Safe to Build and Safe to Use - A Total Safety Management System

J.K. Tan, D.R. Stolz & S. Mijan
Land Transport Authority, Singapore

ABSTRACT: In its Safety Policy Statement, the Chief Executive declares that "The Land Transport Authority's (LTA's) mission is to build a world class transport system for Singapore, in discharging our responsibilities we accord paramount importance to safety". For the North East Line (NEL) project a Safety Management System encompassing construction safety, rail system safety and road system safety was implemented. It reflected the philosophy of "safe to build and safe to use" – a total Safety Management System. LTA's commitment to construction safety is based on the three areas of Engineering, Education/Promotion and Enforcement. Rail system safety and road system safety are assured through the Project Safety Review (PSR) process. PSR provides for the formal and structured assessment of the "safe to use" aspect of LTA projects from the beginning of their lifecycles. PSR is in compliance with best international practice, and is well supported by an effective organisational framework. For rail system safety, PSR places great emphasis on the rigour of hazard identification

1 INTRODUCTION

The Land Transport Authority (LTA) was formed in September 1995, and in September 1997 it issued its first Safety Policy Statement. In the Policy Statement, the Chief Executive declared that "The Land Transport Authority's mission is to build a world class transport system for Singapore, in discharging our responsibilities we accord paramount importance to safety".

The Safety Management System for the NEL project encompassed construction safety, rail system safety and road system safety. It reflected the philosophy of "safe to build and safe to use" - a total Safety Management System.

LTA's commitment to construction safety is based on three areas:

- Engineering.
- Education/Promotion.
- Enforcement.

For Engineering, the objective is to address risk at source. Effort is put in to ensure that structural design, fabrication and construction, and heavy equipment/machine operation and maintenance, are in compliance with best engineering standards and practices. For Education/Promotion, greater safety awareness is generated through worker/staff involvement in training and safety seminars and conventions. For Enforcement, proactive steps are taken to ensure safe work practices are adhered to, and safe work conditions are maintained.

Rail system safety and road system safety are assured through the Project Safety Review (PSR) process. PSR was formally implemented in 2000 to assure the safety of persons using or otherwise affected by transport systems implemented by LTA. It provides for the formal and structured assessment of the safety aspects of LTA projects from the beginning of their lifecycles. The project developer/designer (and the system operator, in the case of rail) is required to make Safety Submissions at a number of key points in the project's lifecycle to demonstrate that acceptable levels

of safety will be, or are being, achieved. PSR was implemented not because LTA (and its predecessors) were unable in the past to deliver systems that were "safe to use" but to provide a safety self-certification process with greater transparency and traceability.

For rail system safety, PSR places great emphasis on the rigour of hazard identification and analysis, and risk assessment, which were carried out by the NEL project designers with assistance and advice from LTA's Systems Assurance Department. The system operator's views and operating strategies were also considered early in the design process. The PSR process is in compliance with the best international practice, and is well supported by an effective organizational framework to ensure that the final product is "safe to use".

The NEL project also included the construction of a number of significant new roads. For road projects, the major component of each Safety Submission made by the project developer/designer is a road safety review undertaken by an independent team that has no direct involvement with the project being reviewed. Road safety review is a technique for hazard identification and risk assessment that focuses on the safety of on-street control equipment and the road environment. PSR for roads was first applied to NEL in October 2000 when a Detailed Design Safety Submission was prepared for the construction and realignment of Race Course Road. Post-construction Safety Submissions were subsequently prepared for three new roads.

2 CONSTRUCTION SAFETY

2.1 The Singapore context

The Ministry of Manpower (MOM) enforces Singapore's Factories Act and its subsidiary legislation to safeguard the safety, health and welfare of workers employed in factories and other workplaces, including construction worksites. One of the more important pieces of legislation applicable to the construction industry is the Factories (Building Operation and Works of Engineering Construction) Regulations, more commonly known as BOWEC. In 1994, MOM promulgated a requirement that all occupiers of worksites, where the contract sum of the work to be carried out is $10 million or more, must implement a Safety Management System (SMS), for the purpose of ensuring the safety, and protecting the health, of their workers. Singapore Standards issued a "Code of Practice on Safety Management System for Construction Worksites" (CP 79) which contains guidelines on the 14 necessary elements of a SMS, and this was subsequently gazetted for compliance by occupiers of factories (including construction worksites).

