Managing Safety and Risks in Singapore Mass Rapid Transit Projects

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Land Transport Authority
Outline of Presentation

- Introduction
- Development of Singapore’s MRT System
- Thomson-East Coast Line
- Management of MRT Construction in Singapore
- Challenges and Innovations in LTA’s MRT Projects
- LTA’s Approach to Construction Risk Management
- LTA’s Insurance Strategy
Singapore

721.5 sq km

High-density housing

Population: 5.6 mil

14% 12%
Housing Roads Others
About Land Transport Authority (LTA)

• Statutory board under the Ministry of Transport, which spearheads the development, operation and maintenance of land transport systems in Singapore.
About Land Transport Authority (LTA)

- LTA consists of over 20 groups supporting projects and regulation in public transportation systems
- Total staff strength of more than 6,000

Vision
A People-centred Land Transport System

Mission
Connecting People and Places, Enhancing Travel Experiences
Land Transport Master Plan

Key Targets by 2030

75%
Of all journeys in peak hours undertaken on public transport

85% < 60 mins
85% of public transport journeys of less than 20km completed with 60 minutes

8 in 10 HOUSEHOLDS
Within 10 mins walk from a train station

To attract commuters to shift from private transport to taking the MRT
Development of Singapore’s MRT System
Singapore’s Mass Rapid Transit System

Rail network nearly doubles from **200km** today to **360km** in 2030!
Components of Rail Transit System

- Operator
- Civil Works
- Power Supply
- Rail Transit System
- Building Services
- Rolling Stock
- Fare Collection
- System

- Tunnels
- Stations
- Architecture
- Trackwork
- Depot
- Survey

- Electrical System
- Fire Protection System
- Escalators, Lift and Passenger Conveyors
- Tunnel Ventilation and Environment Control Systems

- Signalling
- Communication
- Supervisory Control System
- Maintenance Management System

- Electric Trains
- Construction Wagons & Service Locomotives
- Depot Equipment
Civil Construction Components

Station Construction

Tunnel Construction
Electrical and Mechanical Components
Typical Rail Project Cycle – Design & Build Projects

- **Civil Contract Award**
- **Design & Temporary Works**
- **Strutted Excavation & Permanent Structures**
- **Basic Structure Completion**
- **E&M and Architectural Works**
- **Revenue Service**

* Typical Project Duration: **8 Years** from Civil Contract Award till Revenue Service

- **4.5 – 6 yrs**
- **2 – 2.5 yrs**
- **0.5 – 0.8 yrs**

* T & C – Testing & Commissioning
Thomson-East Coast Line
**Thomson-East Coast Line**

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<td>No. of Depots:</td>
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<td>Route Length:</td>
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<td>Project Daily Ridership:</td>
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<td>No. of TBMs:</td>
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</table>
Thomson-East Coast Line

- Woodlands North
- Woodlands
- Woodlands South
- Springleaf
- Lentor
- Mayflower
- Bright Hill
- Upper Thomson
- Caldecott

2019

2020

2021

2023

2024
Thomson-East Coast Line – Depots

Mandai Depot

East Coast Integrated Depot
Management of MRT Construction in Singapore
Key Pillars of Project Management

Safety & Environment Management

Budget Management

Schedule Management

Quality Management

Community Engagement
Key Pillars of Project Management

**Safety & Environment Management**
- Safety Process & Risk Management
- Safety Targets
- Audits
- Noise & Dust Management
- Water and Energy Efficiency

**Budget Management**
- Financial Controls
- Best Value
- Value Engineering
- Commercial Considerations
- Fair Risk Sharing

**Schedule Management**
- Structured Programme
- Achievable Schedule
- Measures to Expedite Works
- Commercial Implications
- Interface Management

**Quality Management**
- Simple, Elegant, Timeless Design
- Reliability
- Built to Last
- Safe to Build
- Safe to Use

**Community Engagement**
- Engagements with Stakeholders
- Measures to Minimize Inconvenience
- Open Channels for Feedback
- Newsletters and Circulars
- Community Involvement
The main types of contracts adopted are “Design & Build” and “Build-Only”.

