

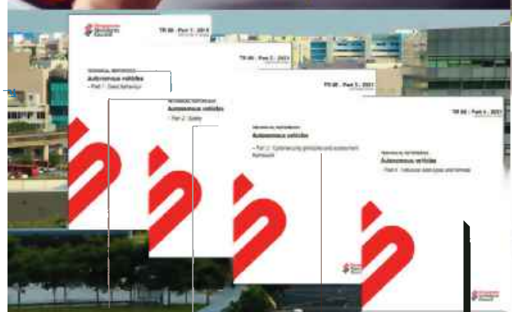



The Institution of Engineers, Singapore

Transport Resource Manual

Volume 3





Transport System Manual

Volume 3

Transport Resource Manual Volume 3

Foreword

“Singapore has come a long way in terms of transportation. Engineering fuelled the nation towards modernisation of the various means of transport. With the sector evolving rapidly towards becoming a Smart Nation, there will be more complex challenges in the road ahead. ”

Dr Richard Kwok
President
The Institution of Engineers, Singapore

As the national society of engineers in Singapore, we strive to advance the field of engineering through knowledge-sharing and capability-building in the various cluster committees under our care. The Institution of Engineers, Singapore (IES) has also spearheaded many initiatives to improve engineering competencies across various fields and industries.

One such example is the ground-up initiative to set up a Technical Committee on Railway Systems, under the national standardisation programme administered by Enterprise Singapore. In close partnership with the Land Transport Authority and the public transport operators (i.e., SMRT and SBST), railway practitioners from the industry and academia came together to discuss and deliberate on existing gaps and how national standards can address them.

Such initiatives serve a higher purpose – to facilitate growth of the engineering sector, improve interoperability, and improve resource efficiency.

Singapore has come a long way in terms of transportation. Engineering fuelled the nation towards modernisation of the various means of transport. With the sector evolving rapidly towards becoming a Smart Nation, there will be more complex challenges in the road ahead.

To address these challenges holistically, a new Transportation Standards Committee will be set up to provide strategic direction for standardisation efforts that would complement regulatory policies and the industry's masterplans.

This new Transportation Standards Committee will house the existing Technical Committee on Railway Systems, Technical Committee on Automotive and a new Technical Committee on Intelligent Transport Systems. The transportation sector enters a new milestone with the amalgamation of these three Technical Committees which will enhance synergy and harmonisation in its standardisation efforts.

This commemorative book, Transport Resource Manual, provides a good introduction of Singapore's transportation system. It touches on the development of intelligent transport systems, automotive technology such as electric and autonomous vehicles, and also various initiatives on traffic management system to enhance safety of our road users and design considerations. It will serve as a rich resource for transportation development and future standards.

Finally, I am pleased to share that IES has been appointed the secretariat of the Transportation Standards Committee – a fitting affirmation to commemorate our 55th year of engineering excellence this year.

I would like to record my appreciation to Enterprise Singapore and the Singapore Standards Council for the support, and look forward to more collaboration ahead.

Message

Ms Choy Sauw Kook
Director-General
Enterprise Singapore

"These standards will enable innovative product owners and system integrators to incorporate reliability, safety and even international best practices into their solutions. "

As Singapore transforms into an increasingly interconnected city, the role of quality and standards in ensuring trusted and reliable transportation becomes even more critical. Standards enable a reliable and safe commuting experience for all passengers by harmonising the requirements, specifications and guidelines to enhance system interoperability, product quality and service consistency.

The Singapore Standards Council (SSC) facilitates the development, promotion and review of standards and technical references in Singapore, under the national standardisation programme overseen by Enterprise Singapore. It also facilitates Singapore's participation in the development of ISO and IEC standards. The SSC currently comprises 11 Standards Committees (SCs), whose key role is to provide strategic leadership to their respective Technical Committees (TCs) to develop and promote standards in the various industry sectors.

Due to the growing demand for new standards to support Singapore's Land Transport Masterplan, we are adding the new Transportation SC which will oversee the TC on Automotive and the TC on Railway Systems. A new TC on Intelligent Transport Systems will also be set up under this SC to explore potential areas of standardisation as the sector continues to evolve with emerging mobility concepts and new technologies. These standards will enable innovative product owners and system integrators to incorporate reliability, safety and even international best practices into their solutions for an intelligent, sustainable and a well-connected transport network.

This Manual offers key information on automotive vehicles and intelligent transport systems. I believe that it will be a useful reference for our standards partners and engineers.

I thank IES and our standards partners for your pioneering work in standards development and look forward to working together to improve overall productivity, innovation and safety for the sector.

Message

Mr Ng Lang
Chief Executive Officer
Land Transport Authority

> "We are shaping our urban mobility to join humanity's march into a greener world."

We are stepping into the exciting world of future mobility. Worldwide, major car manufacturers are stepping up production of electric vehicles and experimentation of cleaner energy vehicles. In Singapore, we have also committed to phasing out internal combustion engine vehicles by 2040 and cease their sales as early as 2030. In public transport, even as we are working on completing the Thomson-East Coast MRT Line by 2026, we have embarked on constructing two more new lines – the Jurong Region Line and the Cross Island Line. At the same time, we are building an island-wide network of cycling lanes.

With these, we are shaping our urban mobility to join humanity's march into a greener world. Walk, cycle and take public transport if you can. If you choose to drive, drive an electric car or a cleaner energy vehicle. However, an urban transformation of this scale is anything but easy. There is a range of challenges to look into, from upgrading urban infrastructure, to introducing new regulation, to developing supporting technology and industry, and upskilling human resource capability.

This Transport Resource Manual is an apt commemorative publication to mark the formation of the new Transportation Standards Committee. Published during this interesting time of transition, it captures both the old and new worlds, and the challenges involved in setting standards during this period. While it covers the fundamentals of current automobile technology, it also offers a glimpse at our intelligent transport systems, electric vehicles, autonomous vehicles, and what lies ahead for us. For anyone interested in the automobile industry, it is an enriching reference.

I take the opportunity to extend my best wishes to the new Transportation Standards Committee. I wish to express our appreciation to the Singapore Standards Council, Enterprise Singapore, and the Institution of Engineers, Singapore for their support in putting the Committee together.

Message

Mr Neo Kian Hong
Group Chief Executive Officer
SMRT Corporation

"I look forward to raising the capabilities and competitiveness of the transport sector with all these new initiatives, and encourage all who are already on this standardisation journey, to soldier on. "

SMRT has been involved with railway standards since the initiative was launched in 2019. It is important that we, as the pioneer railway operator, are in sync with and contribute to national standards in this aspect.

I am excited to learn that a new Transportation Standards Committee will be set up, which aims to enhance collaboration between three Technical Committees, on: Railway Systems, Automotive and Intelligent Transport Systems.

As a multi-modal public transport operator which provides rapid transit, bus and taxi services, standards are vital to sustain optimal levels of reliability, safety and productivity, and bring our development and growth to the next level.

But we need to balance economics with the environment. With the uptick in vehicle electrification and greener transport modes, SMRT is converting our taxi fleet to be fully electric within the next five years. Three of our bus services are already electric, and we are piloting on-demand autonomous buses. This is part of our growth strategy to be more sustainable.

Automotive standards, such as Technical Reference 25 on electric vehicle charging system, and Technical Reference 68 on Autonomous Vehicles would be useful for the industry. The Transport Resource Manual would also serve as good base material for engineers.

I look forward to raising the capabilities and competitiveness of the transport sector with all these new initiatives, and encourage all who are already on this standardisation journey, to soldier on.

Message

In a densely populated country with limited land space like ours, the need for smart solutions in managing public transportation challenges is a pressing one and this will become more acute with time.

Our land transport industry focuses on efficiency, reliability and safety - not just only for the passengers whom we serve but also the people who work tirelessly to deliver our public transport services. As a member of the Technical Committee on Railway Systems, SBS Transit is honoured to have contributed towards developing the industry's railway standards for effective operations and maintenance in support of these goals.