2.2 Construction safety within LTA

LTA's Construction Safety Department was formed in 1998 within the then Projects & Engineering Division. The primary role of the Department was to provide advisory support to the Division in their pro-active effort to promote construction safety and safe work practices. As the construction of the North-East Line (NEL) progressed, LTA made an organizational-wide commitment to accord safety paramount importance in the delivery of all projects. This commitment brought everyone together as a team, focusing on the "safe to build, safe to use", philosophy. In accordance with this philosophy, a new Safety Department was created in 1999 within LTA's Contracts and Process Division. This new department brought together 3 distinct sections, namely, Construction Safety, Rail Transit Safety and Road System Safety. The latter two sections formerly constituted LTA's Safety Assurance Department that focussed on the "safe to use" aspect of the total philosophy.

Also in 1998, an Executive Safety Committee, chaired by LTA's Deputy Chief Executive was formed to set policies and directions relating to construction safety matters. This Committee comprises members from the senior management level of LTA's Projects & Engineering, and Contracts & Process Divisions, while Safety Department provides secretariat and advisory support. The Committee meets quarterly to review contractor's safety performance on all LTA road and rail projects, and to review LTA's safety promotion programmes. The Committee discusses any identified safety concerns and initiates appropriate corrective actions. Implementation of those actions is then monitored by the Committee.

In August 2000, LTA's Deputy Chief Executive issued his "Commitment to Safety". In this he commits LTA's Projects & Engineering and Planning & Transportation Divisions to implementing LTA's Safety Policy to assure safety during the design and construction phases of LTA projects. He commits that they will establish management systems and risk control measures to ensure the safety of the community, employees and contractors.

2.3 LTA's approach to construction safety

While LTA recognized that it is the occupier of the work site (that is, the contractor) who is legally and solely responsible for their workers' safety, LTA, as a developer, takes proactive steps in ensuring its staff and contractors' workers have a safe work environment on the worksites. LTA also wants to ensure that its activities cause minimal disruption to the public and community. To achieve this, LTA works closely with its contractors using an approach towards construction safety that has the following three prongs:

- Engineering.
- Education/Promotion.
- Enforcement.

These three prongs are described in more detail in the following sections.

2.4 Engineering

LTA believes that safety should be considered at source and all risks addressed as far upstream in the design phase as possible. Safety must be considered by designers from the conceptual stage through to final design. The designers must consider how the structures will be constructed, and how they will be maintained when completed. Wherever possible, risk is eliminated or mitigated during the design phase, and only risks that need to be further mitigated are passed downstream to the contractors. During construction, LTA's project managers ensure that the constructed structures meet LTA's stringent safety standards, and oversee the engagement of contractors who are best suited to the specific project. The contractors must further mitigate the identified risks via their construction method statements. Site safety procedures are a vital aspect of accident prevention. Construction Safety Section regularly reviews the method statements submitted by contractors for specific work processes, to ensure that potential risks are identified and proper safeguards are established to eliminate, or mitigate and control them. Downstream in the construction phase, the LTA project teams assist the project managers to ensure that contractors follow safe work procedures and employ competent workers. The workers must be properly trained in safety, and equipment must be properly maintained and the most suitable for the job.

To enhance the safety of the work environment, Construction Safety Section regularly reviews LTA's General Specifications of Contract. New or more stringent safety criteria have been introduced with the aim of compelling contractors to comply with best engineering practices. Among these were the requirement for the use of 110 volt hand-held electrical tools on site (regardless of under or above ground), the requirement for the use of socket outlet assemblies, and the introduction of new standards for lifting operations, all of which contributed to lowering accident and incident rates on NEL.

2.5 Education/Promotion

Education and promotion are used to develop and maintain awareness, among all personnel on all worksites, of the commitment to safety, and the individual's responsibility to support that commitment.

2.5.1 Safety awards

At the direction of the Executive Safety Committee, two reward schemes were introduced in 1999, with the aim of giving recognition to LTA contractors and LTA staff who excel in Safety. The *Annual Safety Award Convention* and the *Construction Staff Safety Award* have been held regularly since, with overwhelming responses.

2.5.2 Safety training

LTA recognizes that safety training and education have a positive impact on safety performance. Starting in 1999, LTA engaged external safety consultants to conduct a safety awareness course. All LTA project staff have now attended this course. Contractor's management and safety personnel have also attended this training course. As a result of this training, project and contractor staff have become more safety conscious and actively involved in handling and sharing safety issues on sites. To complement this training, site-based training on specific topics such as "Safe Lifting Operations" and "Falling from Height" was conducted by Construction Safety Section in 2001. Positive feedback has been received from participants. In 2002, Construction Safety Section took over the role of training from the external consultants, and continued to provide quality and professional training to the project teams.

