TRANSIT COOPERATIVE RESEARCH PROGRAM

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TCRP Synthesis 23

Inspection Policy and Procedures For Rail Transit Tunnels and Underground Structures

A Synthesis of Transit Practice

Transportation Research Board
National Research Council

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Synthesis of Transit Practice 23

Inspection Policy and Procedures for Rail Transit Tunnels and Underground Structures

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, inclease service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropliate new technologies fiom other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213--Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Federal Transit Administration (FTA). A report by the American Public Transit Association (APTA), *Transportation 2000,* also recognized the need for local, problem-solving research TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of vice configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academy of Sciences, acting through the Transportation Research Board (TRB), and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at anytime. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end-users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. TCRP results support and complement other ongoing transit research and training programs.

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the Transit Development Corporation, the National Research Council, or the Federal Transit Administration of the U.S. Department of Transportation

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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PREFACE

A vast storehouse of information exists on many subjects of concern to the transit industry. This information has resulted from research and from the successful application of solutions to problems by individuals or organizations. There is a continuing need to provide a systematic means for compiling this information and making it available to the entire transit community in a usable format. The Transit Cooperative Research Program includes a synthesis series designed to search for and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in subject areas of concern to the transit industry.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of interest to transit agency general managers; design, maintenance, and standards engineers; and inspection and maintenance staff. This synthesis describes the current state of the practice for specific management policies and procedures and engineering/physical techniques used to inspect rail transit tunnels and underground structures. It discusses the available data on, different approaches of, and potential data inadequacies for agency rail transit tunnel inspection policies and procedures and inspection techniques.

Administrators, practitioners, and researchers are continually faced with issues or problems on which there is much information, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered or not readily available in the literature, and, as a consequence, in seeking solutions, full information on what has been learned about an issue or problem is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to the available methods of solving or alleviating the issue or problem. In an effort to correct this situation, the Transit Cooperative Research Program (TCRP) Synthesis Project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common transit issues and problems and synthesizing available information. The synthesis reports from this endeavor constitute a TCRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to a specific problem or closely related issues.

This report of the Transportation Research Board (TRB) presents data obtained from a review of the literature and a survey of North American and international transit agencies. In addition, five case studies are presented to look more closely at the tunnel inspection practices of four domestic and one foreign transit agency. The Appendix material includes examples of the inspection forms used by the five agencies profiled.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, available information was assembled from numerous sources, including a number of public transportation agencies. A topic panel of experts in the subject area was established to guide the researchers in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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Information on current practice was provided by many transit agencies. Their cooperation and assistance were most helpful.

INSPECTION POLICY AND PROCEDURES FOR RAIL TRANSIT TUNNELS AND UNDERGROUND STRUCTURES

SUMMARY

A transit agency's inspection program for rail transit tunnels and underground structures is a formally adopted system of institutional objectives, standards, and procedures that collectively describe the tunnel inspection practice.

Rail tunnel inspection has received relatively little attention as a professional practice from the transit industry, its professional organizations, or from the federal government. Little information has been compiled, and few professional organizations focus on the development, evaluation, and enhancement of the practice of rail tunnel inspection. Given the importance of rail tunnels to metropolitan transportation, this synthesis was undertaken to address the absence of information in this area.

A survey of tunnel inspection practice was conducted to review the status of the rail tunnel inspection practice in North America and overseas. The survey was sent to 47 transit agencies, 24 domestic and 23 foreign. In addition, five case studies were conducted to look more closely at the tunnel inspection practices of four domestic and one foreign transit agency. The results of this review of the practice are mixed, in the sense that less was learned about the practice than might have been expected, but what was learned confirmed the need for further research and development of universal, standardized tunnel inspection procedures. Transit agency tunnel inspection practices reflect different histories, underground systems, problems, and challenges. Therefore, it would be expected that their inspection procedures would be as individualized as the differences in their experience or underground systems.

For example, results from a review of tunnel structure inspection frequency demonstrated many different inspection cycles, sometimes even within the same transit system. Frequency of inspection does seem, however, to substantially depend on agency history. That is, if an underground tunnel section has a history of leaks, for example, that section would probably tend to be more frequently inspected.

Similar variability is found in other aspects of the tunnel inspection practice. Inspection protocols such as scheduling, inspection depth (visual vs. destructive testing methods), inspection documentation (photos, sketches, narratives of the inspection) and management focus (inspection planning and accountability) differ from agency to agency. Likewise, staffing of tunnel inspections varies. Number of crew members, their training or accreditation requirements are different from one transit agency to the next.

There is one aspect of the tunnel inspection practice on which transit agencies, their consultants and professional peers are agreed: the number one problem affecting tunnels and underground structures is groundwater intrusion and the subsequent damage caused by the presence of tunnel leaks. This groundwater intrusion is responsible for more problems affecting a tunnel's concrete liners and steel reinforced concrete than all other tunnel structural problems combined.

It is not at all clear that the variability in the practice of transit rail tunnel inspections described demonstrates a condition of substandard transit rail tunnel inspections. However, since respondent transit systems have tunnels and underground structures that are between

50 and 100 years old, the absence of similar inspection standards raises useful questions about the tunnel inspection practice. In the context of the agency and public safety issues inherent in the rationale for the tunnel inspection practice, and given the resource challenges currently confronted by transit agencies, the absence of universal standards of adequacy for tunnel inspection procedures is of concern.

Management of infrastructure systems is typically more efficient and productive, individual issues of work performance aside, if management operates from a set of standards that have been thoroughly reviewed and proven and that are repeatable. However, since there have not been demonstrable failures in rail tunnel structures as a result of inadequate inspection procedures, the argument for universal procedural or performance standards in the practice is less vigorous than it might otherwise be.

Rail tunnel environments adversely impact structural materials. Changes in tunnel loadings and human error do occur. Loss of life or property and the inconveniences that could result from structural failure are costs whose probability can be significantly reduced through adequate tunnel inspection and needed repairs.

Further questions remain to be more specifically addressed by subsequent research. Some suggestions are offered for the direction of that additional research. Clearly, questions regarding tunnel integrity and safety are too important to leave unaddressed until potential tunnel structural failure prompts the inevitable investigations and emphasis on tunnel infrastructure maintenance.

CHAPTER ONE

INTRODUCTION

STUDY BACKGROUND

Transit tunnels and underground structures are vital links in the metropolitan economic system that represent enormous, long-term public investments by the communities, municipalities, and regions they serve. Without the use of tunnels, transit systems could not mitigate the natural and man-made constraints necessary for safe and competitive public rail transportation that our metropolitan public transportation markets demand.

People most knowledgeable about rail transit tunnel environments identified a need to review transit system tunnel inspection policies and procedures to better understand and document industry practices, to provide transit agencies with the information discovered, and to explore the potential need for and alternative approaches to improved rail tunnel and underground structure inspection policy and practice. This synthesis was conceived as an initial step in that process within the larger context of a growing interest to assure the traveling public that the national transportation infrastructure is as safe and efficient as possible.

The majority of rail transit tunnels now in use in North America were constructed between 30 and 100 years ago *(1);* the oldest rail tunnels are located within the older (and typically larger) North American transit systems (see table 1 in chapter 2). It seems reasonable to assume that a rail transit tunnel constructed in the 1890s might not be in the same structural condition today as when first opened for service. Although structure age alone does not invariably mean structural deterioration, factors such as accidents, accelerated deterioration, or inadequate maintenance have adversely impacted bridges (and other roadway infrastructure), and have for some time, drawn considerable public attention to our national highway transportation investments and their related issues. Prudent national transportation infrastructure policy would seem to warrant a more detailed exploration of rail transit tunnel and underground structure inspection practice.

Currently there are no national or industrywide standards or guidelines for the inspection of rail transit tunnels and underground structures. Guideline materials, handbooks, and procedural manuals for inspection of an underground transit system's structural elements have been developed by individual transit agencies. However, an agency-by-agency approach to management of tunnel structure inspections shows considerable variability in both depth and breadth of inspection procedures followed (see chapter 2 for transit agency survey results). Such procedural variability inevitably raises concerns and questions about the adequacy of tunnel inspections.

No inspection system can be so thorough and consistent as to eliminate all risks and concerns associated with the public's use of rail tunnels and underground structures. The objective of such inspections is, in part, to assess those risks, and determine their acceptability. In the absence of applied industry (and/or governmental) standards for rail tunnel structural conditions or inspection procedures, it is difficult to imagine how rail tunnel inspections could efficiently, thoroughly and uniformly assess rail tunnel conditions from one transit system to another. However, the undetermined impacts of a lack of such standards on industry inspection policy and practice could be profound.

PROBLEMS AND ISSUES

This synthesis addresses inspection practices that assess what kinds of rail tunnel structural conditions pose potential public safety or infrastructure investment risks. The practices described take into account the various elements impacting tunnels (initial design, construction methods, specified materials, tunnel environment and use, or deferred maintenance) and the associated cost implications. The extent to which the *system* of rail tunnel inspections (inspection funding, inspection procedures, tunnel material testing methods, inspection data management, inspection staff training) impacts the assessment of tunnel structural conditions is also considered. Inspection procedures that effectively and efficiently reduce the risks of tunnel structure deterioration are drawn from survey responses and the case studies. These issues are usefully framed by an example of a tunnel inspection and maintenance failure that occurred on the MTA NYCT system.

On August 28, 1973, one of the hottest days of New York City's summer, a duct bank and associated concrete delaminated from the reinforcing steel in the archway of the old "Steinway Tunnel" on the Flushing Line, and struck a Queens-bound IRT 11-car train. More than 1,000 passengers were trapped for over an hour in 115 degree heat. A subsequent short-circuit ignited a fire in accumulated rubbish near the first car, creating smoke that impaired breathing and visibility. In the ensuing panic to escape the train, tunnel, and smoke, a 37-year old man died. Many others were hospitalized.

This serious incident was caused by inadequate tunnel inspection and maintenance practices. An aggressive inspection and maintenance program could have avoided the concrete spalling and delamination that lead to the tunnel accident. In addition, New York City's transit administration could have avoided the questions subsequently raised about transit tunnel safety.

While every rail tunnel accident is unique in its circumstances, structural accidents can nevertheless have devastating consequences for the business and other activities that are impacted. Substantial loss of building equipment, as well as the cost of productive time lost in replacement can serve to demonstrate the interrelatedness of rail tunnel structures with surrounding private structures. Any tunnel incident suggests that accidents of the least-expected kind do occasionally happen, and that when they do, the adverse impacts they produce can be socially and economically profound, with potentially long-lasting impacts to many who use the system.

The adequacy of existing procedures for rail tunnel inspections takes on added importance in the context of potential accidents. What are the actual procedures employed in rail transit agency inspections, the recordkeeping and data management, and the procedures for follow-up repairs to tunnel structural defects? For example, can emergency tunnel structural conditions be repaired without time-consuming public bidding procedures? Do media attention and voter scrutiny of such a public sector budgetary process allow for prudent administrative discretion when needed to protect public safety?

There is a great deal of national and international variability in transit tunnel conditions and tunnel inspection policy and procedures, notwithstanding general agreement about the importance of tunnel inspections to protect public safety and infrastructure investment. While such variability may be internally appropriate, it does increase the difficulty of reconciling inspection results between agencies, determining national maintenance priorities, establishing industrywide standards for tunnel inspection, and reaching industrywide agreements on which procedures are most needed to protect public safety and infrastructure investments.

To make specific findings about national or international rail transit tunnel and underground structural conditions, and to determine the need for a national (or international) tunnel inspection policy and procedures, broader understanding and useful discussion of transit agency tunnel inspection practices, and of tunnel inspection problems and issues seem essential.

PURPOSE AND ORGANIZATION

The purpose of the synthesis is to review existing rail transit agency inspection policy and practices to develop a clearer understanding of the specific management and engineering/physical techniques used to inspect rail tunnel structures and ancillary facilities. The prevailing assumption is that the purpose of rail tunnel inspections is to determine tunnel and underground structure defects to subsequently prioritize tunnel and underground structure maintenance.

The objectives of the synthesis are defined as follows:

1. To query the rail transit industry regarding their tunnel inspection practices, including:
    - the existence of an inventory of underground structural conditions,
    - utilization of inventory data, and
    - factors affecting agency inspection and repair priorities.
2. To review several transit agency rail tunnel structure inspection policies and procedures and to determine and discuss similarities and differences between their practices.
3. To improve understanding of existing rail tunnel inspection practices among interested practitioners and other professionals.

The synthesis was developed from two principal sources of information:

1. A questionnaire on rail tunnel inspection policy and procedures distributed to 47 transit agencies around the world by the Transportation Research Board (see the questionnaire in Appendix A and responses in Appendix B); and,
2. Five case studies on selected transit agencies that have evolved different approaches to rail tunnel inspection policy and procedures (see chapter 3). These five transit agencies were selected for case studies both because available information on their inspection practice permitted greater depth of inquiry and because they demonstrate how differently rail tunnel inspection is practiced among transit agencies.

The study approach combines:

1. A compilation of available data on rail transit tunnel inspection policy and procedures, including significant literature findings.
2. A discussion and comparison of different approaches to rail transit tunnel inspection policy and procedures.
3. A discussion of potential rail transit tunnel inspection data inadequacies.

Throughout preparation of the synthesis, the principal motivation has been the need to develop information about current rail transit tunnel inspection practices; to what extent they are similar or dissimilar; and whether there seems to be a need for standardized rail tunnel inspection policy and procedures.

CHAPTER TWO

SURVEY OVERVIEW

INSPECTION ISSUES

The design, construction, and management of transit rail tunnels and their appurtenant structures is a complicated technical, administrative, and operational responsibility. The potential for human error or poor judgment with respect to design, construction, and management is a constant challenge to transit agencies. Oversights or budgetary "shortfalls" during design and construction, unanticipated vibration from earth movements or equipment, administrative maintenance "cost-cutting," and the constant struggle to protect tunnels from groundwater and sediment intrusion all contribute to the challenge

Additionally, the small, specialized group with a professional interest in tunnels and underground structures is not necessarily inclined toward nor active within local or national public transportation policy circles where issues might be advanced.

The elements of a national transportation policy that most motivate policy makers are certainly the public safety issues and tunnel safety is the most prominent tunnel inspection issue. Other policy issues are serviceability, longevity, and cost.

The primary purpose of rail tunnel inspections, particularly within the context of an infrastructure management system, is to determine a tunnel's structural condition by locating and prioritizing tunnel structure defects and repairs. Transit tunnel inspections are intended to determine the physical condition of tunnels by indicating where structural defects are located and how detrimental those defects are. The prioritization of tunnel defects initiates needed maintenance within a routine or an emergency maintenance procedure, and encourages the most effective management of tunnel deficit repairs, including financing, information storage and retrieval, staff training, and subsequent inspections, all in a systematic, integrated fashion. In short, such an infrastructure management system ideally establishes well-organized procedures for tunnel and underground structure inspections and maintenance.

Rail tunnel inspections relate to the following general areas of transit system operations and administration:

1. Rail tunnel and ancillary facility structural design.
2. Rail tunnel and ancillary facility structural construction.
3. Rail tunnel and ancillary facility structural inspection budget
4. Administration of rail tunnel and ancillary facility structural inspection, including:
   - sufficient support for structural inspections,
   - inspection type (emergency, routine) and thoroughness,
   - adverse environmental impacts,
   - standardization of structure defect terminology,
   - standardization of priority structure defect criteria,
   - inspection documentation and recordkeeping,
   - inspection system redundancy/oversight (interface with other staff),
   - staff experience, skill competency and certification process,
   - staff consultant support (lab testing, engineering assessment, etc.), and
   - frequency of inspections and follow-up activities.
5. Rail tunnel inspection policy support (in all above areas).

Tunnel inspections reveal defects, not only in a tunnel's structural conditions, but also in elements of a tunnel's design and/or construction. Design or construction "defects" may reflect potential budget inadequacies for either. These budget inadequacies are usually seen and treated as a "less useful" management recommendation than those recommendations directed to spending less for the same productivity.

Tunnel Design

Rail transit tunnel design is affected by several factors which, if inadequately assessed, may have adverse impacts on subsequent inspections; the intended and actual use of a tunnel, the physical conditions within which a tunnel is constructed, and the construction materials used in a tunnel that affect both the types and frequencies of tunnel inspection.

Tunnel design criteria, aside from optimizing construction methods and costs, must also consider tunnel longevity, serviceability, and maintainability within the context of existing site conditions and the challenges those conditions may present. The transit tunnel planning and design process itself may ultimately reflect a kind of tunnel vision, most conspicuously in the form of subsequent tunnel defects that were avoidable during design, unless information from the performance of existing tunnel structures is available.

Design parameters for major infrastructure projects have changed over the years. The most significant of those changes has been the growing need to use public dollars more efficiently through better conceptual planning, value engineering, and life-cycle costing. Transit tunnel design should include a reviewable, collaborative process to input design criteria oriented to tunnel maintainability, serviceability, and longevity

Tunnel Construction Materials

The type of tunnel construction substantially influences subsequent underground facility inspection procedures. In fact, construction materials are significant determiners of the types and frequencies of subsequent inspections. For example, a steel and cast iron lined tunnel with a mild steel lining, without cathodic protection, will require more frequent inspection than a reinforced concrete tunnel structure, since reinforcing in concrete has less exposure and therefore less potential for electrolysis than unprotected steel framing or lining.

Other Tunnel Inspection Issues

In addition to the need for more efficient use of tunnel inspection funds, it appears inspection budgets are perceived to be insufficient by many transit agency inspection managers who responded to the Questionnaire (see the Survey Part 4, Questions 1 and 2 in Appendix A, which includes tunnel rehabilitation budget needs as well, and see Table 5). The perception of inspection funding inadequacy is significant since without sufficient funds, no inspection procedure, however wellcrafted, can fully locate and prioritize a tunnel's structural defects, and prevent possible interruptions to revenue service.

A lack of funding for rail tunnel inspections can frustrate development of answers to questions of how and when to conduct inspections. Such financial environments are common with the public sector, and underscore the need for prioritization of inspections and defect repair. Numerous issues associated with the rail tunnel inspection categories enumerated above reflect understandable differences in perception regarding tunnel inspection and rehabilitation problems (their depth or immediacy, for example), and the priorities attached to available inspection/maintenance funding.

There are no existing uniform rail tunnel inspection standards from transit agency to agency. Transit agency tunnel inspection standards are, in some instances formal and clear, and in other cases, they are inferred. Perhaps more than tunnel inspection procedures, uniform structural inspection standards need development within the practice. Theoretically, it seems useful to try to begin to develop industry standards (or some kind of interim, uniform standard) to determine various (prioritized) tunnel structural conditions (pre-defect), structural defects, and maintenance alternatives in light of transit agency experience with their applied effectiveness and cost.

DESCRIPTION OF RAIL TUNNEL INSPECTION SURVEY

This is the first published effort to conduct a national rail transit tunnel inspection survey. As such, there is no benchmark with which to compare the results obtained. Surveys sent to 47 transit agencies in North America, Europe, and Asia (24 domestic, 23 international), largely based on a review of which operating transit systems had tunnels. Surveys were returned by 14 agencies (see below for respondent agencies), or approximately 30 percent of those mailed. While this return represents a statistically valid sampling of transit agency practice, it nevertheless raises questions about the procedural and technical aspects of non-respondent transit agency inspection policy and practices. At the very least, such a substantial percentage of survey non-respondents indicates the need for additional information gathering on transit agency tunnel inspection procedures.

Survey Purpose and Organization

The purpose of conducting the tunnel inventory survey was primarily to gather rail transit information (see survey contents below) in order to document and better understand the existing practice of rail tunnel and underground structure inspections as represented by respondent agencies. An ancillary purpose of the survey was to initiate a process of inquiry into tunnel inspection policy and practices which, it is hoped, will ultimately serve to improve the practice itself, through a more collaborative orientation to the goal of improved rail tunnel inspection practices.

Respondent Transit Agencies

The following transit agencies returned survey questionnaires. Their abbreviated names are used in the tables that follow:

- Bay Area Rapid Transit (BART); San Francisco
- Peninsula Corridor Joint Powers Board (CalTrain); San Carlos, California
- Chicago Transit Authority (CTA)
- City of Calgary Transportation Department (Calgary Transit)
- Mass Transit Administration of Maryland (MTA); Baltimore,
- Mass Transit Railway Corporation (MTRC); Hong Kong
- Metro-North Railroad (MTA); New York City
- Bi-State Development Agency (MetroLink); St. Louis
- Metropolitan Atlanta Regional Transit Authority (MARTA)
- New Jersey Transit (NJT); Newark
- MTA New York City Transit (NYCT)
- Port Authority Trans-Hudson Corporation (PATH); Jersey City
- Societe de Transport de la Communaute Urbaine de Montreal (STCUM)
- Toronto Transit Commission (TTC).

Agency Inspection Survey

Part 1 of the survey (Appendix A) included general respondent agency information (name, address, agency contact person). In addition, there were three questions in Part 1: one asking principal agency function; another asking whether the agency systematically inspected underground structures; and the third asking what factors governed inspection and repair priorities (funding, legislative, etc.). This information was not considered sufficiently useful to compile.

Part 2 of the survey (Appendix A) compiles the physical and dimensional information about respondent transit agency

TABLE 1
AGE OF TUNNEL STRUCTURES

Transit Agency	Structure Age	Transit Agency	Structure Age
Toronto Transit	20-50 years	NJ Transit	85 years
STCUM	10-25 years	CTA	10-50 years
CalTrain	25-30 years	City of Calgary	10-20 years
PATH	80-100+ years	MTRC	10+ years
MetroLink	100+ years	BART	25 years
MTA of Maryland	10+ years	NYCTA	80+ years
Metro-North	65-125 years	MARTA	20-25 years

NOTE: See page 6 for respondent transit agency names in all subsequent tables.

tunnels. Of most interest was information about the average age of tunnel structures. There is a wide variability in tunnel age information from respondents. Tunnels vary in age from 10 to 20 years in newer systems such as those in Montreal and Baltimore to well over 100 years in the older urbanized transit systems of New York and New Jersey (Table 1).

The differences in ages of transit system tunnel structures shown in Table 1 have potential impacts on agency maintenance requirements, and therefore potentially on inspection policy and procedures as well. It could certainly be assumed that older tunnel systems exhibit greater numbers of and/or more severe structural tunnel defects, potentially requiring

TABLE 2
FREQUENCY OF TUNNEL STRUCTURE INSPECTION

	CalTrain	PATH	Metrolink	MTA-Maryland	Metro-North	NJ Transit
More than once a week					Wk track inspection	
Once a week			#001			
Once a month						
Once each 6 months						
Once a year	For rail and ped. Tunnel	Item #1			Visual inspection all tunnels	7.23 Main, .46 M&E (N) and (S)
Once each 5 years				All tunnels and Underground Structures		
None to date						
Emergency basis only						
Other, please specify	Plus, as required rail and ped. Tunnel	Item #2, 3a and 3b, 5a and 5b, Item #4, Item $6			All tunnels twice a year	Track through tunnels inspected twice a week in periods of freezing weather the M&E Tunnels are inspected for ice in vicinity of catenary wires
More than once a week						
Once a week						
Once a month						
Once each 6 months			Under-river tubes			
Once a year		All inspected once a year	Subway structure	00,002,003		
Once each 5 year				001,002,003 plus structural		
None to date						
Emergency basis only						
Other, please specify	Every 6 years (1, 2, and 3)	Underground stations and tun-nels are Inspected			Once every 2 Years	Subways are inspected at night with a 3 hour work window, Inspectors have been sched-uled from day shift to work this window. Inspections may be deferred due to manpower and time shortage.

TABLE 3

TRANSIT AGENCY INFORMATION ON TUNNEL STRUCTURE DEFECTS

Tunnel Defects	SCTUM	CalTrain	PATH	Metrolink	MTA-Maryland	Metro-North	NJ Transit
Water leakage, infiltration	X	X	Items 1,2,3,4,5,6	#001	Rock tunnels and joints	HU 44-40	1 46M&E(N) 1.46M&E(S) 7 23 Main
Corrosion and deterioration of lining	X	X	Items 1,2,3,4,5,6		Steel liners		1.46M&E(N) 1.46M&E(S)
Spalling of lining, delami- Nation	X	X	Items 1,2,3,4,5,6		Concrete wall, beams and slabs		1.46M&E(S) 7.23 Main
Need for new or additional Support			Items 1,2,3,4,5,6				7 23 Main
Need for enlargement or in- cleased capacity, clearance							
Cracking of lining		X					7 23 Main
Piping of silt from outside lining	X			#001	Concrete liners		
Siltation, lock falls or other blockages, please specify	X				At X-passage between Market Station		
Collapse		X					
Others, please specify		Drainage Problem				Ice conditions-HU 33.39	

more frequent, more costly and more thorough inspections, and if so, would consume more inspection and maintenance dollars than more recently constructed transit system tunnel structures. However, it also has been observed that more recently constructed transit system tunnel structures often exhibit a surprising number of defects; numbers of defects seemingly incongruent with their age. Tunnel structure age may, therefore, not be as useful a predictor of tunnel condition as might be assumed

Tunnel Inspection Practice Inventory

Part 3 of the survey (see Appendix A) contains eight questions, the answers to which are reviewed in the discussion and tables that follow. Table 2 describes differences among respondent transit agency's tunnel structure inspection cycles. To better understand Table 2 entries, reference should be made to the original survey contained in Appendix A (Part 3, #2, Inventory) for transit system ID numbers identifying track/line locations. Table nomenclature makes reference to different sections of respondent agency's underground system. Appendix B includes a summary of the Inventory Form responses, as well as response data for the rest of the survey questions.

Chapter 3 case studies contain tunnel inspection frequency information for five transit systems. Table 2 contains information from all respondent transit agencies, and like the case study summary, confirms the variability of tunnel inspection frequency among these rail transit agencies.

It would be useful to further investigate rail tunnel inspection frequency, for example, correlated with variables such as tunnel age and inspection budget. Perhaps there are statistical correlations that might explain (better than prevailing rail transit inspection practice) the substantial differences between the various transit agency approaches to tunnel inspection frequency. For example, it appears that most respondent transit agencies have administrative procedures for variable inspection frequencies (whether for track, liner, switching equipment, under-river tubes, etc.), based on operational experience not now fully understood.

Table 3 provides transit system information on tunnel structure defects, without any effort at defect prioritization However, as in the case studies that follow, this table reflects a clear preponderance of water intrusion-related tunnel defects. This conclusion comes as no surprise to those familiar with rail tunnel conditions and maintenance priorities. Water leakage, infiltration, corrosion, spalling, delaminations, potential cracking, and siltation all indicate the intrusion of water, usually associated with chloride or calcium carbonate (from the deterioration of concrete). Keeping water out of tunnels, and adequately draining the water that intrudes into tunnels are perhaps the two most substantial issues reported by responding rail transit system inspection managers, and the most intractable problems for transit tunnel inspectors and maintenance crews.

Table 3 entries refer to the transit agency surveys contained in Appendix A (Part 3, #7, regarding track/line identification). Table nomenclature makes reference to different sections of respondent transit agency's underground systems

Most respondent transit agencies have formalized inspection reports, data sheets, or graphics to accurately record and subsequently communicate tunnel defects requiring maintenance. However, the method (and procedures) by which tunnel structural defects are recorded and communicated within a transit agency is, like other aspects of tunnel inspection, quite variable. Table 4 also reflects responses to the transit agency survey from Part 3, #6 (see Appendix A).

CTA	MTRC	Calgary	MTA/NYC	Toronto	MARTA	BART
1, 2, 3	X	386.402	X	001, 002, 003	Mainly cut and cover sections Also at Omni Station under railroad.	
	X		X			
	X		X			
1,2, 3	X		X		Some cracking of concrete rack tunnel linings (N/S line)	
	Rarely					
					Minor rock falls Peachtree Center	
						Encrustation efflorescence

TABLE 4

TUNNEL, INSPECTION REPORTING PROCEDURES

Transit Agency Listings	Formal Report	Drawings	Field Notes	Only if a Problem Exists	Other, Please Specify
STCUM	X				
PATH	X	X	X		Letter report
CalTrain	Accompany inspection report, if required.	Accompany inspection report, if required.			
MetroLink	X				Spread sheets
MTA, Maryland	X		X		Database
Metro-North Railroad	X				
NJ Transit	X				Special forms
Chicago Transit Authority					Standard report Form
MTRC, Hong Kong		Condition structure mark on drawings	Details on form		Magnetic medium, CADD
MTA, New York City Transit	X			X	Details on forms.
City of Calgary	X				
Toronto Transit Commission	X				
MARTA			X		
BART	X		X		

With the next several questions (Tables 5-7), the process of rail tunnel structural inspections (and maintenance) reflects the competition inherent in transit agency financial resource limitations Table 5 (Part 3, #8) describes respondents annual tunnel inspection costs. The question attempts to categorize answers in various ways, but most respondents chose to respond for their entire underground system. NJ Transit did not include costs for its track inspection, winter ice inspection, or consultant inspection. Table 6 (Part 4, #1) describes annual structure repair needs, and Table 7 (Part 4, #2) describes annual structure repair expenditures. In each instance, most entries were systemwide, and other survey cost categories were not used.

For that reason, it is difficult to make assumptions about Table 5 data on annual inspection costs. Any number of factors (aggregate costs of system size and prevailing labor rates, for example) could account for those differences. Additionally, agency budget limitations, accounting practices, tunnel system age and/or length, priorities attached to tunnel inspections within the transit agency could all have impacted respondent agency's answers to the cost questions below. Notwithstanding these obvious potential differences, it is clearly apparent

TABLE 5

ANNUAL TUNNEL STRUCTURE INSPECTION COSTS (x $1,000s U.S.)

Transit Agency Listings	Per Mile of Structure (Tunnel)	Per Tunnel Structure Per Station	Per Entire System	Unknown
STCUM	39			
PATH			300	
CalTrain			5	
MetroLink			5	
MTA of Maryland			400	
Metro-North Railroad			2	
NJ Transit			3	
Chicago Transit Authority			80	
MTRC, Hong Kong	4.35	6.14	23.35	
MTA, New York City Transit			900	
City of Calgary		1		
Toronto Transit Commission			50	
MARTA			75	
BART			65	

TABLE 6

ANNUAL TUNNEL STRUCTURE REPAIR NEEDS (x $1,000s U.S.)

Transit Agency Listings	Per Mile of Structure (Tunnel)	Per Tunnel Structure Per Station	Pet Entire System	Unknown
STCUM	104			
PATH			820	
CalTrain			100	
MetroLink			20	
MTA of Maryland				To be determined
Metro-North Railroad			57	
NJ Transit			2,000	
Chicago Transit Authority			500	
MTRC, Hong Kong	27.9	39.37	1,500	
MTA, New York City Transit				X
City of Calgary			30	
Toronto Transit Commission			500	
MARTA			100	
BART				X

how the large differences in transit agency reportage reflected in Table 5 can be explained.

Tunnel Rehabilitation and Funding Inventory

The questions in Part 4 of the survey focus on tunnel maintenance (repairs and rehabilitation), the follow-on activity to tunnel structure inspections (to eliminate tunnel structural defects); and a mixture of other questions (tunnel structure longevity, QA/QC programs, etc.). All transit agency respondent costs are estimates, and Tables 5-7 should be read accordingly.

Two newer rail transit agencies had specific repair cost information for their tunnel system (per mile of tunnel) while most rail transit respondents answered this question for the entire transit system. Since variations in transit system size and budget are so substantial, the dollar responses in Table 6 are diverse. Therefore, these data do not support conclusions about transit system maintenance costs.

Some rail transit agencies, for whatever reasons, may simply place a higher emphasis (by budgeting more resources) for tunnel structure maintenance, or may have a newer tunnel system requiring less maintenance. It would not be possible to clarify those rail transit agency tunnel maintenance cost interrelationships without further breakdowns of the cost information contained in the last three tables through additional investigation and analysis of transit agency inspection budgeting practices. That information would be helpful in understanding the priorities that various transit agencies attach to tunnel maintenance needs and repairs.

These budget issues need revisiting in any subsequent effort to analyze the relationship between tunnel structure inspection costs, repair needs, and current repair expenditures (see chapter 5 for further discussion on recommendations for additional study). The data gathering required by the survey may have represented more difficulty for transit agency respondents than was assumed. In any event, drawing conclusions from the above cost information (Tables 5-7) seems

TABLE 7

ANNUAL TUNNEL STRUCTURE REPAIR EXPENDITURES (x $1,000s U.S.)

Transit Agency Listings	Per Mile of Structure (Tunnel)	Per Tunnel Structure Per Station	Per Entire System	Unknown
STCUM				X
PATH			820	
CalTrain			0	
MetroLink			5	
MTA of Maryland			250	
Metro-North Railroad				X
NJ Transit			2,000	
Chicago Transit Authority			500	
MTRC, Hong Kong	25.9	36.6	1,390	
MTA, New York City Tiansit			40,000	
City of Calgary			30	
Toronto Transit Commission				
MARTA			1,000*	
BART				X

*MARTA's Table 7 costs included aerial structures as well as tunnel structures

speculative at best. Inferentially, the wide disparity in data responses to survey cost questions suggests a difficulty in securing straightforward information about tunnel structure inspections and maintenance. Perhaps, in turn, the tables reflect a data collection need that merits a subsequent effort to clarify.

TRANSIT AGENCY RAIL TUNNEL STRUCTURE INSPECTION ISSUES

Rail transit tunnels, if not properly maintained, represent potential impediments to the operation of public transportation systems in which they are located. A tunnel blockage of even short duration in any urban setting would cause substantial social and financial impacts. As forgiving as tunnel structures are, they support large earth loads in environmentally hostile conditions that cannot be sustained over the long term without major capital investments

Inspections are the "early warning system" to identify the need for such investments. The effective use of inspection information can direct the prudent use of funds to delay and minimize major capital investments. Tunnel age appears to be less of a controlling factor in the quantity of defects observed. Newer tunnels (see the MTRC case study) appear to have as many structural defects (or more aggressive inspection/maintenance procedures for identifying defects) as do older rail transit tunnels. Inspection dollars appear to have a very costeffective use of limited transit agency resources, in order to budget capital repairs prudently.

The issues that have arisen throughout this discussion of rail tunnel structural inspections are:

- Work environments for rail transit inspections: system age, operational policies/procedures, inspection conditions;
- Inspection/design-construction interrelationships;
- The budget: policy standards vs. rail tunnel inspection funding (resource priorities);
- Perceived necessity for rail tunnel inspection: the case for regulations;
- Methodological approaches to tunnel inspection, reportage, and follow up;
- Standards for periodic vs. random inspection;
- Priorities for rail tunnel inspection: tunnel maintenance frequency; and
- The constituency for rail tunnel inspections: claims on rail transit system resources.

CHAPTER THREE

CASE STUDIES

Five case studies on transit system tunnel and underground structure inspection practices are presented in this chapter: the Mass Transit Administration of Maryland (Baltimore); the Bay Area Rapid Transit (San Francisco); the New York City Transit Authority (MTA); the Chicago Transit Authority (CTA); and the Mass Transit Railway Corporation (MTRC) in Hong Kong. The five transit systems were chosen because good information on their inspection practices was available, and because these cases offer useful contrasts in inspection practices which raise significant issues for discussion of rail tunnel structural inspection.