As a multi-modal operator in bus and train as well as taxi through our parent company, ComfortDelGro, we see integration between the different modes of transportation as key. We have a robust rapid transit system and a comprehensive bus and taxi network, which we note are increasingly supported by intelligent transport infrastructure.

Digital and electric technology will be the future of public transportation. Hence, we will continue to explore and invest efforts in sustainable energy, integrated urban mobility and smart mobility technologies, while the Authorities continue with their programme to replace the entire fleet of public buses with green energy ones by 2040.

We believe all these efforts count towards making our passengers' experience more pleasant, intuitive, inclusive and definitely more sustainable. The industry will scale up even more with the introduction and implementation of transport-related standards going forward.

The public transport industry is a growing one and those who are keen on or are considering a meaningful career in this sector will find the Transport Resource Manual valuable in offering insights. The Manual will also serve as a good reference for transport professionals. As a leading Public Transport Operator, SBS Transit is honoured and privileged to be a part of this journey.

Mr Cheng Siak Kian
Chief Executive Officer
SBS Transit

"We believe all these efforts count towards making our passengers' experience more pleasant, intuitive, inclusive and definitely more sustainable."

Message

Mr Chew Men Leong
President, Urban Solutions
ST Engineering

“In tandem with the transformation in the urban mobility landscape, transportation standards will likewise need to evolve to stay current.”

As a homegrown global technology, defence and engineering group, ST Engineering has always been a part of Singapore’s land transport landscape. We have grown alongside, and contributed to the advancement of the industry with our innovative technology and engineering capabilities.

Through our corporate history, our suite of land transport offerings have evolved, first in response to global trends such as urbanisation, and later in anticipation of changing demands in light of Industry 4.0 and sustainability drives. Today, our Smart Mobility portfolio encompasses an extensive range of rail electronics, intelligent road traffic management, electric and autonomous vehicle solutions that help cities around the world address some of their key mobility challenges.

In tandem with the transformation in the urban mobility landscape, transportation standards will likewise need to evolve to stay current. We are honoured to contribute our insights to the advancement of Singapore’s transportation standards, which are documented in this commemorative Transport Resource Manual.

The manual provides a good introduction of Singapore’s transport system and covers recent developments such as electric vehicles, autonomous vehicles, intelligent transport systems and traffic management initiatives that improve road safety. We believe the manual will serve as a valuable resource for engineers and innovators across the entire mobility value chain, in helping them set new benchmarks that will redefine the future of mobility.

Our heartiest congratulations to IES on the successful launch of the Transport Resource Manual.

Message

In an era where borders and physical parameters are increasingly blurred due to the easy availability of online communication, there are multiple opportunities for cross-border learning and global collaboration.

We believe in preparing our students to be industry-ready, apart from academic rigour. While we have the integrated work study programme where students are given an early taste of the workforce, we also strive to bring the industry into our classrooms as much as possible.

The Singapore Institute of Technology is currently involved in the Technical Committee on Railway Systems, under the national standardisation programme. Through our participation, we keep our Sustainable Infrastructure Engineering (Land) programme current on the latest technology, regulations, and practices.

Standardisation plays a key role in our economy, in improving quality, productivity and safety. Educators have a collective responsibility to build up the capabilities of the future workforce. Equipping our students with the knowledge of standardisation and best practices—both international and local—will enable them to be future-ready. In doing so, we are nurturing the next generation of engineers who will be able to add value to employers.

I am heartened to see standardisation efforts streamlined, through the formation of the new Transportation Standards Committee. There will be greater cooperation, coordination and collaboration, with the Technical Committees on Railway Systems, Automotive and Intelligent Transport Systems housed together.

I look forward to introducing the industry's standards into our academic programmes.

Prof Tan Thiam Soon
President
Singapore Institute of Technology

> "Standardisation plays a key role in our economy, in improving quality, productivity and safety."

Transport Resource Manual Volume 3

Traffic Management and Road Safety

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Preface

The development of the road network that connects all corners of the island facilitates the movement of cars, buses, goods vehicles, pedestrians and active mobility users. It is important to ensure the safety of the road network and efficiency of the traffic flow with increasing road users sharing the road environment. Traffic analysis and design tools coupled with effective traffic management strategies are adopted for road network development to meet the demand and allow for smooth manoeuvring. Emerging technologies and various Intelligent Transport Systems are also harnessed to maximise road network efficiency and capacity as well as monitor performance and manage traffic flow.

Safety is well-considered in the design, operation and maintenance phases of the road system for the safe travel of the road users. While practically applying technical guidelines, the designer needs to exercise sound judgement and relevant experience of the interaction and behaviour of all road users to develop a safe to use road system. To ensure safe operation of the road, there are real-time round the clock traffic monitoring and incident management on the expressways and road tunnels leveraging on the Intelligent Transport Systems by the Operation Control Centres. Regular inspection and maintenance of the roads with timely rectification work are carried out. This approach helps to ensure functionality of the road and meet public expectations with lower safety risks to road users.

Safety scheme and features such as Silver Zone, School Zone, Green Man Plus signal and Give Way to Pedestrians sign are implemented on the road network to enhance the safety of pedestrians, especially elderly and children, being the vulnerable road users.

On top of Engineering measures, multi-pronged approach of road safety education, driver licensing, public safety awareness engagement and enforcement have been adopted by the Singapore Road Safety Council and Traffic Police as part of the safe system strategies to enhance road safety.

This document provides an overview of the traffic management and road safety for the road development. It includes information on the design, operation and maintenance aspects of the road and active mobility infrastructures. It also shares the road safety programs and brief enforcement measures conducted.

Section 1

Overview of Road Development in Singapore

1. Overview of Road Development in Singapore

In the early days, Public Works Department (PWD) was in-charge of building and managing the public roads besides the other public infrastructures including bridges, carparks, sewage systems, housing, libraries and even bus shelters in Singapore.

The 1980s saw the completion of several major transport infrastructure projects inked in the first Concept Plan in 1971, such as the first expressways that provided faster island wide connectivity such as the Bukit Timah Expressway (completed in 1986) which connects the Pan Island Expressway (completed in 1981) at Bukit Timah to the Woodlands Causeway. The rest of the expressways were completed at various milestones from 1981 when East Coast Parkway (ECP) was completed till 2013 with the opening of the Marina Coastal Expressway. The expressways were built to link residents in growing satellite towns to their workplaces and the Central Business District.

Since the inception of Land Transport Authority (LTA) on 1 September 1995, the land transport network of Singapore has transformed significantly. Singapore’s road network connects all corners of the island with more than 9,000 land-km of roads and expressways. LTA has also developed an MRT network of more than 200km, 120km of cycling paths and increasingly varied commuting options. LTA builds, manages and maintains this extensive network and infrastructure. With roads already occupying 12 per cent of our total land area, LTA takes into account the projected growth in both existing and future areas to plan road use carefully. Existing roads are upgraded to improve reliability and connectivity, and new connections are created to serve growing communities. LTA also manages vehicle ownership and road usage to ensure that the traffic flows smoothly and efficiently on the roads.

To achieve the vision of a car-lite nation, LTA prioritise movement for the masses, with priority lanes for buses and efforts to improve first-and-last-mile connectivity to our public transport hubs.

The comprehensive land transport network and infrastructure continue to grow and improve, to achieve the vision for a reliable and people-centred land transport system and make commuting more efficient and exploring more enjoyable.

Singapore is a built-up city state with limited land space. It is thus important to provide a road transport infrastructure that is safe, efficient and cost effective for motorists, Active Mobility users, pedestrians and commuters. This is facilitated through continual review, design and implementation of traffic management schemes and road safety engineering programmes, and proper management and maintenance regime of commuter, road-related facilities and infrastructures.