2.5.3 Information and knowledge sharing

Information and knowledge sharing are important for maintaining and increasing safety awareness. Avenues that have been established within LTA for information and knowledge sharing on construction safety are as follows:

a. Safety Mini-workshop
   A forum where speakers from various projects are invited to share with the rest of the project staff on construction safety issues encountered during design and construction. Such workshops enhance the knowledge of LTA staff and reinforce their commitment towards safety.

b. Construction Safety News
   An internal newsletter is published on a quarterly basis, to educate and promote Occupational Safety and Health (OSH) to LTA staff and contractors. This publication is also distributed to selected professionals within the construction industry.

c. Legislative Updates
   Safety Department updates the project teams on OSH matters (e.g. MOM circulars) regularly through internal e-mail. This is to ensure that everybody is kept within the loop concerning changes in legislation or other OSH matters.

d. LTA Safety Intranet Web-page
   LTA Safety Department maintains an Intranet Web-page to share OSH related information with staff.

e. Safety Information System (SITS)
   A computerised database is maintained that tracks all accidents and incidents on-site. The SITS allows LTA to analyse accident and incident causation and statistical data, and take corporate wide corrective action.

f. Safety Videos
   Safety Department regularly sources for relevant safety videos to distribute to project teams for their knowledge and awareness.

g. Annual Construction Safety Performance Report
   An annual report is produced which outlines statistical performance on every project, a breakdown of accident information into different types, root causes etc, and suggestions for improvement.

2.6 Enforcement

Enforcement is used to ensure compliance with statutory requirements, and in-house rules and regulations. The objective is that obligations and responsibilities with respect to safety are understood and perpetuated.

LTA site management conducts formal site safety inspections jointly with the Contractor's Registered Safety Officer and sub-contractor representatives. These inspections are called Planned General

Inspections (PGIs). The purpose of the inspections is to identify any OSH shortcomings arising from the site activities and to advise on the necessary action to rectify these shortcomings. Various levels of LTA project staff diligently carry out the PGIs, and have put in a concerted effort to ensure that safe work practices and conditions are well established and maintained on the worksites. To reinforce LTA's total commitment to safety, Project Directors conduct 6-monthly Safety Tours and Senior Project Managers conduct 3-monthly Safety Reviews. In driving home the message of safety, LTA's Project Directors and Senior Project Managers not only cover their own sites during the inspections but also take pains to explain and share with contractors the lessons learnt from all recent accidents and incidents on other LTA's sites. The frequency of site safety inspections is shown in Table 1.

Table 1. Frequency of Site Safety Inspections by Type

Type	Frequency	By
Safety Tour	6-Monthly	Project Director
Safety Review	3-Monthly	Senior Project Manager
Planned General Inspections	Monthly	Project Manager
	Weekly	Senior Project Engineer

2.6.1 Thematic Exercises and Safety Audits

Thematic Exercises involve staff from Safety Department and the LTA project teams, together with the contractor's personnel, inspecting the worksite focussing on a chosen theme (e.g. falling from heights and falling objects, excavations, lifting operations, etc). At the end of each Thematic Exercise, the shortcomings of each individual contractor are highlighted for rectification. LTA Safety Department also extends the findings of each Thematic Exercise to other LTA contractors and project teams. Similarly, Safety Audits of contractor's work procedures are conducted regularly. These audits check that the contractor's field operations match their written policies and procedures. The audit findings, together with any recommendations for improvement, are disseminated to all relevant parties. The Thematic Exercises and Safety Audits have increased the safety knowledge of LTA staff, and reinforced our staff's and contractors' commitment to safety.

2.7 The results of LTA's approach to construction safety

As can be seen in Table 2, the above three-prong approach contributed to a significant improvement in the Accident Frequency Rate (AFR) for NEL in 2001, and in the Accident Severity Rate (ASR) for NEL in both 2000 and 2001. Similar improvements were also achieved for other LTA projects in year 2001, when an increased number of Thematic Exercises, Safety Audits and Safety Mini-workshops raised the level of safety awareness of LTA staff and contractors. In year 2001, both the NEL AFR and ASR were also lower than the national average of 2.8 and 405 respectively.