MASS TRANSIT ADMINISTRATION OF MARYLAND (BALTIMORE)

Characteristics Of The Transit System

The Mass Transit Administration (MTA) in Baltimore serves an area of 1800 sq mi. The MTA annually transports an average of 87 million passengers on Baltimore's bus, Metro and light rail systems. The MTA provides public transportation services on several different modes: light rail transit (LRT), heavy rail transit (HRT), and MARC commuter trains and bus transit service. MARC carried five million riders in fiscal year 1994. Bus transit service exceeds 250, 000 passengers per day.

The light rail transit system began service in 1992. It carries in excess of 18,000 passengers per day along the central LRT Line. It has 22.5 mi of track with 17 stations plus seven station stops in downtown Baltimore. The heavy rail system (Baltimore Metro) is approximately 10 years old. The HRT line travels along 15.5 mi of track and carries approximately 37,000 passengers per day. It also has six underground stations in the downtown area.

Type and Frequency of Rail Tunnel Inspection

The Metro has a consultant-prepared inspection manual *(2)* with sections on the various subway structures that are inspected, inspector qualifications and responsibilities, typical structural defects, structural inspection procedures, and inspection reportage and documentation.

The Metro requires that subway structures have in-depth inspections at least once every 5 years unless the deterioration of structural conditions warrants inspections at more frequent intervals. This inspection cycle is also consistent with procedures at the Port Authority of New York and New Jersey which performs inspections of their inland subway structures on the same 5-year cycle. Based on an inspection analysis from *the Inspection Manual for Baltimore Metro Subway Structures (2),* the following inspection frequency was recommended:

1. All subway stations, fabricated steel lined tunnels, rock tunnels, cross passageways, mid-line vent shafts, and retaining walls should be inspected every 5 years.
2. The precast concrete lined tunnel should be inspected every 2.5 years.
3. Areas where leaks are repaired should be reinspected after one year. If no further leaks are found, in-depth inspections can be conducted during the 5-year cycle.

Rail Tunnel Inspection Procedures

Access to track level inspections is limited from 1:00 a.m. to 4:00 a.m. on weekdays or to a time on weekends governed by other construction schedules and the schedule for Baltimore Oriole baseball games. The intent is that track level inspections not interfere with revenue service.

The inspection of stations and ancillary rooms is conducted during normal working hours from 8:00 a.m. to 5:00 p.m. However, inspections on the station platforms are limited to off-peak hours from 9:00 a.m. to 3:00 p.m. Inspections above the stairs and escalators are performed only on weekends, and then only when the stations are closed.

The equipment used to access various structural elements for up-close visual inspections requires that additional tools and equipment be used. For the tunnel sections, cross-over structures and underside ancillary spaces, a man-lift truck mounted on a hi-rail vehicle is required.

For the cut-and-cover Sudbrook Park Tunnel and Mondawmin Portal Structure, a 12-ft step ladder is required. For the retaining walls adjacent to the Sudbrook Park Tunnel, ladders ranging in height from 12 to 24-ft or a man-lift truck on hi-rails is required. For the station structures, a variety of equipment is required including 12-ft step ladders, extension ladders, personnel man-lifts ranging in height from 20 to 36 ft and a man-lift truck on hi-rails for the structure immediately over the tracks.

During inspections, the MTA requires inspection teams to have access to and be able to use the equipment shown in Table 8.

For ancillary spaces and vent shafts, both step-ladders and extension ladders may be required. For exterior canopies and elevator enclosures, ladders are needed. These types of inspection equipment permit inspectors to gain an up-close, hands-on view of most structural elements. However, it is understood that for certain structural elements over the escalators

TABLE 8

MTA INSPECTION EQUIPMENT

Equipment Type	Equipment Purpose
Aerial Bucket Truck	For lifts to inaccessible areas from track or platform levels.
Binoculars	To inspect inaccessible components.
Calipers	To measure plate thickness.
Camera (35 mm) w/Flash	To take photos for documentation of the inspection.
Chalk, Keel, or Markers	To make reference marks on structures.
Chipping Hammer	Used to sound concrete.
Clip Board	Used to take notes and fill out inspection forms during the inspection.
Crack Compactor Gauge	To measure crack widths in inches.
Field Forms	To document the findings, take notes and draw sketches for the various structures.
Pencil	Used to take notes and make sketches
Plumb Bob	Used to check plumbness of columns and wall faces.
Pocket Knife	Used to examine loose material and other items.
Screw Driver	Used to probe weep holes to check for clogs.
Tapes	Pocket tapes and folding rules used to measure dimensions of defects.
Wire Brush	Used to clean debris from the surface to be inspected.

and stairs, hands-on inspection can only be achieved by erecting scaffolding. As an alternative to the difficulty of erecting scaffolding, binoculars can sometimes be used from nearby man-lifts to locate surface defects; and sometimes stairs are sufficient for inspection unless defects are found that, because of their potential seriousness, require closer inspection.

Inspection Reporting and Documentation

Appendix C contains a number of the inspection forms used by the MTA within the Baltimore Region for subway structure field inspections (including stations, crossovers, earth, rock, and mixed face tunnel segments, cross passageways, cut-and-cover box structures, etc.). A review of these forms is helpful in appreciating how the MTA collects tunnel structure inspection information.

Using some of the above equipment, visual inspections are conducted on exposed surfaces of all structural elements. All noted defects are documented by location and size. Severe spalls in concrete surfaces are measured for their length, width and depth. Steel corrosion is also measured for length, width and depth. Since a visual inspection requires that the structural element be visible, inspectors clear away debris, efflorescence, rust, or other foreign substances from surfaces prior to the inspection. Once the defect is noted, it is classified as minor, moderate, or severe, as explained above.

In addition to a visual inspection, structural elements are periodically sounded with hammers to identify unseen defects. After being struck with a hammer, the surface of the structural element will produce a sound that indicates if a potential defect exists below the surface. A high-pitched or ringing sound indicates good material below the surface. Conversely, a dull thud or hollow sound indicates that a potential defect exists below the surface. Such a defect in concrete may indicate potential delamination below the surface, or that the concrete is potentially loose and may spall. Once a defect is suspected, the surface of the structural element in the vicinity of the defect is sounded until its spatial area has been estimated and recorded.

The MTA requires that all structural inspections be thoroughly and accurately documented. The documentation of severe defects requires inclusion of a narrative description, as well as a sketch showing its location and size. All severe defects are also photographed, although any defect may be photographed if the degree of its severity is in question. All defects are described, and sketches are only needed with severe defects.

Sketches of defects are made on pre-drafted plans and/or on forms. These forms show the applicable plans, elevations and views for the structural elements to which they pertain. Blank forms are also provided to inspectors for inclusion of additional sketches, if necessary. All defects are recorded on sketches by referencing defect location with the beginning and end locations of all structural members to which they pertain.

To consistently document inspection findings, each inspector uses the system defects code which describes and classifies defects as shown in Table 9. Photographic records can be attached to photo sheets along with any additional sketches that may be useful to better document the inspection. The MTA recommends always completing the spaces at the top of the

TABLE 9
MTA INSPECTION DEFECT CODE

Defect Description	Abbreviation	Classification
Crack	CR	1 - Minor
Scaling	SC	2- Moderate
Spall	SP	3 - Severe
Exposed Reinforcement	E	
Rust	R	
Honeycomb	H	
Patch Failure	PF	
Hollow Area	HA	
Debris	D	
Buckle	B	
Efflorescence	EF	
Leakage	LK	

form that identify the applicable structural element. That kind of thoroughness helps to avoid confusion when forms contain several structural elements.

A 35-mm camera is always used to take photographs during inspections. Each inspector keeps a log of all photographs taken. This log identifies the connection between film counter number and log roll number. The MTA recommends that an inspector use the first letter of their first or last name, and to follow that with the film roll number. For example, an inspector named Rod may use R1 as the designation for roll 1. Such a system allows coordination between all inspectors which may serve to avoid overlap of inspection responsibilities or confusion about the origins of defect photographs.

Inspection procedures vary somewhat depending on the type of structure being inspected. When inspecting soft-ground tunnel liners, inspectors rate the physical condition and functional capability of fabricated steel liners, precast concrete liners, connection bolts and gaskets between liner segments. These elements are rated for each 200-ft segment of tunnel between station markers, with separate ratings for inbound and outbound tubes.

Inspectors also rate the physical condition and functional capability of cast-in-place concrete linings. Again, the lining is rated for each 200-ft segment with separate ratings for the inbound and outbound tunnels. Inspectors also rate the physical condition and functional capability of the concrete track pads under the primary rail fastener plates or the third rail, as well as the invert slab and floating slab under the concrete support pads. Concrete support pads and invert slabs are rated for the various sections of earth tunnels, and for all stations, mid-line vent shafts and portal structures.

Inspectors also rate the physical condition and functional capability of drainage conveyances, railings, safety walks, utility supports and electrical bonding. These elements are rated at all locations of the tunnels, stations, mid-line ventilation shafts and portal structures.

Inspectors follow the same inspection procedures in rating the physical condition and functional capability of the structures described as follows: the top and bottom slabs, the sidewalls, precast walkway panels, entrance doors (cross-passageways), concrete beams, slabs, columns, walls, steel beams, architectural panels, railings, stairs, entrance canopies, elevator enclosures, parapet walls, track supports, street-level steel grating (stations), concrete walls and roof slabs, track supports and invert/floating slabs, drainage, railings, utility supports (crossover structures), concrete walls and slabs, track supports, stairs, street-level steel grating, drainage, railings, safety walks, utility supports and mid-line ventilation shafts.

Identification of Major Structural Problems and Issues

To ensure that all structural elements are inspected, a tabular listing of the various structures within the subway system has been developed by the MTA. The Metro system has two types of tunnel liners (precast concrete and fabricated steel). In addition, there are numerous crossover structures, cross-passageways and mid-line ventilation shafts.

The goal of any comprehensive tunnel structure inspection is to identify structural defects in the various subway elements, and to evaluate how those defects may affect the structural element's capacity to carry the designed or imposed loads.

TABLE 10

MTA STRUCTURAL DEFECT RATING

Rating	Description
9	Newly Completed Construction
8	Excellent Condition; No Defects Found
7	Good Condition; No Evidence of Deterioration
6	Shading between 5 and 7
5	Fair Condition
4	Shading between 3 and 5
3	Poor Condition
2	Serious Condition
1	Critical Condition
0	Critical Condition (Closed-Beyond Repair)

The MTA assigns a numerical rating of 0 to 9 for each structural element inspected. Zero is the worst condition and 9 is the best condition (see Table 10). The rating is based on the degree of deterioration found in the structural element inspected, as well as on the extent to which the element retains its originally designed functional capacity. To judge the extent to which the structural element retains its functional capacity, the inspector must understand how that structural element has been designed, and how the observed defect adversely impacts the design (see the section below on inspection staffing).

Inspection Staffing

Gannett Fleming, an engineering consultant to the MTA, recommended that the MTA require tunnel inspections be performed by teams of two individuals, at a minimum, and that the leader of a team be a professional engineer. Further recommendations would require that professional engineers be experienced in both structural inspections and designs, and that all inspections be reviewed by an engineer licensed in the State of Maryland. All teams are expected to perform inspection work only after having read and understood the inspection manual. The inspection team must meet the qualifications below *(2):*

Team Leader Requirements

- Be a registered professional engineer.
- Have design experience in underground concrete structures and tunnels.
- Have a minimum of 5 years inspection experience with the ability to identify and evaluate defects that may pose a threat to the integrity of a structural element.
- Be able to evaluate whether cracks are shrinkage or flexural, and whether such cracks may cause structural problems.
- Be able to assess the degree of concrete, steel and aluminum deterioration.

- Be able to climb and/or use equipment to access the higher regions of structures.
- Be able to evaluate and determine the types of equipment or testing required to fully define a structural deficiency.
- Be able to write legibly and to draw understandable sketches.

Team Member Requirements

- Should be either an engineer or trained inspector.
- Have a minimum of 5 years inspection experience in concrete and steel structures.
- Be able to climb and/or use equipment to access the higher regions of structures.
- Be able to write legibly and to draw understandable sketches.
- Be able to read and interpret drawings.

Each member of the inspection team must fulfill certain responsibilities in order for the work to be accomplished in an efficient manner.

The Team Leader is responsible for coordination with appropriate MTA staff for access to tunnels and subway stations; for scheduling the use of equipment and scaffolding; for determining the type of inspection required; for evaluating all structural deficiencies; for ensuring that all inspection forms are completed in a legible manner; and for notifying appropriate MTA staff of any potentially dangerous condition.

The other team member is expected to assist the Team Leader in the inspection. Duties may include performing a portion of the inspection; carrying the equipment and inspection forms; or taking photographs and making sketches.

SAN FRANCISCO BAY AREA RAPID TRANSIT (BART)

This case study reflects information currently available from the Bay Area Rapid Transit District (BART) on rail tunnel inspection policies and procedures as a result of BART's ongoing development of a draft *Structural Inspection Manual (3)*. BART provided a copy of the draft manual on inspection and evaluation of subway and tunnel structures and the section on administrative procedures.

Characteristics of the Transit System

San Francisco's BART is a 71.5 mi, semi-automated rapid transit system serving over three million people in the three BART counties of Alameda, Contra Costa, and San Francisco, as well as northern San Mateo County.

There are approximately 19 mi of track through subways and tunnels; not including the 3.6 mi twin-section transbay tube, and the 3.5 mi Berkeley Hills tunnel; 23 mi of aerial track and 25 mi of surface track. There are also 4 mi of double-track in subway.

There are 34 BART passenger stations located along four double-tracked rapid transit lines comprising seven surface, 13 aerial and 14 subway stations. Four of these stations are a combination of BART and MUNI Metro Stations located in downtown San Francisco.

Type and Frequency of Rail Tunnel Inspections

BART's Structural Inspection Program is the method by which the transit system's structures are inspected, evaluated and maintained at levels adequate to assure their integrity and safety for transit riders and BART employees. Structural types and station/mile post marker locations have been established for every structure throughout the BART system. Structures are numbered and on a specified inspection cycle, not to exceed 2 years. Shorter inspection intervals may be warranted for a particular structure based on its age and/or known or newly discovered defects. Some structures are inspected during even and others during odd years.

Table 11 describes the various items inspected in each transit structural category. Those Structural Inspection Program administrative procedures designed to achieve transit system structural integrity include:

1. the inspection schedule
2. the inspection system
3. records
4. the loop system.

The normal inspection schedule described above identifies all structures scheduled for inspection at specified intervals.

TABLE 11
BART STRUCTURES INSPECTED

Type of Structure	Structural Elements
Transbay Tube	Concrete, Structural Steel, Miscellaneous Steel, Seismic Joints, Doors, Hatches, Paint, Seepage, Signs and Lighting
Subway Structures	Concrete, Structural Steel, Bolts, Miscellaneous Steel, Bridge Beams, Cross Passages, Walkways, Drainage, Seepage, Doors, Lighting
Elevated Structures	Piers, Bents, Abutments, Concrete Girders, Steel Girders, Bearing Seats, Key Cap, Walkways, Decks, Paint, Drainage, Soil Conditions
At Grade Structures	Slopes, Ditches, Culverts, Inlets, Drainage, Retaining Walls, Maintenance-of-Way Access Points, Appurtenant Structures, Fences, Gates, Vegetation, Encroachments

The inspection system, inspection records and loop system are described in the next section.

There are two types of structural inspections: scheduled and unscheduled. Scheduled inspections have been described above. Unscheduled inspections include:

1. emergency inspections
   - accidents
   - natural disasters
2. request from BART's Safety Department
3. request from BART's Maintenance Department
4. request from BART's Engineering Department.

Emergency inspections are conducted on rail transit structures after each earthquake, accident and/or other disaster, or as requested by the maintenance department for structural problems that have been identified and whose structural deterioration has been followed. Structural items in need of continuing observation or repair are assigned to one of the following priority codes based on the severity of their deterioration:

1. a possible condition observed at this time
2. a condition that should be scheduled with routine maintenance
3. a condition that requires action as soon as possible
4. a condition that requires immediate action.

Rail Tunnel Inspection Procedures

BART's structural inspection procedures include: the inspection schedule, the inspection system, records, and the loop system.

The field inspection system is an administrative control whose purpose is to assure that inspections are carried out in a systematic and organized fashion in order to minimize the possibilities of overlooking any important steps in the inspection process, or any relevant pre-existing structural information. Therefore, the following BART inspection requirements were established:

1. always carry the previous inspection report(s) of the structure(s) under current inspection as a reference
2. assign a priority code to each structural element inspected

For example, the inspection of structural concrete members is made more relevant by ongoing reference to the original inspection report(s) wherein any concrete defect was recorded. The progression of concrete deterioration is thereby more meaningfully evaluated. Concrete inspection also includes both visual and physical examinations. The visual examination notes observed defects. For example:

1. Describe the type, size, length, direction and location of cracks. Since cracks are potential indicators of future structural problems, their cause and extent must be recorded.
2. Describe the rust staining on concrete since it results from corroding reinforcing steel. Corroded reinforcing steel produces loss of strength within the concrete. The location and extent of the rust stain should be measured and recorded.
3. Describe the type of any observed horizontal, vertical or longitudinal structural movement.

The physical examination includes hammer sounding to enable detection of any concrete deterioration, including possible delaminations. The sound produced by tapping concrete surfaces produces a resonance that is a good indication of the concrete's structural integrity.

Maintaining clear and accurate records is every bit as important as the process of inspection. Complete and up-to-date records of all transit system structures is perhaps the most important purpose of the inspection process. Accuracy is ensured by maintaining separate field inspection reports for each structure. The BART field inspection form contains the following information:

1. The date of the structural inspection,
2. Personnel performing the inspection,
3. Structural identification number,
4. Mile post or engineering station,
5. Listing of possible defects,
6. Listing of items to be inspected and reported,
7. Priority codes, and
8. Type of structure.

Notes on inspection forms may contain any remarks identifying structural problems or the condition of the structure. This field information is then subsequently entered into BART's central computer data base where it can be used as a management tool in the scheduling of inspections or defect repairs. BART inspection reports are audited every quarter. Figure 1 indicates that both of BART's Operating Divisions (Engineering & Construction and Power & Way), conduct structural inspections.

The Structural Inspection Program's auditing process is intended to reconcile inconsistencies in inspection reporting, as well as to reinforce communication about what the inspection reporting process found and how it should be evaluated Some redundancy and potential inspection "oversight" therefore appear to be built into BART's Structural Inspection Program. Table 12 demonstrates how the inspection reporting process (an excerpt from the *Summary of Findings* for the 1993 First Quarter inspection report audit) can raise good questions for managers by providing useful information on tunnel structure defect evaluations.

What BART means by the "loop system" is a procedural and organizational "system" which ensures that any structural item found to be deficient and in need of repair will be repaired in a timely and appropriate manner. Part of that system is the previously mentioned priority codes assigned to structures with defects:

1. Possible condition observed at the time,
2. Condition to be scheduled with routine maintenance,

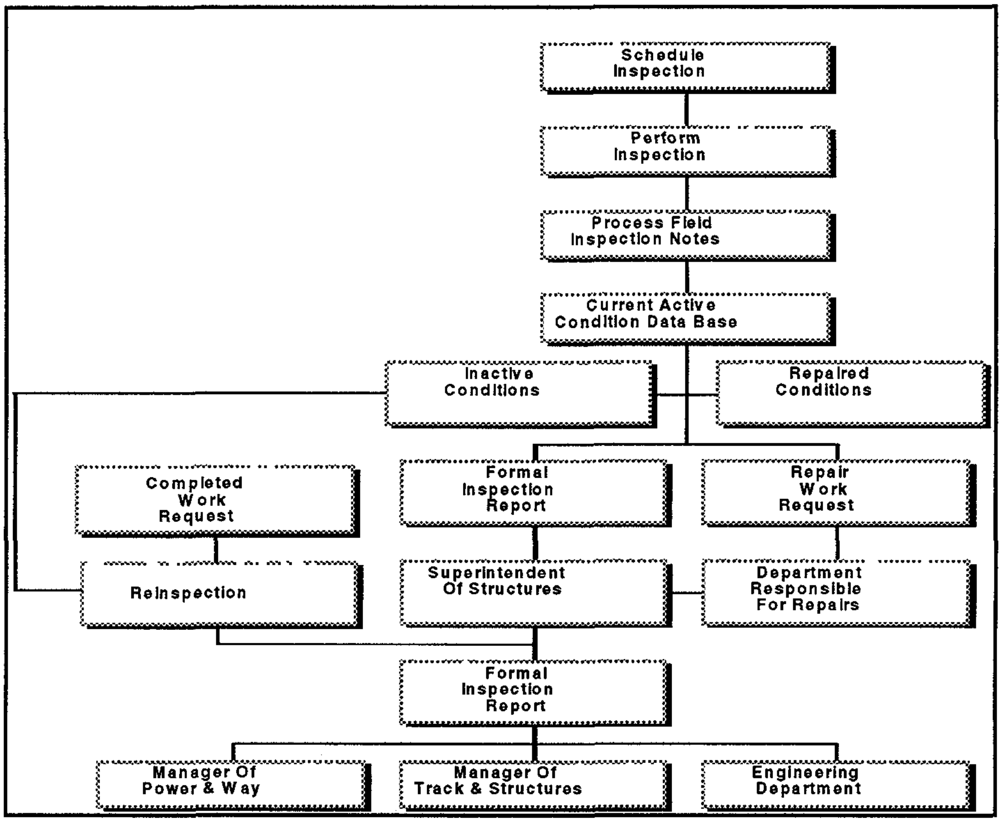

FIGURE 1 BART structural inspection flow chart *(3)*.

3. Conditions requiring immediate action, and
4. Conditions requiring immediate emergency action.

Some rail tunnel structure repairs are minor, while others are major. Minor repairs are typically conducted by BART's Maintenance Department, but major repairs are conducted by outside contractors. Figure 1 is an approximation of the BART inspection to repair process which reflects the abovementioned organizational redundancy while also demonstrating the flow of information from inspection to repair. Figure 2 is the BART administrative organization for the inspection to repair process. Figure 2 depicts essentially the "who" to the "what" of Figure 1. Minor repairs are in-house responsibilities while major repairs are forwarded to the Engineering Department for prioritization and scheduling.

See Appendix C for a variety of BART inspection forms and inventory sheets. At-grade, transbay tube and subway structure field inspection report forms, as well as numerous inventory sheets catalogue the data sought by BART inspectors and/or consultants.

Identification of Major Structural Problems and Issues

Inspection and evaluation of subway and tunnel structures is conducted on a variety of structural elements (as shown in Table 11). A large percentage of the BART system is constructed of concrete and steel. The types of defects that are encountered during an inspection are dependent on the material being inspected. It is important that inspection personnel are familiar with the basic properties of those materials, and the manner in which they deteriorate over time.

Cut and cover concrete box structures (subway structures) and hardrock tunnels with concrete lining make up a large percentage of BART's underground system. If these structures experience any unusual stresses, it is usually seen in the form of cracking, shearing or spalling around construction joints. Other problems are encrustation from leaching water, scaling, corrosion, delamination, scaling, efflorescence, pop-outs and damage from transit collisions (see the Glossary for a definition of these terms).

MTA NEW YORK CITY TRANSIT (NYCT)

Characteristics of the Transit System

The MTA New York City Transit (NYCT) operates 24 hours a day over 240 route mi of elevated, viaduct, open-cut, embankment and subway structures with 469 stations systemwide. Within that system, the NYCT has approximately 145 route mi of subway structures, 227 subway stations and 14 under-river tubes. It is one of the largest transit systems in the world.

Responsibility for the structural integrity of this large transit system rests with the NYCT Department of Capital Program Management and the Division of Infrastructure. It is the Division of Infrastructure's responsibility to conduct the daily inspections of NYCT structures.

TABLE 12
SUMMARY OF TYPICAL BART INSPECTION FINDINGS

Description	Evaluation	Recommended Action
Fruitvale Station	All four escalator soffits have oil stains.	Insulate the walls of the oil reservoir with non-permeable material (plastic)
Lake Merritt Subway Structure:	The following are the areas of concern:	
It consists of a cut-and-cover reinforced concrete dual bod structure. The center portion is supported on piles, and is built under the Lake Merritt Channel which supplies sea water to the lake. The two end portions are on spread footings. The subway is located approximately 30 feet below ground level, and approximately 20 feet below the ground water table. Generally, the center portion defects were in a more advanced stage as compared to the end portions.	1 Leaks of varying severity throughout have been an on-going problem in this subway. The amount of water is such that some areas are continuously damp.	The services of a consultant or a specialty contractor should be obtained to find a possible permanent solution to stop the leaks.
	2. The high chloride content in the water, the constant moist condition and the availability of oxygen are the major causes of corrosion and concrete delamination	
	3 Cracks are common in concrete structures However, at this subway these cracks are wider than hair line and extend up the walls and continue into the ceiling. They occur at regular intervals which may indicate structure movement.	Structure should be surveyed for the possibility of horizontal or vertical movement.
	4. Some areas that were patched under a recent subway repair contract, which consisted of chipping loose concrete and shotcreting spalls, sounded hollow under the hammer test.	Further investigation of patches is recommended for adequacy of contract repairs, before the one-year warranty expires
	All items noted on the E & C audit were in agreement with Power & Ways inspection reports. However, the items below are repeated for emphasis:	
	5 At A2 Station 955 + 50 the construction joint is leaking heavily. The rail and rail fasteners in this area are severely corroded	
	6 Accumulation of water in the drainage trough of the Lake Merritt Subway.	Leaks should be stopped by epoxy grout injection. Six rail fasteners should be replaced. Drainage should be cleaned.

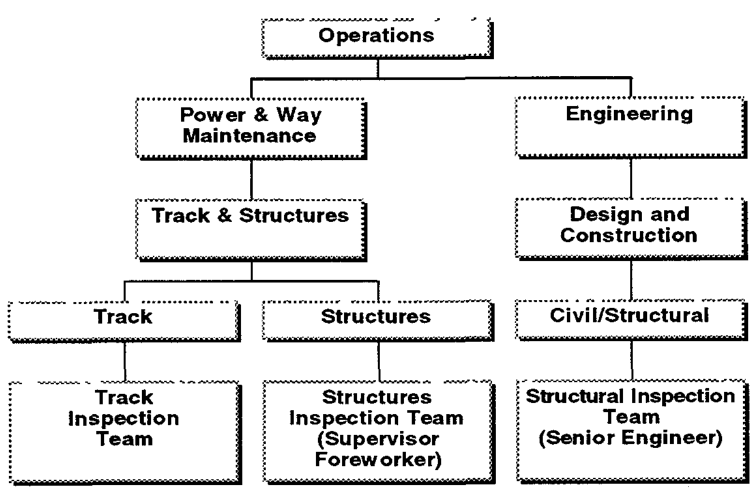

FIGURE 2 BART structural inspection organization chart *(3)*.

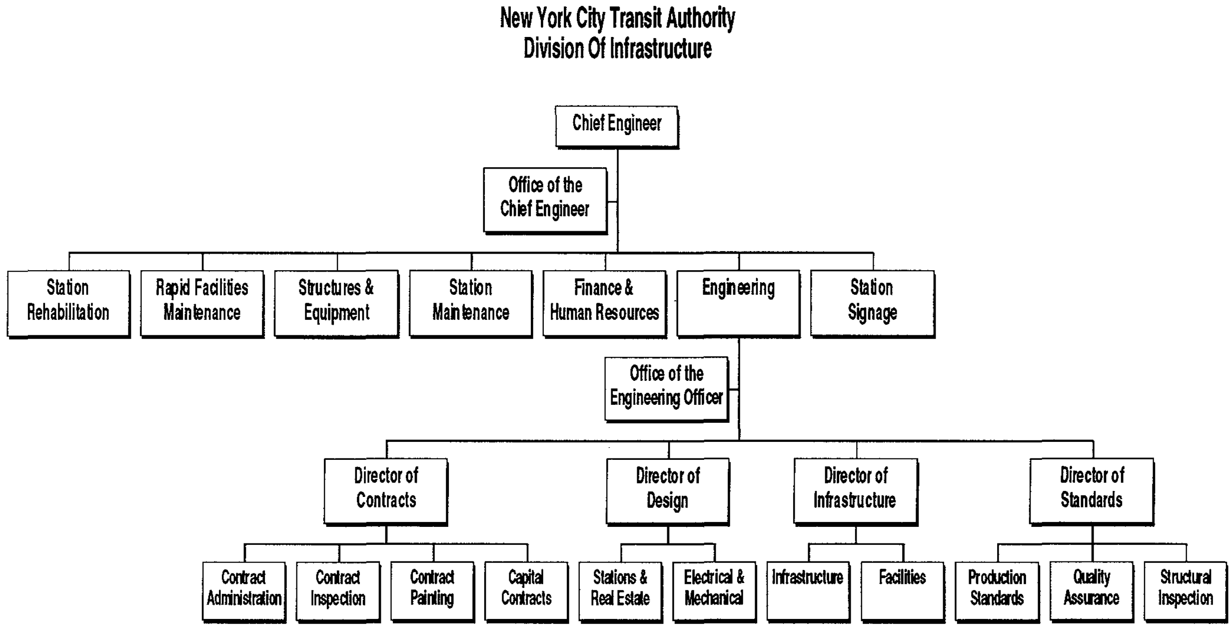

FIGURE 3 NYCT staff organization for rail structure inspection *(4)*.

Type and Frequency of Rail Tunnel Inspection

Subway structures and stations are inspected on an annual, repeating cycle. The under-river tubes are inspected semiannually. In order to accomplish this kind of inspection regime, at least 1 mi of two-track subway needs to be inspected every night of the working week.

Responsibility for station inspections is divided between two groups. Structural elements are inspected by the subway inspection group while other elements (e.g. architectural, electrical, mechanical, etc.) are inspected by personnel from the Borough Manager's office (see Figure 3).

Rail Tunnel Inspection Procedures

Inspectors perform initial structural inspections visually, by walking along the tracks or through the stations. In order to optimize the time available for inspections, they are performed during the night, when train headways are least frequent. Table 13 describes NYCT inspection frequency for various structural elements.

Table 14 describes NYCT inspection procedures, further explained in the summary below.

1. *Make Daily Assignments:* A flagman for the day is designated on a rotating basis. The remainder of the inspectors are assigned specific structure spans to inspect.
2. *Establish Flagging Protection:* Flags are posted on all tracks of the structure as per Authority rules to protect the day's work area. The flagmen protect one track at a time and all inspection is performed under their protection.
3. *Track Level Inspection:* Inspectors perform a visual inspection of their assigned structure spans, noting deficiencies in their record-keeping pads ("Butcher Books"), and paying strict attention to primary structural members and connections.
4. *Street Level Inspection:* Upon completion of the track level inspection, inspectors will move to the street below the elevated structure and inspect columns, column bases and the underside of the structure.

TABLE 13
NYCT RAIL TUNNEL INSPECTION FREQUENCY

Structure	Frequency
Tangent Elevated Structure	Annually
Curved Elevated Structure	Semi-Annually
Viaduct Structure	Annually*
Open Cut Structure	Annually
Embankment Structure	Annually
Subway Structure	Annually
Station Structure	Annually
River Tubes	Semi-Annually
Elevated Expansion Joints	Semi-Annually
Emergency Inspection	As Required
Bridges*	Annually

*Concrete viaduct structures are inspected for structural sufficiency annually However, an external surface sound inspection is conducted in the spring and fall, in addition to the removal of loose material which might present a hazard to pedestrians and vehicles

TABLE 14
NYCT INSPECTION PROCEDURES

Inspection Procedures	Elevated Structure Inspection	Elevated and Viaduct Station Structure Inspection	Subway, Open Cut and Embankment Station Structure Inspection	Subway, Open Cut, Embankment, River Tube Structure Inspection
1 Make Daily Assignment	X	X	X	X
2 Establish Flagging Protection	X	X	X	X
3 Track Level Inspection	X	X	X	
4 Street Level Inspection	X	X	X	
5 Emergency Inspection	X	X	X	X
6 Platform Level Inspection		X		X
7 Platform Stairway Inspection		X		X
8 Mezzanine Level Inspection				X
9 Mezzanine and Street Stair way Inspection				X

5. *Emergency or Questionable Condition: If* an inspector discovers any condition which may cause an immediate hazard to safe operations, or that they are unsure of, that condition is to be immediately brought to the attention of the Supervisor.
6. *Platform Level Inspection:* Inspectors walk along each platform conducting a visual inspection of platform, canopy, canopy supports, railings and track ladders.
7 *Platform Stairway Inspection:* A visual inspection is made of the platform stairways to include stringers, step angles, treads, risers and handrails.
8. *Mezzanine Level Inspection:* The mezzanine is visually inspected in its entirety including exposed hangers and supporting elements.
9. *Mezzanine and Street Stairway Inspection:* A visual inspection is conducted on mezzanine and street stairways to include stringers, steps, angles, treads, risers, handrails, railings, canopy and canopy support.

Each inspector is assigned a specific area or structural section to inspect each night. For example, an inspector may be assigned to the "East Wall, West Wall, Invert and Roof." The inspection is made in a systematic manner so that no areas are overlooked. Each inspection gang maintainer is trained to spot and report defects in steel or concrete. The Inspection Supervisor, in the absence of permanent rail transit markers, maintains inspection location markers during the course of the inspection. The Supervisor ensures that inspections are done in a safe and timely manner, and defect priorities are determined using the priority list (see Tables 15 and 16) for subway inspections as a guideline.

Inspectors look for concrete defects, such as loose, spalled, cracked or deteriorated concrete They also look for leaks in the structures and endeavor to determine leak source and severity Inspectors are also expected to determine whether or not drains in the vicinity of leaks are clogged, and if drains have sufficient capacity to handle existing/anticipated water flows.

Steel is also inspected for cracks, distressed members, corrosion or large section loss. The inspector is expected to be alert for any potential safety or hazardous conditions (especially overhead hazards) as they could adversely impact transit passengers, employees or equipment. Defects in handrails, paper catchers, track ladders, lights, and the presence of debris, stalactites, and so on are also reported. The roof inspector records all changes to structures and includes them in the final inspection report. The person who inspects the East or West Wall reports all ends of stations and includes them in the final report. The person who inspects the inverts reports all changes in track from ballast to concrete or from concrete to ballast and records them in the final inspection report.

Emergency Conditions

If an inspector discovers any condition that may cause an immediate hazard to safe transit operations, or if such a condition is suspected, the inspector is asked to bring that condition to the immediate attention of the Supervisor. There is a separate response procedure for the determination and resolution of all tunnel structure emergency conditions:

1. In the event of an emergency condition report, the Manager of Structural Inspection is notified of all the information about the emergency.
2. A decision is then made about what level of response is appropriate for the incident reported.
3. The individual selected to respond to the emergency is given all pertinent information about the incident.
4. The individual reports to the area of the incident quickly, and makes an on-site evaluation of damage to determine appropriate response actions.
5. Findings are then immediately reported to the Control Room.