Section 2

Overview of Traffic Management

Author:

Chan Hua Kiat   Land Transport Authority

2. Overview of Traffic Management

2.1 Introduction

Land transportation is looked at in totality, involving cars, public transports, goods vehicles, pedestrians and active mobility users. The emphasis is improving the overall system on moving people and goods, and not just vehicles. It is therefore important to improve on the interaction and coordination among three main players, namely road user, vehicle and road network in order to improve the road safety and efficiency of traffic flow

Intelligent Transport Systems

Across the island, over a 160km network of expressways and road tunnels, hundreds of gadgets, sensors and cameras gather data on traffic flow, travelling times and road demand to give you the information that helps you make decisions on how you get to places.

Collectively called the Intelligent Transport Systems (ITS), this web of data collection technologies forms a dynamic, real-time picture of the ebb and flow of a population moving through their daily lives. ITS uses the sensors, traffic and control systems, and data analytics, to maximise road network efficiency and capacity, to monitor and manage traffic flow, and make our roads safer.

The vision, key strategies and focal areas of ITS is set out in the Smart Mobility 2030 master plan, a roadmap jointly developed by LTA and the Intelligent Transportation Society. The goal of this plan is to meet transport challenges in a systematic and coordinated manner for smarter urban mobility in the future.

2.2 Singapore Experiences in Traffic Management

Implementation of Traffic Signals along Major Arterial Roads

The road network in Singapore has a gridiron pattern with closely spaced junctions. It is necessary to install traffic signals at the major junctions to regulate traffic flows when traffic flow increases. When traffic signals at closely- spaced junctions work in an uncoordinated pattern, motorists would encounter a lot of stop-go congestion. This causes traffic delay, increase in fuel consumption and emission of carbon. To overcome this problem is to link the operations of these signals so that vehicle can proceed from junction to junction with minimum or no stop.

In the early 1980s, about 180 traffic signals installed in the city area were connected to a central computer, which provided instructions to the signals. The whole central area was subdivided into 11 regions and an Area Traffic Control Centre (ATC) was set up to manage and monitor the system. Traffic speeds within the controlled area in 1982 increased as much as 20% as a result of reduction in the number of stops at junctions. It was estimated that the system, which cost about S$10 million in 1981 paid for itself within 2 years based on 30% savings in fuel consumption. Another advantage of the central control is that traffic signal faults were automatically detected by the central computer as soon as they occurred. This improved the response and recovery times in traffic signal maintenance to minimise downtime of traffic signals.

To catch up with changes in traffic condition due to rapid infrastructure development in Singapore, the area traffic control system was upgraded to a traffic-adaptive system, GLIDE (i.e., Green Link Determining System) in 1988. The GLIDE system detects traffic flow in real time and works out the required cycle times, allocate green times and works out the required offsets to provide linking between junctions automatically to meet the dynamic changes in the traffic condition. After implementation, traffic monitoring showed that the speed increased by a further 4%.
Currently, more than 2000 sets of our traffic lights are controlled by the computerized area control traffic light system (GLIDE) that is adaptive and able to provide linking between signalized junctions to give motorists a “Green Wave” as they proceed from junction to junction consecutively. This helps to reduce the numbers of stops and delays at traffic junctions, hence improves on fuel consumptions and reduction in carbon emission.

Our strategy for traffic signal control is to minimize delays to motorists when traffic flow is low and equalize the delays when traffic flow is saturated. This means that we target to keep the waiting time of the motorists at junctions to the minimum during off-peak hours, and to distribute the green times equally to all motorists during peak hours like the morning and evening peak hours.

Along road corridors that have a few closely spaced signalized junctions, we adjust the off-set of the traffic signal timings to allow motorists to catch the “Green Wave” when they passed consecutive junctions. The GLIDE system also provides priority for emergency vehicles such as fire engines/ambulances, and public transports like buses

<u>Implementation of Advance Traffic Management System on Expressways</u>

About 55% of average daily traffic flow in Singapore is on expressways. Any incidents such as vehicle breakdown and traffic accident can cause a rapid built up of traffic and eventually lead to congestion on the expressways if not responded to promptly. The first Intelligent Transport System (ITS) implemented on the expressways was the installation of SOS phones in mid 1980s to allow motorists in distress to call for assistance. In 1991, a central control room was set up to monitor our first expressway tunnels, the CTE Tunnel of a total length of 2.4km.

Surveillance of traffic flow and detection of incident were carried out by the detection cameras using virtual loops. CCTVs were used to monitor traffic and find out the cause of congestion. Tow truck was then sent to remove stalled vehicle and traffic police will be notified to carry out accident investigation.

The control room was expanded to monitor all the expressways in the mid 90s using an Advance Traffic Management System (ATMS) called the Expressway Monitoring and Advisory System (EMAS). The detection cameras with virtual loops were also extended to count traffic and determine vehicle occupancy. The information can be used to obtain traffic counts, measure speeds and detect congestion. Variable Message Signs (VMS) located strategically along the expressways provide traffic and incident information to motorists. Besides improving road safety on expressways, the information allows motorists to make more informed decision on the choice of routes.

With the enhanced incident detection capability, the average response time of our towing crew was about 9 mins and the recovery operations (other than accidents that involved injury) took about an average of 8 mins. To improve on the accident clearance time, traffic marshals who are Auxiliary Police Officers (APO), empowered to carry out On-Scene Management duties such as evidence preservations for minor accident are deployed. The traffic marshals partner with towing crew in handling incident significantly improved our incident management capability.

On our highways/expressways, the EMAS is an intelligent incident management tool that monitors traffic and manage incidents on our 160km length of expressways including road tunnels. More than 1100 surveillance and detection cameras are used to assist in traffic surveillance, incident detection and verification. The incident detection function has been computerized to compliment the monitoring work carried out in the Operations Control Centre (OCC). A traffic alert will be sent to the operators in the OCC automatically upon detection of an incident. The operator will then use the surveillance camera to verify the traffic alert and implement the appropriate incident management plans to manage the incident until the end of the incident, and the recovery of traffic condition back to its normal state.

The EMAS also serves as a mean to disseminate traffic and incident information to motorists via the electronic message signboards strategically located along expressways and roads leading to the expressways. Besides enhancing road safety, the timely information also enables motorists to make more informed decision on the choice of routes available, and more importantly assisting us in managing congestions on incident road.

In the above two cases, Singapore had ensured that basic traffic schemes were put in place before embarking on any ITS programmes. In the case of traffic signal control, required lane markings and signs were implemented so that vehicles formed up accordingly when approaching the junctions. This is important because motorists must exercise proper lane discipline for an effective operation of the traffic signals.

The other important factor of an effective traffic management is to get all traffic and enforcement authorities to agree on their roles in traffic control and management. The engineering authority's roles are to implement traffic engineering schemes and institute controls, and the traffic police's role is to enforce traffic regulations, carry out accident investigation and educate motorists on good driving behaviours. The Traffic Police will also be consulted during the design stage of some of the traffic schemes for their advice and inputs. This is because if the police takes over the control of traffic movement and bypass the ITS equipment too often, the effectiveness of the ITS in traffic management will be diluted.

Managing Congestion at Car Parks' Entrance and Reducing Circulating Traffic

To manage the congestion at car parks' entrances and circulating traffic to look for alternate parking space, a Parking Guidance System (PGS) was introduced. Motorists can be informed of the availability of parking lots in parking facilities near to them when they approach their destinations. The PGS has successfully helped to reduce the queueing outside car parks when they are fully occupied and reduces the cruising time of motorists in search for parking lots. This in turn reduce potential congestion at these areas and improves on fuel consumptions as well as reduction in carbon emission.

Integrating Various ITS for More Efficient Traffic Management

To enable data transfers and efficient traffic monitoring & control via a single common platform, Singapore had integrated the various ITS into an integrated and centralized IT platform called the i-Transport system. This IT platform also enables the monitoring of the condition of road tunnels (including Kallang Paya Lebar Expressway (KPE), the Southeast Asia longest underground expressway).

Island-wide traffic data and information are gathered via detector loops, detection cameras and in-vehicle GPS devices. These enable good measures of traffic condition on the road network that include the traffic volumes, speed, travel times, etc.