Selective tendering process adopted for the selection of contractors for the construction works. Contractors are pre-qualified for the project based on the following criteria:

- Technical Expertise
- Project Management
- Safety & Quality Management
- Relevant Track Records
- Current Workload & Capacity and Financial Capacity
Tender Evaluation and Contractor Selection Process

- Price-Quality (PQ) Method to evaluate the tender submissions.

- The price is only evaluated if the quality submission meets LTA’s requirements and quality standards.

- Quality submission includes technical proposal (methods of construction and preliminary risk assessments), safety records, past project performance etc.

- Tender technical evaluation eliminates high risk proposals.
Effective Management of the Rail Project Construction

- Dedicated and qualified LTA project teams present at each project site full-time to monitor and manage its implementation.
- Project Teams supported by various divisions within LTA throughout the project implementation.
LTA Project Teams

Project Teams are supported by various divisions within LTA throughout the project implementation.
Challenges and Innovation in LTA’s MRT Projects
Key Challenges Encountered during MRT Construction

- Densely Built-Up Areas
- Variable Ground Conditions
- Protecting Existing MRT Infrastructure
Densely Built-Up Areas

- Land Acquisition
- Multi-Stages Traffic Diversion
- Tunnelling under Buildings / Structures
- Proximity to Residential Estates and Commercial Establishments
Land Acquisition

While all efforts have been made to minimize land acquisition, the Government has had to acquire private land for the construction of the MRT lines.

- Pearls Centre (L) and Semi-detached houses @ Amber Rd (R) acquired for construction of Thomson-East Coast Line
- Block 303 acquired for construction of Jurong Regional Line
- Palmer House partially acquired for construction of Circle Line Stage 6
Multi-Stages Traffic Diversions

- Stations are typically located underneath roads in order to maximize the use of limited land available.

- Multiple stages of traffic diversions required to construct the stations.

- Increased use of innovative trenchless technologies (e.g. Pipe Roofing, RTBM) to minimize surface disruption.
Tunnelling under Buildings / Structures

- Due to limited space available and heavily built-up nature, the MRT tunnels often constructed beneath or in close proximity to existing buildings and structures.

- Foundation investigations / underpinnings carried out to ensure the tunnelling works do not impact the building / structure.

- Examples of underpinning in TEL:
  - 4-storey Block 258 at Ang Mo Kio Ave 4
  - 9-storey building at Botanic Gardens View

4-storey HDB Block 258

9-storey block of Botanic Gardens View

TEL Tunnels undercrossing multiple properties between Stevens and Napier Stations
**Proximity to Residential Estates and Commercial Establishments**

**PR Strategy**
- Dedicated PR officers from LTA and Contractor
- Regular engagements via briefings and circulars
- Involvement of community in the MRT development.

**Noise and Dust Control**
- Extensive noise and dust mitigation measures prescribed upfront to minimize the inconveniences.
- Contractor to abide by NEA’s regulations on working hours and permissible noise limits.

- 12m-high noise barriers around the site perimeter
- Noise enclosure around tunnel launch shaft and STP
Variable Ground Conditions

- Highly variable ground conditions
- Construction in soft fluvial and marine clay layers
Highly Variable Ground Conditions
Highly Variable Ground Conditions

- Extensive soil investigations carried out before contract award to establish the ground conditions.

- Provision of a Geotechnical Interpretative Baseline Report (GIBR) to the contractor documenting the baseline ground conditions at the project area.

- Construction methods (top-down / bottom-up), ERSS designs (dwall / CBP / SBP), type of TBM (EPB / Slurry) prescribed based on the anticipated ground conditions.

- Extensive ground treatment carried out to strengthen areas with soft soil (marine clay / fluvial layers). Methods of ground treatment include Jet Grout Piles, Deep Soil Mixing, Deep Cement Mixing etc.

- Installation of Recharge Wells before the commencement of deep excavation works at all sites.
Commonly Used Pre-Treatment Methods for Soft Ground Conditions

Jet Grout Pile (JGP) Method

Deep Soil Mixing (DSM) Method

TAM Grouting Method

Chemical Grouting
Protecting Existing MRT Infrastructure

- E.g.: TEL Marina Bay Station
TEL Marina Bay Station

- Interchange station for 3 lines
  - North South Line
  - Circle Line
  - Thomson-East Coast Line

- Due to the ground conditions, pre-treatment has been carried out for the mined tunnels.