Inspection Reporting and Documentation

Appendix *C* contains various NYCT inspection forms, including structural layout and defect forms; subway inspection and progress forms and status reports. These forms are a useful source of information for demonstrating the kind of

TABLE 15
NYCT CONCRETE DEFECT PRIORITIES

Structural Defect	Condition Priority # 1	Condition Priority # 2
Leaks or Flooded Areas	Heavy flow, active leak over third rail, signal boxes, cables or electrical devices. Leaks with large build-ups or large stalactite drains must be able to handle flow and water must be below base of running rail Water higher will be considered an emergency and reported accordingly	Any water leaks from inactive to active, petro leaks from slight to inactive, or any leaks not described in Priority #1.
Clogged Drains	Multi drains (track invert) clogged with water below base of running rail (as above)	Any clogged drain or water condition on catwalk, benchwall or inverts.
Benchwalls, Catwalks, Duct Bank, Toe Benchwall	Large running cracks with crack thickness more than 1", multi cracks on face of benchwall, etc. Cracks that are pulling away from wall with gap more than ¾" Deteriorated concrete with conduit, rebars exposed, large hole with exposed cables.	Any crack in face of benchwall or cracks less than 1" thickness Cracks that are pulling away fiom wall with gap less tan 3/4" Any deteriorated, spalled or spalling concrete not described in Priority #1
Concrete	Any loose concrete on roof or walls that may stop service or cause injury to passengers, employees or damage to trains, etc	Any loose concrete that poses no danger of stopping service or causing injury to passengers, or damage to trains, etc. Any cracks in walls or ceiling. Spalled areas and deteriorated areas etc., not described in Priority #1.
Inverts: Track Bank	Cracks with active water leaks, undermining one rail lower than another 3/4" or more (Straight run) dips in road bed. Broken and loose concrete around ties 50' or more	Any cracks, deteriorated, broken and loose concrete around ties 50' or less, uneven (level) track straight run, or any defect not described in Priority #1
Drip Pans	Loose and hanging from roof, missing with active leaks over electrical devices, etc	Broken, clogged or missing with active or in- active leaks Any defect that is not hazardous and not described in Priority #1
Handrails	Broken of missing 25' or more	Broken or missing for less than 25'. Broken brackets, etc.
No Clearance Signs	Missing	N/A
Debris	Any debris that poses a major fire hazard.	N/A
Rubbing Board:	Missing for 20' or more Gap of 1" or more.	Any defect in rubbing boards not described in Priority #1.

TABLE 16

NYCT STEEL DEFECT PRIORITIES

Rating Description	Priority # I	Priority # 2
Cracks	In any leg of girder 1/5 or more of the span Length from the nearest support	In any leg of girder less than 1/5 of the span length from the nearest support
Corrosion	75% or more in girder located 1/5 or more of span length from the nearest support	75% or less in girder located less than 1/5 of span length from the nearest support
Crack in Web of Girder	Located 1/5 or less of the span length from the Nearest support.	Located 1/5 or more of the span length from the nearest support
Corrosion on Web of Girder	1/5 or less of span length from the nearest sup-Ports	1/5 location of the span length from the nearest support.
Corrosion on Cross Section	75% or more of total cross sectional area for 3 or more consecutive columns	More than 50% but less than 75% of total cross sectional area for 3 or more consecutive columns
Columns--Moving or Leaning	In any direction in excess or 3/4"	In any direction 3/4" or less
Knee Brace Corroded	N/A	50% or more, bent and/or damaged or loose connection at ceiling or column.
Other Defects	N/A	Any other defect not described in the criteria but deemed reportable.

structural inspection information that is collected, and also how (format) that information is collected. The "what" and "how" of tunnel structural inspection reportage would be an interesting subject for future analysis.

After the inspection of an area has been completed, inspectors fill out subway defect sheets in a prescribed manner, and submit the defect sheets to the appropriate Supervisor. The Supervisor reviews all defects for completeness, accuracy and conformity. The Supervisor initials the defect sheet indicating whether or not the report is correct. The report is then submitted for entry into the NYCT data base system.

Inspection records are maintained on a computerized data base system and are updated regularly. Subway and station reports are maintained under separate files:

1. Records are kept based on each type of structure. Inspectors note deficiencies in their record-keeping pads ("Butcher Books") in the field.
2. The inspector transcribes each deficiency into a structure inspection report form in triplicate, color-coded by priority.
3. The inspection supervisor reviews these reports and signs them.
4. Completed structure inspection reports are then forwarded to the inspection coordinator. He reviews them and inputs the deficiency information into the data base. One copy is retained and another forwarded to the structure subdivision for corrective action.
5. Once repairs have been completed, a copy of the original inspection report is returned to the inspection coordinator in order to update the data base.

The Superintendent of Subways reviews the data base file for accuracy and completeness at the conclusion of the inspection for each transit line. The Superintendent also audits the records for the subdivision at the end of each year.

Annual Inspection Plan

Each Superintendent is required to submit an annual inspection plan for each inspection gang under their control. Each plan includes the gang number, type of inspections to be performed, the lines to be inspected and the anticipated time frame for each line. Each inspection plan is due November 15th for the calendar year to come.

Weekly Inspection Projection

Every Friday, Superintendents are required to submit a weekly inspection projection for the following week, detailing the anticipated work assignments for each inspection gang.

Weekly Inspection Progress

Superintendents are required to submit a weekly inspection progress report which details the work completed for the previous week.

Weekly Status Report

Superintendents are required to submit a status report that details variations between projections made and'progress Zaccomplished for the previous week.

"1" and "2 " Defects Report

Each Superintendent is required to submit a "1" and "2" Defects Report (subways) on a weekly basis, listing defect priorities (1 being the highest priority) by transit line.

Daily Inspection Summary

Each gang supervisor is expected to complete a daily inspection summary, detailing areas inspected and types of construction (subway only).

Procedures for inspection record-keeping for subway, subway station and river tube structures is exactly the same as the description with one variation. Once the inspection has been completed, the inspector transcribes all deficiencies into a subway inspection form and submits it to the supervisor for review. Supervisors review subway inspection forms for accuracy, completeness and conformity.

Identification Of Major Structural Problems and Issues

The NYCT data base (Structural Defects Reporting System) organizes various reported subway defects into various fields for defect tracking and analysis. In reviewing two defect reports for separate subway lines (with entries from 19911993), it became apparent that the majority of the 150 entries during that period were water-related defects. Leaks, malfunctioning drains, spalled concrete, corroded beams, etc. indicated water intrusion of one kind or another. Tables 15 and 16 describe more specifically the NYCT prioritization of concrete and steel defects.

Inspection Staffing

The subway inspection force consists of two teams of four structure maintainers and a maintenance supervisor. Each team consists of two masons, two ironworkers and a maintenance supervisor. Both maintenance supervisors report directly to the Superintendent, Subway Inspection, who reports directly to the Manager, Structural Inspection.

Figure 3 depicts the overall organizational structure for the Division of Infrastructure, within which the Director of Standards' Structural Inspection group resides. Other infrastructure management responsibilities are as follows:

1. Director, Engineering Standards has the responsibility to develop policies and provide direction to subordinate managers to establish procedures and standards for the inspection of all NYCT infrastructure.
2. Manager, Structural Inspection has the responsibility to plan and administer regularly scheduled inspections for all NYCT elevated and tunnel structures, and to issue reports of the defects discovered.

3. Superintendent, Structural Inspection has the responsibility to provide close managerial support and supervision for conducting structural inspections.
4. Inspection Coordinator has the responsibility to provide day-to-day coordination of inspection gang activities, to provide administrative support, review inspection reports and to maintain the computer data base.
5. Inspection Supervisor has the responsibility to plan and to implement daily inspection activities, provide supervisory support, review and sign inspection reports and to respond to emergencies, as required.
6. Inspector has the responsibility to perform a complete inspection of assigned structural components and to prepare complete, accurate and legible inspection reports.
7. Director, Infrastructure Engineering has the responsibility to provide necessary engineering and technical support for the inspection and repair of NYCT infrastructure, and to assure compliance with applicable codes and standards.

CHICAGO TRANSIT AUTHORITY (CTA)

Introduction

This case study is based on data collected during a 1990 Phase One Work Plan and Report prepared under contract to the Regional Transportation Authority (RTA) in Chicago for an Engineering Condition Assessment of CTA Rail Transit Subway Infrastructure. The RTA and CTA worked together on the Engineering Condition Assessment Project whose principal significance was the establishment of improved tunnel structure inspection procedures for CTA inspections *(5).*

The Engineering Condition Assessment Project was conducted on the State Street portion of the CTA Rapid Transit Subway System (approximately one mi of twin, single-track tunnel). Initiated during 1990, the project's objective was to prepare a program for the subsequent inspection of all CTA subway system components. The objective, therefore, for Phase Two of the Engineering Condition Assessment was to inspect the remainder of the CTA subway system. Focus in this case study will be on the consultant-prepared CTA inspection program and the structural defects found in the State Street portion of the system (6).

Characteristics of the Transit System

The State Street portion of the CTA Subway System includes:

1. 200 ft of submerged twin tunnels under the Chicago River
2. 1,723 ft of twin tunnel section
3. 355 ft of crossover section
4. 1,000 ft of tunnel in the Grand Avenue Station.

State Street tunnel inspections, which provided the following information on CTA defects and problems, included the above tunnel sections, the station from the street level to the platform, all auxiliary structures, the power, communication and signalization system and the track. All tunnels were single-track, except at the crossover, and the station inspection was at Grand Avenue.

Rail Tunnel Inspection Procedures

The condition assessment's process of inspection, testing and evaluation of rail tunnel structural elements followed four sequential steps:

1. A general visual inspection,
2. A detailed visual inspection,
3. A detailed inspection combined with non-destructive testing, and
4. A detailed engineering assessment

During the inspection/testing process, a condition rating was assigned to each of the tunnel structural elements evaluated, as described in the previous section on inspection problems. That rating system generally conformed to the ratings then employed by the CTA. See Table 17 for the tunnel inspection narrative/numeric rating system.

Generally, tunnel inspections proceeded upstation in each tube. Team members (see the section below on staffing) were assigned a portion of the tunnel cross-section to inspect. Inspection findings were then logged on forms as the inspection proceeded. Roof areas exhibiting defects were noted for more detailed investigation during follow-on single track inspections.

Where CTA maintenance records indicated "critical" deterioration of a tunnel component, special thoroughness was

TABLE 17

CTA CONDITION ASSESSMENT RATINGS

Rating		
1	*Critical Condition:*	Extensive and dangerous defects in need of immediate repair.
2.	*Poor Condition:*	Defects or deterioration that will progress quickly to a severe and serious problem. Repair or rehabilitate within one year.
3.	*Marginal Condition:*	Moderately defective or deteriorated member that will ultimately progress to a Serious defect. Repair or rehabilitate within five years.
4.	*Fair Condition:*	Slightly defective or deteriorated member. Repair or replace within 10 years.
5.	*Good Condition:*	No visible defects. No repairs necessary. Continue to observe.

taken in the inspection process; and any tunnel conditions requiring immediate attention were reported to the Chicago Transit Authority. Finally, spot checks of team inspections were made to assure compliance with the Work Plan, the QA/QC Plan, the project Safe Manual, and to establish that inspections had been conducted with care and accuracy.

Each inspection team leader maintained a daily job diary which was used to record the day's activities; start and finish times of important tasks; site conditions and any other information relevant to the day's activities. Upon completion of an inspection, team leaders collected and tabulated the inspection/testing results. Information from the inspection forms was maintained in a data base program established for the project (in program dBase III plus).

Detailed Visual Inspection

Four teams were used; two in the northbound and two in the southbound tunnels. One member of each team was the recorder; one member inspected from the track-level walkway; and one member inspected from the high-level walkway on top of the ductbank The recorder provided general oversight and direction Positions among the team members were periodically rotated to provide experience in all aspects of team responsibility Inspections were conducted during the day.

During this part of the tunnel inspection process, the tunnel walls below the cable runs (generally 8 ft over the high-level walk and 12 ft over the track-level walk) were subjected to hammer sounding and detailed visual inspection. The roof above the cable runs was subjected to visual inspection only. The duct bank under the high-level walk was not considered part of the tunnel structure, so was inspected for spalls only. The surface of the lower walkway was sounded for delaminations.

Detailed Visual Inspection with Testing

These inspections were conducted during the night. Without the interference of train traffic, the inspection teams were able to sound the tunnel crown from the track level with extensible poles, or from an A-frame ladder. A two-person team was used to perform this task, consisting of a team leader and an inspector.

Detailed Engineering Assessment

Using the information collected from field inspections, an engineering assessment was made of system component conditions. That assessment consisted of the following elements:

1. A review of design standards to establish acceptable post-repair conditions.
2. A structural condition assessment rating (see Table 17).
3. An evaluation of concrete structures including portal, incline and retaining walls, subway tube, mezzanine, vent shafts and vertical accesses.
4. An evaluation of stations, substation, platforms, vertical accesses, escalators, lighting and right-of-way ancillary facilities for structural integrity.
5. An evaluation of the condition of rail, contact rail, ties and ballast at 100-ft segments.
6. An evaluation of the right-of-way drainage pump system and ventilation.
7. An evaluation of the power distribution network, including traction power equipment, cabling and switching mechanisms.
8. An evaluation of the signal and communications network.
9. An evaluation of the right-of-way security fencing at inclines.
10. An evaluation of any track-level footwalk and planked areas at 100-ft segments.

The above evaluations were used to determine the extent of any needed repairs or replacements. These evaluations took into account the deteriorated condition of the concrete; the existing load environment and the potential for future increased loadings.

After these detailed inspections and assessments, final rating decisions were made; inspection summaries prepared and results reported to the RTA/CTA.

Identification of Major Structural Problems and Issues

The Engineering Condition Assessment Project was designed to structurally inspect, evaluate and provide an assessment of all the above elements within the tunnel segment, and then to apply the resulting inspection program to the remainder of the transit system. The inspection included the track infrastructure, power distribution system, signal and communication systems and ancillary r-o-w facilities. The condition assessment was intended to identify structural defects such as spalling, delamination, cracking and deteriorated concrete, deterioration of any structural members, cracked, missing or loose fasteners, exposed rebar and any damage to other associated structures.

Based on the rail tunnel inspection procedures, each tunnel subsection was rated by major structural component according to the condition assessment ratings shown in Table 17. Inspection findings were assembled into narratives and associated tables, with component ratings given at each station marker (100-ft segments), and specific comments occasionally elucidating the numerical rating where observed conditions appeared to warrant the usefulness of additional information.

Tunnel Structure

The overall condition rating for the tunnel structure was fair. The most significant defects were leaking transverse joints in tunnel walls and roofs at the track crossover and station. Water and sediment inflow had begun to corrode and foul the track and ballast.

The testing program that was part of this condition assessment indicated that there was a potentially corrosive environment along tunnel joints and fractures. Chloride content and xray diffraction analyses (on concrete samples from cracks) showed that chloride corrosion threshold levels were being exceeded in almost every instance (0.02-0.03 percent by weight), and that calcium carbonate (from the calcium hydroxide in concrete) was the major component in cracks. Thus, the tunnel exhibited substantial transverse and longitudinal cracking, but the tunnel was not indicating any signs of structural instability.

The inspection's findings demonstrated that water infiltration is slowly deteriorating tunnel concrete and reinforcement. While not creating an immediate problem, this condition had adverse implications for the longer-term service life of the tunnel, particularly if left unaddressed.

Tunnel Ancillary Structures

The 24 tunnel ancillary structures (emergency exits, vent shafts, splice chambers, etc.) were rated in fair condition Most structures showed some degree of concrete cracking, minor surface rust and damaged floor gratings. Some of the vent shafts showed visible water inflow and others showed concrete spalling (in one instance with loss of rebar section). Another vent shaft that appeared to be sited too close to the tunnel lining showed "deterioration" of original tunnel ribs and lagging (apparently never covered with concrete after vent shaft construction). There did not, however, appear to be any structural instability.

Station Structures

The structure and architectural finishes were in fair condition although there was some spalling and rebar loss in several beams supporting the mezzanine floor. In addition, leakage through the station roof at several locations (platform level) was corroding column bases and bolts. See Table 18 for a rating of various station components.

Testing Program

The results of the testing program indicated that the tunnel lining concrete and reinforcing were in fair to good condition. What was of concern were corrosion-related deposits in cracks, such as high levels of chloride and gypsum (suggesting the presence of sulfuric acid). Notwithstanding the concern, no critical conditions were found.

With respect to corrosion testing, field carbonation measurements generally indicated small depths of reduced alkalinity (and associated loss of steel protection). Carbonation was measured to depths of generally less than 0.5 in., and to greater than 1.3 in. at only 2 locations (1.4 and 1.8 in.). In contrast, the half-cell potential surveys (see Table 19 for field and laboratory testing methods) did indicate the onset of reinforcement corrosion. However, due to stray currents induced by the contact rail, those results were considered questionable Test results indicated that the tunnel concrete and reinforcement were slowly deteriorating due to water infiltration. While not an immediate structural problem, this condition, if left uncorrected, will have an adverse impact on the long-term service life of the tunnel.

Inspection Staffing

The inspection team usually consisted of three people: a team leader and two inspectors. Occasionally a team would consist of two people (as described in the section on inspection procedures). All team members had attended CTA safety school and project safety meetings. The team leaders had tunnel design and/or inspection experience. Inspectors were graduate engineers and/or had inspection experience.

Prior to detailed tunnel inspections, the project management team walked the tunnel with RTA and CTA personnel to discuss the nature and extent of the work. An examination was also made of existing tunnel plans and maintenance reports. At that time, inspection forms and defect codes were prepared to reflect expected tunnel conditions. Inspection teams then independently inspected the same 100-ft section of tunnel. The test section of tunnel was chosen to represent a typical tunnel

TABLE 18

CTA STATION CONDITION RATING SUMMARY

Station Element	Condition Rating	Comments
Interior Finishes	4	Chipped paint; rough surfaces; rust
Station Structure	3	Spalling of machinery room ceilings with loss of section of rebar
Communications	5	(No notes)
Station Lighting	2	Significant number of burned-out bulbs and inoperative Fixtures; old wiring
Drainage and Pumps	3	No vacuum breakers on hose bibbs--sump pump, Ejector pump and compressor obsolete
Passenger Conveyance	3	Escalator switch gear--obsolete; no disabled person Access
Plumbing and Miscellaneous Fixtures	2	Obsolete components; damaged partitions

*NOTE: see Table 17 for an explanation of condition assessment ratings.

TABLE 19

CTA FIELD AND LABORATORY TESTING METHODS

Test	Quantity	QA/Reference Standard	Comments
R-meter survey to locate reinforced steel	3 locations (1 each study area)	Manufacturer's procedure	At each location: locate longitudinal bars from top of arch to walkway; locate transverse bars for 10 ft. length along sidewall; determine cover based on bar size shown on plans
Corrosion potential surveys	3 locations (1 each study area)	ASTM C 876	At each location: measure potential to ground to determine if stray currents will distort results; take measurements on a 3 ft grid in a 9 ft. x 30 ft. area along sidewall
Field carbonization of concrete	9 locations (3 each study area)	See comments	At each location: hammer drill 3/4 in. holes in 1/8 in increments (mark drill bit); apply 1% phenolphthalein solution to drilled surface after each increment; record depth of carbonization as depth to which drilled surface is not pink
Removal and compression testing of concrete core samples	6 locations (3 strength tests)	ASTM C 42	Cores to be patched
Column base examination	3 locations in station area	See comments	At each location: sawcut aroung column flanage to 1 in min depth; remove concrete with chipping hammers to 3 in depth adjacent to column; examine and photograph; measure section loss
Impact echo survey	3 locations (1 each study area)	Experimental only	At each location: take readings at 2 ft centers from arch to Walkway; use rebound hammer as impact source; analyze frequencies using a Scientific Atlanta SD380 Analyzer
Chemical analysis of concrete samples for chloride content	10 samples	ASTM C 114	For each sample: remove powder samples in field or sawcut from core samples at 2 to 3 in. depths; analyze for chloride content using the acid-digestion, potentiometric-titration procedure per ASTM C 114, paragraph 19
Chemical analysis of mineral deposits	10 samples	See comments	For each sample: identify crystalline components by standard methods of x-ray diffiactometry; quantity chloride content per ASTM C 114, and as described above
Petrographic examination of core samples	3 samples	ASTM C 856	For each sample: describe aggregates and cementitious matrix; estimate degree of hydration; estimate water/cement ratio; evaluate air void system; check for freeze/thaw damage and reactive aggregates

segment. The inspection was carried out under traffic and was used to orient the teams to tunnel inspection methodology (a calibration inspection). The purpose of the orientation was to assure repeatability and consistency during inspections. Problems noted (some confusion was seen in inspections between cracks and open construction or expansion joints; and in estimating the length of cracks) were the subjects of postinspection team briefings.

MASS TRANSIT RAILWAY CORPORATION (MTRC-HONG KONG)

Characteristics of the Transit System

The Mass Transit Railway Corporation (MTRC) of Hong Kong was established in 1976 for the purpose of constructing and operating a mass transit railway system in order to meet Hong Kong's anticipated public transportation requirements. The MTRC system was constructed at a cost of approximately 26 billion Hong Kong dollars, and consists of three branches: the Kwun Tong, Tsuen Wan and Island Lines. Service was first initiated in late 1979.

The overall route length of the existing system is 43.2 kilometers (26.8 mi), and has a total of 38 stations. Of that length, 34.4 kilometers (21.3 mi) and 31 stations are located underground. With an average weekday total of 2.2 million passengers (1992; peak daily total of 2.8 million), the MTRC is one of the most heavily used transit systems in the world (see Table 20).

Type and Frequency of Rail Tunnel Inspection

MTRC policy stipulates differential inspection frequencies for various structures. The policy for tunnels and viaducts, for example, requires a detailed inspection once every 3 years and a superficial inspection every year. However, if a detailed tunnel inspection is conducted one year, no superficial inspection would be required that year (see the sections below on "inspection procedures" and "staffing" for a discussion of detailed and superficial inspections).

Rail Tunnel Inspection Procedures

The Mass Transit Railway Corporation has developed a *Manual For Inspection Of Railway Structures (7)*. The purpose of this routine structural inspection manual is to

TABLE 20

PASSENGER UTILIZATION IN SELECTED FOREIGN TRANSIT SYSTEMS

	Hong Kong	London	Sao Paulo	Singapore	Tokyo
Route Length	43.2 km	392 km	40.3 km.	67 km.	155.9 km
Av Weekday Passengers	2 2 million	2 51 million	1.8 million	0 6 million	5 86 million
Weekday Passengers/Km	50,900	6,403	44,665	9,149	37,588

TABLE 21

MTRC CES INSPECTION PROCEDURES AND RESPONSIBILITIES

Before Inspection	During Inspection	After Inspection
confirm inspection program requirements	advise on particular problem	advise on particular problems
check inspection program requirements	1. monitor inspection progress 2. advise on major (urgent/unsafe) defect remedies	1 check summaries 2.advise on major defect remedies
1 provide inspection drawings and forms	1. inspect, advise and report on urgent/ unsafe direct remedies	1. comment on reports
2 advise on inspection program requirements	2 spot check inspections	2. prepare summaries 3. inspection investigations as necessary 4. check remedial actions

TABLE 22

MTRC CW SECTION INSPECTION PROCEDURES AND RESPONSIBILITIES

Before Inspection	During Inspection	After Inspection
confirm inspection program requirements	advise on particular problems	advise on particular problems
provide program manpower requirements	1. supervise inspections 2 report of inspection progress 3. advise on urgent and unsafe defects 4. arrange for remedial work	1 check reports and forward 2. arrange for follow-up actions 3. report on follow-up actions
1. learn program requirements and procedures 2 collect relevant forms and drawings 3. secure tools and equipment 4 arrange for access	1 conduct inspection and complete inspection forms 2 report on urgent and unsafe defects	1. send out completed reports 2. carry out recommended remedial actions

identify and locate structural defects before they jeopardize safe operation of the MTRC and to:

1. Define the job and responsibility of each party concerned in the railway structure inspection process.
2. Describe in detail the procedures to be used in the inspection of railway structures, including the preparation, inspection, reporting, commenting and follow-up activities The manual is intended to serve as a guideline for both the inspectors and engineers to ensure consistent and cooperative staff performance.

Organizationally, structural inspections are the responsibility of the Civil Engineering Services Department (CES). CES is responsible for investigating structural defects and for determining the appropriate defect remedies while the Civil Works Section (CW) of the Operations Engineering Department is responsible for carrying out and supervising defect repairs. This traditional maintenance policy (organizational separation of inspections and repairs) is intended to ensure that staff and/or financial pressures do not limit organizational awareness of those factors affecting employee/passenger safety. Organizational awareness of inspection's role in employee/passenger safety is most effectively institutionalized through clearly established staff procedures, responsibilities and accountabilities (see Tables 21 and 22). Simplifying the two tables and sequencing the principal CES and CW Section inspection activities results in the MTRC inspection procedures outline shown in Figure 4.

Railway Structure Inspections

MTRC inspection procedures apply to the following structures: MTRC depots (storage and maintenance facilities) and plant rooms; stations; tunnels and immersed tubes; viaducts; ventilation buildings, vent shafts, and intake structures; portals; distribution substations, and all other structures used by MTRC passengers.

MTRC tunnel inspection procedures are conceived of as preparations made before tunnel inspections; procedures used during tunnel inspections; tunnel defects that require urgent actions, and tunnel defects requiring routine maintenance.

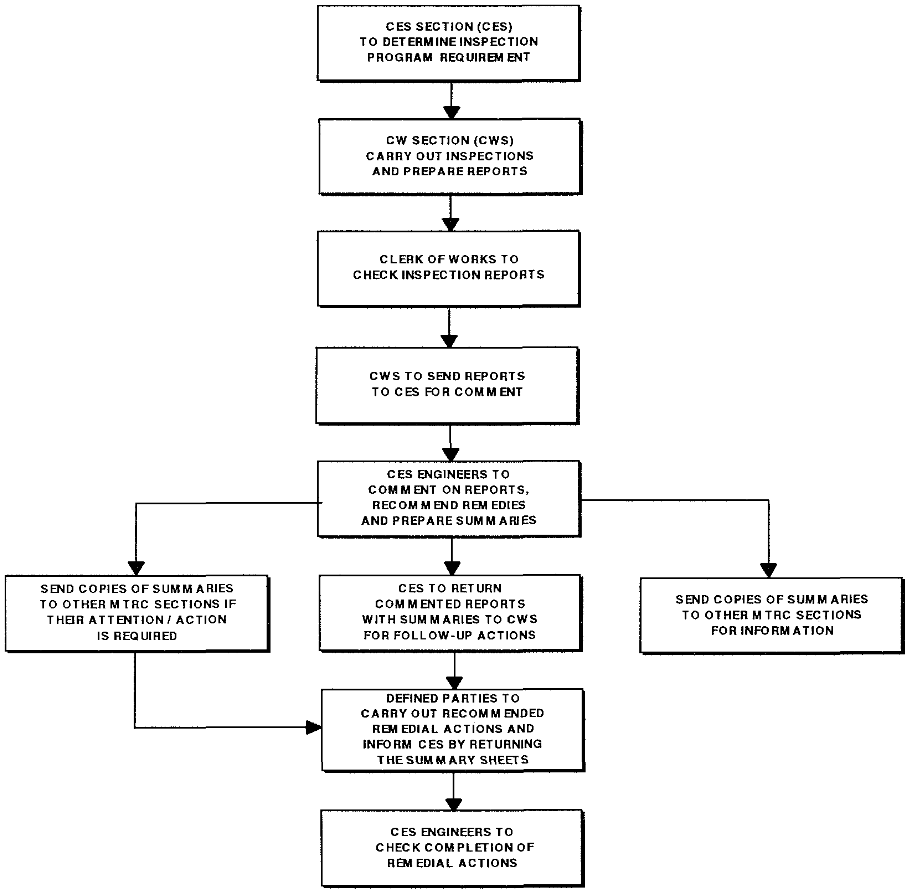

FIGURE 4 MTRC inspection procedures *(7)*.

In tabular summary fashion, preparations made before tunnel inspection include:

1. An understanding of inspection requirements, including "Procedures For Examination"; and an understanding of how inspection forms should be completed (see Appendix D for MTRC "Tunnel Inspection Guidelines").
2. Knowledge of which tunnel structures are to be inspected and the programmed length of the scheduled inspection.
3. Selection of the relevant forms for tunnel inspection.
4. Knowledge of the checklist for structural and architectural defects (architectural defects may presage structural defects), and with the previously conducted tunnel inspection (to facilitate a cross-checking during the current inspection).
5. Selection of the needed tunnel inspection tools and equipment
6. Permission to enter any restricted areas, and track clearance for inspection.

During tunnel inspections, the following procedures are observed:

1. Completing the inspection forms: there are different inspection forms for the main structures and for restricted areas (plantrooms and accommodation areas); the standard structure inspection forms are used for typical rail tunnel structural inspections; with specialized forms used for specific unique structures.
2. Tunnel inspections: the tunnel inspection form is a graphic form to allow inspectors to visualize existing tunnel conditions and note clearly those changes since the last tunnel inspection. Different forms exist for single-track and double-track tunnels and for cross-overs. The procedures for tunnel inspection include the manner in which they are to be completed:
   - Identifying the left/right defect locations defined when the examiner is facing a particular station
   - Identifying the typical defects including cracks, spalling, damp patches, ponding, and separation of the trackbed and drip channels on the form.

- Special defects are identified on the form with a reference number and are described on a separate data sheet (see Appendix D "Tunnel Inspection Guidelines" for additional information).

3. For superficial inspections, all areas except those which are covered or inaccessible are inspected; and for detailed inspections the examiner is expected to make arrangements to gain access to covered or inaccessible areas (by removing wall panels, getting behind suspended ceilings, etc.). In a detailed inspection, structural accessibility constraints are expected to be surmounted.

   Items to be inspected in a tunnel include the lining, the trackbed, the plinth, the E & M cable brackets, the E & M plant fixings (impulse fan fixings) and the drainage system (line and invert sumps and drip channels included). In a detailed inspection, tapping the lining and the trackbed to check for hollowness or spalling is carried out with use of a high level platform wagon for the crown levels and steel chain for the trackbed.

Defects requiring urgent action are those that could affect the safe running of the trains and a procedure is established for those defects to be described, referenced and reported to personnel within the MTRC whose responsibility it is to take corrective action. To that end, the MTRC has a number of Fault Report Centers Those defects requiring routine maintenance are marked "R M." in the defect description sheet. The CW Section is expected to automatically implement the appropriate remedial action.

Tunnel Inspection Report Analysis

Tunnel inspection report analysis is carried out by CES engineers. The MTRC, in principle, suggests that all inspection reports be reviewed and returned to the CW Section with recommended remedial actions within two months from their receipt. Every defect description should be commented upon. For every inspection report, there is a CES summary, whose purpose is to:

1. Summarize major structural defects with recommended remedial actions
2. Highlight any change in condition (from the previous inspection) requiring special action
3. Comment on the condition described in the report
4. Record the implementation of all follow-up actions.

In commenting on the inspection reports, and in completing the CES summaries, the following guidelines are part of tunnel inspection procedures:

1. Location of the structure inspected
2. Indication of structural type (from "General Information Drawings")
3. Date the inspection was completed
4. Reference number of the inspection
5. CES engineer reviewing the inspection report
6. Date the summary was completed
7. Whether the inspection was detailed or superficial
8. A summary of the current condition of the structure
9. If a corrective action is needed; for what defect and by what group
10. Recommended action.

CES reviews the summary sheets and assesses the completeness of remedial actions taken. They then advise what follow-up actions may be needed. Once it is confirmed that any remedial and follow-up actions have been satisfactorily completed, the summary sheet is signed.

Further Development of Rail Tunnel Inspection Procedures

The 1993 Annual Report recommends consideration of new inspection investigation techniques, such as the use of x-ray, thermographic or infrared methods, for identification of certain structural conditions, such as the condition of prestressed tendons or of precastings. The MTRC appears committed to the use of whatever cost-effective inspection methods may offer the prospect of greater analytic efficiency and accuracy.

Identification of Major Structural Problems and Issues

The Civil Engineering Services Department (CES) Investigation and Repair Section (railway structures) has summarized railway structure inspections, conditions, investigations and repairs for the 1993 MTRC Annual Report.

In view of the relative "newness" of the system's tunnel construction (late 1970s), and the thoroughness of MTRC management's attention to structural inspections and repairs, the 1993 report demonstrates some significant deterioration to the system's tunnel structures. The various causes of structural deterioration to new tunnels would be a useful addition to subsequent study of the practice of rail tunnel inspection and maintenance.

In general terms, the 1993 report reflects well on the overall MTRC inspection and maintenance effort. Ninety-one percent of the programmed inspections were completed, and that record was achieved in the face of a major unscheduled inspection of station top-down soffits. Repair contracts increased from 15 in 1992 to 20 in 1993. An initial investigation report on roof slab prestressed tendons was completed with only minor defects found. The MTRC also commenced development of computer software to record and analyze the condition of railway structures, expected to save time and lead to more complete analysis of structural conditions. It was implemented in 1994.

All tunnels, immersed tube tunnels, stations and associated structures were inspected in 1993. Within the MTRC, the CES Investigation and Repair Section (IRS), which provides an engineering consultancy service to MTRC managers, provided the Civil Works (CW) Section with the results of tunnel permeability, compression and bond tests vis-A-vis their compliance with the tunnel repair contract. Chloride test results (from dust samples at various depths) were also analyzed to confirm the need for tunnel repairs and/or for rail plinth repairs.

There are other examples of MTRC rail tunnel inspection defects not included above. The number and seriousness of these tunnel defects as outlined in the 1993 Annual Report was surprising. Perhaps 1993 was atypical, or perhaps the MTRC has unusually rigorous tunnel inspection standards, but without further investigation it is not clear what implications might be drawn from this MTRC inspection and maintenance experience. Those factors contributing to long-term tunnel deterioration or longevity seem important to more thoroughly assess.

What may be more significant is the following tabular summary of the structural design elements which MTRC inspectors believe may usefully profit from unspecified technical improvements (and then possibly incorporated into the MTRC Design Standards Manual and/or into submissions from Detailed Design Consultants) based on previous inspection and defect repair experience. The information below on annual defect repair costs may be the principal catalyst in the search for methods to reduce repairs.

Annual Defect Repair Costs

The MTRC has tracked repair costs annually. The curve of average repair costs for MTRC structures shows a steady cost increase per structure for each year plotted. With annual repair cost increases of approximately 63 percent from 1985 to 1989, and a total increase in structural repair costs of 140 percent from 1985 to 1993, the MTRC has ample incentive to maintain the growth of repair costs at reasonable levels through the confirmed need for structural remediation. and recommendations for optimally cost-effective repairs.