These traffic data are pumped into the i-Transport system whereby it collates and further processes them for operations and disseminations to the motorists. Besides through EMAS signboards, the traffic information such as traffic speeds, travel times and incident information are also made available to motorists via the internet website (www.onemotoring.com.sg). Real-time traffic situations are also disseminated to motorists through the nation-wide radio broadcasts.

Moved from System-based Traffic Operations to Area-based Traffic Operations

With the integration of various ITS via the i-Transport system, our traffic operations has moved from system-based to area-based traffic monitoring and incident management. The road network is delineated into 5 areas or zones with each zone consists of part of the expressways network and the arterial roads system. Very often, an incident on an expressway will have impact on its adjacent arterial roads and/or the nearby road network. With the common i-Transport control platform, the operators in the OCC can monitor the interactions of the expressways and arterial roads traffic and implement the incident response plans for both the road network concurrently.

For incident site management, there are dedicated teams of vehicle recovery crews including traffic marshals on active standby at strategic locations so that they can respond to any incident on the expressways swiftly round the clocks. The recovery crew and traffic marshals have high performance standards of responding to all incidents upon activation, and to clear the incident site after they arrived at the incident locations.

The whole operations of the traffic monitoring and incident management are carried out in an OCC at the LTA Intelligent Transport Systems Centre (ITS Centre). Close coordination exists with other emergency response agencies such as the Traffic Police and Singapore Civil Defence Force (SCDF), particularly in major incident management. Traffic information also flows seamlessly among different agencies such as sharing of cameras images with the Police and SCDF.

Congestion Control

In Singapore, we have by and large managed to avoid city-wide gridlocks to maintain relatively smooth-flowing traffic. This is due in no small part to COE and ERP. They each have a different role to play.

The ERP follows a pay-as-you-use principle for congested roads at peak hours. This optimises our transport networks as motorists have the choice of considering alternative routes or travel times, or even change their mode of transport. It's fair as those who do not add to the public costs of congestion are not charged.

Without ERP as a congestion charge, there would be heavy traffic leading to loss of productive time and unnecessary fuel burnt for motorists. Pollution levels would also be higher and it would impact pedestrians and other road users. The urban environment would be a much less pleasant one.

Singapore's use of road pricing has been so successful in easing the gridlock on heavily used roads that it serves as a benchmark for cities like London and Stockholm.

A two-pronged approach

The COE and ERP systems work in tandem to ensure smoother traffic flow and a more pleasant environment for all residents in Singapore. Having the COE keeps overall demand for road space under control, while ERP reduces traffic jams. Together, they offer an effective traffic management strategy.

COE

The COE quota system helps to keep the overall vehicle population at levels supportable by planned public transport developments and road infrastructure. Land scarcity is the main issue-roads already take up about 12% of our total land area, compared to 14% for housing. Building more roads is not a long-term solution.

Without the COE system, more people will buy cars, and this will add to congestion and pollution. More extensive road pricing would then have to be the main solution to managing traffic, leading to higher costs, especially for businesses in the Central Business District. More land would also be needed for parking spaces across the island, which would in turn mean less land for parks and public spaces.

Maintaining the COE system helps to conserve Singapore's environment, from our green spaces to better air quality, and keeps road usage costs manageable.

ERP

To help keep our roads congestion-free, besides regulating vehicle growth and promoting the use of public transport, Electronic Road Pricing (ERP) is also an important tool. Road pricing was first implemented in the form of the Area Licensing System in 1975, which levied a flat charge on all vehicles entering the Central Business District (CBD). In 1998, this was replaced by the ERP system, which leverages on technology to allow for a more effective and flexible method of congestion charging. The Radio Frequency Identification (RFID) technology used also allows for the automatic collection of a congestion fee from any vehicle passing under a ERP gantry during its operating hours.

Purpose & Effectiveness

The ERP system provides a targeted solution for congestion pricing. It allows us to pinpoint specific congested spots and vary the congestion charge and operating hours according to prevailing traffic conditions. Therefore, the charges will either increase or decrease according to congestion levels on the priced-road or expressway. As charges are levied on a per-use basis, the negative externalities of road congestion caused by road users can be accounted for, and the objective is to encourage road users to use public transport, or other routes and travel timings.

Since its introduction, the ERP system has been effective in managing traffic congestion and keeping traffic speeds within the optimal range.

Traffic Speed Measurement Method

Since July 2008, LTA has applied the 85th percentile speed measurement method instead of average (mean) speeds to determine whether ERP rate changes are necessary.

This revision was made as the minimum average speed thresholds (45 km/h on expressways and 20 km/h on arterial roads) set in 1998 were too low and traffic could easily slip into the unstable zone where 'stop-start' conditions became common. To create a sufficient buffer, the 85th percentile speed measurement method was adopted as it was assessed to be more representative of actual traffic conditions. It is also in line with international traffic engineering practices for assessing traffic conditions. With this, 85% of motorists will experience speeds above the minimum threshold.

Next Generation ERP System

While the current ERP technology has served Singapore well, we need to look ahead and develop an even more effective and responsive system to manage congestion - one that is less costly to build and maintain, more space-efficient and requires a shorter lead time to implement compared to the current gantry-based system.

The next-generation ERP system (ERP2) makes use of advanced technologies to provide more flexibility in managing traffic congestion. It will allow distance-based road pricing, where motorists are charged according to the distance travelled on congested roads. This will be more equitable than the current system, which charges all motorists the same amount as long as they pass a gantry, regardless of the distance they travel on the congested road.

In addition, ERP2 will offer exciting new opportunities for LTA and its industry partners to develop value-added services for the benefit of motorists, such as traffic advisories and parking availability information on the new On-Board Unit that will replace the existing In-Vehicle Unit (IU).

Section 3

Overview of Road Safety

Authors:

Dr Koh Puay Ping Land Transport Authority

Ding Woon Keong Land Transport Authority

3. Overview of Road Safety

3.1 Overview of Road Accident and Fatality Rate in Singapore

Singapore road safety level has improved over the years. Besides the decrease in accident fatality numbers (decrease from 195 in 2011 to 107 in 2021), fatality rates (normalised by key national figures such as human and vehicle populations) in general are also on decreasing trends. Based on the past 10 years (2011 to 2021), Figure 3.1 and Figure 3.2 show the fatality rates per 100,000 population and 10,000 vehicle population have decreased by 48% and 46% respectively.