- LTA is using ground freezing for the first-time ever to prevent water seepage during mined tunneling works for the Woodlands Bound tunnel.

- Jet Grout Pile method has been used to treat the ground for the Changi Bound tunnel.
Ground Freezing at TEL Marina Bay Station

Advantages of Ground Freezing

Water Cut-off Wall
- More effective in reducing permeability in OA than other methods

Groundwater Control

Bearing Wall
- Less disturbances to the ground
- Formation of 1.8m ice wall through the use of 100mm diameter pipes
Innovation and Productivity

Integrated 4-in-1 Depot

Retractable micro-TBM with Internal Interlocking Pipe Configuration

Rectangular Box Jack TBM
Integrated 4-in-1 Rail and Bus Depot

- First in the world to integrate three train depots (EWL, DTL and TEL) and one bus depot within a single site
- Total capacity of the integrated depot is around 220 trains and 760 buses
- Challenge in relocating live EWL depot and ensuring minimal disruption
Integrated 4-in-1 Rail and Bus Depot

- 44 hectares in land savings and approx. $2 billion savings in construction cost
- Overall shorter construction duration as structural elements are shared. Reduce the duplication of some facilities.
Retractable Micro Tunnel Boring Machine (mTBM) fitted with Extension Kit and Internal Inter-locking Pipes
TEL T219 Orchard Station and Tunnels - Overview

- Retrieval Shaft
- Jacking Shaft
- No. of pipes: 18
- Diameter of each pipe: 1.27m
- Pipe Roof dimension: 15m x 7.6m x 50m
Features of the mTBM

The first combined retractable mTBM fitted with extension kit and internal inter-locking pipes system in Singapore

1. Retractable Cutterhead with Extension Kit

   - No need for a retrieval shaft
   - Allows for changing of cutter tools depending on ground characteristics

2. Internal Inter-Locking Pipes System

   - Reduces likelihood of unplanned cutterhead intervention
   - Prevents pipes being jacked out of planned alignment
Rectangular Box Jack Tunnel Boring Machine (RTBM)
Features of the RTBM

**Main Body**
Capping bridge to maintain annulus for injection of anti-friction bentonite

**Thrust Ring**
Cylinders push the thrust ring during excavation to create clearance for ring installation

**Main Thrust System**
24 nos of jacks with maximum jack stroke of 2200mm and thrust force of 72,000kN to propel the machine forward during excavation

**Intermediate Jacking System**
Provided in conjunction with main jacks to supply additional thrust

**Back Support**
Acts as reaction frame for even load distribution onto the earth retaining stabilizing structures
Features of the RTBM

**Six Independent Cutterheads**
Six Independently rotated cutterhead with low torque to minimize disturbances to the ground above at shallow depths.

**Manlock**
Manlock retrofitted to facilitate cutterhead interventions for the first time ever in a RTBM.

**Double Screw Conveyor**
Double conveyor for even muck discharge due to large cutting area.
Monolithic Precast Box Segments

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<tr>
<td>Overall dimension:</td>
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<tr>
<td>Width:</td>
<td>1.5m</td>
</tr>
<tr>
<td>Thickness:</td>
<td>500mm</td>
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<tr>
<td>Weight:</td>
<td>50 ton</td>
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**Grouting Sockets**
Injection of backfill grout at the end of the RTBM drive

**Lifting Sockets**
To facilitate the lifting of the box segment

**Turning Sockets**
To facilitate the turning of the segment for the installation of the gaskets and lowering into the shaft

**Lubrication Sockets**
Injection of bentonite to minimize the frictional force between the segment and ground during jacking

Waterproofing Gaskets

*Double Wedge Gasket*

*EPDM Gasket and Plywood*
Advantages of Using the RTBM compared to Conventional Cut-and-Cover Method

- Achieved 30% increase in productivity due to reduced man-hours and construction duration
- Simpler and safer method
- Minimal disruption to the surface
- Minimal noise and dust generated
- No utilities diversion / protection required
- Better quality and workmanship
LTA’s Approach to Construction Risk Management
Risk Management –

A systematic approach to control the level of risk to mitigate its effects. Risk management process recognizes that construction work will always involve uncertainties. It introduces the procedures to ensure that the risks to the successful completion of the projects are systematically reduced to an acceptable level.
Risk Management is a continuous cyclic process.
Typical Construction Risks Encountered

- Natural
- Safety
- Commercial
- Political
- Construction Related
- Design
- Environment
- Programme
Key Basis to Construction Safety

- Engineering
- Education
- Enforcement
Engineering

Implement effective review process to address and track potential risks at each stage of the project.