While protecting structural investments makes good sense for managers of any rail transit system, the accessibility of the above MTRC cost information draws a picture that underscores concerns about long-term tunnel structure deterioration, and the importance of documenting tunnel structure conditions over time to mediate the kind of tunnel structure decline described above. To the extent that such tunnel structure repair cost information is available from other transit systems, it serves to underscore the importance of standardizing approaches to tunnel structure design, construction, protection, inspection, repair and record-keeping.

Inspection Staffing

An inspection program is issued annually by CES to the CW Section for implementation. With respect to tunnel inspections, the manpower assumption for inspections is that the annual superficial inspection requires 1 team-week. The detailed triennial inspection requires 2 team-weeks. A team is assumed to consist of an examiner with two assistants, or three persons.

One of the best indications of the attitude the MTRC seeks to instill in its inspection staff is reflected in the following quote from the 1988 Manual:

> During the inspection, the examiner should be observant and have an inquisitive mind. He should remember that a small clue such as a stain or hair crack can often lead to the discovery of something important and he should thus be careful in deciding that something is insignificant. *(7)*

The earnestness inherent in the above statement suggests that good quality (conscientious, thorough) rail tunnel inspections may, in part, result from a management expectation of good quality inspections. Without continual management emphasis on and development of that "good quality" expectation within a transit agency inspection staff, it is likely that such staff, like the tunnel structures they inspect, would be adversely impacted over time.

SUMMARY OF CASE STUDY FINDINGS

Characteristics of the Five Transit Agencies

The following five transit agencies were the subject of brief case studies:

1. Mass Transit Administration of Maryland (MTA--Baltimore)
2. Bay Area Rapid Transit (BART)
3. Chicago Transit Authority (CTA)
4. Mass Transit Railway Corporation (MTRC--Hong Kong)
5. MTA New York City Transit (NYCT).

Table 23 compares the general characteristics of the transit systems described in the case studies and shows the substantial variability among them.

Type and Frequency of Rail Tunnel Inspection

There is wide variation between the type and frequency of inspections among the five case study transit systems. Vagueness attends the use of such terms as "in-depth" inspections or "detailed" inspections to describe the manner in which a transit agency conducts its tunnel structural inspections. How often an inspection is conducted becomes less valuable as a piece of information about inspections if it is unclear what is inspected and how thoroughly the inspection is conducted within the various inspection cycles. The question of thoroughness has as much to do with inspection staff work ethic and transit agency management emphases, as it does with staff training and/or certification programs for tunnel structural inspection. The former factors are not the subjects of this synthesis.

The five transit systems listed in Table 24 conduct tunnel structural inspections in a range that varies as widely as five separately selected transit systems could vary: from one to five years.

On the strength of the above information, it is obvious that frequency of structural inspections alone is not a variable that has predictive value, or that inspection frequency alone

TABLE 23

PASSENGER UTILIZATION IN SELECTED TRANSIT AGENCIES

Transit Agency	Route Length (km)	Av. Wkday. Pass	Wkday Pass./km
MTA of Maryland	58.6	37,000	631
BART	115	255,000	2,217
CTA	157	436,750	2,782
MTRC	43 2	2,200,000	50,926
NYCT	398	1,700,000	4,271

TABLE 24

INSPECTION TYPE AND FREQUENCY

Transit Agency	Frequency	Exceptions	Type
MTA of Maryland	Once/5 years	Leak repairs/annually; tunnel liner/2.5 years	"In-depth"
BART	Once/2 years	Based on age, request or discovered defects	"Scheduled"
CTA	Once/6 years	Special as needed	"Scheduled"
MTRC	Once/3 years once/yearly	N/A	"Detailed" "superficial"
NYCT	Semi-annually	Under river tubes	"Scheduled"
	Annually	Other structures	Visual

TABLE 25

INSPECTION PROCEDURES

Transit Agency	Inspection Protocol	Documentation	Management Focus
MTA of Maryland	Visual inspection, sounding in- Spection	Narrative, sketch, forms, photo- graphs for each structure	Focus on system physical condi- tion, functional capability
BART	Use previous reports, assign prior- ity codes, thorough inspection	Separate reports for each structure, data base record-keeping	Focus on organization for defect review, repair, reinspection
CTA	Previous reports, visual, sounding, testing, engineering assessment	Forms, photographs, daily diary, data base record-keeping	Focus on work plan, QA/QC plan, Project Safe Manual
MTRC	Preparations before, procedures during and after inspections	Forms, photographs, sketches, data base record-keeping	Focus on system accountability, detailed procedures
NYCT	Specific area assignments, struc- tural inspection protocols	Defect sheets, data base record- keeping, annual, weekly, daily plans and summaries	Focus on continuous inspections, efficiency, completion

may signify anything useful about the "adequacy" of any tunnel structure inspection frequency. On the contrary, the age of the above transit systems and their tunnel structural conditions (and other localized factors as well) may significantly affect inspection frequency. For example, NYCT inspects its under-river tubes semi-annually because they are apparently persuaded that such an inspection frequency is appropriate for those tunnels in that environment. Semi-annual inspection may be too frequent in one circumstance, appropriate in another and, potentially, insufficient in a third.

Rail Tunnel Inspection Procedures

The technical and administrative procedures (or methods) used to inspect rail transit tunnel structures, in addition to the more human elements in a professional practice (thoroughness, conscientiousness, etc.) determine the adequacy of inspections, and their conformity to the objectives those inspections are intended to fulfill. The general objectives of any rail tunnel inspection practice includes the following:

- Create a set of objectives that seeks to protect life and property from the normal and extraordinary hazards of rail tunnel environments.
- Analyze those objectives to define a specific group of complementary administrative, procedural and technical protocols which when implemented, day-in and day-out, fully accomplish the intent of rail tunnel inspection objectives.
- Continuously refine specific tunnel structural inspection protocols on the basis of documented experience, providing sufficient redundancy and rigor in the inspection system so that human error or other inspection "slippage" does not result in serious inspection system failure (i.e., loss of property or life).
- To expand the rail tunnel inspection practice into a fully open and accountable function and/or profession, with the responsibility to periodically review individual system practice through external professional peers in order to assess and improve its adherence to accepted standards of the professional practice.

Inspection procedures for case study transit systems vary widely in their organizational structures (see Table 25). Many procedural similarities between transit systems can be found, as well as many dissimilarities. To what extent tunnel inspection similarities reflect accepted practice (and therefore constitute adequate standards), and dissimilarities reflect the potential need for standardization (and potentially inadequate standards) rather than simply different approaches to inspection practice (perhaps reflecting particular differences in transit systems or differences in management perspective) would be interesting to investigate further.

Identification of Major Structural Problems and Issues

There seems to be uniformity among rail transit managers as to what category of tunnel structural problem is the most widespread and potentially serious. Table 26 assumes some subjectivity in arriving at priority conclusions for any particular transit system (only one of the five transit systems has clearly established its priority tunnel structural problems).

The fact that the above transit systems identified tunnel leaks as their most substantial structural problem probably comes as no surprise to those familiar with typical rail transit tunnel problems. Most of the other structural problems encountered by tunnel inspectors derive from tunnel water intrusion, through walls and roof structures, thus creating additional problems, among which are concrete cracking, spalling, etc. In this regard, there is little variability between the "priorities" attached by respondent rail transit agencies to their tunnel structural defects.

Inspection Staffing

Most of the respondent transit systems require some degree of training and experience for their inspection personnel, and especially for their inspection leaders or supervisors. The kind of training and experience varies between transit systems. However, all of the above transit systems listed in Table 27 require that inspectors spend some period of time training as an assistant tunnel structural inspector (or similar position), and undergo some form of safety training.

TABLE 26
TUNNEL PROBLEM PRIORITIES

Transit Agency	Priority # 1	Priority # 2	Priority # 3
MTA of Maryland	Tunnel leaks	Concrete cracking	Concrete spalling
BART	Tunnel leaks	Concrete cracking	Steel corrosion
CTA	Tunnel leaks	Concrete cracking	Concrete delamination
MTRC	Tunnel leaks	Concrete spalling	Concrete cracking
NYCT	Tunnel leaks	Subway drainage	Concrete spalling

TABLE 27
STAFFING TUNNEL INSPECTIONS

Transit Agency	Number of Inspectors in Team	Training Requirement	Certification Requirement
MTA of Maryland	2	Leader: engineer with design/ inspection experience	Leader: P.E. registration
BART	3	Professional training	Yes
CTA	3 or 2	Leader has design, inspection experience, safety training	Unknown
MTRC	3	Yes	Unknown
NYCT	5	4 years experience	In-house training

CHAPTER FOUR

ADMINISTRATION OF RAIL TUNNEL INSPECTION

INTRODUCTION

The administration of rail tunnel inspection activities consists of achieving tunnel structure inspection objectives, maintaining the integrity of inspection procedures, staff training, coordination and oversight, as well as inspection data management, which includes procedures for accurate recordkeeping and periodic data analyses. In addition, tunnel inspection administration includes the internal and external coordination of periodic transit agency reviews of inspection procedure effectiveness; of the adequacy of inspection expenditures; and of agency need for emphasis on or redirection of inspection policy objectives to better direct and prioritize various aspects of the tunnel inspection practice.

Status of Inspection Standards

All respondent transit agencies have formal tunnel structure inspection standards. Those standards identify what is inspected, when and how it is inspected, and how the data derived from inspections are managed. However, the transit agency survey and case studies could identify no specific technical or procedural inspection standards that were common to all agencies. While tunnel inspection objectives are undoubtedly very similar, inspection procedures are not.

On the contrary, specific transit agency inspection procedures vary, often quite considerably, which suggests that the underlying explicit or implicit inspection standards may vary as well. However, any such variation does not suggest an absence of adequate inspection standards. Nor do variations in transit agency inspection standards necessarily preclude future adoption of universal tunnel inspection standards, were transit agencies persuaded that the merits of universal standards outweighed the difficulty of required procedural or technical change. The practice of rail tunnel inspections has evolved in respondent transit agencies in particular ways for historical reasons that merit more detailed exploration.

The survey and case studies suggest that more recently constructed rail transit systems or system expansions (in North America and abroad) have among the more detailed and rigorous written standards for tunnel inspection procedures. If this observation is correct, it may be due to the more vigorous public and administrative scrutiny large public capital investments now receive in the public sector. The contemporary nature of major new public indebtedness can provide strong management incentives for use of the most efficient technological and administrative practices to maintain capital investments. In addition, transit agencies' need to complete the same, increasingly expensive, inspection and maintenance work with existing or fewer resources is a modern budgetary dilemma that places ever more pressure on any public transit agency's organizational and productive capacities.

These infrastructure investment and maintenance dynamics, together with the differences between transit agency tunnel inspection procedures will no doubt continue to raise some questions about particular inspection practices. Perhaps the differences in the practice of rail tunnel inspections together with growing agency budgetary demands can more substantially catalyze coordinated transit agency efforts to respond to questions pertaining to professional standards of the rail tunnel inspection practice.

However, the above questions about the practice do not necessarily signify the need for concern. Some older transit agencies have very thorough and rigorous standards for tunnel structural inspections. In addition, in some older transit systems, tunnel inspections may be conducted in an indifferent, or perhaps even a hostile environment, encountering very different inspection and maintenance challenges than may be the case in more recently constructed transit systems. Further case study analysis of transit system practice would be useful in better understanding the issue of inspection standards.

Organization of the Inspection Practice

Inspection procedures are the heart of any rail tunnel structure inspection practice. Procedures define the practice dynamically, how the objectives of tunnel inspection are accomplished. The technical and administrative procedures, the methods used to inspect tunnel structures, are themselves structured within a transit agency corporate culture for various historical reasons that provide the inherent rationale for that agency's choice of tunnel inspection procedures. Change to any institutional practice is usually quite slow, particularly if the rationale for that change, as applied, is not clear, perceived as legitimate, and reasonably synchronous with transit agency culture.

In an effort to frame the various transit agency tunnel inspection procedures, it is useful to summarize what have been perceived to be the general objectives for the more specific inspection procedures arising from this review of the practice:

- To protect life and property from the normal and extraordinary hazards of rail tunnel environments by locating, describing, prioritizing, and establishing responsibility for repairing structural defects.
- To define a specific group of complementary administrative and technical procedures which, if implemented day-in and day-out, fully accomplish the purposes of a responsible and accountable rail tunnel inspection practice.

TABLE 28
TUNNEL INSPECTION ORGANIZATION

Transit Agency	Technical	Procedural
MTA of Maryland	Frequency, equipment, defect rating, prioritization and documentation	Existing manual, team leader and member requirements
BART	Frequency, defect prioritization, documentation, etc	Manual in development, established administrative procedures, audit
CTA	N/A	N/A
MTRC	Frequency, defect rating, documentation and prioritization	Manual, specific structure, specific procedures, updating process
NYCT	Frequency, documentation, database, defect prioritization, data analysis	Team training, system assignment and inspection organization

- To provide sufficient redundancy and checks in the inspection system so that natural events, and human or procedural shortcomings do not result in structural failures during the practice of rail tunnel inspections.
- To develop the rail tunnel inspection practice into a fully responsible professional activity, with sufficient personal/organizational review to periodically critique the tunnel inspection practice by professional peers, and to assist in the development of new and improved standards for the professional practice of tunnel inspections.
- To prioritize required structural maintenance based on tunnel inspections in order to develop a capital improvements plan for the transit system.
- To perform tunnel inspection practices without adversely impacting transit agency revenue service.

On the basis of the information available from transit agencies, several respondent agencies have established rigorous organizational procedures for either or both the technical and procedural sides of the tunnel inspection practice. (See Table 28)

The table demonstrates that no two transit agencies appear to have either the same procedural approach to tunnel inspections, or by inference, the same degree of rigor in their inspection procedures.

At present there is no means of establishing legitimate baseline conditions for minimal transit agency tunnel inspection practices. In addition to the more specific analyses of individual tunnel inspection procedures suggested previously, establishing a minimum baseline condition for rail tunnel inspections represents a significant collective challenge to the effectiveness of the practice.

Effectiveness of Inspection Activities

The concept of effectiveness suggests productivity, results, getting something done. Effectiveness is a concept that involves an individual or institutional perception, a subjective valuing, unless technical or methodological standards exist that permit collective or consensual measuring of the effectiveness concept. In such an instance, one can then say that a particular standard of effectiveness has achieved a certain legitimacy; a wide subscription within the inspection practice.

Given its subjective quality, effectiveness as a concept for tunnel inspections quickly moves to the standards for tunnel inspection applied to the notion of effectiveness being advanced. The standards applied in the field are transit agencyderived standards, developed through that agency's history of rail tunnel inspections.

CHAPTER FIVE

CONCLUSIONS

The technical and administrative procedures used to inspect rail transit tunnel structures largely determine the perceived adequacy of subsequent inspections, and the degree to which that inspection practice conforms to the management objectives it is intended to fulfill.

In the evolution of management within any professional practice, management objectives become ever more specifically focused on the abatement of the mission's priority problems, and the problems themselves become more widely discussed among practicants from other management structures. In that way, the good news of what works to abate problems in one location can be widely shared, as the practice becomes more aware of the value in communicating its problems and needs. The practice thereby develops greater ability at healthy self-critique, and at more openly discussing issues relating to the adequacy of its practice

The principal elements of the tunnel inspection practice that have emerged from the preceding review, and about which some general conclusions can be drawn, are tunnel inspection problems, issues, and inspection procedures.

- Transit agency tunnel structure inspection practices reviewed here vary widely in their frequency, their testing requirements, and most other aspects of inspection procedure. It is not possible to reach supportable conclusions about the adequacy of any aspect of a transit agency inspection procedure on the basis of the information contained here, or to develop universal inspection standards from among the inspection practices reviewed.
- Respondent transit systems identified tunnel leaks or groundwater intrusion as their number one structural inspection problem. Most structural problems encountered by tunnel inspection procedures originate from groundwater intrusion.
- Additional structural problems, including concrete cracking, spalling, steel corrosion and others are created by groundwater intrusion. Tunnel leaks are the common enemy of the inspection practice.
- There are no universal inspection standards for the many aspects of rail tunnel structure inspection procedure.
- There is no federal or state government regulatory oversight of the rail tunnel inspection process, including tunnel inspection standards or documentation, as is the case for both railroad and highway facilities. The same observation can be made with respect to tunnel rehabilitation.
- The funding environment within which tunnel inspection now takes place suggests that, given the absence of universal tunnel inspection standards, and given the growing pressures on available government funding at all levels, there may be an opportunity for further exploration of tunnel inspection procedures. That potential exploration is suggested by the development of systems theory applications to the management of public infrastructure needs, including rail tunnel inspections and maintenance.

Some needs that arise from the above conclusions are:

- Development of short- and long-range tunnel inspection policy objectives, including the need for adequate resources for the tunnel inspection function given demands from other transit system functions on available resources.
- Development of industrywide standards for the practice of rail tunnel inspections, including prioritization of tunnel defect repairs, development of emergency administrative procedures for catastrophic system failures, and further development of tunnel structure database management systems.
- Development of system information on "typical" underground structure life expectancies and *"major/minor"* maintenance requirements.
- Development of a tunnel inspection incentive program as a requirement for certain categories of federal transit agency funding.
- Analysis of selected transit agency technical and procedural practices, as part of a larger analysis of the tunnel inspection practice would have been a welcome addition to this subject's background literature. Such an analysis is needed.

It would be useful at some future time to thoroughly investigate the various design, construction, and environmental factors that may contribute to the long-term deterioration or longevity of rail tunnel structures, such as tunnel design practices and specifications, building materials, construction methods, management and thoroughness, differential tunnel environments, approaches to maintenance, and other factors.

It would also be useful to review and assess transit agencies with respect to development of their technical (engineering assessment) tunnel inspection procedures. Better developed information on state-of-the-art inspection procedures, including destructive and nondestructive testing analyses, for example, for determination of structural defects, and transit agency experiences with those technical procedures would be helpful in furthering discussion of alternative technical approaches and useage in the industry.

Of course, any transit agency's tunnel inspection unit, however sophisticated its procedures for inspections may be, is administratively organized within a larger transit agency which may be more or less supportive of the tunnel inspection function, as one of the many transit agency activities competing for agency management attention and limited resources. A case study analysis of those resource competitive organizational dynamics would likewise be a useful addition to the literature on rail tunnel structural inspections.

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GLOSSARY

BART	Bay Area Rapid Transit (San Francisco).
CalTrain	Peninsula Corridor Joint Powers Board, California Commuter rail line.
Column	A vertical structural element that supports another structural element such as a floor or beam.
Crack	A linear fracture in concrete that may extend partially or completely through the concrete member.
Creep	Continuous slow movement of soil, often referred to as a slow movement in railroad track subbase.
CTA	Chicago Transit Authority.
Column Cladding	Architectural material placed around the steel columns.
Delamination	A hollow or "drummy" sounding concrete in which the surface of the concrete has separated from the parent concrete body.
E & M	Electrical and Mechanical.
Efflorescence	A white deposit on concrete caused by crystallization of soluble salts (calcium chloride) brought to the surface by moisture in the concrete.
Field Carbonation	A method of corrosion testing designed to indicate depths of potentially reduced alkalinity (and associated loss of steel protection).
Guideline	A recommendation; a directive
Honeycomb	An area of the concrete surface that was not completely filled during initial construction.
Hydrodemolition	Concrete removal by high pressure water.
Intrados	The interior curve of an arch, as in a tunnel lining.
Isotropy	A structural material that has the same mechanical properties in all directions, regardless of the direction of its loading.
MARTA	Metropolitan Atlanta Rapid Transit Authority (Atlanta, Ga.).
MTA	Mass Transit Administration of Maryland (Baltimore, Md.).
MTRC	Mass Transit Railway Corporation (Hong Kong).
NYCTA	New York City Transit Authority.
PATH	Port Authority of New York and New Jersey
PCC	Portland Cement Concrete.
Plenum	Air ducts in top or bottom of tunnel.
Pop-Outs	Conical fragments that break out of the surface of the concrete leaving small holes.
Routine	A function that is performed based on timing or other events.
Scaling	The gradual and continual loss of a concrete surface.
Spalling	A depression in the concrete that results from the separation and removal of a portion of the surface concrete, revealing a fracture roughly parallel to the surface
Stalactite	An icicle-shaped mineral deposit, usually calcite or aragonite, hanging from the roof, formed from the dripping of mineral-rich water.

APPENDIX A

Questionnaire Survey Form and Inventory Sheets

TRANSIT COOPERATIVE RESEARCH PROGRAM
PROJECT J-7, TOPIC SD-2

RAIL TRANSIT TUNNEL AND UNDERGROUND STRUCTURES
INSPECTION POLICY AND PROCEDURES

QUESTIONNAIRE

PART I - RESPONDENT PROFILE

1. Name of owner/agency ______________________________

2. Address of owner/agency ______________________________
____
____

3. Principal function of owner/agency: Light Rail ( ) Heavy Rail ( ) Railroad ( ) Other ( ) please explain:
____
____

4. Does your organization maintain a systematic inventory of underground structures and their conditions? Yes No

   If yes, how are the data organized and used, (use of database programs, Tabular format, etc.)?
   ____
   ____
   ____
   ____

5. What factors govern inspection and repair priorities, (e.g. legislative, funding, maintenance, etc.)?
____
____
____
____
____

6. Individual responding or contact person if clarification to responses is required.

Name: ______________________________
Title/Position: ______________________________
Business Address: ______________________________
____
____
Business Phone No: ______________________________

If you cannot complete portions of the survey, please, indicate not applicable where appropriate, or insert unknown and complete those portions of the survey for which you have information, please provide any written policy, procedures or manuals available

TCRP PROJECT J-7, TOPIC SD-2
AGENCY:___________________

PART II - INVENTORY

Please fill in the inventory form attached to the end of the survey to provide information about your tunnels, and make additional copies. Inventory Form. as required, to categorize your underground structures.

PART III - INVENTORY

1. Do you have a comprehensive, systematic program of inspection (circle one)? Yes No

2. If yes, how often do you inspect your structures? Please relate to ID numbers listed previously on Inventory Form filled **in** under PART II of survey.

Indicate by ID Numbers

a.	More than once a week.	___________	___________	__________
b.	Once a week.	___________	___________	__________
c.	Once a month	___________	___________	__________
d.	One each 6 months.	___________	___________	__________
e.	Once a year.	___________	___________	__________
f.	Once each 5 years.	___________	___________	__________
g.	None to date.	___________	___________	__________
h.	Emergency basis only	___________	___________	__________
i.	Other, please specify.	___________	___________	__________

3. If inspections are not performed, please identify reason(s) for not inspecting.
____
____
____
____

4. What do you look for during an inspection? (Please attach any guidelines or manuals)
____
____
____
____

5. Who performs inspections? Please relate to Structure ID numbers listed previously on Inventory Form under
PART II of survey.

Indicate by ID Numbers

a.	Own staff - Tunnel Walker	_________	________	_________
b.	Own staff - Staff Engineer	_________	________	_________
	Specialist	_________	________	_________
c.	Consulting Engineer	._________	________	_________
d.	Other, please specify	._________	________	_________

TCRP PROJECT J-7, TOPIC SD-2
AGENCY: ___________________

6. How are inspections reported:

a. Formal report.
b. Drawings.
c. Field notes.
d. Only if a problem excess
f. Other, please specify. ____

7. What types of defects or deficiencies are encountered during your inspections? Please relate to Structure ID numbers listed on Inventory Form (Part II).

Indicate by ID Numbers

a. Water leakage, infiltration ____________ ____________
b. Corrosion/deterioration of lining/support ____________ ____________
c. Spelling oflining/delaminations ____________ ____________
d. Need for new or additional support ____________ ____________
e. Need for enlargement/increased capacity/clearance ____________ ____________
f. Cracking of lining ____________ ____________
g. Piping of soil form outside lining ____________ ____________
h. Sitation, rock falls or other blockages, please specify: _________________________
i. Collapse _________________________

j. Other, please specify ____
____

8. What are the annual costs to inspect your underground structures? Only need to fill in one

a. $________________ per mile of structure (tunnel)
b. $________________ per tunnel structure $___________ per Station
c. $________________ for entire system
d. $________________ Unknown (Please check, if appropriate).

PART IV – REHABILITATION, FUNDING, AND PRACTICE

1. What are your agency's current budgetary needs for repairs/rehabilitation annually? Only need to fill in one.

a. $_________________ per mile of structure (tunnel)
b. $_________________ per tunnel structure, $__________ per Station
c. $_________________ for entire system
d. $_________________ Unknown (Please check, if appropriate).

2. What are your agency's current expenditures on rehabilitation annually? Only need fill in one.
a. $_______________ per mile of structure (tunnel)
b. $_______________ per structure, (station)
c. $_______________ for entire system
d. $_______________ Unknown (Please check, if appropriate)

TCRP PROJECT J-7, TOPIC SD-2
AGENCY____________________

3. What are the life experience of your underground structures? Please relate to ID numbers listed previously on Inventory Form(II).

Indiate by ID Numbers

a. Less than 10 years __________ __________ __________
b. 10 to 20 years. __________ __________ __________
c. 20 to 50 years. __________ __________ __________
d. Greater than 50 years __________ __________ __________
(please specify_________

4. What types of major rehabilitation projects (costs in excess of $1 million) have you performed in the past 10 years? Please relate numbers listed previously on Inventory Form (PART II)

____
____
____
____
____
____

5. Who performs your rehabilitation construction? Please check all applicable responses and relate to ID numbers listed previoulsy Inventory Form (PART II)

Indiate by ID Numbers

a. Own staff. __________ __________ __________
b. General Contractor. __________ __________ __________
c. Specialty Contractor. __________ __________ __________
(please specify.) __________
d. Other, (please specify.) __________

6. What are your organization's rehabilitation plans for the next 5 years?

____
____
____
____
____
____

7. Do you have a preventive maintenance program Yes ( ) No ( ) Provide if possible

8. Do you have a QA/QC program for inspection program Yes ( ) No ( ) Please provide if possible.

9. What amount of money do you expect to spend on rehabilitation over the next 5 years? $________________

10. What amount of money do you expect to spend on new construction or replacement over the next 5 years? $______________

11. Are you using or intend to implement within the next 5 years, an Assets Database System Yes ( ) No ( )

12. What are your sources of funding for rehabilitation work?_____________________________________
____
____

TCRP PROJECT J-7. TOPIC SD-2
AGENCY:___________________

13. What is your basic inspection polic **in** terms of emphasis resource allocation and short and long term objectives? ____
____
____
____

14. What **is** the repair/rehabilitation priontization process? (please attach any information on process)
____
____
____

15. Please state what proportion of the inspection and rehabilitation needs are satisfied by the available funding?

Inspection	Rehabilitation
100%_________	100%_________
90%_________	90%_________
80%_________	80%_________
50%_________	50%_________
other_________	other_________

16. Do you have an emergency response program (alternative service and repair) in the event of shutdown? Please describe nature of the plan.
____
____
____
____
____
____

END OF SURVEY
THANK YOU FOR YOUR ASSISTANCE

Please return survey:

HENRY A. RUSSELL
% Parsons Bnackerhoff
120 Boylston St.
Boston, MA 02116

If you have any questions. please call Henry Russell, on (617) 426-7330. If you wsh to submit your questionnaire by FAX please do so on (617) 482-8487. Please respond by April 7, 1995.

ORGANIZATION: ________________________
____

TCRP PROJECT SD-2 INSPECTION AND REHABILITATION SURVEY
INVENTORY FORM

DATE: ________________________
PAGE ________ of ___________

	A	B	C	D	E	F	G	H	
IDENTIFICATION NO.	STRUCTURE TYPE	DIAM/SIZE	SHAPE	AGE	NUMBER	AVERAGE LENGTH	AGGREGATE LENGTH	GROUND CONDITIONS	LINING

Codes:

A. Structure Type
a. Roadway Tunnel
b. Rail Tunnel
c. Transit/Subway Tunnel
d. Stations
e. Pedestrian Tunnel
f. Large Underground Chambers
g. Ventilation Shafts
h. Others, please specify

B. Diameter/Size
a. 10 to 15 ft.
b. 15 to 20 ft.
c. 20 to 25 ft.
d. 25 to 30 ft.
e. 30 to 35 ft.
f. Other, please specify

C. Shape
a. Circular
b. Oval/Egg Shape
c. Rectangular
d. Horseshoe
e. Other, please specify

D. Ages of Structures
a. Less than 10 years
b. 10 to 20 years
c. 20 to 50 years
d. Greater than 50 years, please specify.

E. Number of Structures in Each Category
Please use actual numbers

F. Average Length of Structures
a. Less than 100 ft.
b. 100 to 200 ft.
c. 200 to 500 ft.
d. 500 to 1,000 ft.
e. 1,000 to 5,000 ft.
f. 5,000 to 10,000 ft.
g. Greater than 10,000 ft., please specify

G. Aggregate Length of Structures
Total of Actual Numbers

H. Construction Ground Conditions
a. Soil
b. Rock
c. Mixed Ground
d. Immersed tube/subaqueous
e. Other, please specify

I. Lining and Support
a. Unlined rock
b. Cast-in-place concrete, no reinforcement
c. Cast-in-place concrete, reinforced
d. Shotcrete/gunite
e. Precast concrete liner segments
f. Precast, prestressed concrete liner segments
g. Steel/iron liner plate
h. Masonry
i. Other, please specify

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	Toronto Transit	Toronto Transit	Toronto Transit
Track Identification	001	002	003
Number of Structures Per Track ID	1	1	1
1. **Structure Type**			
a. Roadway Tunnel			
b. Rail Tunnel			
c. Transit/Subway Tunnel	•	•	•
d. Stations			
e. Pedestrian Tunnel			
f. Large Underground Chambers			
g. Ventilation Shafts			
h. Others, Please Specify			
2. **Diameter Size**			
a. 10 to 15 ft			
b. 15 to 20 Ft	•		•
c. 20 to 25 ft			
d. 25 to 30 ft			
e. 30 to 35 ft			
f. Other Please specify		15'4"w x 13'9"H	
3. **Shape**			
a. Circular	•		•
b. Oval Egg Shape			
c. Rectangular		•	
d. Horseshoe			
e. Other Please Specify			
4. **Ages of Structures**			
a. Less than 10 years			
b. 10 to 20 Years			
c. 20 to 25 Years	•	•	•
d. 25 to 30 Years			
e. 30 to 35 Years			
f. Other Please Specify			
5. **Average Length of Structures**			
a. Less than 100 ft.			
b. 100 to 200 ft.			
c. 200 to 500 ft.			
d. 500 to 1,000 ft.			
e. 1,000 to 5,000 ft.			
f. 5,000 to 10,000 ft.			
g. Greater than 10,000 ft. Please Specify			
6. **Aggregate Length of Structures**			
Total of Actual Numbers	13,000 ft	110,000 ft	17,000 ft

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	Toronto Transit	Toronto Transit	Toronto Transit
Track Identification	001	002	003
Number of Structures Per Track ID	1	1	1
7 **Construction Ground Condition**			
a. Soil			
b. Rock			
c. Mixed Ground			
d. Immersed Tube/Subaqueous			
e. Other, Please Specify			
g. **Lining and Support**			
a. Unlined Rock			
b. Cast-in-Place No Reinforcement			
c. Cast in Place Concrete, Reinforcment		•	
d. Shotcrete/gunite			
e. Precast Concrete Liner Segments			•
f. Precast Prestressed concrete Liner Segments			
g. Steel/Iron Liner Plate	•		
h. Mansonry			
i. Other Please specify			

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	STCUM	STCUM	STCUM	STCUM
Track Identification	Line 1	Line 2	Line 4	Line 5
Number of Structures Per Track ID	4	4	4	4
1. **Structure Type**				
a. Roadway Tunnel				
b. Rail Tunnel	•	•	•	•
c. Transit/Subway Tunnel				
d. Stations				
e. Pedestrian Tunnel				
f. Large Underground Chambers				
g. Ventilation Shafts				
h. Others, Please Specify				
2. **Diameter Size**				
a. 10 to 15 ft				
b. 15 to 20 Ft				
c. 20 to 25 ft				
d. 25 to 30 ft	•	•	•	•
e. 30 to 35 ft				
f. Other Please specify				
3. **Shape**				
a. Circular				
b. Oval Egg Shape				
c. Rectangular				
d. Horseshoe	•	•	•	•
e. Other Please Specify				
4. **Ages of Structures**				
a. Less than 10 years				
b. 10 to 20 Years	•	•		•
c. 20 to 25 Years	•	•	•	
d. 25 to 30 Years				
e. 30 to 35 Years				
f. Other Please Specify				
5. **Average Length of Structures**				
a. Less than 100 ft.				
b. 100 to 200 ft.				
c. 200 to 500 ft.				
d. 500 to 1,000 ft.				
e. 1,000 to 5,000 ft.				
f. 5,000 to 10,000 ft.				
g. Greater than 10,000 ft. Please Specify				
6. **Aggregate Length of Structures**				
Total of Actual Numbers	68 km	68 km	68 km	68 km

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	STCUM	STCUM	STCUM	STCUM
Track Identification	Line 1	Line 2	Line 4	Line 5
Number of Structures Per Track ID	4	4	4	4
7 **Construction Ground Condition**				
a. Soil				
b. Rock				
c. Mixed Ground				
d. Immersed Tube/Subaqueous				
e. Other, Please Specify				
g. **Lining and Support**				
a. Unlined Rock				
b. Cast-in-Place No Reinforcement				
c. Cast in Place Concrete, Reinforcment				
d. Shotcrete/gunite				
e. Precast Concrete Liner Segments				
f. Precast Prestressed concrete Liner Segments				
g. Steel/Iron Liner Plate				
h. Mansonry				
i. Other Please specify				

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	CALTRAIN	CALTRAIN	CALTRAIN	CALTRAIN	CALTRAIN
Track Identification	Tunnel 1	Tunnel 2	Tunnel 3	Tunnel 4	Ped. Tunnels
Number of Structures Per Track ID	1	1	1	1	4
1. **Structure Type**					
a. Roadway Tunnel					
b. Rail Tunnel	Brick & Concrete	Brick & Concrete	Brick & Concrete	Brick & Concrete	
c. Transit/Subway Tunnel					
d. Stations					•
e. Pedestrian Tunnel					•
f. Large Underground Chambers					
g. Ventilation Shafts					
h. Others, Please Specify					
2. **Diameter Size**					
a. 10 to 15 ft					•
b. 15 to 20 Ft					
c. 20 to 25 ft					
d. 25 to 30 ft	•	•	•	•	
e. 30 to 35 ft					
f. Other Please specify					
3. **Shape**					
a. Circular					•
b. Oval Egg Shape					
c. Rectangular					
d. Horseshoe	•	•	•	•	
e. Other Please Specify					
4. **Ages of Structures**					
a. Less than 10 years					
b. 10 to 20 Years					
c. 20 to 25 Years					
d. 25 to 30 Years	•	•	•	•	•
e. 30 to 35 Years					
f. Other Please Specify					
5. **Average Length of Structures**					
a. Less than 100 ft.					60'
b. 100 to 200 ft.					
c. 200 to 500 ft.					
d. 500 to 1,000 ft.					
e. 1,000 to 5,000 ft.	1617'	1086'	2364'	3547'	
f. 5,000 to 10,000 ft.					
g. Greater than 10,000 ft. Please Specify					
6. **Aggregate Length of Structures**					
Total of Actual Numbers	1617'	1086'	2364'	3547'	240'