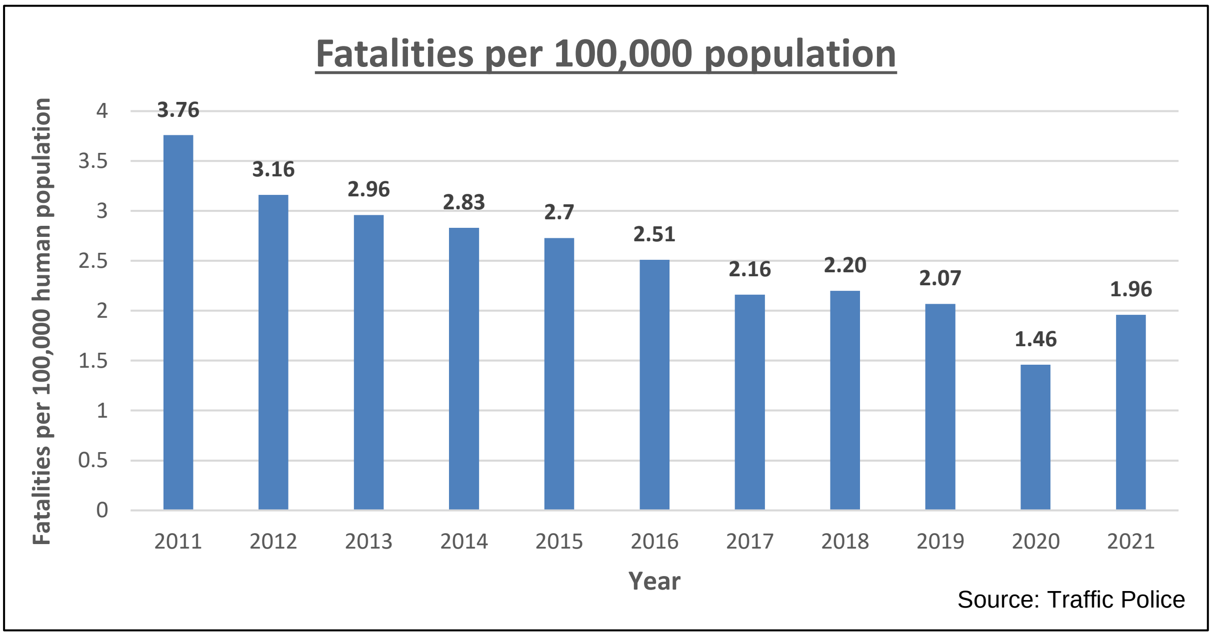

Figure 3.1: Fatalities/100,000 population between 2011 and 2021

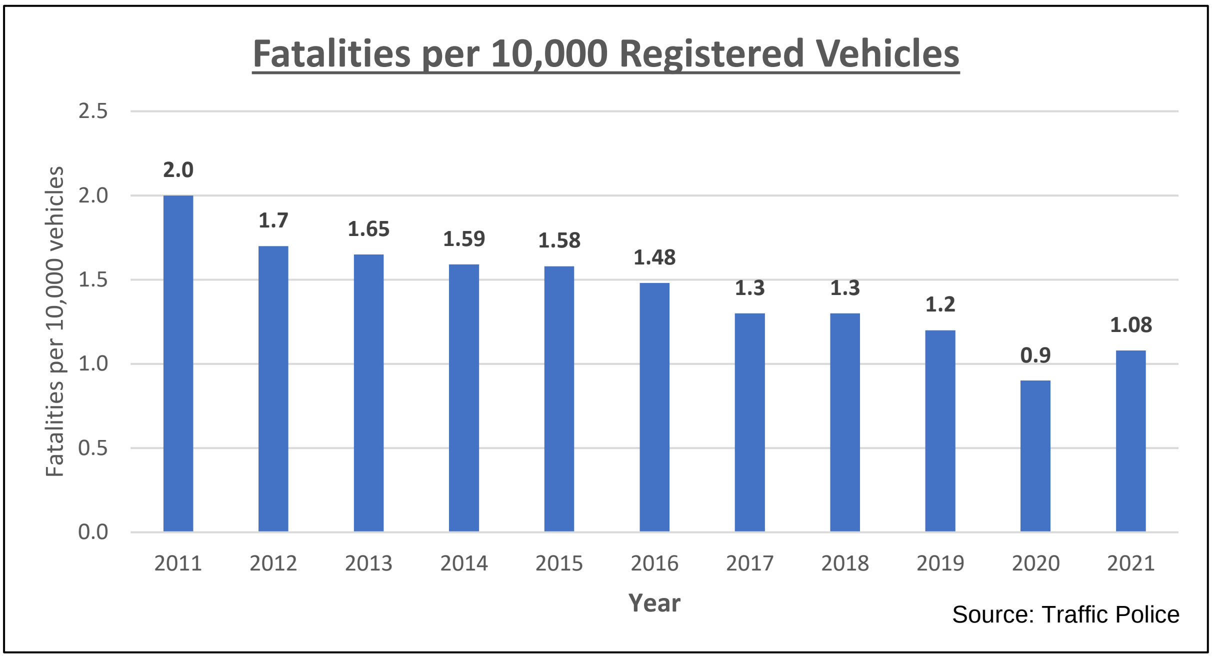

Figure 3.2: Fatalities/10,000 registered vehicles between 2011 and 2021

In 2021, there were 100 fatal and 5,909 injury accidents that resulted in 107 fatal and 7,184 injured casualties. Motorcyclists and pillion riders make up 57.1% of overall traffic accidents and 46.7% of traffic fatalities in 2021. Fatal accidents involving elderly pedestrians accounted for more than 65% of fatal accidents involving pedestrians in 2021.

3.2 Adopting a Safe System Approach in road safety management

Over the past few decades, Singapore has been adopting the Safe System Approach (Austroads, 2021), embarking on the 4-pronged efforts: Engineering, Education, Enforcement and Emergency Preparedness, to curb and mitigate road traffic accidents. The Land Transport Authority together with Traffic Police have work hand-in-hand with other key stakeholders to inculcate a shared responsibility in everyone in the transport system. LTA provides a safe physical road network for road users, while TP enforces traffic regulations with public education. In addition to the efforts made by the government, LTA and TP partner with other non-government organisations such as the Singapore Road Safety Council (SRSC) to educate and promote road safety.

Accidents occurred due to a variety of reasons including human, road environmental and vehicle factors. While vehicle safety is covered in the Transport Resource Manual Volume 1 (Automotive technology and standard), this Volume 3 focuses on providing a safer road infrastructure and dealing with human factors. Human factors contribute to close to 90% of the accidents that have occurred. It is important to study how human interacts with the road system, in order to effectively reduce the number of accidents occurring. Both proactive and reactive approaches should be put in place to ensure road safety quality along the roads. Proactive measure includes a non-accident-based methodology that applies the human factor's principles in road design to identify infrastructure deficiencies or potentially risky situations and select countermeasures to prevent accidents. Misleading and/or unexpected road features are often the causes of driver's mistakes leading to accidents. The psychological and physiological threshold values of human abilities also play an important role in accident causation. On the other hand, reactive targeted at accident reduction based off historical accident records and trends. The identification of accident triggers allows a more effective choice of the most appropriate safety countermeasures.

The safe system approach targets to accept that humans are fallible, and mistakes are inevitable but these mistakes should not result in injuries so serious that the victims die on the way to or in the hospital. We should ensure that eliminating serious injuries and fatalities on our roadways is wholly compatible with other transportation goals of system efficiency and access and we should plan for all users, influence policy, anticipate conflicts, control design and retrofit existing infrastructure for modern use. All parts of the system must be strengthened to multiply their effects, so that if one part fails, road users are still protected.

3.3 Road Safety Initiatives in Singapore

While safety is of paramount importance, there is also a need to have a balance between road safety and traffic efficiency. The LTA implements the world's best practices for road safety management and delivers safe roads to the public, through the planning, implementing and managing of various road safety initiatives. Processes and techniques such as Black Spot Programme, Crash Site Investigation, Road Safety Audits/Reviews and remedial treatment programmes are well established best practices being used.

3.3.1 Black Spot Programme (BSP)

BSP is an accident reduction (reactive) programme that was launched in 2005. In BSP, locations with a high occurrences of traffic injury accidents (at least 10 or more accidents within 3 years) are identified. Engineers are required to conduct desktop study (gathering information: detailed accident reports, cleaning up of the accident data, checking on upcoming projects) and site check, to identify possible mitigating measures that will reduce the number or severity of the similar accidents occurring at these locations.

The Blackspot Programme cycle consists of 5 stages and each stage is elaborated in detail below.