Table 2. Safety Indices for NEL from 1998 to 2001

Index	1998	1999	2000	2001
Accident Frequency Rate	4.09	4.92	5.32	2.62
Accident Severity Rate	586	738	101	41

3 RAIL SYSTEM SAFETY

3.1 Self-certification strategy

The Land Transport Authority (LTA) is an unusual organisation in that it not only acts as Singapore's land transport system developer but also as its regulator. LTA recognised the need to have a systematic and structured approach to assuring the safety of the land transport system, and to have rigorous checks and balances on its system safety assessments. To address these requirements, work commenced on the development of a self-certification, or Project Safety Review (PSR), process in 1996. The PSR process was formally implemented in 2000.

The PSR process for rail systems requires the demonstration of project safety by two separate parties, namely the system developer and the appointed operator. The system developer is required to

demonstrate that it has adequate commitments and resources to manage safety effectively, and that the system is designed and constructed to achieve a high level of safety. The system operator must demonstrate that it has the necessary organisational structure and processes in place to operate and maintain the system to an acceptable level of safety.

The PSR process for rail systems involves four main roles, namely those of reviewer, submitter, auditor and endorser or arbitrator. For the demonstration of system safety, LTA's Systems Assurance Department plays the dual role of reviewer/submitter. It reviews and collates all the necessary safety assessments and evidence, and submits its Safety Submission for audit. While Systems Assurance Department gathers and presents its case on behalf of the system developer, it also has to review all the evidence from an independent perspective and convince itself before making the safety assertion. The operator must also arrange for a review of its own readiness and make a Safety Submission to LTA.

LTA's Safety Department acts as the auditor to verify that the assertions made in the Safety Submissions are substantiated, and highlight any further tasks or evidence necessary to support the submissions. Upon completion of the audit, Safety Department will recommend to PSR Committee (RTS) that it either endorse or reject the Safety Submission.

The role of PSR Committee (RTS) is to either endorse or reject the Safety Submissions. It will also deliberate and attempt to resolve any disagreement between the submitter and Safety Department. If necessary, the Committee can also appoint a Technical Working Group (independent of the particular project under deliberation) to assist in resolving technical disagreements.

This framework provides confidence that the safety aspects of the system are handled in a systematic and structured manner, and also ensures that effective checks and balances are incorporated into the process (Lim 2000). Figure 1 shows the review process for Safety Submissions.

3.2 Safety Submissions

The fundamental element of PSR is the Safety Submission, through which the system developer and operator demonstrate safety at each phase of the project. The Safety Submissions for rail projects have been divided into four phases, namely Concept, Design, Handover and Operation. The Concept Safety Submission aims to demonstrate that the conceptual design of the system is acceptably safe, and the Design Safety Submission that the system design can achieve the level of safety intended at the concept stage. The Handover Safety Submission must demonstrate that the system has been successfully tested and commissioned to achieve the intended level of safety, and is thus ready to be handed over to the operator for trial running. The operator completes the cycle with the Operation Safety Submission.