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	CALTRAIN	CALTRAIN	CALTRAIN	CALTRAIN	CALTRAIN
Track Identification	Tunnel 1	Tunnel 2	Tunnel 3	Tunnel 4	Ped. Tunnels
Number of Structures Per Track ID	1	1	1	1	4
7 **Construction Ground Condition**					
a. Soil	•	•	•	•	•
b. Rock					
c. Mixed Ground					
d. Immersed Tube/Subaqueous					
e. Other, Please Specify					
g. **Lining and Support**					
a. Unlined Rock					
b. Cast-in-Place No Reinforcement					•
c. Cast in Place Concrete, Reinforcment					
d. Shotcrete/gunite					
e. Precast Concrete Liner Segments					
f. Precast Prestressed concrete Liner Segments					
g. Steel/Iron Liner Plate					
h. Mansonry	•	•	•	•	
i. Other Please specify					

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	PATH	PATH	PATH	PATH
Track Identification	Item 1	Item 2	Item 3a	Item 3b
Number of Structures Per Track ID	1	2	1	1
	Tunnel A	Exchange PL - WTC	14th Hoboken Under Water	14th Hoboken Land
	Brick Section			
1. **Structure Type**				
a. Roadway Tunnel				
b. Rail Tunnel	•	•	•	•
c. Transit/Subway Tunnel				
d. Stations				
e. Pedestrian Tunnel				
f. Large Underground Chambers				
g. Ventilation Shafts				
h. Others, Please Specify				
2. **Diameter Size**				
a. 10 to 15 ft	15'-10"X17'-10"	15' 3"	15' 3"	15' 3"
b. 15 to 20 Ft				
c. 20 to 25 ft				
d. 25 to 30 ft				
e. 30 to 35 ft				
f. Other Please specify				
3. **Shape**				
a. Circular		•	•	•
b. Oval Egg Shape	•			
c. Rectangular				
d. Horseshoe				
e. Other Please Specify				
4. **Ages of Structures**				
a. Less than 10 years				
b. 10 to 20 Years				
c. 20 to 25 Years				
d. 25 to 30 Years				
e. 30 to 35 Years				
f. Other Please Specify	100 yrs. +	60 yrs. +	80 yrs. +	80 yrs. +
5. **Average Length of Structures**				
a. Less than 100 ft.				
b. 100 to 200 ft.				
c. 200 to 500 ft.				
d. 500 to 1,000 ft.				
e. 1,000 to 5,000 ft.	2000'			
f. 5,000 to 10,000 ft.		5300'	9000'	15000'
g. Greater than 10,000 ft. Please Specify				
6. **Aggregate Length of Structures**				
Total of Actual Numbers	2000'	10600'	9000'	15000'

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	PATH	PATH	PATH	PATH
Track Identification	Item 1	Item 2	Item 3a	Item 3b
Number of Structures Per Track ID	1	2	1	1
	Tunnel A	Exchange PL - WTC	14th Hoboken Under Water	14th Hoboken Land
7 **Construction Ground Condition**				
a. Soil				
b. Rock				
c. Mixed Ground				
d. Immersed Tube/Subaqueous	•	•	•	
e. Other, Please Specify				silt
g. **Lining and Support**				
a. Unlined Rock				
b. Cast-in-Place No Reinforcement				
c. Cast in Place Concrete, Reinforcment				
d. Shotcrete/gunite				
e. Precast Concrete Liner Segments				
f. Precast Prestressed concrete Liner Segments				
g. Steel/Iron Liner Plate		•	•	•
h. Mansonry				
i. Other Please specify	Brick			

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	PATH	PATH	PATH	PATH	METROLINK
Track Identification	Item 4	Item 5a	Item 5b	Item 6	001
Number of Structures Per Track ID	1	1	1	1	1
	14th to 33rd St. Sta.	Caisson 2 to Exch. Pl.	Caisson 2 to Exch. Pl.	Exch. Pl. Tun. G & H	
1. **Structure Type**					
a. Roadway Tunnel					
b. Rail Tunnel	•	•	•	•	•
c. Transit/Subway Tunnel					
d. Stations					
e. Pedestrian Tunnel					
f. Large Underground Chambers					
g. Ventilation Shafts					
h. Others, Please Specify					
2. **Diameter Size**					
a. 10 to 15 ft	30' x 15'	15' 3'	15' x 15'	30' x 15'	
b. 15 to 20 Ft					•
c. 20 to 25 ft					
d. 25 to 30 ft					
e. 30 to 35 ft					
f. Other Please specify					
3. **Shape**					
a. Circular		•			
b. Oval Egg Shape					
c. Rectangular	•		•	•	
d. Horseshoe					
e. Other Please Specify					Doub. Arches
4. **Ages of Structures**					
a. Less than 10 years					
b. 10 to 20 Years					
c. 20 to 25 Years					
d. 25 to 30 Years					
e. 30 to 35 Years					
f. Other Please Specify	80 yrs. +	80 yrs. +	80 yrs. +	80 yrs. +	124 yrs.
5. **Average Length of Structures**					
a. Less than 100 ft.					
b. 100 to 200 ft.					
c. 200 to 500 ft.					
d. 500 to 1,000 ft.					
e. 1,000 to 5,000 ft.					
f. 5,000 to 10,000 ft.	4000'	5500'	5500'	5000'	•
g. Greater than 10,000 ft. Please Specify					
6. **Aggregate Length of Structures**					
Total of Actual Numbers	4000'	5500'	5500'	5000'	4114'

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	PATH	PATH	PATH	PATH	METROLINK
Track Identification	Item 4	Item 5a	Item 5b	Item 6	001
Number of Structures Per Track ID	1	1	1	1	1
	14th to 33rd St. Sta.	Caisson 2 to Exch. Pl.	Caisson 2 to Exch. Pl.	Exch. Pl. Tun. G & H	
7. **Construction Ground Condition**					
a. Soil					
b. Rock				•	•
c. Mixed Ground					
d. Immersed Tube/Subaqueous	•				
e. Other, Please Specify		silt	silt		
g. **Lining and Support**					
a. Unlined Rock					
b. Cast-in-Place No Reinforcement					
c. Cast in Place Concrete, Reinforcment	•		•	•	
d. Shotcrete/gunite					
e. Precast Concrete Liner Segments					
f. Precast Prestressed concrete Liner Segments					
g. Steel/Iron Liner Plate		•			
h. Mansonry					•
i. Other Please specify					

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	Baltimore MTA	Baltimore MTA	Baltimore MTA	Baltimore MTA	Baltimore MTA
Track Identification	Lafayette	Ruskin	Ocala	Sudbrook Park Track 1	Sudbrook Park Track 2
Number of Structures Per Track ID	1	1	1	1	1
	Vent Shaft	Vent Shaft	Vent Shaft	Track 1	Track 2
1. **Structure Type**					
a. Roadway Tunnel					
b. Rail Tunnel					
c. Transit/Subway Tunnel				•	•
d. Stations					
e. Pedestrian Tunnel					
f. Large Underground Chambers					
g. Ventilation Shafts	•	•	•		
h. Others, Please Specify					
2. **Diameter Size**					
a. 10 to 15 ft					
b. 15 to 20 Ft					
c. 20 to 25 ft					
d. 25 to 30 ft					
e. 30 to 35 ft				•	
f. Other Please specify	53'	90'	56'		
3. **Shape**					
a. Circular					
b. Oval Egg Shape					
c. Rectangular	•	•	•	•	•
d. Horseshoe					
e. Other Please Specify					
4. **Ages of Structures**					
a. Less than 10 years					
b. 10 to 20 Years	•	•	•	•	•
c. 20 to 25 Years					
d. 25 to 30 Years					
e. 30 to 35 Years					
f. Other Please Specify					
5. **Average Length of Structures**					
a. Less than 100 ft.	•	•			
b. 100 to 200 ft.			•		
c. 200 to 500 ft.					
d. 500 to 1,000 ft.				•	•
e. 1,000 to 5,000 ft.					
f. 5,000 to 10,000 ft.					
g. Greater than 10,000 ft. Please Specify					
6. **Aggregate Length of Structures**					
Total of Actual Numbers	74'	96'	108'	540'	540'

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	Baltimore MTA	Baltimore MTA	Baltimore MTA	Baltimore MTA	Baltimore MTA
Track Identification	Lafayette	Ruskin	Ocala	Sudbrook Park Track 1	Sudbrook Park Track 2
Number of Structures Per Track ID	1	1	1	1	1
	Vent Shaft	Vent Shaft	Vent Shaft	Track 1	Track 2
7 **Construction Ground Condition**					
a. Soil	•			•	•
b. Rock		•	•		
c. Mixed Ground					
d. Immersed Tube/Subaqueous					
e. Other, Please Specify					
g. **Lining and Support**					
a. Unlined Rock					
b. Cast-in-Place No Reinforcement					
c. Cast in Place Concrete, Reinforcment	•	•	•	•	•
d. Shotcrete/gunite					
e. Precast Concrete Liner Segments					
f. Precast Prestressed concrete Liner Segments					
g. Steel/Iron Liner Plate					
h. Mansonry					
i. Other Please specify					

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	METRO - NORTH	METRO - NORTH	METRO - NORTH	METRO - NORTH	METRO - NORTH
Track Identification	HU 0.73 A	HU 0.73 B	HU 0.73 C	HU 36.77 A	HU 36.77 B
Number of Structures Per Track ID	4	4	4	1	1
1. Structure Type					
a. Roadway Tunnel					
b. Rail Tunnel	•	•	•	•	•
c. Transit/Subway Tunnel					
d. Stations					
e. Pedestrian Tunnel					
f. Large Underground Chambers					
g. Ventilation Shafts					
h. Others, Please Specify					
2. Diameter Size					
a. 10 to 15 ft					
b. 15 to 20 Ft	•				
c. 20 to 25 ft					
d. 25 to 30 ft		•	•	•	•
e. 30 to 35 ft					
f. Other Please specify					
3. Shape					
a. Circular					
b. Oval Egg Shape					
c. Rectangular	•	•	•		
d. Horseshoe	•	•	•	•	•
e. Other Please Specify					
4. Ages of Structures					
a. Less than 10 years					
b. 10 to 20 Years					
c. 20 to 25 Years					
d. 25 to 30 Years					
e. 30 to 35 Years					
f. Other Please Specify	125	125	125	82	82
5. Average Length of Structures					
a. Less than 100 ft.					
b. 100 to 200 ft.					
c. 200 to 500 ft.					
d. 500 to 1,000 ft.					
e. 1,000 to 5,000 ft.					
f. 5,000 to 10,000 ft.					
g. Greater than 10,000 ft. Please Specify					
6. Aggregate Length of Structures					
Total of Actual Numbers					

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	METRO - NORTH	METRO - NORTH	METRO - NORTH	METRO - NORTH	METRO - NORTH
Track Identification	HU 0.73 A	HU 0.73 B	HU 0.73 C	HU 36.77 A	HU 36.77 B
Number of Structures Per Track ID	4	4	4	1	1
7 Construction Ground Condition					
a. Soil					
b. Rock					
c. Mixed Ground					
d. Immersed Tube/Subaqueous					
e. Other, Please Specify					
g. Lining and Support					
a. Unlined Rock					
b. Cast-in-Place No Reinforcement					
c. Cast in Place Concrete, Reinforcment					
d. Shotcrete/gunite					
e. Precast Concrete Liner Segments					
f. Precast Prestressed concrete Liner Segments					
g. Steel/Iron Liner Plate					
h. Mansonry					
i. Other Please specify					

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	METRO - NORTH	METRO - NORTH	METRO - NORTH	METRO - NORTH	METRO - NORTH
Track Identification	HU 43.62	HU 44.39	HU 45.07	HU 45.04	HU 50.06
Number of Structures Per Track ID	1	1	1	1	1
1. **Structure Type**					
a. Roadway Tunnel					
b. Rail Tunnel	•	•	•	•	•
c. Transit/Subway Tunnel					
d. Stations					
e. Pedestrian Tunnel					
f. Large Underground Chambers					
g. Ventilation Shafts					
h. Others, Please Specify					
2. **Diameter Size**					
a. 10 to 15 ft					
b. 15 to 20 Ft					
c. 20 to 25 ft					
d. 25 to 30 ft	•	•	•	•	•
e. 30 to 35 ft					
f. Other Please specify					
3. **Shape**					
a. Circular					
b. Oval Egg Shape					
c. Rectangular					
d. Horseshoe	•	•	•	•	•
e. Other Please Specify					
4. **Ages of Structures**					
a. Less than 10 years					
b. 10 to 20 Years					
c. 20 to 25 Years					
d. 25 to 30 Years					
e. 30 to 35 Years					
f. Other Please Specify	90	92	90	66	66
5. **Average Length of Structures**					
a. Less than 100 ft.					
b. 100 to 200 ft.					
c. 200 to 500 ft.					
d. 500 to 1,000 ft.					
e. 1,000 to 5,000 ft.					
f. 5,000 to 10,000 ft.					
g. Greater than 10,000 ft. Please Specify					
6. **Aggregate Length of Structures**					
Total of Actual Numbers					

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	METRO - NORTH	METRO - NORTH	METRO - NORTH	METRO - NORTH	METRO - NORTH
Track Identification	HU 43.62	HU 44.39	HU 45.07	HU 45.04	HU 50.06
Number of Structures Per Track ID	1	1	1	1	1
7 **Construction Ground Condition**					
a. Soil					
b. Rock					
c. Mixed Ground					
d. Immersed Tube/Subaqueous					
e. Other, Please Specify					
g. **Lining and Support**					
a. Unlined Rock					
b. Cast-in-Place No Reinforcement					
c. Cast in Place Concrete, Reinforcment					
d. Shotcrete/gunite					
e. Precast Concrete Liner Segments					
f. Precast Prestressed concrete Liner Segments					
g. Steel/Iron Liner Plate					
h. Mansonry					
i. Other Please specify					

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	METRO - NORTH	METRO - NORTH	METRO - NORTH	NJ TRANSIT	NJ TRANSIT
Track Identification	HU 54.52A	HU 54.52B	HA 8.80	7.23 Main,	1.46 M&E (N)
Number of Structures Per Track ID	1	1	1	1	3
1. **Structure Type**					
a. Roadway Tunnel					
b. Rail Tunnel	•	•	•	•	•
c. Transit/Subway Tunnel					
d. Stations					
e. Pedestrian Tunnel					
f. Large Underground Chambers					
g. Ventilation Shafts					
h. Others, Please Specify					
2. **Diameter Size**					
a. 10 to 15 ft					
b. 15 to 20 Ft					
c. 20 to 25 ft		•	•		
d. 25 to 30 ft	•				
e. 30 to 35 ft				•	•
f. Other Please specify					
3. **Shape**					
a. Circular					
b. Oval Egg Shape					
c. Rectangular			•		
d. Horseshoe	•	•		•	•
e. Other Please Specify					
4. **Ages of Structures**					
a. Less than 10 years					
b. 10 to 20 Years					
c. 20 to 25 Years					
d. 25 to 30 Years					
e. 30 to 35 Years					
f. Other Please Specify	90	68	68	92	119
5. **Average Length of Structures**					
a. Less than 100 ft.					
b. 100 to 200 ft.					
c. 200 to 500 ft.					
d. 500 to 1,000 ft.				•	
e. 1,000 to 5,000 ft.					•
f. 5,000 to 10,000 ft.					
g. Greater than 10,000 ft. Please Specify					
6. **Aggregate Length of Structures**					
Total of Actual Numbers					
				400 ft	4,278ft

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	METRO - NORTH	METRO - NORTH	METRO - NORTH	NJ TRANSIT	NJ TRANSIT
Track Identification	HU 54.52A	HU 54.52B	HA 8.80	7.23 Main,	1.46 M&E (N)
Number of Structures Per Track ID	1	1	1	1	3
7 **Construction Ground Condition**					
a. Soil					
b. Rock					•
c. Mixed Ground				•	
d. Immersed Tube/Subaqueous					
e. Other, Please Specify					
g. **Lining and Support**					
a. Unlined Rock					
b. Cast-in-Place No Reinforcement				•	•
c. Cast in Place Concrete, Reinforcment					
d. Shotcrete/gunite					
e. Precast Concrete Liner Segments					
f. Precast Prestressed concrete Liner Segments					
g. Steel/Iron Liner Plate					
h. Mansonry					
i. Other Please specify					

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	NJ TRANSIT	CTA	CTA	CTA	MTRC Hong Kong
Track Identification	1.46 M&E (S)	#1	#2	#3	
Number of Structures Per Track ID	4	6	21	104	
1. **Structure Type**					
a. Roadway Tunnel					
b. Rail Tunnel	•				
c. Transit/Subway Tunnel		•			
d. Stations			•		
e. Pedestrian Tunnel					
f. Large Underground Chambers					
g. Ventilation Shafts				•	
h. Others, Please Specify					
2. **Diameter Size**					
a. 10 to 15 ft					
b. 15 to 20 Ft		•	•	•	
c. 20 to 25 ft					
d. 25 to 30 ft					
e. 30 to 35 ft	•				
f. Other Please specify					
3. **Shape**					
a. Circular				•	
b. Oval Egg Shape					
c. Rectangular					
d. Horseshoe	•	•	•		
e. Other Please Specify					
4. **Ages of Structures**					
a. Less than 10 years					
b. 10 to 20 Years					
c. 20 to 25 Years					
d. 25 to 30 Years					
e. 30 to 35 Years					
f. Other Please Specify	84	55	55	55	
5. **Average Length of Structures**					
a. Less than 100 ft.				•	
b. 100 to 200 ft.					
c. 200 to 500 ft.			•		
d. 500 to 1,000 ft.					
e. 1,000 to 5,000 ft.	•				
f. 5,000 to 10,000 ft.		•			
g. Greater than 10,000 ft. Please Specify					
6. **Aggregate Length of Structures**					
Total of Actual Numbers					
	4281 ft	58,878'	14,900'	2,100	

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	NJ TRANSIT	CTA	CTA	CTA	MTRC Hong Kong
Track Identification	1.46 M&E (S)	#1	#2	#3	
Number of Structures Per Track ID	4	6	21	104	
7 **Construction Ground Condition**					
a. Soil		•	•	•	
b. Rock	•				
c. Mixed Ground					
d. Immersed Tube/Subaqueous					
e. Other, Please Specify					
g. **Lining and Support**					
a. Unlined Rock					
b. Cast-in-Place No Reinforcement		•	•		
c. Cast in Place Concrete, Reinforcment				•	
d. Shotcrete/gunite					
e. Precast Concrete Liner Segments					
f. Precast Prestressed concrete Liner Segments					
g. Steel/Iron Liner Plate					
h. Mansonry	•				
i. Other Please specify					

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	City of Calgary	City of Calgary	City of Calgary	City of Calgary	City of Calgary
Track Identification	382.143	386.401	386.402	386.403	386.403
Number of Structures Per Track ID	1	1	1	1	1
1. **Structure Type**					
a. Roadway Tunnel					
b. Rail Tunnel					
c. Transit/Subway Tunnel	•	•	•	•	•
d. Stations					
e. Pedestrian Tunnel					
f. Large Underground Chambers					
g. Ventilation Shafts					
h. Others, Please Specify					
2. **Diameter Size**					
a. 10 to 15 ft					
b. 15 to 20 Ft					
c. 20 to 25 ft					
d. 25 to 30 ft					
e. 30 to 35 ft	•	•	•	•	•
f. Other Please specify					
3. **Shape**					
a. Circular					
b. Oval Egg Shape					
c. Rectangular	•	•	•	•	•
d. Horseshoe					
e. Other Please Specify					
4. **Ages of Structures**					
a. Less than 10 years					•
b. 10 to 20 Years	•	•	•	•	
c. 20 to 25 Years					
d. 25 to 30 Years					
e. 30 to 35 Years					
f. Other Please Specify					
5. **Average Length of Structures**					
a. Less than 100 ft.					
b. 100 to 200 ft.					
c. 200 to 500 ft.					
d. 500 to 1,000 ft.					
e. 1,000 to 5,000 ft.	•	•	•	•	•
f. 5,000 to 10,000 ft.					
g. Greater than 10,000 ft. Please Specify					
6. **Aggregate Length of Structures**					
Total of Actual Numbers	361'	2288'	1509'	797'	1335'

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	City of Calgary	City of Calgary	City of Calgary	City of Calgary	City of Calgary
Track Identification	382.143	386.401	386.402	386.403	386.403
Number of Structures Per Track ID	1	1	1	1	1
7 **Construction Ground Condition**					
a. Soil					
b. Rock					
c. Mixed Ground	•	•	•	•	•
d. Immersed Tube/Subaqueous					
e. Other, Please Specify					
g. **Lining and Support**					
a. Unlined Rock					
b. Cast-in-Place No Reinforcement					
c. Cast in Place Concrete, Reinforcment	•	•	•	•	•
d. Shotcrete/gunite					
e. Precast Concrete Liner Segments					
f. Precast Prestressed concrete Liner Segments					
g. Steel/Iron Liner Plate					
h. Mansonry					
i. Other Please specify					

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	City of Calgary	NYCT	MARTA	BART
Track Identification	386.405			
Number of Structures Per Track ID	1			
1. **Structure Type**				
a. Roadway Tunnel				
b. Rail Tunnel				
c. Transit/Subway Tunnel	•			
d. Stations				
e. Pedestrian Tunnel				
f. Large Underground Chambers				
g. Ventilation Shafts				
h. Others, Please Specify				
2. **Diameter Size**				
a. 10 to 15 ft				
b. 15 to 20 Ft				
c. 20 to 25 ft				
d. 25 to 30 ft				
e. 30 to 35 ft	•			
f. Other Please specify				
3. **Shape**				
a. Circular				
b. Oval Egg Shape				
c. Rectangular	•			
d. Horseshoe				
e. Other Please Specify				
4. **Ages of Structures**				
a. Less than 10 years	•			
b. 10 to 20 Years				
c. 20 to 25 Years				
d. 25 to 30 Years				
e. 30 to 35 Years				
f. Other Please Specify				
5. **Average Length of Structures**				
a. Less than 100 ft.				
b. 100 to 200 ft.				
c. 200 to 500 ft.				
d. 500 to 1,000 ft.				
e. 1,000 to 5,000 ft.	•			
f. 5,000 to 10,000 ft.				
g. Greater than 10,000 ft. Please Specify				
6. **Aggregate Length of Structures**				
Total of Actual Numbers	787'			

Rail Transit Tunnels And Underground Structures Inventory Sheet

Agency Name	City of Calgary	NYCT	MARTA	BART
Track Identification	386.405			
Number of Structures Per Track ID	1			
7 **Construction Ground Condition**				
a. Soil				
b. Rock				
c. Mixed Ground	•			
d. Immersed Tube/Subaqueous				
e. Other, Please Specify				
g. **Lining and Support**				
a. Unlined Rock				
b. Cast-in-Place No Reinforcement				
c. Cast in Place Concrete, Reinforcment	•			
d. Shotcrete/gunite				
e. Precast Concrete Liner Segments				
f. Precast Prestressed concrete Liner Segments				
g. Steel/Iron Liner Plate				
h. Mansonry				
i. Other Please specify				

APPENDIX B

Questionnaire Responses

Summary of Questionnaire

Page 1

Agency Name	Montreal Transit	CALTRAIN	PATH
	S.T.C.U.M Montreal, P.Q.	Peninsula Corridor Joint Powers Board	Port Authority Trans-Hudson Corporation
[illegible]			
1. Principal function of agency: LRT, Heavy Rail, RR	LRT		Heavy Rail Transit
Other		Peninsula Corridor Service is essentially a transit railroad system with trackage rights for freight railroad.	
2. Does your organization maintain a	Yes	Yes	Yes
systematic inventory of underground structures and their conditions? If yes, please specify.	Data base, (4d relational) inspection based on statistics, 1.7% observed each month.	We maintain record of inspections in inspection forms.	Computer database programs are used to maintain an inventory of all deficiencies detected during inspections.
3. What factors govern inspection and repair priorities, (e.g. legislative, funding, maintenance, etc.	Reliaiblity and Security	Structures Inspected Annually and when required.	Inspections are performed on a routine scheduled basis which has been determined by the agency. Repairs are prioritized based on the severity of the condition identified during inspections. Repairs judged to be a priority are funded
			while funding for less severe maintenance conditions is decided annually.
[illegible]			
1. Do you have a comprehensive, systematic program of inspection? Y/N?	Yes	Yes	Yes
2. Yes, how often do you inspect your structures?			
More than once a week?			
Once a week.	Switch equipment		
Once a month			
Once each 6 months			
Once a year.		For Rail Tunnel & Pedestrian Tunnel.	Item #1
Once each 5 years			
None to date.			
Emergency basis only			
Other, please specify	Twice a month for Tunnel	Plus, as required Rail Tunnel & Pedestrian Tunnel	Item #2, 3a & 3b, 51 & 5b, item #4, item #6.
3. If inspections are not performed, please identify reason(s) for not inspecting.		n/a	n/a
4. What do you look for during an inspection?	Any anomalies for each kind of equipment.	No form specified	See backup

Summary of Questionnaire

Page 2

Agency Name	Montreal Transit	CALTRAIN	PATH
	S.T.C.U.M Montreal, P.Q.	Peninsula Corridor Joint Powers Board	Port Authority Trans-Hudson Corporation
5. Who performs inspections?			
Own staff- Tunnel Walker	73-210, 73-320		
Own Staff - Staff Engineer/ Specialist		X, X *(Amtrak Specialist)	Items 1,2,3,4,5,6
Consulting Engineer			Items 1,2,3,4,5,6
Other, please specify			
6. How are inspections reported?			
Formal report	X		yes
Drawings.		These accompany inspection report, if required.	yes
Field Notes.		These accompany inspection report, if required.	yes
Only if a problem exists.			
Other, please specify.			letter report
7. What types of defects or deficiencies are			
encountered during your inspections?			
Water leakage, infiltration	X	X,X	Items 1,2,3,4,5,6
Corrosion/deterioration of lining/support	X	X,O	Items 1,2,3,4,5,6
Spalling of lining/delaminations	X	X,X	Items 1,2,3,4,5,6
Need for new or additional support			
Need for enlargement/increased capacity/clearance			Items 1,2,3,4,5,6
Cracking of lining		X,X	
Piping of soil from outside lining	X		
Siltation, rock falls or other blockages, be specific.	X		
Collapse		X	
Other, please specify.		Drainage Problems	
8. What are the annual costs to inspect your			
underground structures?			
$ Per mile of structure (tunnel)	$39,000.00		
$ per tunnel structure, $ per station			
$ for entire system		$5,000.00	$300,000.00
Unknown			
[illegible]			
1. What are your agency's current budgetary			
needs for rehabilitation annually?			
$ per mile of structure (tunnel)	$104,000.00		
$ per structure $ per station			

Summary of Questionnaire

Agency Name	Montreal Transit	CALTRAIN	PATH
	S.T.C.U.M Montreal, P.Q.	Peninsula Corridor Joint Powers Board	Port Authority Trans-Hudson Corporation
$ for entire system		$100,000.00	1995 $820,000.00
Unknown, (Please check, if appropriate)			
2 . What are your agency's current expenditures on rehabilitation annually?			
$ per mile of structure (tunnel)			
$ per structure (station)			
$ for entire system		NIL	1995 $820,000.00
Unknown, (Please check, if appropriate)			
3. What are the life expectancies of your underground structures?			
a. Less than 10 years.			
b. 10 to 20 years.			
c. 20 to 50 years.			All items
d. Greater than 50 years. Please specify.	X	90 - 100 yrs	
4. What types of major rehabilitation projects (costs in excess of $1 million) have you performed in pase 10 years? Please relate all numbers listed previously on Inventory form. (Part II)	Rail welds inspection and correction., *Tunnel Structure* Repair (major)., Rebuild switch equipment.	Nil for the structures, track rehabilitated in Tunnel 4 in *1985.*	Tunnel ring bolt replacement (Items 2,3,4,5,6); *Construction of emergency* evacuation and ventilation shafts.
5. Who performs your rehabilitation construction?		n/a	
Own Staff	X		Items 2 - 6
General Contractor	X		Items 1 - 6
Specialty Contractor			Items 1 - 6
Other, (please specify)			
6. What are your organization's rehabilitation plans for the next 5 years?	Same as #4	We plan to rehabilitate the drainage and track in Tunnels 1 & 3 in the next 5 years. Expected expenditure $3.5 million.	Tunnel ring bolt replacement, Brick Tunnel Rehabilitation, Sealing of Tunnel Leaks, Station Rehabilitation.
7. Do you have a preventive maintenance program? Y/N? Please provide is possible.	Yes	Yes	Yes
8. Do you have a QA/QC program for Inspection program? Y/N? Please provide if possible.	Yes	Yes	Yes
9. What amount of money do you expect to spend on rehabilitation over the next 5 years.	$4,840,000.00	3.5 million on track & drainage.	$ 50 million

Summary of Questionnaire

Agency Name	Montreal Transit	CALTRAIN	PATH
	S.T.C.U.M Montreal, P.Q.	Peninsula Corridor Joint Powers Board	Port Authority Trans-Hudson Corporation
10. What amount of money do you expect to spend on		$0 (Nil)	
new construction or replacement over the next 5 years.	$10,485,000.00		$0
11. Are you using or intend to implement within the next 5 years, an Assets Database System? Y/N?.	No.	Yes	No
12. What are your sources of funding for rehabilitation work?	Quebec Government for Budgets and Credit.	FTA. Grants., Some Funds available from State also.	Port Authority Budget
13. What is your basic inspection policy interms of emphasis on resource allocation and short and long term objectives?	Statistical analysis of tunnel and equipment conditions.	Tunnels also get inspected along with track by Track Inspectors.	All inspections as described above are a priority for resource allocation and funded. Short term objectives are to assure the Safety of the tunnels and long term objectives are to extend the life of the underground structures.
14. What is the repair/rehabilitation prioritization process?	*Metro service* prioritization process.	*Nil*	*See I - 5 above*
15. Please state what proportion of the inspection and rehabilitation needs are satisfied by the available funding.			
Inspection Rehabilitation			
100% 100%	100% Inspection	Inspection 100%	100% Insp, Rehab., 100%
90% 90%			
80% 80%			
50% 50%		Rehabilitation 50%	
other other			
16. Do you have an emergency response program (Alternative service and repair) in the event of shutdown?			
	We have a bus service backup in case of shutdown.	none	Yes Path has a system safety program in place. Additionally, there is an emergency call-in contract in force to facilitate response.

Summary of Questionnaire

Agency Name	MetroLink	MTA	Metro North Railroad
	Bi-State Development Agency	Mass Transit Admin - Baltimore	New York, New York
[illegible]			
1. Principal function of agency: LRT, Heavy Rail, RR	LRT	LRT, Hvy Rail, RR, Bus	Heavy Rail
Other			
2. Does your organization maintain a	Yes	Yes	Yes
systematic inventory of underground structures and their conditions? If yes, please specify.	Information is updated weekly in a spreadsheet format. (Sample Attached)	Database Program	Tunnels are identified by line and mileage location. Information is shown on the Track Charts and the Bridge and Tunnel Schedule.
3. What factors govern inspection and repair priorities, (e.g. legislative, funding, maintenance, etc.	Safety & Maintenance Concerns	Maintenance / Funding	Structural Inspection - Maintenance. Track Inspection - FRA Requirements. Repairs are made as needed base on priorities.
[illegible]			
1. Do you have a comprehensive, systematic program of inspection? Y/N?	Yes	Yes	
2. Yes, how often do you inspect your structures?			
More than once a week?			Wk Track Inspection, All Tunnels 2 times per year.
Once a week.	#001		
Once a month			
Once each 6 months			
Once a year.			Visual Inspection All Tunnels
Once each 5 years		All Tunnels & Underground Structures	
None to date.			
Emergency basis only			
Other, please specify			
3. If inspections are not performed, please identify reason(s) for not inspecting.	n/a	n/a	n/a
4. What do you look for during an inspection?	Unusual deposits of silt on tunnel floor; wet spots on tunnel wall, water leaks;	See Inspection Manual	Loose rock, cracked or spalling concrete, condition of exposed steel, portal

Summary of Questionnaire

Agency Name	MetroLink	MTA	Metro North Railroad
	Bi-State Development Agency	Mass Transit Admin - Baltimore	New York, New York
5. Who performs inspections?			
Own staff- Tunnel Walker			All Tunnels - Track
Own Staff - Staff Engineer/ Specialist	#001		All Tunnels - Structure
Consulting Engineer		All Structures	
Other, please specify			
6. How are inspections reported?			
Formal report		formal report	
Drawings.			
Field Notes.		field notes	
Only if a problem exists.			
Other, please specify.	Formal reports are produced for specific incidents. An inspection spreadsheet is updated on a weekly basis as part of routine inspection.	database	
7. What types of defects or deficiencies are			
encountered during your inspections?			
Water leakage, infiltration	#001	Rock tunnels & joints	HU 44-40
Corrosion/deterioration of lining/support		Steel Liners	
Spalling of lining/delaminations		Concrete Walls, Beams & Slabs.	
Need for new or additional support			
Need for enlargement/increased capacity/clearance			
Cracking of lining			
Piping of soil from outside lining	#001	Concrete Liners	
Siltation, rock falls or other blockages, be specific.		At X-passage between Charles Ctr., and Lexington Market Station.	
Collapse			
Other, please specify.			Ice Conditions - 44.40
8. What are the annual costs to inspect your			
underground structures?			
$ Per mile of structure (tunnel)			
$ per tunnel structure, $ per station			
$ for entire system	$50,000.00	$400,000.00	$2,000.00
Unknown			
Part IV			
1. What are your agency's current budgetary			
needs for rehabilitation annually?			
$ per mile of structure (tunnel)			
$ per structure $ per station			

Summary of Questionnaire

Agency Name	MetroLink	MTA	Metro-North Railroad
	Bi-State Development Agency	Mass Transit Admin - Baltimore	New York, New York
$ for entire system	$20,000.00	TBD	$57,000.00
Unknown, (Please check, if appropriate)			
2 . What are your agency's current expenditures on rehabilitation annually?			
$ per mile of structure (tunnel)			
$ per structure (station)			
$ for entire system	< $5000.00	$250,000.00	
Unknown, (Please check, if appropriate)			XXX
3. What are the life expectancies of your underground			
a. Less than 10 years.			
b. 10 to 20 years.			
c. 20 to 50 years.			
d. Greater than 50 years. Please specify.	#001	All Structures	All
4. What types of major rehabilitation projects (costs in excess of $1 million) have you performed in pase 10 years? Please relate all numbers listed previously on Inventory form. (Part II)	#001 structure recently underwent a major rehab. & was placed in service in 1993.		HU 44.40 Increase clearance and shot crete. $3.7m. HU 0.73 Replace drainage system, renew four (4) tracks general rehabilitation of structure $160 mil.
5. Who performs your rehabilitation construction?			
Own Staff			
General Contractor		All Structures, as need	HU 0.73, HU 44.40
Specialty Contractor			
Other, (please specify)			
6. What are your organization's rehabilitation plans for the next 5 years?	#001 No major rehab's, planned within next 5 years.	1. Waterproofing at joints & cracks: Rock Tunnels and Station Areas. 2. Repair of precast concrete liner segments.	HU 0.73 Repair portion of brick arch.
7. Do you have a preventive maintenance program?	No	No, as need basis	
Y/N? Please provide is possible.			No
8. Do you have a QA/QC program for Inspection	No	Yes	
program? Y/N? Please provide if possible.			Yes
9. What amount of money do you expect to	$ 50,000.00	TBD	
spend on rehabilitation over the next 5 years.			don't know

Summary of Questionnaire

Agency Name	MetroLink	MTA	Metro-North Railroad
	Bi-State Development Agency	Mass Transit Admin - Baltimore	New York, New York
10. What amount of money do you expect to spend on			
new construction or replacement over the next 5 years.	$0	None	None
11. Are you using or intend to implement within the next 5 years, an Assets Database System? Y/N?.	No	Yes	Yes
12. What are your sources of funding for rehabilitation work?	General Transit Maintenance Budget	Federal & State	no answer
13. What is your basic inspection policy interms of emphasis on resource allocation and short and long term objectives?		Comprehensive Inspection to develop Preventive maintenance Rehabilitation Program.	Regular annual inspections are our top priority.
14. What is the repair/rehabilitation prioritization process?	Safety issued are addressed immediately, other repairs are handled by in-house crews depending on the severity of the problem, since the system was recently rehabbed, a privatization process for rehabbing has ~~not yet been developed.~~	Based on condition Rating (See Inspection Manual.)	Any critical condition are repaired immediately. Less serious problems are addressed in an annual repair program on a priority which is established by joint restrictions.
15. Please state what proportion of the inspection and rehabilitation needs are satisfied by the available fundin			
Inspection Rehabilitation			
100% 100%	Insp. 100%, Rehab., 100	Insp. 100%	Insp., 100%
90% 90%			
80% 80%			Rehabilitation 80%
50% 50%			
other other			
16. Do you have an emergency response program (Alternative service and repair) in the event of shutdowr	Yes, in the event of an emergency, the agency is capable of providing bus service between affected stations within the limits of the tunnel Operating efficiencies decrease significantly during such an operation, so all available maintenance repair resources are directed to the problem	Single Tracking or Shuttle Bus Service.	Tracks could be taken out of service id necessary to make repairs where there are parallel tunnels. In some locations, repairs would have to be done after midnight when there is little or no service.