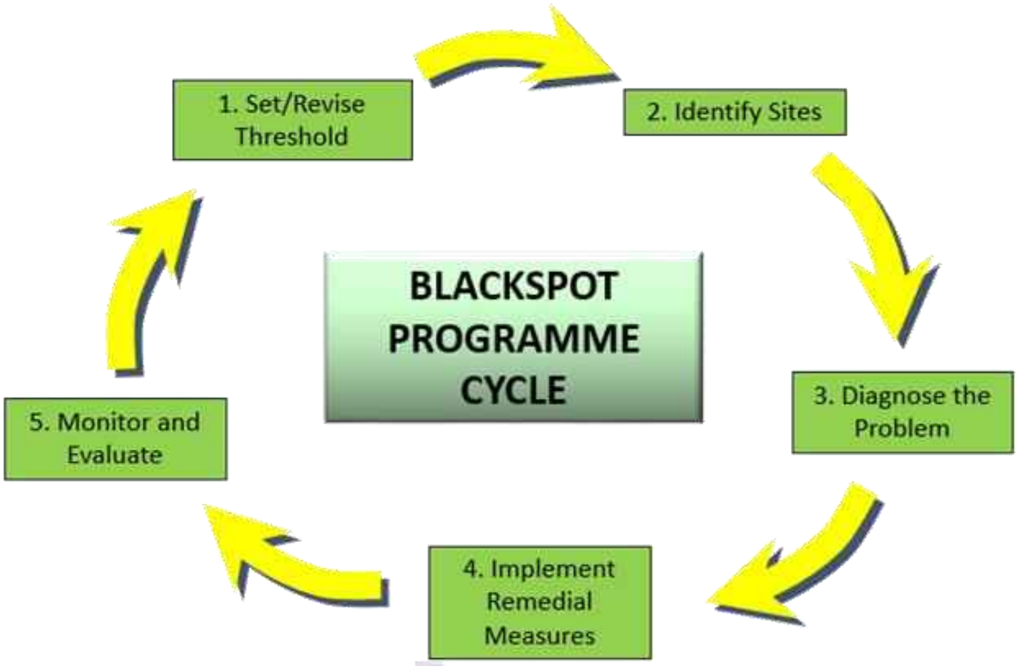

Figure 3.3: The 5 stages of the Black Spot Programme

The 1st stage: Look at all the accidents geographically through an in-house accident application. The types of accident locations are then segregated into junctions/ arterial roads/ expressways. Then, decide on the blackspot size based on area size (junctions) or length of the road (arterial roads or expressways). Lastly, after selecting a period of the last 3 years records, the in-house accident application can be used to generate the list of black spots (locations with more than 10 accidents over 3 years). A targeted black spot assessment can also be done based on accident/road user type or special area (e.g. school zones).

The 2nd stage: A further filtering of the blackspots is done by applying weightage of the accident severity (Fatal/Serious/Slight). This gives priority to locations with higher severity accidents when prioritising the list of blackspots.

The 3rd stage: For each identified black spot, conduct a desktop and site analysis. A collision plan provides a clear picture of the predominant problem(s) at the location, so that improvement measure(s) and resources can be better targeted and deployed.

The 4th stage: Identify the main problem and propose improvement measures to reduce the accident numbers. If there are defects to the road infrastructure or sub-standard design flaws, these need to be rectified too, either through internal or external agency.

The 5th stage: Once the proposed scheme is implemented on site, the monitoring period will begin. This will take at least 3 years before the team conducts another post assessment exercise to determine if the result of the scheme. If the result shows an improvement with a significant drop in accident numbers, the black spot can be discharged, if not, it will go for another round by a different team for reassessment.

Many black spot locations have benefited from BSP since its launch. On average, the LTA has successfully treated and removed five to ten locations each year from its list of black spots.

3.3.2 Crash Site Investigation (CSI)

CSI is another accident reduction programme, set up in 1998, that deals with the assessment of fatal traffic accidents. Cases that are excluded are those involving users who are drink driving or under medical conditions. Assigned teams will conduct site checks to identify potential road safety engineering deficiencies, if any, and propose countermeasures to further enhance road safety. Every year, there are over 100 fatal accident cases investigated.

The flow chart here shows the various stages of the CSI programme which is started when the road safety engineer received the brief facts of the fatal accidents from Traffic Police. The respective teams will also bring along a CSI check list during their site checks, to aid in identifying necessary information and observations that could further assist with their assessment of the fatal accident site. Meanwhile, the TP brief report provides detailed information about how the accident unfolded. This would help the team understand the possible accident cause(s) and identify measures to be recommended, in order to mitigate any potential road safety engineering deficiencies.

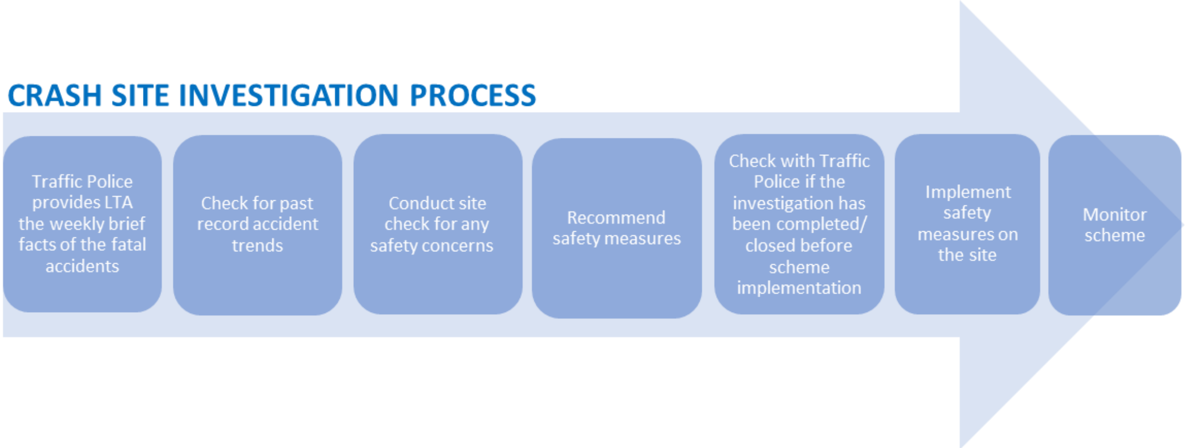

Figure 3.4: Flow chart of various stages in the CSI programme

3.3.3 Targeted Road Safety Initiatives

As revealed in the accident statistics, the top 2 vulnerable road users are motorcyclists and pedestrians, representing 60% and 21% of the road fatalities. Targeted efforts have been made to explore initiatives or schemes that will enhance these two groups of road users.

For motorcyclists, given their vulnerability in the road system (not protected by the vehicle body unlike other motorists), attention focussed on preventing crashes and reducing the severity of the crashes of motorcyclists when they occurred. Hot spots of motorcyclist accidents were studied and many were related to self-skidded accidents at bends. Higher skid resistance materials were paved to minimise skidding accidents. Another effort worth mentioning is the special impact guardrails (Motorcyclist Protection System) that do not have sharp edges like that typical vehicular impact guardrail which might cut the motorcyclists into half when they slide over or underneath them in an accident.

Figure 3.5: Motorcycle Protection System (before and after)

Pedestrians, being the other group of vulnerable road users, are of prioritised concerns. There are many initiatives that have been put in place to further enhance safety of pedestrians. These include raised zebra crossings, warning signages and markings and dedicated signal phasing.

3.3.4 Road Safety Audits/ Reviews

Road safety audit or review is a proactive engineering measure that involves a formal and independent process to audit and treat potential road hazards, targeting to reduce the likelihood of accident occurrences or the severity if an accident occurs.

Safety assessment on all road projects that involved physical change to the road system, and to all projects related to the temporary control of traffic on the road system are carried out under the Project Safety Review (PSR) process. It was introduced in 2000 as part of the LTA's total safety management framework to enhance the safety of road users in new road projects. The purpose of the process is to eliminate safety issues early before project implementation. Under this PSR process, potential safety hazards of the proposed schemes were identified and mitigated or designed out at each stage of the project development lifecycle from planning through design and construction till completion.

During the operational phase of the road system, road safety audit (RSA) is also conducted. Austroads Road Safety Audit (Austroads, 2009) procedure is adopted for RSA program in Singapore. The first RSA on existing roads was carried out on Pioneer Road in 1999. This was then followed by the expressways spanning from 1999 to 2000. Subsequently, assessments of arterial roads were carried out from year 2002 onwards. The roads identified for assessment were prioritized based on speed limit and accident occurrences. Arterial roads with higher speed limit and accident occurrences are assessed first.

During RSA, the auditors walk or drive through the roads as pedestrians and motorists in both directions during day and night to identify the potential hazards. Both general and site–specific observations were reported with recommending measures. The recommended measures are then implemented or addressed with alternate measures if the recommended measures are unable to be implemented due to site constraints.