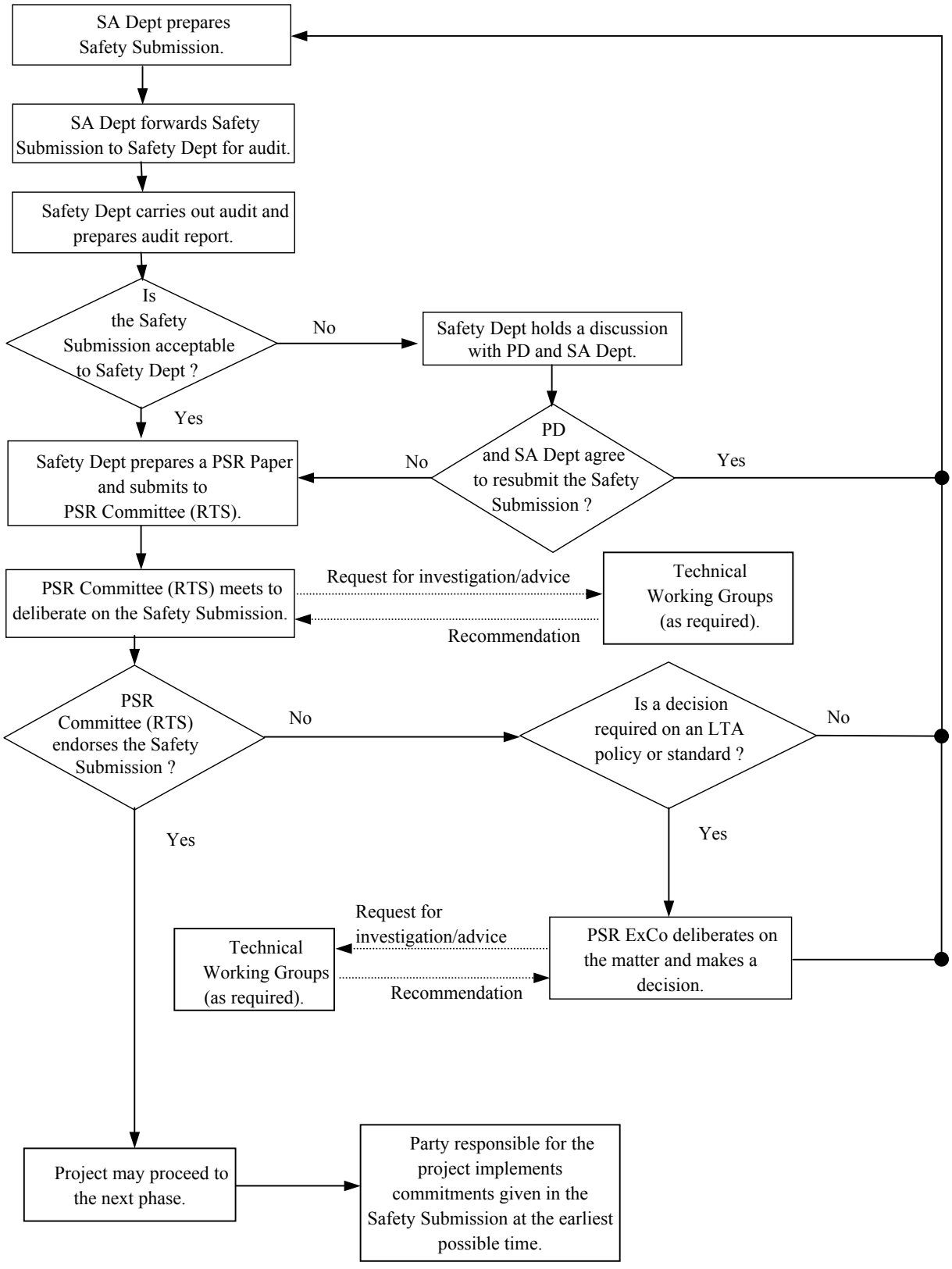
Safety Submissions are similar in structure to a "Safety Case" (European Prestandard ENV50129:1998), and specific guidelines for their preparation and content are provided in the Procedure Manual for PSR For Rapid Transit System Projects (Land Transport Authority 2001). The intention is for the Safety Submissions to adequately address and emphasize certain minimum requirements for safety assessments and evidence, as highlighted in the checklist provided for each phase in the Manual. This is to avoid "Safety Cases" that are too broad and argumentative.

3.2.1 Concept Safety Submission (CSS)

From the very beginning of a project, a clear safety plan is necessary to demonstrate that a robust and sufficient framework and set of processes are available to execute the various safety tasks effectively. Other issues to be addressed in the CSS are the system safety targets, adoption of safety principles and the preliminary hazards study. The preliminary hazards study addresses the major safety concerns and these are then translated into design requirements.

3.2.2 Design Safety Submission (DSS)

At this stage, the various system disciplines, such as signalling, rolling stock, communications and control, are subject to thorough hazard studies. Hazards identified through various analyses, such as



Dept	- Department	PSR	- Project Safety Review
ExCo	- Executive Committee	RTS	- Rapid Transit System
PD	- Project Director	SA	- Systems Assurance

Figure 1. Review process for Safety Submissions

Interface Hazard Analysis and Sub-System Hazard Analysis, are managed and recorded using a hazard log. Those hazards that can be mitigated or eliminated by design verification or compliance to recognised standards or legislation are closed-out at this stage. However, most hazards require not only design verification but also validation tests before they can be closed-out and these have to be accounted for at the testing or Handover Stage.

While addressing each of the identified hazards individually satisfies the basic requirement of hazard control, it is equally important, if not more so, that we know the combinations of the individual hazards that can result in major accident events. A common methodology used for this at the integrated system level is Fault Tree Analysis (FTA). This top-down approach used at the integrated system level provides a useful understanding of the possible combinations of lower-level events or hazards associated with various systems that can lead to major accident events (Roland et al. 1990). It is through this understanding that the designer is guided in deciding the necessary mitigation measures. It is also through this understanding that LTA, as a regulator, can have confidence that the system has structurally identified and addressed the possible accident events and minimised potential gaps in the hazard analyses.

3.2.3 Handover Safety Submission (HSS)

The HSS is the last step for the system developer (LTA) to demonstrate that the system has achieved its intended level of safety. Hazards that require test validations are closed-out at this stage. Since the role of the operator is separate from that of the system developer, hazards transferred to the appointed operator are reviewed to ensure that they can be effectively mitigated through procedural and maintenance controls.