▪ Thorough review of the structural design, construction methodologies, materials and equipment.
▪ Preparation of a comprehensive Flood Protection Plan.
▪ Provision of flood protection wall around deep excavated zones.
▪ Fire Prevention Plan
Education & Promotion

To inculcate greater safety awareness within the project

- Risk can only be prevented when it is known
- Organise more safety awareness courses for the workers
- Send the workers for proper skill training
- Get the more senior staff to attend seminars and forums to update the latest safe practices
- Put up promotional posters and slogan at site
- Reward workers who have constant good safety performance and use them as role models
Enforcement

It does not make sense if measures put in place are not followed

- Proactive steps have to be taken to ensure safe work practices are adhered to

- Examples:
  - Structured regular inspection regime
  - Thematic Exercise to check on workers’ awareness and competency
  - Safety Audit
  - Near-Miss Reporting
  - Incident and Infringement Reporting
  - Taking action on any breach
Project Risk Management Processes in LTA

- Project Safety Review (Safe-To-Build)
- Approval-in-Principle Process
- Design Approval & Supervisory Requirements
- Instrumentation & Monitoring
- Contractor’s Risk Management Plan
- Risk Management Meetings
- International Panel of Advisors
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Project Safety Review (Safe-to-Build)

- The purpose of the procedure is to apply the principles of risk identification and mitigation in construction design and project management for LTA projects.

- A systematic risk management approach from feasibility stage to handover stage. Hazards must be identified at every phase and eliminated where possible.

- The following RTS projects are subject to the PSR (Safe-to-Build) process:
  - All new Rapid Transit System (RTS) line
  - Addition of a station to existing line
  - Extension of an existing line
Safety Organisation Structure

Safety Governance Advisory Committee

Corporate Safety Committee
Chief Executive

Safety Division

Project Safety Review (Safe-to-Build)
Chief Engineer, Civil

Project Safety Review Committee (RTS)
Group Director, Safety & Contracts

Project Safety Review Committee (Roads)
Group Director, Safety & Contracts

Project Safety Assurance Committee

Project Safety & Environment Committee
Project Directors
Types of Safety Submission

- Civil Feasibility Safety Submission (CFSS)
- Civil Concept Safety Submission (CCSS)
- Civil Design Safety Submission (CDSS)
- Civil Construction Safety Submission (CNSS)
- Civil Handover Safety Submission (CHSS)
Timeline for Safety Submission

- **Feasibility Study Report**
- **D&B or A/E Tender Call**
- **Design Submission**
- **Build Only Civil Tender Call**
- **Handover for Trial Running**

**CFSS** → **CCSS** → **CDSS** → **CNSS** → **CHSS**

- **D&B Tender Award**: 2 mths
- **Build Only Civil Tender Award**: D&B: 2 mths before application permit to excavate
- **Test Running Begins**: A/E: 2 mths before application permit to excavate or 2 mths before making structural submission to BCA for underground building works
- **RTS**: 4 mths before completion of system test running or handing over of project to operator

- **1 mth after final design submission**
- **2 mths** after final design submission
Roles & Responsibilities

Risk Management Facilitator (RMF)
- Facilitate in risk workshops
- Preparation of safety submissions
- Liaise with the external RMFs on hazard management
- Trained in hazard identification and risk assessment methodology
- At least 10 years experience in civil construction industry (5 years for major rail and/or road projects)

Independent Reviewer
- Assist the PSR Sub-Committee in reviewing the safety submission
- Identify missing hazards
- Review sufficiency of proposed control measures
- Reasonableness of Risk Assessment
## Construction Risk Matrix for Rail and Road Projects

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<tr>
<th>Risk Category</th>
<th>Accident Frequency Category</th>
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<th>II</th>
<th>III</th>
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<td>Catastrophic</td>
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<td>B</td>
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<tr>
<td></td>
<td>Negligible</td>
<td>B</td>
<td>C</td>
<td>C</td>
<td>D</td>
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<tr>
<td></td>
<td>Improbable</td>
<td>C</td>
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### Hazard Resolution Matrix:

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<th>Risk Level</th>
<th>Description</th>
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<tr>
<td>A</td>
<td>Intolerable</td>
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<tr>
<td>B</td>
<td>Undesirable</td>
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<tr>
<td>C</td>
<td>Tolerable</td>
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<tr>
<td>D</td>
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Project Risk Management Processes in LTA

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LTA’s Approval-In-Principle (AIP) Process

- Modelled after the Technical Approval of Highway Structures BD 2/02, UK Highways Agency.
- The AIP process is an additional level of design check carried out before the preparation of the detailed design.
- The AIP document records the agreed basis and criteria for the detailed design.
- The process gives greater assurance that the proposals are safe to implement and that the structures are serviceable in use, economic to build and maintain.
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Design Approval & Supervisory Requirements

- The design approval and supervision process for construction projects are prescribed by Building & Construction Authority (BCA).
- Roles of the parties involved are –
  - PE: Professional Engineers to prepare the designs
  - AC: Independent Accredited Checker appointed to review the designs
  - BCA: Government Authority approving the designs.
  - QP(S): Independent supervisory team appointed to supervise and inspect the works at site.
- Specially qualified personnel are required to design, review and supervise underground building works.
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Instrumentation & Monitoring in LTA’s Projects

- Installation of instruments and monitoring works *carried out independently* for all projects.
- Instrumentation contractor is separately engaged by LTA.
- Frequency of the monitoring (6-hourly, daily, weekly etc.) is determined based on the activity and nature of surrounding area.
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The contractor is required to submit a Risk Management Plan at the start of the project with the following items:

- Risk Assessment Plan
- Construction Risk Register
- Safety, Health and Environment Control Plan
- Project Quality Plan
- Key Method Statements
- Inspection and Test Plans

Prior to each activity, the contractor shall submit a detailed Method Statement that includes the methodology and required resources for that particular activity.

Along with the Method Statement, a risk assessment is submitted that covers the specific risks associated with that particular activity and its corresponding mitigation measures.
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Risk Management Meetings

- Regular meetings held to review the risks associated with each activity, taking into consideration any new risks that emerge as the project progresses.

- The types of meetings conducted during the project duration include:
  - **Specific Works Hazard Assessment Workshop**: Conducted prior to the start of any major work activities.
  - **Joint Risk Register Meeting**: Conducted on a monthly basis.
  - **Project Director’s Review of Top Risks Meeting**: Conducted on a quarterly basis.
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LTA engages an International Panel of Advisors (consisting of 1 Chairman and 4 members) which helps to identify risks, critique for the engineering safety of our works and recommend potential mitigation measures that could be undertaken.

The Advisors are selected based on their backgrounds (consultant, contractor or academia) and also geographical locations (Singapore, Asia, North America, Europe etc.) to harness a wide range of experiences.
LTA’s Insurance Strategy
Summary of Insurances for LTA Projects

- **Major Transit & Road Projects**
  - Contractor Arranged Insurances
    - All Risks Insurance on Construction Equipment & Site Offices
    - Motor Vehicle Insurance for contractors’ motor vehicles
    - Work Injury Compensation/Employer’s Liability insurances for all employees outside Singapore
    - Liability insurances for Aircraft and Waterborne Vessels
  - Authority-Arranged Insurances on Project basis
    - Builders’ Risks Insurance on Works/Material Damage
    - Third Party Liability Insurance on legal liability arising from construction activities
    - Work Injury Compensation/Employer’s Liability Insurances for all employees within Singapore
    - Marine Cargo insurances for E&M shipments from overseas

- **Minor Transit & Road Projects**

*Centrally procured for all projects by LTA*
Authority – Arranged Insurance

Benefits

• Broader insurance cover for LTA and her contractors
• Avoid conflicts in claims involving several contractors
• Economies of scale for premiums
No construction project is risk free, risk can be managed, minimized, shared, transferred or accepted but it cannot be ignored.

With the increasing complexity of the infrastructure projects undertaken by LTA, robust risk management processes are necessary to ensure the safety of the project. Multiple processes such as the PSR process have been implemented to manage and mitigate the risks at various stages from project initiation to completion, which have greatly benefitted the project.
Thank You!