Section 4

Design, Operation, Maintenance

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4. Design, Operation, Maintenance

4.1 Design

4.1.1 Road Design and Safety Audit

Introduction

LTA is involved in the design development of safe and cost-effective commuter and road schemes that are user-centric as well as community-centric at various stages of the project from planning, preliminary design to final detailed design. This is achieved through Design Thinking Workshops, Value Management Workshops and regular review of the Standard Details of Road Elements.

Definition of Road Design

Road design is a complex task in which judgement and experience play significant roles. Design is the process of selecting and combining appropriate elements that will develop a fit-for-purpose solution. It is an iterative process that requires a designer to exercise their judgement and experience whilst also practically applying accepted technical guidelines and continually evaluating the design to assist in the selection of the appropriate values for the design elements.

All road design is a compromise between the ideal and what is a reasonable solution. It needs to consider the objectives of the project, the objectives of road design and the context of the site. It is essential that designers understand the effects (particularly on safety) of combining limiting values of different design elements under different circumstances.

Factors affecting Road Design

There are three main elements that determine how a road or a design will perform, mainly in terms of safety – vehicle, human and road environment.

Vehicle Factors

There are three broad categories of road network/ path users:

- Motorised vehicles such as trucks, buses, cars and motorcycles
- Non-motorised vehicles or low-powered vehicles such as bicycles, Personal Mobility Device (PMD), Power-Assisted Bicycle (PAB), and Personal Mobility Aid (PMA)
- Without vehicles, that is, pedestrians

Users in the first category influence road design primarily through the characteristics of the vehicles they operate. For convenience, these are often represented by the characteristics of design vehicles. The physical and operating characteristics of vehicles using major roads are important factors in geometric design. The design vehicle is a hypothetical vehicle whose dimensions and operating characteristics are used to establish lane width, intersection layout and road geometry. For most design situations on arterial roads, car is used as the design vehicle for horizontal and vertical geometry, while a prime mover with semi-trailer is used as the design vehicle for cross-section elements and intersections. In some cases, it may be appropriate to consider expected bicycle usage. However, it is important to ensure that roads are designed to cater for commonly used vehicles.

Users in the second and third categories influence road and path design in many ways, but primarily through their two major distinguishing characteristics:

- their vulnerability relative to motorised traffic
- their lower speeds of operation compared to motorised traffic

Because of these characteristics, it may be desirable to provide separate facilities for these users, in the form of footpath, cycling path or shared path on the sidetable, away from the road carriageway. Pedestrians, cyclists and other active mobility users in the second and third categories also require designers to give specific consideration to their needs in crossing motorised traffic flows, at intersections or at mid-block locations as well as at conflict areas like bus stops, cross paths and development gates.

		
Segregation Dedicated footpath to separate pedestrian and vehicle.	Separation (Space) Physical centre divider to provide a refuge for pedestrians to cross the road safely.	Separation (Time) Provision of signalised pedestrian crossing to enable pedestrians to cross the junction safely.

Figure 4.1: Different ways of providing safe facilities for pedestrians, cyclists and active mobility users

Human Factors

Road user behaviour is central to almost all decisions required in the design of roads. The efficient and safe operation of the road system depends greatly on the performance of drivers of vehicles, riders of motorcycles or bicycles, and pedestrians. Common aspects of road user behaviour provide the basis for many design parameters such as speed selection, curve design, and operation of intersections and crossings. An understanding of road user behaviour may assist designers to better understand the basis of standards and guides and hence to produce appropriate designs.

Driving or riding a vehicle involves three essential tasks:

- navigation – trip planning and route following
- guidance – following the road and maintaining a safe path in response to traffic conditions
- control – steering and speed control

These tasks require a vehicle operator to receive inputs (most of which are visual), process them, make predictions about alternative actions and decide which is the most appropriate, execute the actions, and observe their effects through the reception and processing of new information.

Many geometric design standards are influenced by the sensory ability of vehicle operators and pedestrians, in particular, vision and hearing (especially for cyclists and pedestrians). Vibration and sound may be important features to give alerts to users by some types of traffic control devices (e.g. audio-tactile edge lines, rumble strips and level-crossing bells). Visual acuity, colour sensitivity, and peripheral vision are all important to the driving or riding task. Driver visual sensitivity deteriorates in poor light conditions, with aging and with alcohol consumption. Visual recognition takes a finite time and the total response time of drivers has a significant effect on a range of design elements, including sight distance requirements and sign face design.

	
Reinforced lighting provided at tunnel entry portal to enable motorists to adjust to tunnel lighting condition when driving during bright daylight condition.	Anti-glare panels provided along centre divider to reduce glare effect due to vehicle headlight from opposite direction.

Figure 4.2: Examples of vision-related traffic control devices

Physical abilities (other than vision) that are relevant to the driving/riding task relate to vehicle/device control, tracking, curve negotiation, and reaction times. Vehicle operators' physical attributes influence standards and guides relating to elements such as deceleration lane lengths, curvature, lane widths (ability to track) and sight distance (reaction time, eye height).

The behaviour of cyclists and pedestrians, as road users, is potentially subject to greater variation than that of motor vehicle drivers because riding or walking does not require a licence and there are thus no formal lower or upper limits placed on the age or the physical abilities of these road users. Children may be particularly vulnerable as cyclists or pedestrians, having wider variations in cycling stability, cycling or walking speeds and general road sense than is the case for the bulk of adult riders or pedestrians. Equally, the elderly may suffer deterioration in vision, hearing, reaction times and/or walking capabilities that need to be taken into account in road design.

	
Young users: Limited ability to recognise road hazards Make less effective decision Under-estimating accident risk Impulsive Often blocked by physical obstacle or thick foliage	**Elderly users**: Reduced mobility Reduced visual field Decreased motion sensitivity Longer perception-reaction time Poorer judgement of risk

Figure 4.3: Common issues associated with young and elderly users in a road system

Provision for those with physical disabilities, who most often are operating as pedestrians or wheelchair users, also places particular requirements on road design, for example, in relation to footpaths or shared paths, crossing locations and design, and needs for non-visual information transfer (e.g. audio-tactile features at traffic light crossing).

Road Factors

Horizontal and vertical alignment, cross-section, surface conditions and roadside design all impact on operating speeds and safety, and the extent of those impacts must be estimated.

Many characteristics of a road link are already established (e.g. topography, traffic volume and composition), but the geometric form is largely under the control of the designer. The provision of consistent geometric design along roads is an important aspect of road safety. There should certainly be ‘no surprises’ for drivers, such as an isolated sharp curve in a section of road where all other curves have large radii.

This approach leads to the concept of the ‘self-explaining road’, that is, a road whose features tell the driver what type of road it is and therefore what can be expected in terms of the elements of the design. This provides a confidence in expectations for the driver, who then operates the vehicle in accordance with those expectations, which in turn are in tune with the nature of the road.

Geometric Design

General

Roads need to provide for the safe, convenient, effective and efficient movement of persons and goods. The design of roads should be based on the capabilities and behaviour of all road users, including pedestrians, cyclists, motorcyclists, and on the performance and physical characteristics of vehicles (including public transport). At the same time, consideration must also be given to the whole range of economic, social, environmental and other factors that may be involved.

The development of any geometric design will typically involve several iterations before achieving a solution that optimises the design criteria, some of which may be conflicting.

Speed Parameters

One of the first requirements in developing a new geometric design is to establish the appropriate operating speed or speeds to use for design. The speed to be adopted, which typically provides some margin over the proposed posted speed limit, directly influences the principal parameters used in road design which include sight distance, horizontal curve radii, vertical alignment, etc.