Summary of Questionnaire

Agency Name	NJ Transit	Chicago Transit Authority
	One Penn Plaza, Newark NJ.	Merchandise Mart Plaza, Chicago
Part I		
1. Principal function of agency: LRT, Heavy Rail, RR	Commuter Rail	Heavy Rail
Other		
2. Does your organization maintain a	Yes	
systematic inventory of underground structures and their conditions? If yes, please specify.	Underground structures (3 tunnels on system) are included in database program with bridges. Database has information regarding structure type, length, age, load rating.	Inspection forms are filed and information entered into database that will generate reports.
3. What factors govern inspection and repair priorities, (e.g. legislative, funding, maintenance, etc.	Inspection interval determined by ARBA criteria and internal policy. Repair priorities determined by safety and operations impacts of not performing repairs.	Inspection are performed on a bi-annual basis. Defects are rated on a scale of from 1 to 5 with a time frame for repair based on the severity of the defects.
Part II		
1. Do you have a comprehensive, systematic program of inspection? Y/N?	Yes	Yes
2. Yes, how often do you inspect your structures?		
More than once a week?		
Once a week.		
Once a month		
Once each 6 months		
Once a year.	7.23 Main,1.46 M&E (N), 1.46 M&E (S)	
Once each 5 years		
None to date.		
Emergency basis only		
Other, please specify	Track through tunnels inspected twice a week in periods of freezing weather the M&E Tunnels are inspected for ice in vicinity of catenary wires.	Every 6 years (1, 2, & 3)
3. If inspections are not performed, please identify reason(s) for not inspecting.		
4. What do you look for during an inspection?	Structural Defects, loose bricks in lining spalling of lining spalling of lining, movement of cracks,	Cracks and/or leakage in tunnel concrete and stairway concrete any spalling concrete.

Summary of Questionnaire

Agency Name	NJ Transit	Chicago Transit Authority
	One Penn Plaza, Newark NJ.	Merchandise Mart Plaza, Chicago
5. Who performs inspections?		
Own staff- Tunnel Walker	7.23 Main,1.46 M&E (N), 1.46 M&E (S)	
Own Staff - Staff Engineer/ Specialist	7.23 Main,1.46 M&E (N), 1.46 M&E (S)	1, 2, 3.
Consulting Engineer		
Other, please specify		
6. How are inspections reported?		
Formal report	formal report	
Drawings.		
Field Notes.		
Only if a problem exists.		
Other, please specify.	Internal bridge inspection forms (MW203).	Standard Report Form
7. What types of defects or deficiencies are		
encountered during your inspections?		
Water leakage, infiltration	1.46M&E(N),1.46M&E(S), 7.23	1,2,3
Corrosion/deterioration of lining/support	1.46M&E(N),1.46M&E(S)	
Spalling of lining/delaminations	1.46M&E(N),1.46M&E(S), 7.23 Main	
Need for new or additional support	7.23 Main	
Need for enlargement/increased capacity/clearance		
Cracking of lining	7.23 Main	1,2,3
Piping of soil from outside lining		
Siltation, rock falls or other blockages, be specific.		
Collapse		
Other, please specify.		
8. What are the annual costs to inspect your		
underground structures?		
$ Per mile of structure (tunnel)		
$ per tunnel structure, $ per station	$3000.00 *	
$ for entire system		$80,000.00
Unknown	* does not include track inspection, winter ice inspection & removal or one time indepth inspection by consultant.	
Part III		
1. What are your agency's current budgetary		
needs for rehabilitation annually?		
$ per mile of structure (tunnel)		
$ per structure $ per station		

Summary of Questionnaire

Agency Name	NJ Transit	Chicago Transit Authority
	One Penn Plaza, Newark NJ.	Merchandise Mart Plaza, Chicago
$ for entire system	$2,000,000.00	$500,000.00
Unknown, (Please check, if appropriate)		
2 What are your agency's current expenditures on rehabilitation annually?		
$ per mile of structure (tunnel)		
$ per structure (station)		
$ for entire system	$2,000,000.00	$500,000.00
Unknown, (Please check, if appropriate)		
3. What are the life expectancies of your underground		
a. Less than 10 years.		
b. 10 to 20 years.	7.23 Main, 1.46 M&E(N) 1.46 M&E(S)	
c. 20 to 50 years.		
d. Greater than 50 years. Please specify.		1,2,3,4,5,6
4. What types of major rehabilitation projects (costs in excess of $1 million) have you performed in pase 10 years? Please relate all numbers listed previously on Inventory form. (Part II)	1.46 M&E (N,S) closed some air shafts to reduce water infiltration, reopened clogged drainage chaseways, undercut track & removed fouled ballast (2M).	ID #1 - Grouting subway tube cracks - ongoing
	7.23 Main - currently installing structural liner with new bench wall-installing drainage pipe in ballast to improve drainage through tunnel (2.7 M)	
5. Who performs your rehabilitation construction?		
Own Staff	7.23 Main	1,2,3,4,5,6
General Contractor	1.46 M&E	
Specialty Contractor		
Other, (please specify)		
6. What are your organization's rehabilitation plans for the next 5 years?	7.23 Main - complete work currently underway (see #4) 1.46 (N&S) - Perform indepth investigation by consultant, design and construct a rehabilitation effort intended to increase tunnel by life by 30 to 50 years.	
7. Do you have a preventive maintenance program?		
Y/N? Please provide is possible.	Yes	Yes
8. Do you have a QA/QC program for Inspection program? Y/N? Please provide if possible.	Yes	Yes
9. What amount of money do you expect to spend on rehabilitation over the next 5 years.	10 Million	$2,500,000

Summary of Questionnaire

Agency Name	NJ Transit	Chicago Transit Authority
	One Penn Plaza, Newark NJ.	Merchandise Mart Plaza, Chicago
10. What amount of money do you expect to spend on new construction or replacement over the next 5 years.	$0	$1,500,000
11. Are you using or intend to implement within the next 5 years, an Assets Database System? Y/N?.	Yes	No
12. What are your sources of funding for rehabilitation work?	Federal Grants and State funds.	Grants from Regional Transit Authority, IDOT or FTA
13. What is your basic inspection policy interms of emphasis on resource allocation and short and long term objectives?	Provide those inspections required to maintain a safe system free of operational failures. Inspections will be adequate to identify short and long term rehab efforts.	Short term objective is to find defects which need immediate repair and long term to determine what capital repair programs should be set-up to provide repairs to extend the life of the subway.
14. What is the repair/rehabilitation prioritization process?	After needs and associated costs ar established, capital funding requests are submitted on pre-printed form to be prioritized among all completing project. A committee prioritizes projects based on safety, impact to service, potential cost savings.	The defects are rated P1 through P5 based on the severity. see attached sheet..
15. Please state what proportion of the inspection and rehabilitation needs are satisfied by the available fundin		
Inspection Rehabilitation		
100% 100%	Inspect. 100%, Rehab. 100%	
90% 90%		
80% 80%		Insp. 80%, Rehabilitation 80%
50% 50%		
other other		
16. Do you have an emergency response program (Alternative service and repair) in the event of shutdowr		
	Yes, plan addresses the evacuation of trains in tunnel, the establishment of a central command center.	Alternative bus transportation would be provided for passengers. Repair forces (in-house) would be called out to provide needed repairs. If in-house forces are not adequate, outside contractors would be mobilized.

Summary of Questionnaire

Agency Name	Mass Transit Railway Corp	City of Calgary
	GPO 9916 HONG KONG	Transportation Dept. Calgary, Alberta.
1. Principal function of agency: LRT, Heavy Rail, RR	High density urban Mass Transit	Light Rail
Other		
2. Does your organization maintain a		Yes
systematic inventory of underground structures and their conditions? If yes, please specify.	Presently the site recording & office analysis is being computenzed by use of the site laptop and office desk PC's and with data base programs. Previously, defects were marked up on drawings and summarized	All underground facilities are included in the City's Bridge & Structures Database. (MICROSOFT ACCESS).
3. What factors govern inspection and repair priorities, (e.g. legislative, funding, maintenance, etc.	Safety, reliability of operation, customer service and Corporate Priorities for funding.	All Facilities are inspected as part of corporate maintenance strategy.
1. Do you have a comprehensive, systematic program of inspection? Y/N?	Yes	Yes
2. Yes, how often do you inspect your structures?		
More than once a week?		
Once a week.		
Once a month		
Once each 6 months		
Once a year.		All inspected once a year.
Once each 5 years		
None to date.		
Emergency basis only		
Other, please specify	Underground stations and tunnels are inspected according to condition, fair condition annually, good condition on every 2 years. (Ac & Ad).	
3. If inspections are not performed, please identify reason(s) for not inspecting.		n/a
4. What do you look for during an inspection?	1. See attached lists of defects and, 2. See copy of 1993 Annual report (1994 report available soon).	Condition of joints, (if leaking), condition of concrete.

Summary of Questionnaire

Agency Name	Mass Transit Railway Corp	City of Calgary
	GPO 9916 HONG KONG	Transportation Dept. Calgary, Alberta.
5. Who performs inspections?		
Own staff- Tunnel Walker		
Own Staff - Staff Engineer/ Specialist		All tunnels listed.
Consulting Engineer		
Other, please specify	Own Staff, Technically qualified Inspectors and Engineers for special problems. (ID Ac Ad)	
6. How are inspections reported?		
Formal report		formal report
Drawings.	Condition of structure marked on drawings.	
Field Notes.	Details on forms.	
Only if a problem exists.		
Other, please specify.	Soon, by disc from Laptop computers with details on CAD drawings and spread sheets.	
7. What types of defects or deficiencies are		
encountered during your inspections?		
Water leakage, infiltration	Yes	386.402
Corrosion/deterioration of lining/support	Yes	
Spalling of lining/delaminations	Yes	
Need for new or additional support	No	
Need for enlargement/increased capacity/clearance	No	
Cracking of lining	Yes	
Piping of soil from outside lining	Rarely	
Siltation, rock falls or other blockages, be specific.	No	
Collapse	No	
Other, please specify.	See attached list of defects.	
8. What are the annual costs to inspect your		
underground structures?		
$ Per mile of structure (tunnel)	HK $36.33K	
$ per tunnel structure, $ per station		Canadian Dollars $1000.00
$ for entire system	HK $195.1K	
Unknown		
Part IV		
1. What are your agency's current budgetary		
needs for rehabilitation annually?		
$ per mile of structure (tunnel)	HK $2328K	
$ per structure $ per station	HK $3289K	

Summary of Questionnaire

Agency Name	Mass Transit Railway Corp	City of Calgary
	GPO 9916 HONG KONG	Transportation Dept. Calgary, Alberta.
$ for entire system	HK $124,987K	$30,000.00
Unknown, (Please check, if appropriate)		(For maintenance on tunnels, exclusive of track, etc.)
2 . What are your agency's current expenditures on		
rehabilitation annually?		
$ per mile of structure (tunnel)	HK $2162K	
$ per structure (station)	HK $3055K	
$ for entire system	HK $116,082K	$30,000.00
Unknown, (Please check, if appropriate)		(For maintenance on tunnels, exclusive of track, etc.)
3. What are the life expectancies of your underground		
a. Less than 10 years.		
b. 10 to 20 years.		
c. 20 to 50 years.		
d. Greater than 50 years. Please specify.	(ID Ac&Ad) design life 120 years	All Tunnels greater than 50 years
4. What types of major rehabilitation projects (costs in excess of $1 million) have you performed in pase 10 years? Please relate all numbers listed previously on Inventory form. (Part II)	Tunnel repair by hydrodemolition & shotcreting (project cost HK$130 million).	None related to concrete Tunnels
5. Who performs your rehabilitation construction?		
Own Staff		
General Contractor		386.402
Specialty Contractor	Yes	
Other, (please specify)	Term Contractor (contract based on rates, one or two contractors do all work)	
6. What are your organization's rehabilitation plans for the next 5 years?	-Tunnel repair by hydrodemolition $ shotcreting (project cost HK$140 mil -Plinth repair project (HK$57 mil) -Concrete repair to stations (project cost HK$103 mil).	Leaks through Joints of tunnel 386.402 are presently being addressed, concrete repairs will be needed also in this same structure.
7. Do you have a preventive maintenance program?	Yes	Yes
Y/N? Please provide is possible.	Grouting leaks, concrete coating.	
8. Do you have a QA/QC program for Inspection		Yes
program? Y/N? Please provide if possible.		
9. What amount of money do you expect to		
spend on rehabilitation over the next 5 years.	HK $125 million/year	100,000 - 200,000

Summary of Questionnaire

Agency Name	Mass Transit Railway Corp	City of Calgary
	GPO 9916 HONG KONG	Transportation Dept. Calgary, Alberta.
10. What amount of money do you expect to spend on		
new construction or replacement over the next 5 years.		$0
11. Are you using or intend to implement within the next 5 years, an Assets Database System? Y/N?.	Yes	Yes
12. What are your sources of funding for rehabilitation work?	Funded out of operating profit through Revenue Account.	Routine inspections/maintenance are funded from millrate support. Significant repairs and rehabilitation are funded from debenture financing.
13. What is your basic inspection policy interms of emphasis on resource allocation and short and long term objectives?	We adopt of scheduled regular inspection program conducted by in-house resources, specially employed for the task.	To identify problems and potential problems and implement repairs or modification to reduce or eliminate future rehabilitation.
14. What is the repair/rehabilitation prioritization process?	We are developing a risk-based process for the prioritization of all of our Capital & Revenue Works but it is not yet completed.	Any identified problems that could affect transit service is handled as high priority. Other none essential or non urgent repairs are budgeted for in next financial year.
15. Please state what proportion of the inspection and		
rehabilitation needs are satisfied by the available fundin		
Inspection Rehabilitation		
100% 100%	Insp, 100%, Rehab, 100%	Insp. 100%, Rehab., 100%
90% 90%		
80% 80%		
50% 50%		
other other		
16. Do you have an emergency response program		
(Alternative service and repair) in the event of shutdowr		
	All inspection, repair, renewal And new works are undertaken during scheduled non traffic hours, the intensity of service is such that planned shut down cannot be contemplated. Response targets in cases of emergency have been agreed with the Operator	Inspection and maintenance crews are on 24 hour call out, if needed. Tracks are switched to allow for repairs during normal operating hours.
	and are supported by contingency scenarios and plans.	

Summary of Questionnaire

Agency Name	NYCTA	Toronto Transit Commission
	New York City Transit	Toronto, Ontario
[illegible]		
1. Principal function of agency: LRT, Heavy Rail, RR Other	Heavy Rail	Light Rail, Heavy Rail
2. Does your organization maintain a systematic inventory of underground structures and their conditions? If yes, please specify.	Yes Dbase program is used on personal computer for maintaining inspection records. See attached Polity Instruction for copy of sample report.	No Pursuing this for future.
3. What factors govern inspection and repair priorities, (e.g. legislative, funding, maintenance, etc.	NYCT operates 24 hours a day. Visual inspection is performed at night, then train headway is at its maximum, by walking along a track. The defects found during the inspection are assigned priority either #1 or #2. See attached P/I for criteria.	Effect on Operations and funding govern repair priority. Inspection governed by safety and legislative concerns.
	Normal repair and maintenance are done under capital contracts.	
[illegible]		
1. Do you have a comprehensive, systematic program of inspection? Y/N?	Yes	Yes
2. Yes, how often do you inspect your structures?		
More than once a week?		
Once a week.		
Once a month		
Once each 6 months	Underriver tubes	
Once a year.	Subway Structures	001,002,003
Once each 5 years		001,002,003 plus structural
None to date.		
Emergency basis only		
Other, please specify		
3. If inspections are not performed, please identify reason(s) for not inspecting.	n/a	
4. What do you look for during an inspection?	See Attached (P/I)	Visual signs of deterioration and or distress. Eventually plan to expand to monitoring/identifying.

Summary of Questionnaire

Agency Name	NYCTA	Toronto Transit Commission
	New York City Transit	Toronto, Ontario
5. Who performs inspections?		
Own staff- Tunnel Walker	All underground structures.	Annually for 001,002,003
Own Staff - Staff Engineer/ Specialist		5 Year Interval, 001,002,003
Consulting Engineer		
Other, please specify		
6. How are inspections reported?		
Formal report	formal report	Formal Report
Drawings.		
Field Notes.		
Only if a problem exists.	Only if problem exists	
Other, please specify.		
7. What types of defects or deficiencies are		
encountered during your inspections?		
Water leakage, infiltration	XX	001,002,003
Corrosion/deterioration of lining/support	XX	001,003
Spalling of lining/delaminations	XX	
Need for new or additional support		
Need for enlargement/increased capacity/clearance		
Cracking of lining	XX	
Piping of soil from outside lining		
Siltation, rock falls or other blockages, be specific.		
Collapse		
Other, please specify.		
8. What are the annual costs to inspect your		
underground structures?		
$ Per mile of structure (tunnel)		
$ per tunnel structure, $ per station		
$ for entire system		$50,000.00
Unknown	$900,000.00	
Part IV [illegible]		
1. What are your agency's current budgetary		
needs for rehabilitation annually?		
$ per mile of structure (tunnel)		
$ per structure $ per station		

Summary of Questionnaire

Agency Name	NYCTA	Toronto Transit Comission
	New York City Transit	Toronto, Ontario
$ for entire system		$500,000 (estimated)
Unknown, (Please check, if appropriate)	Unknown	
2 . What are your agency's current expenditures on rehabilitation annually?		
$ per mile of structure (tunnel)		
$ per structure (station)		
$ for entire system	40 mil avg. (Capital funds)	$50,000.00
Unknown, (Please check, if appropriate)		
3. What are the life expectancies of your underground		
a. Less than 10 years.		
b. 10 to 20 years.		
c. 20 to 50 years.	X	
d. Greater than 50 years. Please specify.		001, 002, 003
4. What types of major rehabilitation projects (costs in excess of $1 million) have you performed in pase 10 years? Please relate all numbers listed previously on Inventory form. (Part II)	1) Water remedy - Lexington Line, from 33rd to 125th St. 2) 8th Ave Line, 59 St to 207 St. 3) Eastern Pkwy Line, Uitica to Atlantic Ave. 4) Nassau Loop, Essex St. to Broadway 5) Nostrand Ave, Franklin to Flatbush Ave.	
5. Who performs your rehabilitation construction?		
Own Staff	X	001, 002, 003
General Contractor		
Specialty Contractor		
Other, (please specify)		
6. What are your organization's rehabilitation plans for the next 5 years?	1) Invert reconstruction, 96th St to 116 St, Lenox Line $150 mil 2) Reconstruct ventilator structures, Brook Avenue Station $50 mil.	Implement annual tunnel leak repair program which is presently done on a sporadic basis.
7. Do you have a preventive maintenance program? Y/N? Please provide is possible.	No	No.
8. Do you have a QA/QC program for Inspection program? Y/N? Please provide if possible.	No	No
9. What amount of money do you expect to spend on rehabilitation over the next 5 years.	$ 200 mil	$2.5 mil

Summary of Questionnaire

Agency Name	NYCTA	Toronto Transit Comission
	New York City Transit	Toronto, Ontario
10. What amount of money do you expect to spend on new construction or replacement over the next 5 years.	Unknown	0
11. Are you using or intend to implement within the next 5 years, an Assets Database System? Y/N?.	Yes	
12. What are your sources of funding for rehabilitation work?	FTA, NY State, NY City and MTA Bonds.	Presently Operating Budget (farebox). Intention is to gain approval for capital program subsidized fully by province and
13. What is your basic inspection policy interms of emphasis on resource allocation and short and long term objectives?	Inspection (operating budget) of subway structures once a year with underriver tubes inspected every six months. Defects found are rated #1 or #2 with #1 being more serious, usually, defects are repaired by in-house forces under operating budget.	Presently geared to ensure safe and reliable operation of transit - longer term and reliable operation of transit Longer term wish to identify need to maintain assets in most cost effective manner.
	When repairs are beyond in-house capability, then under capital contract.	
14. What is the repair/rehabilitation prioritization process?	Emergencies and high priority repairs are done by in-house and other defects by capital contracts.	Safety governs structural. Minimal work has been identified and repaired to date. Leaking which affects service is dealt with ASAP to provide safe and unaffected passage.
15. Please state what proportion of the inspection and rehabilitation needs are satisfied by the available fundin		
Inspection Rehabilitation		
100% 100%	Rehabilitation, 100% Capital	50% Inspection, 20% Rehab.
90% 90%		
80% 80%		
50% 50%		
other other		
16. Do you have an emergency response program (Alternative service and repair) in the event of shutdowr		
	$5 million are annually budgeted for emergency repairs in capital budget. In case of an emergency, in house operating personnel make temporary repairs for safe operation. Permanent repairs are made by in-house or capital emergency funds depending	Contingency would be the use of surface vehicles (Buses and light Rail) provided by same authority. No specific emergency plan formalized beyond short term situations.
	on severity of situation.	

Summary of Questionnaire

Agency Name	MARTA	BART
	2424 Piedmont Road, N.E., Atlanta, GA.	800 Madison St. Oakland, CA. 94607
Part 1		
1. Principal function of agency: LRT, Heavy Rail, RR	Heavy Rail	Heavy Rail
Other		
2. Does your organization maintain a	Yes	Yes
systematic inventory of underground structures and their conditions? If yes, please specify.	Tabular format at Present time. Intend to expand our computer system data base to include tunnels.	Database Program
3. What factors govern inspection and repair priorities, (e.g. legislative, funding, maintenance, etc.	Safety and funding; set repair priorities.	1) Maintenance, 2) Funding
Part 3		
1. Do you have a comprehensive, systematic program of inspection? Y/N?	Yes	Yes
2. Yes, how often do you inspect your structures?		See Attachment
More than once a week?		
Once a week.		
Once a month		
Once each 6 months		
Once a year.		
Once each 5 years		
None to date.		
Emergency basis only		
Other, please specify	Once each 2 years	
3. If inspections are not performed, please identify reason(s) for not inspecting.		Subways are inspected at night with a 3 hour work window. Inspectors have been scheduled from day shift to work this window. Inspections may be deferred due to manpower & time shortage.
4. What do you look for during an inspection?		

Summary of Questionnaire

Agency Name	MARTA	BART
	2424 Piedmont Road, N.E., Atlanta, GA.	800 Madison St. Oakland, CA. 94607
5. Who performs inspections?		
Own staff- Tunnel Walker		Tunnel Walker
Own Staff - Staff Engineer/ Specialist	All except exposed rock	Staff Engineer
Consulting Engineer	Exposed rock in Peachtree Center Station.	
Other, please specify		
6. How are inspections reported?		
Formal report		Formal Report
Drawings.		
Field Notes.	Field notes.	Field Notes
Only if a problem exists.		
Other, please specify.		
7. What types of defects or deficiencies are		
encountered during your inspections?		
Water leakage, infiltration	Mainly cut and cover sections. Also at Omni station under railroad.	
Corrosion/deterioration of lining/support		
Spalling of lining/delaminations		
Need for new or additional support		
Need for enlargement/increased capacity/clearance		
Cracking of lining	Some cracking of concrete rack tunnel linings (N/S line)	
Piping of soil from outside lining		
Siltation, rock falls or other blockages, be specific.	Minor rock falls Peachtree Center	
Collapse		
Other, please specify.		Encrustation, exudation, efflorescence.
8. What are the annual costs to inspect your		
underground structures?		
$ Per mile of structure (tunnel)		
$ per tunnel structure, $ per station		
$ for entire system	$75,000. (approx. for tunnel sections only)	$65,000.00
Unknown		
Part IV		
1. What are your agency's current budgetary		
needs for rehabilitation annually?		
$ per mile of structure (tunnel)		
$ per structure $ per station		

Summary of Questionnaire

Agency Name	MARTA	BART
	2424 Piedmont Road, N.E., Atlanta, GA.	800 Madison St. Oakland, CA. 94607
$ for entire system	$100,000, (approx. for tunnel sections only)	
Unknown, (Please check, if appropriate)		unknown
2 . What are your agency's current expenditures on		
rehabilitation annually?		
$ per mile of structure (tunnel)		
$ per structure (station)		
$ for entire system	$1.0 mil (approx. for all structures including aerials, stations and tunnels)	
Unknown, (Please check, if appropriate)		unknown
3. What are the life expectancies of your underground		
a. Less than 10 years.		
b. 10 to 20 years.		
c. 20 to 50 years.	Cut & Cover Sections	
d. Greater than 50 years. Please specify.	Rock Sections	Greater than 50 years.
4. What types of major rehabilitation projects (costs in excess of $1 million) have you performed in pase 10 years? Please relate all numbers listed previously on Inventory form. (Part II)		
5. Who performs your rehabilitation construction?		
Own Staff		A1002, MTUBE
General Contractor	All	A1002
Specialty Contractor		MTUBE
Other, (please specify)		
6. What are your organization's rehabilitation plans for the next 5 years?	Scaling of exposed rock (Peachtree Section), Painting of tunnel liner (North of Five Points), Omni station Arched Roof.	
7. Do you have a preventive maintenance program?	Yes	
Y/N? Please provide is possible.		
8. Do you have a QA/QC program for Inspection	No	
program? Y/N? Please provide if possible.		
9. What amount of money do you expect to	Minimal for Tunnels	
spend on rehabilitation over the next 5 years.		unknown

Summary of Questionnaire

Agency Name	MARTA	BART
	2424 Piedmont Road, N.E., Atlanta, GA.	800 Madison St. Oakland, CA. 94607
10. What amount of money do you expect to spend on	None	unknown
new construction or replacement over the next 5 years.		
11. Are you using or intend to implement within the next 5 years, an Assets Database System? Y/N?.		
12. What are your sources of funding for rehabilitation work?	Federal funding, fare gate and local sales tax.	Operation
13. What is your basic inspection policy interms of emphasis on resource allocation and short and long term objectives?		
14. What is the repair/rehabilitation prioritization process?	Generally, safety related with available funds.	
15. Please state what proportion of the inspection and		
rehabilitation needs are satisfied by the available fundin		
Inspection Rehabilitation		
100% 100%	100% Inspect. 100% for tunnel sections.	
90% 90%		90%, Inspection
80% 80%		
50% 50%		
other other		
16. Do you have an emergency response program	MARTA has a emergency response program to be used in many situations.	
(Alternative service and repair) in the event of shutdowr		
	Final note: MARTA really does not have many problems with out tunnels or underground structures. Most of our inspection effort and problems are with aerial structures and stations.	Yes

APPENDIX C

Typical Inspection Forms

MTA of Maryland

STATE OF MARYLAND DEPARTMENT OF TRANSPORTATION
MASS TRANSIT ADMINISTRATION
BALTIMORE REGION RAPID TRANSIT SYSTEM
SUBWAY STRUCTURE FIELD INSPECTION FORM

SUBWAY STATIONS

Line ☐☐☐☐ Station ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Date of Inspection ☐☐ ☐☐ ☐☐ Inspector(s) ____________

Contract No. ☐☐☐☐☐☐☐☐ Year Built ☐☐☐☐

Primary Elements	Rating		Rating	Secondary Elements	Rating
Trans. Beams (Roof)	☐	Walls (Station)	☐	Concrete Track Pads	☐
Long. Beams (Roof)	☐	Stairs (E. Ancillary)	☐	Elevator Enclosure	☐
Roof Slab	☐	Columns (E. Ancillary)	☐	Exterior Canopy(s)	☐
Trans. Beams (Mezz.)	☐	Slabs (E. Ancillary)	☐	Exterior Parapet	☐
Long. Beams (Mezz.)	☐	Walls (E. Ancillary)	☐	Street Level Grating	☐
Floor Slab (Mezz.)	☐	Slabs (W. Ancillary)	☐	Entrance Plaza	☐
Trans. Beams (Transf.)	☐	Walls (W. Ancillary)	☐	Joints	☐
Long. Beams (Transf.)	☐	Columns (W. Ancillary)	☐	Architectural Finishes	☐
Floor Slab (Transf.)	☐	Stairs (W. Ancillary)	☐	Drainage	☐
Floor Slab (Plat.)	☐	Pump Station (Ancillary)	☐	Railings	☐
Walls (Plat.)	☐	Invert Slab	☐	Utility Supports	☐
Stairs (Station)	☐				

Overall Rating

East Ancillary Space ☐☐ Station Area ☐☐

West Ancillary Space ☐☐

Maintenance Required: Immediate ☐ Programmed ☐ ☐☐ None ☐

COMMENTS

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Baltimore Region Rapid Transit System
Topic: FIELD INSPECTION FORM.

STATE OF MARYLAND DEPARTMENT OF TRANSPORTATION
MASS TRANSIT ADMINISTRATION
BALTIMORE REGION RAPID TRANSIT SYSTEM
SUBWAY STRUCTURE FIELD INSPECTION FORM

SUBWAY STATIONS

Line ________ Station ____________ Date of Inspection ____________

Inspector(s) ______________________________

THIS SPACE TO BE USED
FOR PHOTOGRAPHS,
SUPPLEMENTAL SKETCHES,
AND/OR COMMENTS

Baltimore Region Rapid Transit System
Topic: PHOTOGRAPHS/SKETCHES/COMMENTS FORM.

STATE OF MARYLAND DEPARTMENT OF TRANSPORTATION
MASS TRANSIT ADMINISTRATION
BALTIMORE REGION RAPID TRANSIT SYSTEM
SUBWAY STRUCTURE FIELD INSPECTION FORM

SUBWAY STATIONS PHOTO LOG

Station ____________________

Roll No.	Photo No.	Description

STATE OF MARYLAND DEPARTMENT OF TRANSPORTATION
MASS TRANSIT ADMINISTRATION
BALTIMORE REGION RAPID TRANSIT SYSTEM
SUBWAY STRUCTURE FIELD INSPECTION FORM

CROSSOVER STRUCTURE

Line ☐☐☐☐ Station South ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Date of Inspection ☐☐ ☐☐ ☐☐ Inspector(s) ____________________

Contract No. ☐☐☐☐☐☐☐☐ Year Built ☐☐☐☐

Primary Elements	Rating	Secondary Elements	Rating
Roof Slab	☐	Concrete Track Pads	☐
Walls	☐	Joints	☐
Invert Slab	☐	Drainage	☐
Floating Slab	☐	Railings	☐
		Utility Supports	☐

Overall Rating ☐☐

Maintenance Required: Immediate ☐ Programmed ☐ ☐☐ None ☐

COMMENTS

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STATE OF MARYLAND DEPARTMENT OF TRANSPORTATION
MASS TRANSIT ADMINISTRATION
BALTIMORE REGION RAPID TRANSIT SYSTEM
SUBWAY STRUCTURE FIELD INSPECTION FORM

TUNNEL SEGMENT

Line ☐☐☐☐ Station South ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Station North ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Track ☐☐☐

Begin Station ☐☐☐☐☐☐☐☐☐☐ End Station ☐☐☐☐☐☐☐☐☐☐

Date of Inspection ☐☐ ☐☐ ☐☐ Inspector(s) ____________________

Contract No. ☐☐☐☐☐☐☐☐ Year Built ☐☐☐☐

Primary Elements	Rating	Secondary Elements	Rating		Rating
Liner	☐	Gaskets	☐	Electrical Bonding	☐
Connection Bolts	☐	Safety Walk	☐	Utility Supports	☐
Invert Slab	☐	Concrete Track Pads	☐	Railings	☐
Floating Slab	☐				

Overall Rating

Tunnel Segment ☐☐

Maintenance Required: Immediate ☐ Programmed ☐ ☐☐ None ☐

COMMENTS

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Baltimore Region Rapid Transit System
Topic: TUNNEL SEGMENT – INSPECTION FORM

STATE OF MARYLAND DEPARTMENT OF TRANSPORTATION
MASS TRANSIT ADMINISTRATION
BALTIMORE REGION RAPID TRANSIT SYSTEM
SUBWAY STRUCTURE FIELD INSPECTION FORM

TUNNEL SEGMENT

Begin Station ☐☐☐☐☐☐☐☐☐☐ End Station ☐☐☐☐☐☐☐☐☐☐

CLEARANCE MEASUREMENTS	CLEARANCE MEASUREMENTS	INVERT CONDITION
Station: ________	Station: ________	Wet Area (%) ________
Horiz: ________	Horiz: ________	Debris (%) ________
Vert: ________	Vert: ________	

GENERAL FINDINGS	Quantity	Leakage	No. Locations
Circumferential Shrinkage Cracks	________	Seepage	________
Concrete Track Pad Cracks	________	Drips	________
Safety Walk Spalls	________	Flows	________
		Total	________

COMMENTS

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Baltimore Region Rapid Transit System
Topic: TUNNEL SEGMENT – INSPECTION FORM.