One requirement at the design stage is that a testing and commissioning plan be devised to validate the system functionality and system performance against the specifications, and to satisfactorily close-out hazards. At the testing and commissioning stage, the plan must be satisfactorily carried out, and most importantly, those tests identified as safety-critical, either at an individual system level or at the integrated system level, must be successfully completed.

3.2.4 Operation Safety Submission (OSS)

It is most important that the appointed operator demonstrate to LTA that it has an effective Safety Management System (SMS) in place to operate and maintain the system safely. The PSR Procedure Manual provides a list of items as guidance to what is expected in the SMS. Some of these items are as follows:

a. Safety policy and organisation.
b. Safety performance target and monitoring.
c. Training.
d. Maintaining staff competency.
e. Communication of safety information.
f. Risk assessment criteria.
g. Hazard identification and control.
h. Modification control.
i. Emergency preparedness.
j. Security.
k. Incident/accident management.
l. External contractor safety.
m. Purchasing.
n. Community safety awareness.

The operator must have an appropriate organisational structure and effective processes to implement the SMS. The requirements of the SMS must be communicated to, and implemented at, the division, department and section levels.

The operator must show that it understands and has addressed the operational assumptions, restrictions and recommendations set out in the HSS. It also needs to demonstrate that those hazards transferred

from the system developer have been effectively addressed either through operational or maintenance control.

While the system developer has conducted various hazard analyses, the operator must also conduct its own Operation and Support Hazard Analysis. It is from this analysis, together with the hazards transferred from the system developer, and the Operation and Maintenance Manuals, that the operator should devise a well coordinated trial running programme. The trial running programme must be conducted under strict compliance with the operating rules and procedures. Various scenarios and incidents are subject to simulation in this programme in order to test the emergency preparedness of the staff and the correctness of procedures. The operator must also demonstrate to LTA that the trial running programme will provide staff with a sufficiently high level of operations and maintenance familiarity, such that it is ready for passenger service.

3.3 Implementation of PSR on NEL

By the time PSR was formally implemented, NEL was well into its construction phase. As such, the full rigour of the PSR process could not be applied as it was too late to prepare a Concept Safety Submission (CSS). In order to demonstrate the system's safety properties, a Design Safety Submission (DSS) was produced.

The DSS was probably the most rigorous and arduous stage of the PSR process for NEL because it was not only necessary to demonstrate the achievement of the design safety based on individual system assessments but also to retrospectively show how the system was conceived with safety interests inherent. In other words, it was necessary to show that at the concept stage, safety aspects, including the safety management framework and system safety requirements, were properly considered.

Plans covering aspects such as the structured project safety set-up, safety tasks, and robust hazard identification and management processes were also addressed and audited to ensure their effective execution during the design stage. Clear mapping of the applicable safety principles to the system design was highlighted, and their respective validation tests checked during the audit. While the hazard log tracked all the identified hazards and their status, the audit process also focused on the demonstration that the system developer clearly understood the contributors to major accidents, and that particular attention was paid to their mitigation.

The HSS was produced to demonstrate that the tests, especially the safety-critical ones, were successfully completed and that hazards requiring test validation were closed-out. Checks were also made to ensure that those hazards transferred to the operator were appropriate for operational and maintenance control.

At this time, the OSS from the operator has not been submitted as the project has just reached its Handover Stage. However, it is observed that the operator's participation from the design stage and through the testing period has allowed significant knowledge transfer between the system developer and the operator in terms of system familiarity, understanding of operational principles and restrictions, and hands-on training. Regular safety meetings between the operator and LTA were conducted and these were essential to iron out safety issues before handover. It is also through these regular meetings that the operator can instil confidence in LTA that it is progressing on the right track to achieve operational readiness.

3.4 Lessons learned from the implementation of PSR on NEL

3.4.1 Standard approach across various systems for risk modeling

PSR encourages an integrated system level understanding of the combination of lower-level events or hazards from various sub-systems. If the complete integrated system including signalling, rolling stock, communications, etc. is undertaken by one organisation, it is likely that one single risk modeling approach will be adopted. However, when different systems or elements are awarded to different contractors, extra attention must be paid to how the risk modeling approach is planned from the early concept stage. Different approaches by the various system contractors in demonstrating the

achievement of safety targets will make the development of an integrated system model much harder. For example, a rolling stock system FTA/safety target demonstration might be based on direct contributions by the sub-systems failures, while another such as signalling might be based on the contribution of the main events associated with the sub-systems.

