian and emergency exit gates to safely direct pedestrians across the at-grade crossing. See Exhibit 9.
- Signs mounted throughout at-grade crossing to caution and direct pedestrians and vehicles. See Exhibit 8.

Exhibit 8
Typical raised median and signs

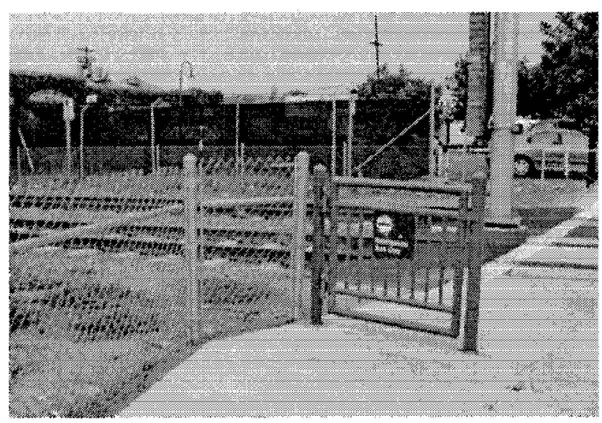


Exhibit 9
Typical mesh fence joining to an emergency exit gate

4.0 DEVICES

In addition to the required standard at-grade crossing engineering safeguards and warning devices, new technology equipment will also be included at selected at-grade crossings along the Expo Line. These new technologies include:

- In-pavement flashers
- Fiber-optic active warning signs
- Photo-enforcement camera system

4.1 In-Pavement Flashers

At selected crossings (street and pedestrian crossings), embedded in-pavement flashers will be installed. The purpose of flashers will be to provide automobile drivers and pedestrians with an additional illuminated indication of the crossing limit line boundary.

Embedded light flasher technology is currently being used in crosswalks in the cities of Santa Monica and Glendale. When a pedestrian activates the system, either by using a push-button or through detection by an automated device, the lights begin to flash at a constant rate, warning the motorist that a pedestrian is in the vicinity of the crosswalk ahead. The vision for this system is to use it in a similar fashion to provide vehicles and pedestrians of an on-coming light rail train.

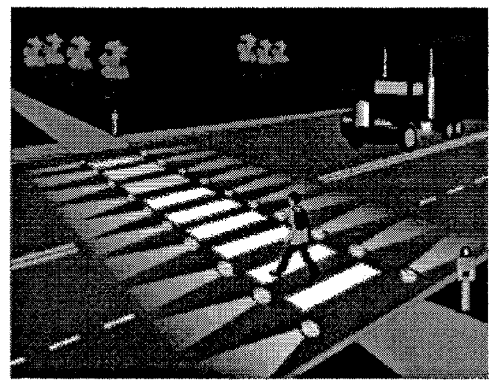


Exhibit 12
In-pavement flashers

4.2 Fiber-optic Active Warning Signs

The Expo Line will incorporate active as well as passive warning signs. The signs envisioned for the Expo Line would be similar (i.e., fiber-optic) to those installed on the Blue Line and Gold Line. These signs have been proven to be an effective indicator to motorists and pedestrians of the presence of an approaching train. In addition, fiber-optic signs will be used for "no right turn on red" and "no left turn on red" indicators.

Exhibit 13
Fiber-optic active warning signs

4.3 Photo-enforcement Camera System

The intent of the photo-enforcement cameras is to prevent automobile drivers from turning into on-coming trains. The cameras are located on the corners of parallel streets to the Expo Line alignment and positioned to capture automobiles illegally turning left crossing the at-grade alignment when a train is approaching. The cameras will take pictures of the automobile's license plate in order for law enforcement to fine the automobile drivers. To date, MTA has installed such cameras at specific locations along the Blue Line.

Insert item 20
color pages