STATE OF MARYLAND DEPARTMENT OF TRANSPORTATION
MASS TRANSIT ADMINISTRATION

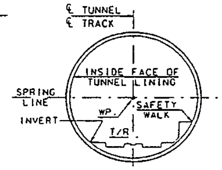
BALTIMORE REGION RAPID TRANSIT SYSTEM
SUBWAY STRUCTURE FIELD INSPECTION FORM

EARTH TUNNEL

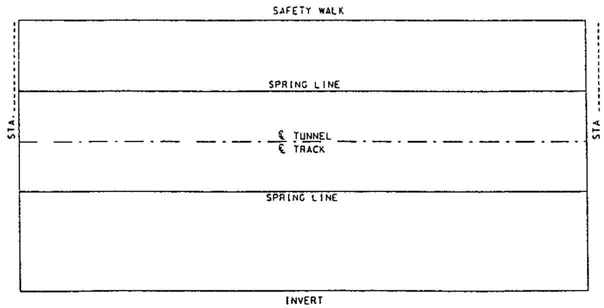
Line ____________ Station South ______________ Station North __________________

Inspectors ______________________________ Date Of Inspection ______________

Liner Type __________________ Track __________



TYPICAL SECTION
(LOOKING STA. AHEAD)



REFLECTED DEVELOPED PLAN

Baltimore Region Rapid Transit System
Topic: Typical Section/Developed Plan Inspection Form

STATE OF MARYLAND DEPARTMENT OF TRANSPORTATION
MASS TRANSIT ADMINISTRATION

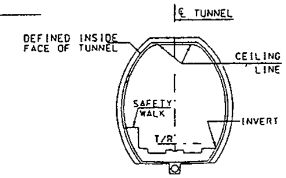
BALTIMORE REGION RAPID TRANSIT SYSTEM
SUBWAY STRUCTURE FIELD INSPECTION FORM

MIXED FACE TUNNELS

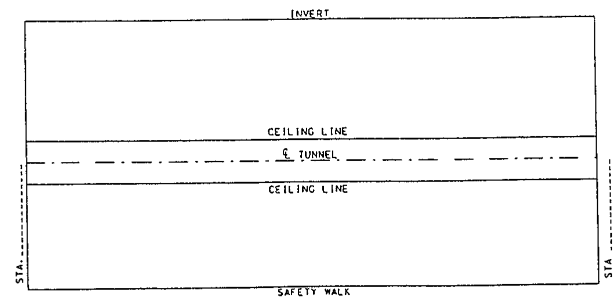
Line ____________ Station South ______________ Station North __________________

Inspectors ______________________________ Date Of Inspection ______________

Liner Type __________________ Track __________



TYPICAL SECTION
(LOOKING STA. AHEAD)



REFLECTED DEVELOPED PLAN

Baltimore Region Rapid Transit System
Topic: Typical Section/Developed Plan Inspection Form

STATE OF MARYLAND DEPARTMENT OF TRANSPORTATION
MASS TRANSIT ADMINISTRATION

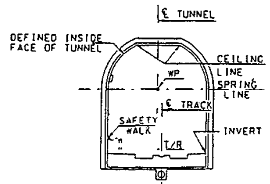
BALTIMORE REGION RAPID TRANSIT SYSTEM
SUBWAY STRUCTURE FIELD INSPECTION FORM

ROCK TUNNEL

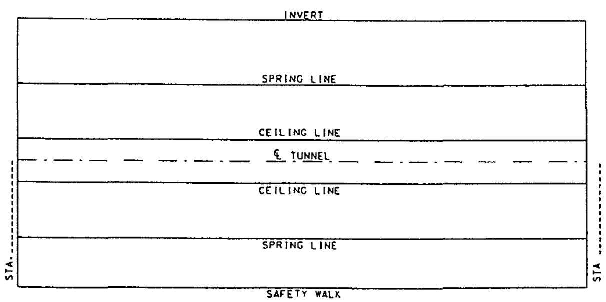
Line ________ Station South ____________ Station North ______________

Inspectors ______________________ Date Of Inspection ____________

Track ____________



TYPICAL SECTION
(LOOKING STA. AHEAD)



REFLECTED DEVELOPED PLAN

Baltimore Region Rapid Transit System
Topic: Typical Section/Developed Plan, Inspection Form

STATE OF MARYLAND DEPARTMENT OF TRANSPORTATION
MASS TRANSIT ADMINISTRATION
BALTIMORE REGION RAPID TRANSIT SYSTEM
SUBWAY STRUCTURE FIELD INSPECTION FORM

CROSS PASSAGEWAYS

Line ☐☐☐☐ Cross Passageway ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Date of Inspection ☐☐ ☐☐ ☐☐ Inspector(s) ____________________

Contract No. ☐☐☐☐☐☐☐☐ Year Built ☐☐☐☐

Primary Elements

	Rating		Rating
Roof Slab	☐	Walls	☐
Floor Slab	☐	Doors	☐

Overall Rating ☐

Maintenance Required: Immediate ☐ Programmed ☐ ☐☐ None ☐

COMMENTS

Baltimore Region Rapid Transit System
Topic: Cross-Passageways - Inspection Form

STATE OF MARYLAND DEPARTMENT OF TRANSPORTATION
MASS TRANSIT ADMINISTRATION
BALTIMORE REGION RAPID TRANSIT SYSTEM
SUBWAY STRUCTURE FIELD INSPECTION FORM

CUT-AND-COVER BOX STRUCTURES

Line ☐☐☐☐ Box ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Track ☐☐☐ Unit No. ☐☐☐☐☐ Inspector(s) ____________________

Contract No. ☐☐☐☐☐☐☐☐ Year Built ☐☐☐☐

Date of Inspection ☐☐ ☐☐ ☐☐

Primary Elements	Rating	Secondary Elements	Rating		Rating
Ceilings	☐	Joints	☐	Railings	☐
Walls	☐	*Concrete Track Pads*	☐	Drainage	☐
Columns	☐	Safety Walk	☐	Utility Supports	☐
Invert Slab	☐	Electrical Bonding	☐		

Overall Rating ☐☐

Maintenance Required: Immediate ☐ Programmed ☐ ☐☐ None ☐

COMMENTS

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Baltimore Region Rapid Transit System
Topic: INSPECTION FORM

Bay Area Rapid Transit Authority
Inspection Forms

STRUCTURES INSPECTION REPORT
AT-GRADE STRUCTURE

INE NO. A STRUCTURE NO. A2003 DATE 11-09-92 REPORT NO. A00483

REA INSPECTED: M.P 13.871 TO M.P 16.683 TOTAL STRUCTURE LENGTH 2.812 Mi

PRTY CODE	KEY ITEM	PRTY CODE	KEY ITEM	PRTY CODE	KEY ITEM
01	15) SLOPES	00	25) INLETS	AN	41) FENCES & GGATES
00	16) DITCHES	01	29) M.W. ACCESS	AN	42) VEGETATION
00	18) DRAINAGE	--	30) APPURTENANT STR.	00	43 ENCROACHMENTS
00	24) CULVERTS	01	37) RETAINING WALLS	00	99) OTHER

ITEM NO.	PRTY CODE	CONDITION	WORK REQUEST NO	DATE OF REPAIR
42	01	A1 1702+88 (MP 14.041) Bush overgrowing A1 track. CFR-A00458		
41	02	A1 1715+80 (MP 14.285), Chainlink portion of fence is damaged and loose. A foot hold has been established near barbed wire to allow easy access to trackway	A00036	
21	01	A1 1719+06 (MP 14.347) Communication equipment cabnet has minor to moderate rust. CFR-A00458		
15	01	A1 1722+22 (MP 14.407) to 1724+62 (MP 14.452) Embankment between ballast and fence shows minor to moderate erosion exposing cable envelope. CFR-A00458		
41	02	A1 1725+90 (MP 14.477), Fence is leaning at roll gate just north of MW 18. Heavy vegetation allows easy access over barbed wire.	A00036	
41	01	A1 1745+00 (MP 14.838) to 1747+00 (MP 14.876) Minor erosion along fence line. Concrete base of fence supports are exposed. CFR-A00458		
41	01	A1 1749+00 (MP 14.914) to 1752+30 (MP 14.977) Minor to moderate erosion along fence line. Concrete base of fence supports are exposed. CFR-A00458		
42	02	A1 1800+00 (MP 15.880) to 1800+05 (MP 15.881),	A00035	

INSPECTED BY: R. Perry F I NO. A00073 WEATHER: Clear

NOTES: N.I. = NOT INSPECTED; A.N. = AS NOTED CFR = CONDITION FIRST REPORTED
PRIORTY CODE:
(00) No defective condition observed at this time.
1) Possible condition, monitor and/or keep under observation.
.2) A condition that should be scheduled with routine maintenance.
(03) A condition that requires action as soon as possible.
(04) A condition that requires immediate action.

Page 1
ATTACHMENT 3

Bay Area Rapid Transit Authority
Topic: INSPECTION FORM

Page 1 of 1

STRUCTURES INSPECTION REPORT
AT GRADE STRUCTURE
SUMMARY REPORT

LINE NO. A STRUCTURE NO. A2003 DATE 11-09-92 REPORT NO. A00483

AREA INSPECTED: M.P. 13.871 TO M.P. 16.83 TOTAL STRUCTURE LENGTH 2.812 Mi

LAST INSPECTION DATE 04-04-91 LAST REPORT NO. A00073 INSPECTION CYCLE 24 MONTHS

CONDITION SUMMARY

No. of conditions from last Inspection Report for PRIORTY CODE (01) 15 ;(02) 2 ;(03) 0 ;(04) 0 ; TOTAL 17

No. of current conditions Reported for PRIORTY CODE (01) 13 ;(02) 12 ;(03) 0 ;(04) 0 ; TOTAL 25

Number of conditions UPGRADED from PRIORTY CODE 01 TO 02 1 ; 02 TO 03 0 ; 03 TO 04 0

REPORT SUMMARY

There is minor to moderate erosion along fence line and on the slopes. This condition has undermined some fence post and areas of the concrete cap over the 34.5 KV cable trench. Some vegetation growth is fouling the toe-path and trackway. There is the usual random cracking on the retaining walls. There is areas of damaged fencing reported.

The condition upgraded from priorty code 01 to 02 pertains to an area of broken concrete over the 34.5 KV trench found at MP 16.103.

The structure appears to be in good condition with exception of noted conditions.

PRIORITY CODE:
(01) Possible condition, monitor and/or keep under observation.
(02) A condition that should be scheduled with routine maintenance.
(03) A condition that requires action as soon as possible.
(04) A condition that requires immediate action.

ATTACHMENT 4

Bay Area Rapid Transit Authority
Topic: SUMMARY REPORT FORM

FIELD INSPECTION REPORT
Transbay Tube

Line No.____ Structure No.____ Area Inspected: M.P.____ to M.P ____
Inspector:________ Date Inspected:_____ Structure Type:_______

Item Description	Priority Code	Condition	Work Request No.	Date of Repair
Concrete Tube Walls:				
Tube Crown				
Walkways				
Second Pour				

1 of 4

Bay Area Rapid Transit Authority
Topic: FIELD INSPECTION REPORT FORM

FIELD INSPECTION REPORT
Transbay Tube

Line No.____ Structure No.____ Area Inspected: M.P.___ to M.P.___
Inspector:________ Date Inspected:_____ Structure Type:_______

Item Description	Priority Code	Condition	Work Request No.	Date of Repair
Gallery: Walls				
Floor				
Ceiling				
Tube Joints				
Seismic Joints S.F.				

2 of 4

Bay Area Rapid Transit Authority
Topic: FIELD INSPECTION REPORT FORM

FIELD INSPECTION REPORT
Transbay Tube

Line No._____ Structure No._____ Area Inspected: M.P.___ to M.P ____

Inspector:_________ Date Inspected:_____ Structure Type:________

Item Description	Priority Code	Condition	Work Request No.	Date of Repair
Seismic Joint Oakland				
Misc. Steel: Ladder				
Handrail				
Door				
Hatches				

FIELD INSPECTION REPORT
Transbay Tube

Line No._____ Structure No._____ Area Inspected: M.P.___ to M.P.____

Inspector:_________ Date Inspected:_____ Structure Type:________

Item Description	Priority Code	Condition	Work Request No.	Date of Repair
Paint				
Seepage				
Signs				

FIELD INSPECTION REPORT
Subway Structure

Line No.____ Structure No.____ Area Inspected: M.P ___ to M.P ___

Inspector:________ Date Inspected:_____ Structure Type:_______

Item Description	Priority Code	Condition	Work Request No.	Date of Repair
Concrete Walls:	____	____		____
Ceiling	____	____	____	____
Walkways	____	____	____	____
Secound Pour	____	____	____	____
Construction Joints	____	____	____	____

Page 1 of 4

Bay Area Rapid Transit Authority

Topic: FIELD INSPECTION REPORT FORM

FIELD INSPECTION REPORT
Subway Structure

Line No.____ Structure No.____ Area Inspected: M.P ___ to M.P ___

Inspector:________ Date Inspected:_____ Structure Type:_______

Item Description	Priority Code	Condition	Work Request No.	Date of Repair
Bridging Beams:	____	____	____	____
Cross Passage:	____	____	____	____
Structural Steel:	____	____	____	____
Liner Plate	____	____	____	____
Bolts	____	____	____	____

Page 2 of 4

Bay Area Rapid Transit Authority

Topic: FIELD INSPECTION REPORT FORM

FIELD INSPECTION REPORT
Subway Structure

Line No.____ Structure No.____ Area Inspected: M.P ___ to M.P ___

Inspector:_______ Date Inspected:_____ Structure Type:_______

Item Description	Priority Code	Condition	Work Request No.	Date of Repair
Misc. Steel:				
Ladder				
Steel Grated Walkway				
Handrail				
Door				

Bay Area Rapid Transit Authority
Topic: FIELD INSPECTION REPORT FORM

FIELD INSPECTION REPORT
Subway Structure

Line No.____ Structure No.____ Area Inspected: M.P ___ to M.P ___

Inspector:_______ Date Inspected:_____ Structure Type:_______

Item Description	Priority Code	Condition	Work Request No.	Date of Repair
Drainage				
Seepage				

Bay Area Rapid Transit Authority
Topic: FIELD INSPECTION REPORT FORM

Chicago Transit Authority
Inspection Forms

CTA Engineering Assessment — Instructions for Assessment Form
SUBWY-1

INSPECTION FOR ENGINEERING ASSESSMENT

ENGINEERING ASSESSMENT FORM SUBWY-1
SUBWAY TUNNEL
FORM INSTRUCTIONS

OVERVIEW

The Structures - Subway Tunnel form, SUBWY-I, shown on page 2, is used to rate subway tunnel elements and components. A new form must be used each time a change occurs in the line code, year built, or track number. Inspectors will report a record for each one hundred foot interval of tunnel. -The entire tunnel enclosure is considered as one element (TN99), including walls, floor, and roof. A record must be created for each track marker and whenever the construction type changes. Rate lighting; handrails and LOSI radio antenna only at even track markers. The track stationing in subways are based on the yellow TSIS track markers. Tunnels are numbered from right to left with your back as you face up station. Numbers must be recorded as "01","02" etc. For example in a tunnel with construction type MB with three boxes: the one on the right is "01"; in the middle is "02"; and on the left is "03".

If a rating needs further explanation, use the space for comments at the bottom of the form. Write in the track stationing and element code from the column heading to identify which record this comment refers to.

DETAILED INSTRUCTIONS

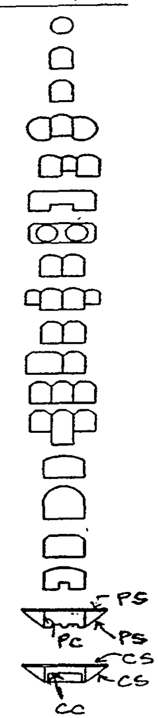
Line Code: Enter the two letter code to identify the line you are inspecting. For example, "SS" for State Street Subway, "DS" for Dearborn Subway, etc. This information must be entered.

Year Built: Record the approximate date the tunnel was built. Enter one digit in each box under this heading. This information must be entered.

Track Number: Enter up to three numbers or letters to identify the track you are on. The center track is always numbered "CTR". This information must be entered.

Construction Codes for Subway Tunnels:

Construction Type Code	Description	Example
ST	Single Tube	
SA	Single Arch	
SB	Single Box	
PT	Single Tube. Station W/ Center Platform	
PA	Single Arch. Station W/ Center Platform	
PB	Single Box. Station W/ Center Platform	
SS	Sunken Tube Section Under Chicago River	
MA	Multiple Archs Sharing Common Wall	
PM	Multiple Archs W/Outboard Passenger Platform	
MB	Multible Boxes Sharing Common Wall	
CL	Crossover W/ Low Arch Roof	
CH	Crossover W/ High Arch Roof	
CB	Crossover W/ Box Section	
PL	Low Arch Station W/ Center Platform	
PC, PS	Passenger Station W/Beam Roof. Curtain Walls. & Slope Walls	
CC, CS	Crossover Section W/- Non-load Bearing Roof & Walls. Slopewalls & Beams Hidden From View	



SUBWY-1A
5/29/91

Page__of___: Number the pages consecutively for this inspection. Make sure to enter the page number of this form and after all pages are finished, enter the total number of pages after the "of" on the last page. Start numbering with page one(l) at the beginning of each day.

Date: Enter the date of the inspection. Enter the number of the month in the first set of boxes, the day in the second set, and the year in the third. It is not necessary to fill in the boxes with zeros when all boxes are not needed. This information must be entered.

Firm: Enter the code for the lead firm on your corridor. This information must be entered. For example, "MDL" for McDonough/Lochner, "KEB" for Kaiser/Bascor, "EEI" for Envirodyne Engineers, and "PBQ" for Parsons, Brinckerhoff, Quade & Douglas.

Inspected By: Enter the employee number you were assigned. This information must be entered. This person must be the same one who signs the form.

Signature: The form must be signed by the person in charge of the inspection. This person must be the same one who entered their employee number above.

Track Stationing: Enter the TSIS track stationing to the nearest foot. Report a record for each track marker. Also enter a record whenever there is a change in construction type or rating code. This information must be entered.

Element(TN99): Enter the two digit location code for the, tunnel. Use one box for each digit. Tunnels are numbered from right to left as you face up station. Numbers must be recorded as "01","02" etc. For exmaple in a tunnel with construction type MB with three boxes: the one on the right is "01"; in the middle is "02"; and on the left is "03". This information must be entered.

CTA Engineering Assessment Instructions for Assessment Form SUBWY-1

Construction Type: Record the two character construction type of the tunnel, one character in each field. This information must be entered. The codes are listed on the back of the form.

Tunnel Rating(1-5): Circle the appropriate rating that best summarizes the condition of the tunnel segment. You must enter a rating or "X" for each line of the form. Use engineering judgement if conditions vary from those described below.

1 - Flowing cracks that allow a large quantity of water into the tunnel that pose an immediate threat to passenger safety or train operations. Signs of serious structural distress that indicate immanent structural instability.

2 - Flowing cracks total up to 100 feet per 100 foot segment. Spalls with significant section loss. Some unusual crack patterns, or indications of structural distress.

3 - Flowing cracks total less than 5 feet per 100 foot segment, with total estimates flow of less than 1 pint in 1 minute. Spalls less then 20 sq. ft. per 100 foot segment, with moderate, isolated section losses. No signs, or minor signs, of structural distress.

4 - No flowing cracks. Moist or glistening surface cracks total less than 100 feet for a 100 foot segment. Minor spalls exposing rebar with no section loss. No unusual crack patterns.

5 - No moist, glistening surface, or flowing cracks. No spalls exposing rebar.

X - Not Applicable

Lighting(LITE) Rating: Circle the Rating Code "1,"2","3","4","5", or "X", for the lights in the 100 foot tunnel section being inspected. Rate a 100 foot segment of lights only at the track markers. Circle "X" if track stationing is not at an even track marker. You must enter a rating or "X" for each line of the form. The codes are:

1 – 50% or more lights out. Loose wires could strike a person on walkways. Dark areas are a significant evacuation problem.

2 – 40% of lights out. Heavy corrosion of fixtures or conduits. Many instances of loose fixtures with exposed wires. Exposed wires are a hazard on the walkway. Dark areas make evacuation different.

3 – 20% of lights in segment out. No significant unlighted stretches that would present an evacuation hazard. No exposed wires in proximity to walkways.

4 – 10% of lights in segment out. No significant unlighted stretches that would present an zevacuation hazard. No exposed wires in proximity to walkways.

5 – All lights in working order. No loose fixtures or significant corrosion.

X – Not applicable.

Handrail Rating: Enter the Rating Code for the continuous handrail being inspected. Rate a 100 foot segment of handrail only at the track markers. Circle "X" if track stationing is not at an event track marker. You must enter a rating of "X" for each line of the form. The codes are:

1 – Broken or missing handrail that is a significant hazard for tunnel evacuation.

-3 – Several loose brackets. Isolated areas of rust or rot. Not an immediate safety threat.

5 – Handrail securely attached. No loose brackets. No significant rust or rot.

Radio (LOST) Rating: Enter the Rating Code for the coaxial radio antenna under consideration. Rate a 100 foot segment of handrail only at the track markers. You must enter a rating or "X" for each line of the form. The codes are:

2 – Cable insulation frayed, or several brackets broken. Cable hanging loose.

5 – Cable insulation is intact. Cable is securely attached to wall.

X – Not applicable.

COMMENTS

This section is optional. Record a comment when you need to explain in most detail the, condition of a particular element. Remember to copy the track marker and element and component codes from above in order to relate the comment back to its rating. Do not enter defects in these comments. Defects are recorded on Form SUBWY-3.

Track Marker: Enter the track marker to which this comment refers.

Element: Copy the element code from the row on the form to identify the item to which this comment refers. For example, "TN01", "TN02", etc.

Component: Copy the component code from the column on the form to identify the item to which this comment refers. For example, "LITE" for lighting, "HRAL" for handrail. Leave this blank for tunnel.

Comments: Enter a free form comment to describe in detail the element you are inspecting. You can use up to 80 characters. If the comment is longer than 80 characters use the next line and indicate that the stationing and component are the same.

Chicago Transit Authority
Engineering Assessment Form
Subway
Tunnel

Page ____ of ____

Line Code ☐☐
Year Built ☐☐☐☐
Track No. ☐☐☐

Date ☐☐/☐☐/☐☐
Firm ☐☐☐
Inspected By ☐☐☐☐☐

Signature: ______________

Track Stationing	Tunnel TN99 Element	Constr. Type	Rating	Lighting (UTE) Rating	Handrail (HRAL) Rating	Radio (LOSI) Rating
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X
+	TN☐☐		1 2 3 4 5 X	1 2 3 4 5 X	1 3 5 X	2 5 X

Track Marker	Element	Component	Comments

See Reverse Side For Construction Types

SUBWY-1
5/20/91

INSPECTION FOR ENGINEERING ASSESSMENT

ENGINEERING ASSESSMENT FORM SUBWY-2
ANCILLARY STRUCTURES AND UTILITY ROOMS
FORM INSTRUCTIONS

OVERVIEW

The Ancillary Structures and Utility Rooms Form, SUBWY-2, shown on page 2, is used for recording the structural inspection of subway tunnel ancillary structures, track drains, track ladders and utility rooms.

On each line of the form, you will record the inspection of one element. Enter the TSIS track station and element code then note the condition of the elements on the form by circling the appropriate condition rating. Circle an "X" if an element or component does not exist at that location. You must start a new line on the form each time an element is located at a new track station.

DETAILED INSTRUCTIONS

Line Code: Enter the two letter code to identify the line you are inspecting. For example, "SS" for State Street Subway, "DS" for Dearborn Subway, etc. This information must be entered.

Track Number: Enter up to three numbers or letters to identify the track you are on. The center track is always numbered "CTR". This information must be entered.

Tunnel No:TN_ _ Enter the two digit number for the tunnel. Use one box for each digit. Tunnels are numbered from right to left as you face up station. Numbers must be recorded as "01" ,"02" etc. For example in a tunnel with construction type MB with three boxes: the one on the right is "01"; in the middle is "02"; and on the left is "03". This information must be entered

Page__of :___: Number the pages consecutively for this inspection. Make sure to enter the page number of this form and after all pages are finished, enter the total number of pages after the "of" from the last page. Start numbering with page one(l) at the beginning of each day.

Date: Enter the date of the inspection. Enter the number of the month in the first set of boxes, the day in the second set, and the year in the third. It is not necessary to fill in the boxes with zeros when all boxes are not needed. This information must be entered.

Firm: Enter the code for the lead firm on your corridor. This information must be entered. For example, "MDL" for McDonough/Lochner, "KEB" for Kaiser/Bascor, "EEI" for Envirodyne Engineers, and "PBQ" for Parsons, Brinckerhoff, Quade & Douglas.

Inspected By: Enter the employee number you were assigned. This information must be entered. This person must be the same one who signs the form.

Signature: The form must be signed by the person in charge of the inspection. This person must be the same one who entered their employee number above.

Track Stationing: Record the track stationing for the location of the centerline of each element during the inspection. A new stationing must be recorded for each element. this information must be entered.

Element Code: Enter the element code for the item you are rating on this line of the form. The elements are listed at the bottom of the form. This information must be entered.

Inlet Rating(INL): Circle the rating code, "2","3", or "5", which best describes the condition of the track drain inlet or ancillary structure drain inlet you are inspecting. If a rating does not apply circle "X". You must enter a rating or "X" for each line of the form.

2 - Inlet blocked.

3 - Inlet partially blocked. Moderate to heavy corrosion.

15 - Inlet functions. Minor corrosion or trash accumulations.

X - Not applicable

Inlet Cover Rating(INLC): Circle the rating code, "2", "3", or "5", which best describes the condition of the Inlet Cover you are inspecting. If a rating does not apply circle "X". You must enter a rating or "X" for each line of the form.

2 - Cover Missing.

3 - Moderate to heavy corrosion and/or cracked cover.

5 - Cover inplace and functioning. Minor corrosion.

X - Not applicable

Walls Rating(WALS): Circle the rating code, "1","2","3","4" or "5", which best describes the condition of the walls of the ancillary structure or utility room you are inspecting. Subway tunnel walls are rated on SUBWY-1. If a rating does not apply circle "X". You must enter a rating or "X" for each line of the form.

1 - Signs of serious structural distress that indicate immanent structural instability.

2 - Flowing cracks total more than 10 feet for a small structure or 20 feet for a large structure. Significant spalls with rebar loss. Unusual crack patterns or indications of structural distress.

3 - Flowing cracks total less than 10 feet for a small structure or 20 feet for a large structure. Flow less than 1 pint/minute for a small structure or 2 pints/minute for a large structure. Spalls areas total less than 5 sq. ft. for a small structure or 10 sq. ft. for a large structure.

4 - No flowing cracks. Moist or glistening surface cracks total less than 10 feet for a small structure or 20 feet for a large structure. Minor spalls exposing rebar with no section loss. No unusual crack patterns.

5 - No moist, glistening surface, or flowing cracks. No spalls exposing rebar.

X - Not applicable.

Floor Rating(FLRS): Circle the rating code, "1","2","3", or *"5"*, which best describes the condition of the floor you are inspecting. These may be the floor of an ancillary structure, emergency exit or utility room. Tunnel floors are rated on SUBWY-1. If a rating does not apply circle "X". You must enter a rating or "X" for each line of the form.

1 - Concrete: Large holes or severe rust. Steel: Large holes or spalls.

2 - Concrete: Spalls with rebar loss, some cracking. Steel: Heavy rust with section loss, some scattered holes.

3 - Concrete: Minor spalls. Steel: Minor rust.

5 - Concrete: No spalls with exposed rebar or large cracks. Minor shrinkage cracks. Steel: Minor surface rust.

X - Not applicable.

Ceiling Rating(CEIL): Circle the rating code, "1","2","4" or *"5"*, which best describes the condition of the ceiling you are inspecting. This may be the ceiling of an ancillary structure, emergency exit or utility room. Tunnel ceilings are rated on SUBWY-1. If a rating does not apply circle "X". You must enter a rating or "X" for each line of the form.

1 - Signs of serious structural distress that indicate immanent structural instability.

2 - Flowing cracks total more than 10 feet for a small structure or 20 feet for a large structure. Significant spalls with rebar loss. Unusual crack patterns, or indications of structural distress 3 - Flowing cracks total less than 10 feet for a small structure or 20 feet for a large structure. Flow of less than 1 pint/minute for a small structure, or 2 pints/minute for a large structure. Spalls areas total less than 5 sq. ft. for a small structure or 10 sq. ft. for a large structure.

4 - No flowing cracks. Moist or glistening surface cracks total less than 10 feet for a small structure or 20 feet for a large structure. Minor spalls exposing rebar with no section loss. No unusual crack patterns.

5 - No moist, glistening surface, or flowing cracks. No spalls exposing rebar.

X - Not applicable.

Vent/Manhole Shaft Rating (SHAF): Circle the rating code, " 1","2","3","4" or "5", which best describes the condition of the element you areinspecting. If a rating does not apply circle "X". You must enter a rating or "X" for each line of the form.

1 - Signs of serious structural distress that indicates immanent structural instability.

2 - Flowing cracks total more than l0 feet for a small structure or 20 feet for a large structure. Significant spalls with rebar loss. Unusual crack patterns, or indications of structural distress.

3 - Flowing cracks total less than 10 feet for a small structure or 20 feet for a large structure. Flow of less than 1 pint/minute for a small structure or 2 pints/minute for a large structure. Spalls areas total less than 5 sq. ft. for a small structure or 10 sq. ft. for a large structure.

4 - No flowing cracks. Moist or glistening surface cracks total less than 10 feet for a small structure or

20 for a large structure. Minor spalls exposing rebar with no section loss. No unusual crack patterns.

5 - No moist, glistening surface, or flowing cracks. No spalls exposing rebar.

X - Not applicable.

Lighting(LITE) Rating:

CircletheRating Code "1","2","3", "4","5", or "X" for the tunnel section being inspected. You must enter a rating or "X" for each line of the form. The codes are:

1 - 50% or more lights out. Loose wires could strike person. Dark areas are a significant safety threat.

2 - 40% of lights out. Heavy corrosion of fixtures or conduits. Many instances of loose fixtures with exposed wires. Exposed wires are a hazard.

3 - 20% of lights in segment out. No significant unlighted stretches that would present safety hazard. No exposed wires.

4 - 10% of lights in segment out. No significant unlighted stretches that would present an evacuation hazard. No exposed wires.

5 - All lights in working order. No loose fixtures or significant corrosion.

X - Not applicable.

Handrails Rating(HRAL):

Circle the rating code, "1", "3", "5" or "X", which best describes the condition of the Track Ladder handrail, or Emergency Exit handrail, or other handrail in the room you are inspecting. You must enter a rating or "X" for each line on the form.

1 - Broken or missing handrail that is a significant safety threat or hazard for tunnel evacuation.

13 - Several loose brackets, isolated areas of rust or rot. Not an immediate safety threat.

5 - Handrail securely attached, no loose brackets, no significant rust or rot.

X - Not applicable.

Ladder Rating(LADR):

Circle the rating code, "1", "3", "5" or "X", which best describes the condition of the Track Ladder, manhole rungs, or other ladder you are inspecting. You must enter a rating or "X" for each line of the form.

1 - Broken or missing.

3 - Several loose rungs, or some with moderate to heavy rust or rot. Still adequate for use.

5 - Ladder or rungs securely attached, no loose components, no significant rot or rust.

X - Not applicable.

Stairs Rating(STAR):

Circle the rating code, "1", "3", "5" or "X", which best describes the condition of the element you are inspecting. You must enter a rating or "X" for each line of the form.

1 - Missing or severely damaged treads. Unsafe for use.

3 - Moderate section loss, missing nosings, loose **treads.**

5 - Treads and risers even with minor section loss.

X - Not applicable.

Doors Rating(DOOR):

Circle the rating code, "1", "3", "5" or "X", which best describes the condition of the Emergency Exit Doors you are inspecting. You must enter a rating or "X" for each line of the form.

1 - Doors inoperative, locked, or blocked.

3 - Doors work properly. Moderate to heavy rust. No impediments to evacuation -immediately outside doors.

5 - Doors work properly. No major defects.

X - Not applicable.

Emergency Exit Rating(EE): Overall rating for emergency exit. Emphasis to be placed on the ability of emergency exit to function in an emergency, including condition, lighting and areas immediately outside doors. You must enter a rating or "X" for. each line of form.

Circle the overall rating code, "1","3", or "5", which best describes the condition of the Emergency Exit. If a rating does not apply circle "X".

I - Exit cannot be safely used in emergency.

3 - Exit in working order, some repairs necessary.

5 - Exit in good working order.

X - Not applicable

COMMENTS

This section is optional. Record a comment when you need to explain in more detail the condition of a particular element. Remember to copy the track stationing and element and component codes from above in order to relate the comment back to its rating. Do not code defects as comments. Defects are recorded on SUBWY-3.

Track Station: Enter the track stationing from above that this comment refers to. The track stationing identifying the comment must match the record it refers to.

Element: Copy the element code from the row on the form to identify which item on the form this comment refers to. For example, "EE" for Emergency Exit, "PR" for Pump Room, etc.

Component: Copy the component code from the column on the form to identify which item on the form this comment refers to. For example, "LITE" for lighting, "HRAL" for handrail, etc.

Comment: Enter a free form comment to describe in detail the element you are inspecting. You can use up to 80

Characters. If the comment is longer than so characters use the next line, and indicate that the stationing and element are the same.