3.4.2 Risk Matrix Application

In a project such as NEL, which involves various separate contractors, the application of a set of standard risk matrix tables is important to prevent potential disparities in risk assessment. This will also be important for future extensions of existing systems.

3.4.3 Operator's Involvement

The system operator's involvement in the early stages of the design process and hazard identification is crucial in developing a system that meets the user's needs. The operator will be more aware of the system principles and operational restrictions, and this generates a smoother transition in terms of operation and maintenance familiarity from the system developer to the operator.

Being involved in the installation and testing process provided the operator with hands-on training during the project development stage, and also allowed the operator to generate effective rules and procedures to run the system in an efficient and safe manner.

3.4.4 Improvements To The PSR Process

Implementation of the PSR process on NEL has helped identify certain areas where PSR can be improved. The PSR process has to be a balanced one, that is, the PSR Procedure Manual should not be too prescriptive in its requirements for evidence of safety but, at the same time, it must ensure that certain safety assessments are consistently addressed. Thus, the approach taken has been to evaluate alternative safety demonstrations and not to impose one particular methodology.

Though the PSR Procedure Manual does provide checklists for the submitter to address certain minimum assessments, one thing that is very clear is that the Safety Submission is not just a collection of documents. It has to be supported by the necessary findings, evaluations and strong assertions for certain safety aspects. It must contain enough information to provide a clear impression of the achievement of system safety.

The PSR process for rapid transit system projects has just passed its infancy, and it must continue to be reviewed in tandem with the development of future projects and changing needs, in order for it to remain relevant and effective. The introduction of PSR has been a successful first step in LTA's implementation of its safety self-certification process. The application on NEL has shown that the PSR process provides a structured, transparent and traceable demonstration of safety, both by the system developer and the operator.

4 ROAD SYSTEM SAFETY

4.1 Introduction

PSR for road projects has the same basic principles as PSR for rail projects but there are some differences in the details of the application. For major road projects, PSR requires Safety Submissions at the following three stages:

- Preliminary Design.
- Detailed Design.
- Post-construction.

Safety Submissions are also required for temporary traffic schemes implemented during the construction phase, where the temporary scheme (including minor variations on the same scheme) will be in place for nine months or longer.

The NEL project included the construction or reconstruction of a number of major roads, including:

- Construction of Sengkang East Road (from Buangkok Drive to Sengkang East Avenue).

- Construction of Sengkang Central (from Buangkok Drive to Compassvale Drive).
- Construction of a dual two lane viaduct along Upper Serangoon Road (from Upper Aljunied Road to Hillside Drive), including at-grade improvements and an underpass for Braddell Road/Bartley Road.
- Realignment of Race Course Road (from Bukit Timah Road to Rangoon Road).

As mentioned earlier, NEL was well into construction at the time that PSR was formally introduced, and as such the Safety Submissions made for roads constructed as part of the project were limited to the following:
- Detailed Design (Race Course Road).
- Post-construction (Sengkang Central, Upper Serangoon Road viaduct, and Race Course Road).

4.2 The PSR process for road projects

For road projects without significant electrical or mechanical systems, the Safety Submissions consist largely of a safety review undertaken by an independent and appropriately qualified person or persons, and a response by the designer and/or constructor to the issues raised in the safety review.

The safety reviewers conduct site inspections and examine in detail all relevant drawings and documentation. The objective of the review is to identify potential safety hazards for road users and other affected parties, and to ensure that measures to eliminate or reduce the hazards are considered fully. The safety review only considers operational safety, and is not intended to be a design check or to cover issues such as structural safety. The review team must consider the following:

a. Have the various standards been applied in a way that maximises safety?
b. Do departures from the standards create unacceptable safety hazards?
c. Have all the permitted movements of the various road users been catered for in a safe way?
d. Are the appropriate operational and control mechanisms in place to promote safety?
e. Will the road facilitate an acceptable level of safety for users in all situations (for example, in poor weather or in the dark)?
f. Can the road be maintained safely?

The safety reviewers must consider all interfaces between the project and the existing road system, and works proposed or under construction on adjoining or nearby sites.

For each hazard identified the safety reviewers must provide:

a. A brief description of the accident types that they consider may result.
b. A risk assessment of the hazard based on an estimate of the accident frequency and an estimate of the likely severity, taking into account a pessimistic but reasonable assessment of consequences.
c. A recommendation of appropriate measures to eliminate or reduce the hazard.
d. An indication of the practicability of the recommendation.

On receiving the safety review report, the designer and/or constructor must prepare a written response that:

a. Indicates whether each safety hazard and its associated risk category are accepted as valid.
b. In relation to each recommendation indicates whether the designer and/or constructor proposes to:
    - implement the recommendation; or
    - implement an alternative; or
    - take no action.

The LTA project team is required to review and endorse the response, and then submit it, together with the safety review report, to Safety Department. Safety Department undertakes an independent review, and prepares a report for PSR Committee (Roads) that recommends either that the Safety Submission be endorsed, that it be endorsed subject to certain conditions, or that it be rejected. If any major policy issues are involved then the issue can be referred to PSR Executive Committee for a decision. PSR Committee (Roads) is chaired by the LTA Director for Contracts and Process, and the members are the LTA Senior Managers for design, transportation, systems and road construction, and

the manager of LTA Safety Department. PSR Executive Committee is chaired by the LTA Chief Executive or Deputy Chief Executive.

4.3 PSR for roads constructed as part of the NEL project

The Safety Submissions for Race Course Road and Sengkang Central did not raise any major issues. Issues raised for Sengkang Central were generally easy to address, and included:

a. Trees obscuring directional signs.
b. Vegetation restricting visibility of pedestrians.
c. Open drains close to the road that needed to be covered.

Race Course Road is a gently curved, dual two lane road with a narrow centre divider, and considerable pedestrian activity is expected once development along the road is completed. Outcomes from the Detailed Design Safety Submission for Race Course Road included:

a. Closure of a break in the central median to convert an unsignalised cross intersection to a safer left-in, left-out arrangement.
b. Provision of kerb-side parking along one side of the road as a traffic calming measure.
c. A slight reduction in traffic lane widths, and a corresponding increase in the central median width to improve safety for pedestrians crossing the road.

These changes were easily made at the detailed design stage. The Post-construction Safety Submission for Race course Road raised similar minor issues to that for Sengkang Central.

The Upper Serangoon Road viaduct was the most complex and extensive road project constructed as part of the NEL project. It is therefore not surprising that the Post-construction Safety Submission for the viaduct raised the most significant issues, including the following:

a. Short weaving distance at the southern end of the viaduct.
b. Various aspects of the parapet wall design for the viaduct.
c. Drainage for the viaduct.
d. Emergency cross-over gate design for the viaduct.
e. Visibility issues for right-turning traffic at-grade due to the viaduct columns.
f. Issues related to traffic signal lantern placement and intersection line-marking.
g. Issues related to at-grade guard-rail arrangements.

It was possible to address most of these issues satisfactorily. However it was considered that issues a. and d. could not be practicably addressed at the post-construction stage. If these issues had been identified at the design stage it is likely that design solutions could have been identified and implemented. This emphasises that identification of safety issues at the preliminary design and detailed design stages provides the greatest opportunity for solutions to be developed with minimum impact on cost and schedule. Unfortunately this was not possible for NEL due to the project timing. The post-construction stage should preferably be restricted to ensuring that mitigation measures identified at earlier stages have been properly implemented, and identifying any other issues that were not apparent from the design drawings.

5 CONCLUSION

For the NEL project, LTA implemented a Safety Management System encompassing construction safety, rail system safety and road system safety. It was a total Safety Management System, reflecting the philosophy of “safe to build and safe to use”.

While the contractors are legally and solely responsible for their workers safety, LTA takes a proactive approach to ensuring that its staff and the contractor’s workers have a safe work environment on the worksites. This proactive approach has three prongs, namely Engineering, Education/Promotion and Enforcement, and contributed to a significant improvement in the Accident Frequency Rate and Accident Severity Rate for NEL. In 2002 MOM awarded LTA a Letter of Commendation (Developer Award) in recognition of its effort and contribution to the good safety performance of its projects.

As part of its total Safety Management System, LTA also recognised the need to have a structured and systematic approach to assuring the safety of the users of the land transport system and others affected by it. Because LTA is both developer and regulator, rigorous checks and balances are needed on its safety assessments. The PSR process was developed to address these requirements. Although NEL was well into its construction phase before PSR was formally implemented, it has still been subjected to a structured, transparent and traceable demonstration of safety. There is confidence that the project has inherent safety values, and that the system operator will be fully equipped and competent to operate and maintain the system safely and effectively. The PSR process also covered the roads constructed as part of the NEL project. The late implementation on NEL highlighted that safety issues are best identified at the design stage, when there is the greatest opportunity to develop solutions with minimum impact on project cost and schedule.

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