Chicago Transit Authority
Engineering Assessment Form

Subway Ancillary Structures And Utility Rooms

Page ____ of ____

Line Code ☐☐
Track No. ☐☐☐
Tunnel No. TN ☐☐

Date ☐☐/☐☐/☐☐
Firm ☐☐☐
Inspected By ☐☐☐☐☐

Signature: ______________________

Track Stationing	Element Code	Inlet Rating (INL)	Inlet Cover Rating (INLC)	Walls Rating (WALS)	Floor Rating (FLRS)	Ceiling Rating (CEIL)	Vent/ Manhole Shaft Rating (SHAF)	Lights Rating (LITE)	Handrails Rating (HRAL)	Ladder Rating (LADR)	Emergency Exit (EE): Stairs Rating (STAR)	Emergency Exit (EE): Doors Rating (DOOR)	Emergency Exit (EE): Rating (EE)
+		2 5 3 X	2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 4 2 5 3 X
+		2 5 3 X	2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 4 2 5 3 X
+		2 5 3 X	2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 4 2 5 3 X
+		2 5 3 X	2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 4 2 5 3 X
+		2 5 3 X	2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 4 2 5 3 X
+		2 5 3 X	2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 4 2 5 3 X
+		2 5 3 X	2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 4 2 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 5 3 X	1 4 2 5 3 X

Comments:

Track Station	Element Code	Component	Comment

TL - Track Ladder (HRAL + LADR)
MN - Manhole

ER - Electrical Room

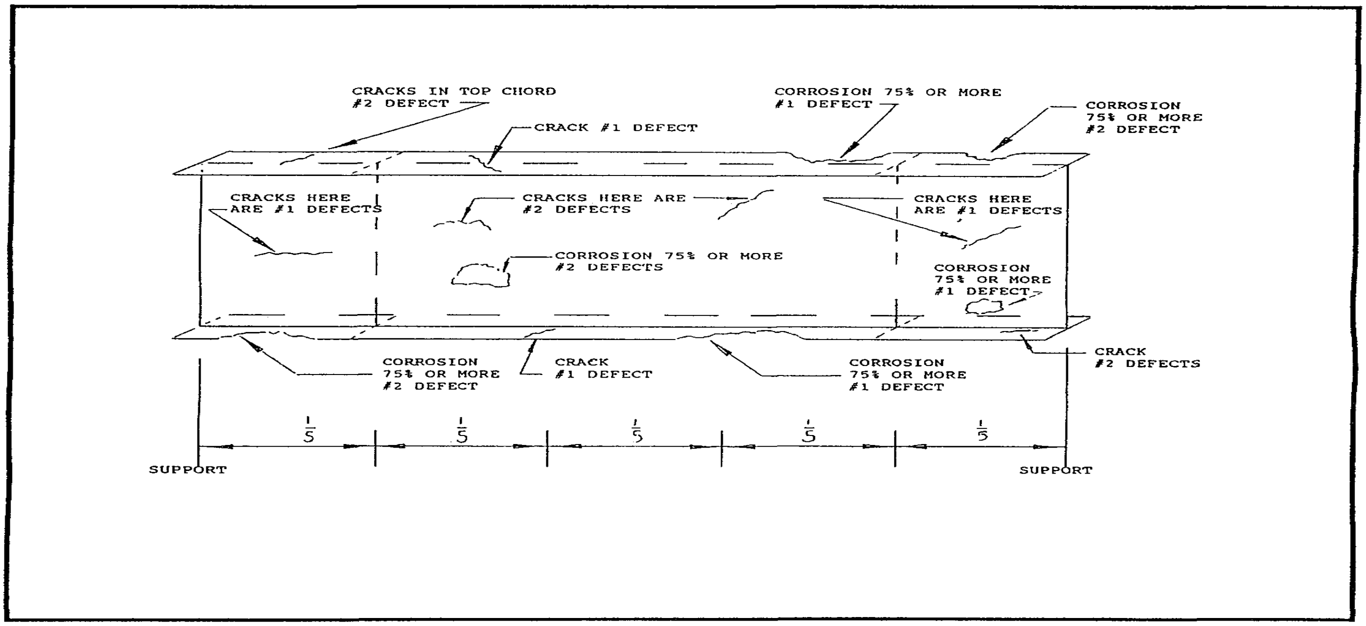
Element Codes:

- SP - Splice Chamber (switched to SC)
- VS - Vent Shaft
- PR - Pump Room
- SR - Signal Room
- EE - Emergency Exit
- TD - Track Drains
- VF - Vent Fan Room
- VL - Vent Louver Room

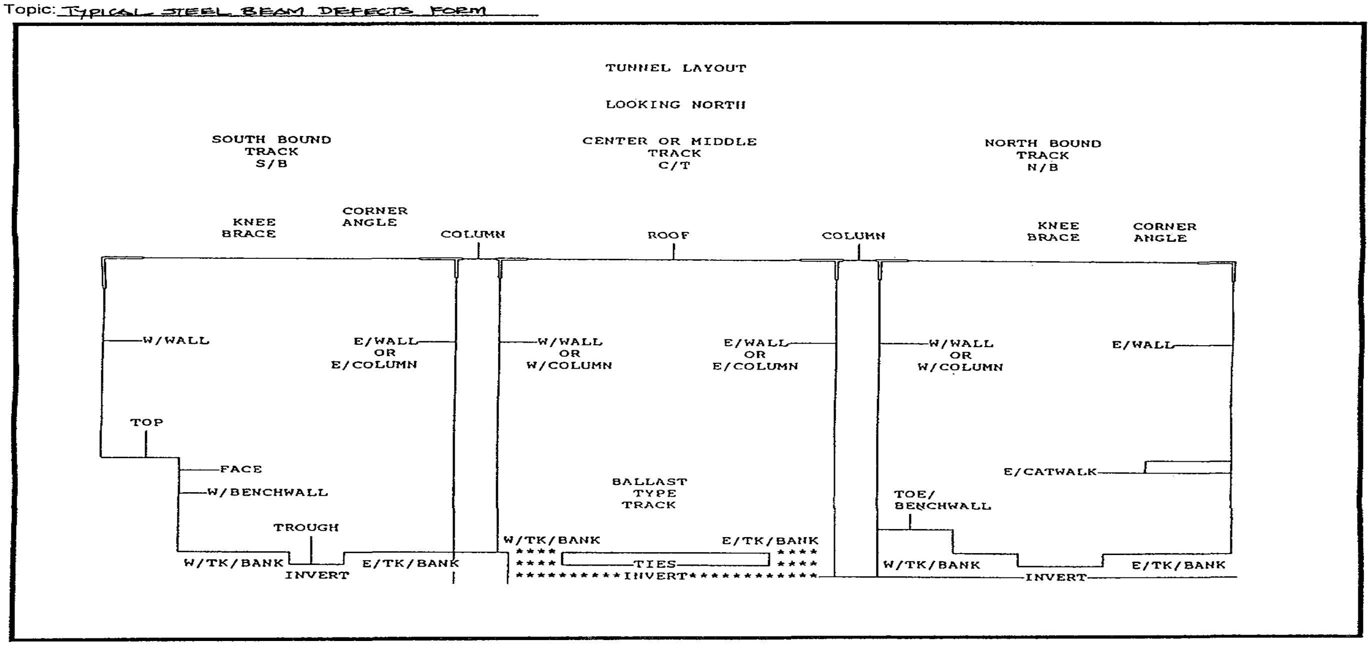
AC - AC breaker room
DC - DC breaker room
RH - Relay House
EP - Ejector Room
PC - Pipe Chase
use instead of BR (breaker rm)

SUBWY-2
5/20/91

MTA New York City Transit Inspection Forms



New York City Transit Authority
Topic: TYPICAL STEEL BEAM DEFECTS FORM



New York City Transit Authority
Topic: TUNNEL LAYOUT FORM

SUBWAY INSPECTION

PLEASE PRINT ALL INFORMATION

FROM/TO N/o of 86TH STREET TO N/E OF 72ND STREET

INSPECTOR ____________ LINE IND 8TH AVE LINE TRACK # A2 N/B DATE ________

NEAREST STATION	STATIONING	DEFECT LOCATION	DEFECT	PRIORITY	STRUC TYPE
86TH STREET STATION	1196+10 TO 1196+00	WEST WALL	RUBBING BOARD ON PLATFORM IS MISSING 10 FEET	2	B
"	1194+60	WEST WALL	RUBBING BOARD ON PLATFORM IS MISSING 5 FEET	"	"
SOUTH OF 86TH STREET	1184+75	WEST WALL	LEAK	"	"
NORTH OF 8TH STREET	1184+65	WEST WALL	HANDRAIL MISSING 5 FEET	"	"
NORTH OF 81ST STREET	1183+10	WEST WALL	LEAK IN CABLE MANHOLE	"	"
"	1182+15	WEST WALL	LEAK	"	"
"	1180+00 TO 1178+75	INVERT	DEBRIS 115 FEET	"	"
"	1178+80	WEST WALL	CONCRETE MISSING ON BENCH WALL 'TRIP HAZARD" 2'x2'x2"	"	"
SOUTH OF 81ST STREET	1168+25	WEST WALL	LEAK	"	"
"	1168+15	WEST WALL	LEAK	"	"
"	1168+10	WEST WALL	LEAK	"	"
NORTH OF	[illegible]				

FIGURE 8

New York City Transit Authority
Topic: INSPECTION FORM

NYC TRANSIT AUTHORITY
PROGRESS REPORT OF THE SYSTEM
STRUCTURAL DEFECTS REPORTING SYSTEM
REPORTED SUBWAY DEFECTS

LINE:EIGHTAVE PAGE: 1

LINE	TRK	STN LOC	NEAREST STATION	PY	DEFECT LOCATION	DEFECT	INSP DATE	REINSP DATE	REPAIR DATE
EIG		0 00	EIGHTH AVE LINE		B'WAY-NASSAU TO	207TH STREET NOS. 679+00 TO 1548+31	/ /	/ /	/ /
EIG	1	678.00	FRANKLIN AVENUE	2	W/TK/BANK	WATER,MUCK & DEBRIS FOR 100'	08/02/92	/ /	/ /
EIG	1	685.00	N/FRANKLIN AVENUE	2	ROOF	LEAK	08/02/92	/ /	/ /
EIG	1	686.00	N/FRANKLIN AVENUE	2	W/WALL	LEAK	08/02/92	/ /	/ /
EIG	1	686.60	N/FRANKLIN AVENUE	2	W/WALL	LEAK	08/02/92	/ /	/ /
EIG	1	686.70	N/FRANKLIN AVENUE	2	INVERT:TROUGH	WATER,MUCK & DEBRIS FOR 195'	08/02/92	/ /	/ /
EIG	1	686.70	N/FRANKLIN AVENUE	2	W/WALL	LEAK	08/02/92	/ /	/ /
EIG	1	689.25	N/FRANKLIN AVENUE	2	W/WALL	CONCRETE CRACK FOR 1/4" X 4'	08/02/92	/ /	/ /
EIG	1	690.30	N/FRANKLIN AVENUE	2	ROOF:VENT AREA	CONCRETE SPALLED	08/02/92	/ /	/ /
EIG	1	691 50	N/FRANKLIN AVENUE	2	ROOF	PLASTIC DRIP PAN & PLASTIC PIPE FOR 10'	08/02/92	/ /	/ /
EIG	1	691.50	N/FRANKLIN AVENUE	2	W/BENCHWALL	CONCRETE CRACK FOR 7,800' (TO 769+50)	08/02/92	/ /	/ /
EIG	1	691.90	N/FRANKLIN AVENUE	2	W/WALL	LEAK	08/02/92	/ /	/ /
EIG	1	692.50	N/FRANKLIN AVENUE	2	W/WALL	LEAK	08/02/92	/ /	/ /
EIG	1	693 00	N/FRANKLIN AVENUE	2	W/BENCHWALL:TOP	CMH DOOR CORRODED 100% FOR 1' X 1' TRIP HAZZARD	08/02/92	/ /	/ /
EIG	1	694.00	N/FRANKLIN AVENUE	2	ROOF	LEAK FOR 50'	08/02/92	/ /	/ /
EIG	1	694.70	N/FRANKLIN AVENUE	2	ROOF	LEAK	08/02/92	/ /	/ /
EIG	1	694 70	N/FRANKLIN AVENUE	2	W/TK/BANK	WATER,MUCK & DEBRIS FOR 15'	08/02/92	/ /	/ /
EIG	1	694.85	S/CLINTON-WASHINGTON	2	W/WALL:EXIT #275	LEAKS	08/02/92	/ /	/ /
EIG	1	696.00	S/CLINTON-WASHINGTON	2	ROOF	LEAK	08/02/92	/ /	/ /
EIG	1	696.85	S/CLINTON-WASHINGTON	2	ROOF	DRIP PAN CLOGGED	08/02/92	/ /	/ /
EIG	1	698.50	S/CLINTON-WASHINGTON	2	W/BENCHWALL	CONCRETE CRACK & PULLING FOR 1/4" X 50'(TO 699+00)	08/02/92	/ /	/ /
EIG	1	706 85	CLINTON-WASHINGTON	2	E/TK/BANK	DRAIN CLOGGED	08/02/92	/ /	/ /
EIG	1	706.85	CLINTON-WASHINGTON	2	E/WALL	DRAIN CLOGGED	08/02/92	/ /	/ /
EIG	1	707.95	CLINTON-WASHINGTON	2	E/WALL	DRAIN PIPE BROKEN FOR 4" X 1'	08/02/92	/ /	/ /
EIG	1	710.00	CLINTON-WASHINGTON	2	PLATFORM	RUBBING BOARD HAS A 2" GAP FOR 50'(TO 710+50)	08/02/92	/ /	/ /
EIG	1	711.20	S/LAFAYETTE AVENUE	2	W/WALL	LEAK	08/02/92	/ /	/ /
EIG	1	711 45	S/LAFAYETTE AVENUE	2	W/WALL	LEAK	08/02/92	/ /	/ /
EIG	1	712.55	S/LAFAYETTE AVENUE	2	W/WALL	LEAK	08/02/92	/ /	/ /
EIG	1	712.75	S/LAFAYETTE AVENUE	2	W/WALL	LEAK	08/02/92	/ /	/ /
EIG	1	720.25	S/LAFAYETTE AVENUE	2	W/WALL:CMH	LEAK	08/02/92	/ /	/ /
EIG	1	742.25	N/LAFAYETTE AVENUE	2	ROOF	LEAK	08/02/92	/ /	/ /
EIG	1	742.70	N/LAFAYETTE AVENUE	2	W/WALL	NO CLEARANCE SIGN MISSING FOR 10'	08/02/92	/ /	/ /
EIG	1	745.00	N/LAFAYETTE AVENUE	2	INVERT	WATER,MUCK & DEBRIS FOR FOR 275' (TO 747+75)	08/02/92	/ /	/ /
EIG	1	748.40	N/LAFAYETTE AVENUE	2	W/WALL	LEAK	08/02/92	/ /	/ /
EIG	1	748.55	N/LAFAYETTE AVENUE	2	ROOF	LEAK	08/02/92	/ /	/ /
EIG	1	748.75	N/LAFAYETTE AVENUE	2	INVERT	LEAK	08/02/92	/ /	
EIG	1	761.35	S/HOYT-SCHERMERHORN	2	INVERT	WATER,MUCK & DEBRIS FOR 665' (TO 768+00)	08/02/92	/ /	
EIG	1	775.25	S/COURT STREET	2	W/WALL	LEAK	08/02/92	/ /	
EIG	1	776.05	N/HOYT-SCHERMERHORN	1	E/WALL	COLUMN FLANGE CORRODED 100% FOR 4" X 3'	08/02/92	/ /	
EIG	1	776.10	N/HOYT-SCHERMERHORN	2	E/WALL	DRAIN CLOGGED	08/02/92	/ /	
EIG	1	892 00	CHAMBERS STREET	2	INVERT	TROUGH:DEBRIS FOR 600 FT (892+00 TO 898+00)	07/01/92	/ /	
EIG	1	893.50	N/CHAMBERS STREET	1	W/WALL	2" WATER PIPE BROKEN	07/01/92	/ /	
EIG	1	898.18	CHAMBERS STREET	2	INVERT	DRAIN COVER:BROKEN	07/01/92	/ /	
EIG	1	899.55	N/CHAMBERS STREET	2	W/WALL	DRAIN CLOGGED	07/01/92	/ /	
EIG	1	900.00	N/CHAMBERS STREET	2	INVERT	TROUGH:WATER,MUCK & DEBRIS FOR 400FT(900+00-904+00)	07/01/92	/ /	
EIG	1	900.10	N/CHAMBERS STREET	2	W/WALL	DRAIN PIPE BROKEN	07/01/92	/ /	
EIG	1	908.50	N/CHAMBERS STREET	2	ROOF	CONCRETE:CRACK FOR 50' X 1/4"	07/01/92	/ /	
EIG	1	911.80	N/CHAMBERS STREET	2	E/CATWALK	CONCRETE:CRACK FOR 6' X 1/2"	07/01/92	/ /	

FIGURE 9

New York City Transit Authority
Topic: DEFECTS REPORTING FORM

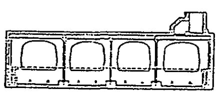
NEW YORK CITY TRANSIT AUTHORITY FIGURE 5 DAILY ASSIGNMENT
INFRASTRUCTURE

REPORTING QUARTERS________________________

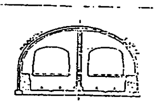
TOUR______________ TO______________

SUPERVISION______________________ DATE____________________

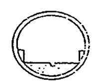
NAME	PASS NUMBER	KIND OF WORK PERFORMED
GANG COUNT:		
SAFETY RULE #		LINE INSPECTED:
TRACK NUMBER:		TYPE:
COLUMN NUMBERS:		TO:
STATION NAMES:		TO:
OTHER:		TO:



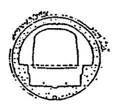
CUT & COVER
TYPE B



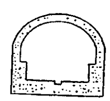
HORSESHOE TWO-TRACK
TYPE C



CAST IRON RING
TYPE D



CIRCULAR CONCRETE TUNNEL
TYPE E



HORSESHOE ONE-TRACK
TYPE F

New York City Transit Authority
Topic: INFRASTRUCTURE / DAILY ASSIGNMENT FORM.

FIGURE 10

JUN.27, 1990 SUBWAY DEFECT REPORT 1

LINE: CON TRACK LETTER: C
NEAREST STATION: S/145TH STREET TRACK NO: 1

STATION MARKER NO: 1347.05

DEFECT LOCATION: W/WALL

DEFECT: LEAK

REFERAL: Z1 REFERAL DATE. / /

REPAIRED BY: REPAIR DATE: / /

JUN.27, 1990 SUBWAY DEFECT REPORT 1

LINE: CON TRACK LETTER: C
NEAREST STATION: S/145TH STREET TRACK NO: 1

STATION MARKER NO: 1347.05

DEFECT LOCATION: W/WALL

DEFECT: LEAK

REFERAL: Z1 REFERAL DATE: / /

REPAIRED BY: REPAIR DATE: / /

New York City Transit Authority
Topic: DEFECT REPORT

FIGURE 11

NEW YORK CITY TRANSIT AUTHORITY

OFFICE OF THE GENERAL SUPERINTENDENT
STRUCTURAL ENGINEERING & INSPECTION

EI-046

EMERGENCY INSPECTION

DATE: 3/27/91 TIME: 10:00 P.M.

LOCATION: BENT # 287, ASTORIA LINE

RECEIVED FROM: CONTROL ROOM

DESCRIPTION OF INCIDENT

TRUCK HIT AT BENT # 287, SOUTH OF ASTORIA BLVD / HOYT AVE STATION, ASTORIA LINE

INSPECTION

DATE: 3/28/91 TIME: 9:00 AM

REPORTED TO: R UDESHI

PHOTO ATT. YES

SKETCH AT YES

FOUND:

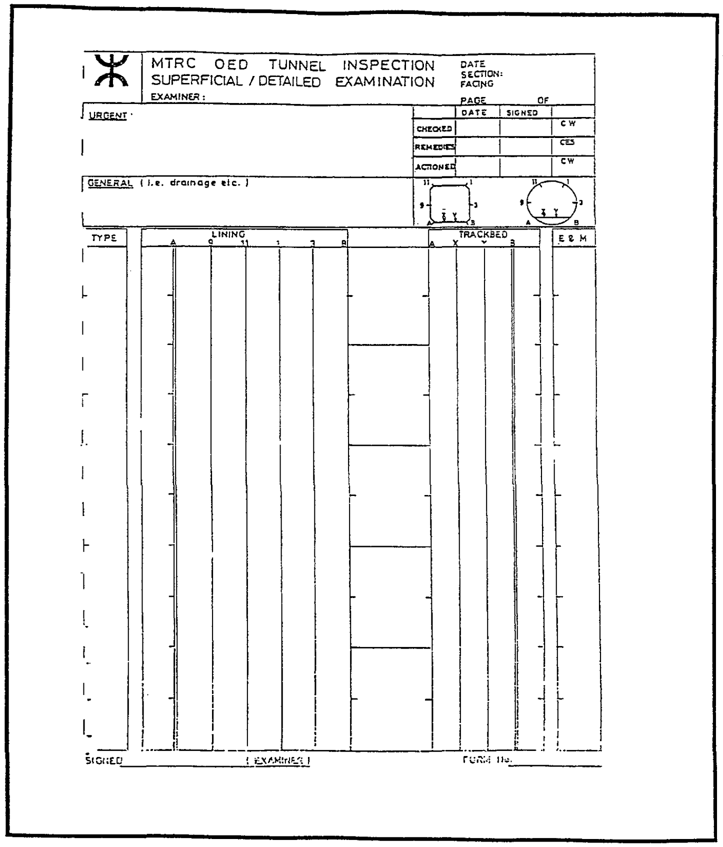
THE TRANSVERSE GIRDER BOTTOM FLANGE ANGLES WERE SEVERELY DAMAGED AND BENT DOWN. ALSO ON THE TRANSVERSE GIRDER WEB, RIGHT BELOW THE WEST LONGITU GIRDER ON THE MIDDLE TRACK, A 6" CRACK WAS OBSERVED. IN HOUSE FORCES WILL PROCEED WITH TEMPORARY REPAIRS TO ENSUR MAXIMUM SAFETY OF THE STRUCTURE. THIS PORTION OF MIDDLE TRACK WILL BE OUT OF SERVICE FOR 2 DAYS UNTIL REPAIRS A DONE. PERMANENT REPAIR OF THE TRANSVERSE GIRDER WILL BE PERF IN THE NEAR FUTURE.

SIGNATURE OF ENGINEER/INSPECTOR

CRT2 #3864

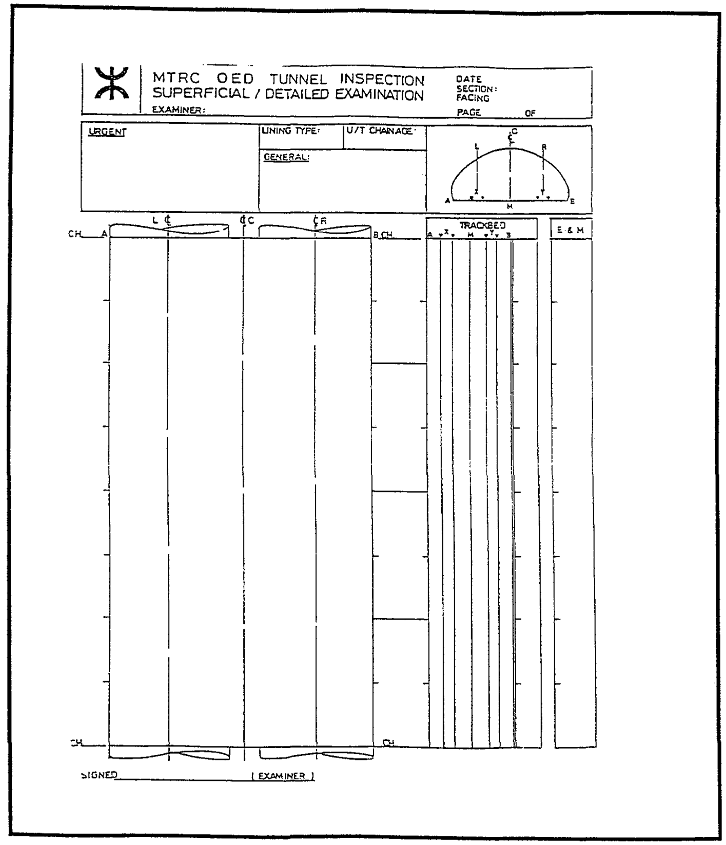
New York City Transit Authority
Topic: ENGINEERING AND INSPECTION FORM.

Mass Transit Railway Corporation (Hong Kong)
Inspection Forms



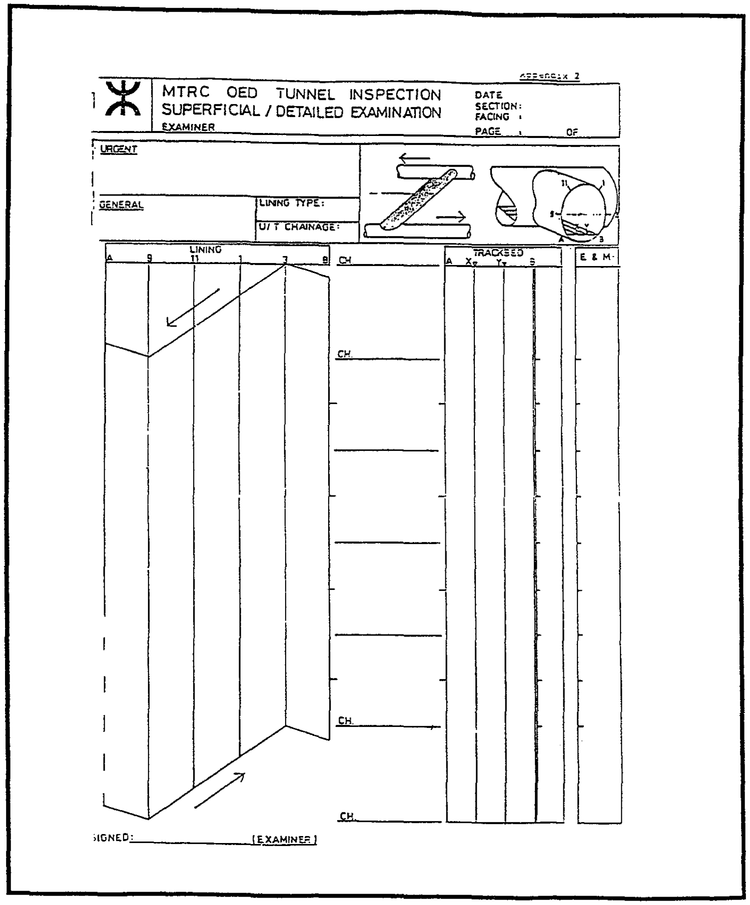
MTRC OED TUNNEL INSPECTION
SUPERFICIAL / DETAILED EXAMINATION
EXAMINER :
DATE
SECTION:
FACING
PAGE OF
URGENT :
DATE SIGNED
CHECKED CW
REMEDIES CES
ACTIONED CW
GENERAL (i.e. drainage etc.)
TYPE
LINING
TRACKBED
E & M
SIGNED (EXAMINER) FORM No.

Mass Transit Railway Corporation (Hong Kong)
Topic: EXAMINATION FORM



MTRC OED TUNNEL INSPECTION
SUPERFICIAL / DETAILED EXAMINATION
EXAMINER:
DATE
SECTION:
FACING
PAGE OF
URGENT
LINING TYPE:
U/T CHAINAGE:
GENERAL:
TRACKBED
E & M
CH
CH
SIGNED (EXAMINER)

Mass Transit Railway Corporation (Hong Kong)
Topic: TUNNEL INSPECTION FORM



APPENDIX 2

MTRC OED TUNNEL INSPECTION
SUPERFICIAL / DETAILED EXAMINATION

EXAMINER

DATE
SECTION:
FACING:
PAGE OF

URGENT

GENERAL

LINING TYPE:

U/T CHAINAGE:

LINING

A 9 11 1 3 B

CH

CH.

CH.

CH.

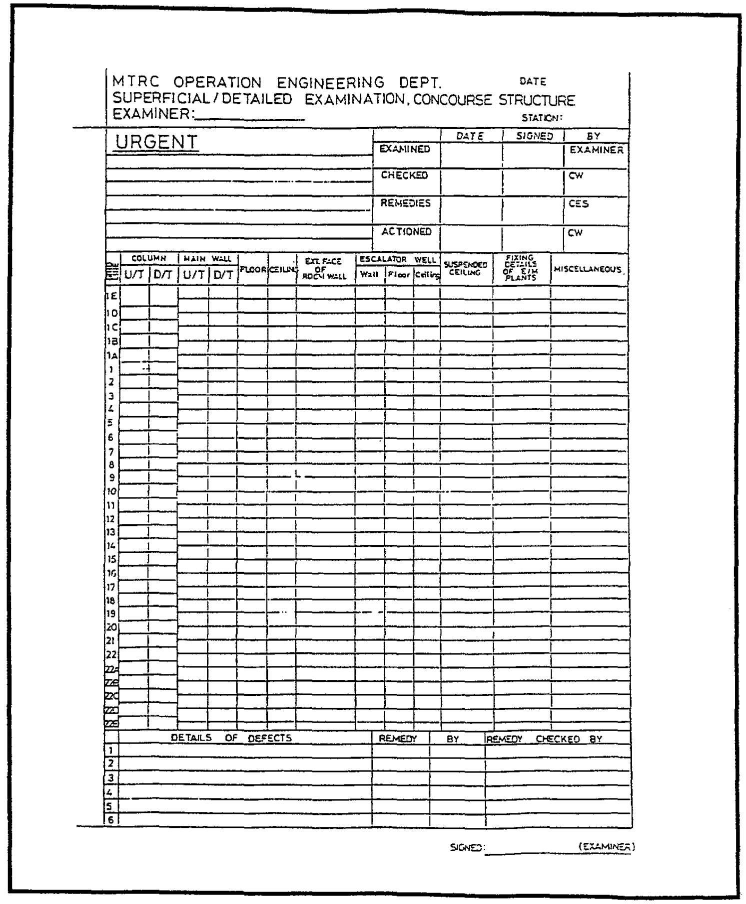
TRACKSIDE

A X Y S

E & M

SIGNED: (EXAMINER)

Mass Transit Railway Corporation (Hong Kong)
Topic: TUNNEL INSPECTION FORM



MTRC OPERATION ENGINEERING DEPT.
SUPERFICIAL / DETAILED EXAMINATION, CONCOURSE STRUCTURE
EXAMINER:

DATE
STATION:

URGENT

	DATE	SIGNED	BY
EXAMINED			EXAMINER
CHECKED			CW
REMEDIES			CES
ACTIONED			CW

	COLUMN		MAIN WALL		FLOOR	CEILING	EXT. FACE OF ROCK WALL	ESCALATOR WELL			SUSPENDED CEILING	FIXING DETAILS OF E/M PLANTS	MISCELLANEOUS
	U/T	D/T	U/T	D/T				Wall	Floor	Ceiling			
1E													
1D													
1C													
1B													
1A													
1													
2													
3													
4													
5													
6													
7													
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17													
18													
19													
20													
21													
22													
22A													
22B													
22C													
22D													
22E													

	DETAILS OF DEFECTS	REMEDY	BY	REMEDY CHECKED BY
1				
2				
3				
4				
5				
6				

SIGNED: (EXAMINER)

Mass Transit Railway Corporation (Hong Kong)
Topic: CONCOURSE STRUCTURE EXAMINATION FORM.

MTRC OPERATION ENGINEERING DEPT — DATE:

SUPERFICIAL/DETAILED EXAMINATION PLATFORM STRUCTURE

EXAMINER: ____________ STATION:

URGENT

	DATE	SIGNED	BY
EXAMINED			EXAMINER
CHECKED			CW
REMEDIES			CES
ACTIONED			CW

	COLUMN		MAIN WALL		PLATFORM			CEILING SUSP		EXT. FACE OF ROCK WALL	TRACK	ADV	O/T	O/T	E & M	STAIRS	END	MISC
	U/T	D/T	U/T	D/T	FLOOR	WALL	SLAB SOFFIT		CEILING		SLAB	PANEL	VENT DUCT	CABLE BRKT	FIXINGS		WALL	
1E																		
1D																		
1C																		
1B																		
1A																		
1																		
2																		
3																		
4																		
5																		
6																		
7																		
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19																		
20																		
21																		
22																		
22A																		
22B																		
22C																		
22D																		
22E																		

	DETAILS OF DEFECTS	REMEDY	BY	REMEDY CHECKED BY
1				
2				
3				
4				
5				

OPM631/7.85

D: ____________ (EXAMINER)

Mass Transit Railway Corporation (Hong Kong)

Topic: PLATFORM STRUCTURE EXAMINATION FORM

APPENDIX D

MTRC Tunnel Inspection Guidelines
Hong Kong

MTRC Tunnel Inspection Guidelines

A) General

1. Defects to be shown in graphical form.

2. Common defects are to be indicated by symbols as listed in the attached "Defects Schedule" Separate Description is not required unless further inspection by engineer or special remedial recommendation is necessary.

3. Defects not listed in the "Defects Schedule" are to be described individually. However, similar defects can be grouped.

B) Content of Inspection Report

1. Urgent: Items which cause immediate danger or require immediate action.

2. Drainage: Description of the general condition specifying any blockage or defects.

3. Miscellaneous: Items not included In the other columns.

4. Tunnel Type: C.I.C. for cast in-situ concrete lining; P.C.P for precast concrete panel lining; S.G.I. for spheroidal graphite iron lining - non-typical tunnel sections {such as rectangular section, twin tunnel or crossover to be specified.

5. Chainage: To be the same as those used by Surveyors. Center of station is regarded as zero chainage. In ISL, chainage plates are Installed at 12m intervals. In THL, chainages are marked in red paint at 50m intervals. In KTL, chainages are marked in red paint at 30m intervals.

6. Defects: For common defects, see attached "Defects Schedule" for details. For special defects, mark with defect number.

7. Details of Defects:

- A separate sheet to be incorporated with the report.
- Details of the corresponding defect numbers are to be described separately. Engineer should recommend remedial actions for these items.
- Engineer may include other items by adding defect number if special remedial action to these items are necessary.

Hong Kong

Items not included in the "Details of Defects" require only routine maintenance. See "Schedule of Common Defects for Tunnels" (below) for details:

Defects Schedule

A) Cracks

Orientation: to be shown as ("sign to be drawn").

Degree:

- hair crack or crack width < 0.5mm (no description required).
- crack width > 0.5mm (mark with a number beside the crack & the same in the remark column. Details to be described in the "Details of Defects").

Condition:

- Dry (No descnption required).
- Damp (Discoloration of part of the surface, moist to touch, Mark with D').
- Seep (Visible movement of a film of water, Mark with S).
- Standing Drop (A drop of water which does not fall within a period of 1 minute, Mark with Do).
- Drip (Drops of water which fall at a rate of at least 1 drop per minute, Mark with Di).
- Continuous (A trickle or jet of water, Mark with K).
- Efflorescent (Mark with E).
- Rusty (Mark with R).
- Reinforced exposed (Mark with Re).

If only part of the crack has the Specified condition, e.g. seeping, mark with a X for a point and a line for a length. Cracks on plinth and not across the trackbed to be shown as ("sign to be shown").

Hong Kong

B) Drip Channels

Onentation to be shown as (sign to be shown).

Condition

- good (mark with G).
- blocked (mark with B).
- loosened/broken (mark with L).

C) Spalling

Location: to be shown as (mark as "sign to be shown").

Condition

- rusty (mark as "sign to be shown").
- reinforced exposed (mark as "sign to be shown").

Size: length x width indicated (mark as "sign to be shown").

D) Damp Patch or Ponding

Location: to be shown as (mark as "sign to be shown").

Damp patch due to seepage from visible crack needs not be shown.

E) Separation of Trackbed

Location: to be shown (mark as "sign to be shown").

F) Segmental Joint/Construction Joint

Location: to be shown as (mark as "sign to be shown").

not necessary unless defective (e.g. with seepage through joint).

THE TRANSPORTATION RESEARCH BOARD is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering It evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 270 committees, task forces, and panels composed of more than 3,300 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, the Association of American Railroads, the National Highway Traffic Safety Administration, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr Bruce Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Robert M.White is president of the National Academy of Engineering.

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