The design speed for a road or section of road should not be less than the measured or estimated operating speed. Designers need to ensure that the design speed of every element is either equal to, or greater than, the operating speed on that element at times of light traffic conditions in order to maintain geometric consistency. This means that if the combination of alignment and operating environment cause the operating speed to vary, the design speed may vary accordingly. At the same time, the design must ensure that where drivers have to slow down for a horizontal curve, the speed reduction must be consistent with normal driver capability and expectations. For the design speed based on road classification, please refer to LTA Civil Design Criteria for Road and Rail Transit Systems (CDC) Rev. A2 Cl. 10.3 and Table 10.2.

Horizontal Alignment

Horizontal alignment of a road is usually a series of straights (tangents) and circular curves that may or may not be connected by transition curves. For the general controls of horizontal alignment and the curve radius requirement based on design speed, please refer to LTA CDC Rev. A2 Cl. 10.4.1.1 and Table 10.2 respectively.

The horizontal alignment should generally provide for safe and continuous operation at a uniform travel speed. Sudden reductions in standard, such as isolated curves of small radius (particularly at the end of long straights), introduce an element of surprise to the driver and should be avoided. The result of drivers not recognising the required action for these geometric features greatly increases the chance of a single vehicle accident occurring. The provision of geometric consistency is a fundamental requirement in geometric road design.

The types of horizontal curves are as follow. For the design requirements for each type of the curves, please refer to LTA CDC Rev. A2 Cl. 10.4.2.3.

- Simple curves
- Compound curves
- Reverse curves
- Broken-back curves
- Transition curves

The common safety concerns associated with horizontal alignment are:

- Lack of continuity along kerb line
- Radius incompatible with operating speed limit
- Inadequate / negative superelevation
- Lane width incompatible with horizontal alignment
- Inadequate transition section
- Inadequate visibility / stopping sight distance
- Inadequate lateral offset between carriageway and roadside obstacles
- Inadequate delineation (signs and lane markings)

Before After

Figure 4.4: Poor alignment along kerbline

**Diagrams affixed "Danger Ahead" sign are designs that can be further improved.*

Before After

- Improve stopping sight distance along road bend:
- Remove obstacle along inner radius to enable motorists to see across the road bend

Figure 4.5: Sight distance along horizontal curve

Crossfall

Crossfall is the slope of the surface of a carriageway measured normal to the design line or road centreline. The purpose of crossfall is to drain the carriageway on straights and curves and to provide superelevation on horizontal curves. For the design requirements of crossfall, please refer to LTA CDC Rev. A2 Cl. 10.4.2.4.

Superelevation

On straights, the pavement has normal crossfall to shed water. This crossfall is provided both ways from the centre on undivided roads. On a divided road, each carriageway usually has one-way crossfall away from the median on straight alignments.

A change from normal crossfall to full superelevation occurs as the road changes from a straight to a curved alignment (except where adverse crossfall is adopted), or from a very large curve with adverse crossfall to a lower radius curve.

The length required to develop superelevation should be adequate to ensure a good appearance and give satisfactory riding qualities. The higher the speed or wider the carriageway, the longer the superelevation development will need to be to meet the requirements of appearance and comfort.

The length of superelevation development (L_e) is the transition of crossfall from a normal roadway on straight alignment to that of a fully superelevated crossfall on a circular curve (refer to LTA CDC Rev. A2 Figure 10.5). The total length required to develop superelevation is called the overall length of superelevation development. To calculate the length of L_e, please refer to LTA CDC Rev. A2 Cl. 10.4.2.5.3.

Vertical Alignment

Vertical alignment is the longitudinal profile along the centreline of a road. It is made up of a series of grades and vertical curves. The profile is determined by a consideration of the planning, access, topographic features, geological, design controls, earthworks and other economic aspects. For the general controls of vertical alignment and the longitudinal gradient requirement based on design speed, please refer to LTA CDC Rev. A2 Cl. 10.4.1.2 and Cl. 10.4.3.1.1 respectively.

The vertical curves are usually parabolic in shape and are expressed as a K value. The K value is the vertical curve constant, used to define the size of a parabola. It is the length (m) required for a 1% change of grade.

The level of a road at any point along its route, and therefore its vertical alignment, is usually controlled to a large extent by features that the road passes through. The following are typical controls for vertical geometry:

- existing topography
- geotechnical conditions
- existing intersections
- property entrances
- overpasses and underpasses
- pedestrian accesses
- service utility assets (and their protection requirements)
- median openings
- Vertical clearances, both to objects over the road and to provide cover to objects under the road, are also a vertical control and must be considered for the whole road cross-section. Changes in the following factors can all have a

bearing on the vertical clearance and must be checked for compliance with the relevant clearance standards of the asset owner:
- crossfall or superelevation
- position of road crown

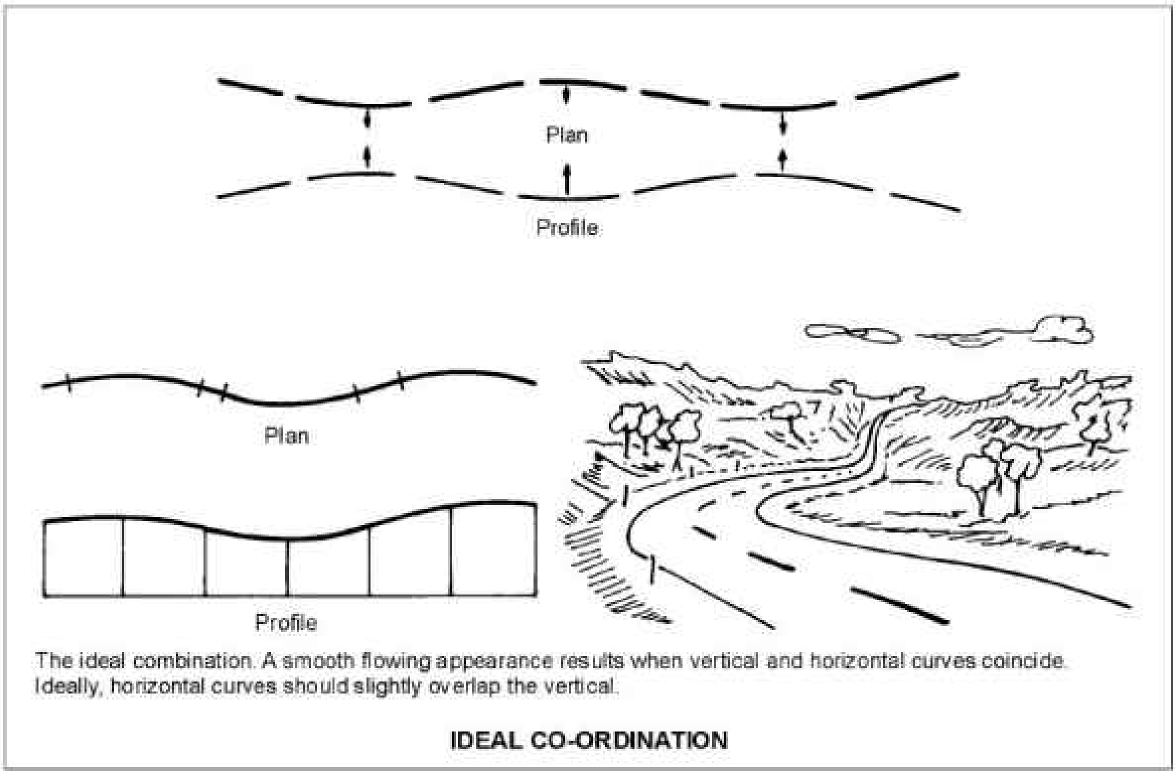
The vertical alignment of a road consists of a series of straight grades joined by vertical curves. In the final design, the vertical alignment should fit into the natural terrain, considering earthworks balance, appearance and the maximum and minimum vertical curvature allowed (expressed as the K value). For the design requirements of crest/sag vertical curve length, please refer to LTA CDC Rev. A2 Cl. 10.4.3.2.

The common safety concerns associated with vertical alignment are:

- Gradient too steep (downgrade / upgrade)
- Limited visibility of road features / conditions beyond crest of vertical curve (pedestrian crossing, side road access, traffic junction, etc.)
- Improper combination of vertical and horizontal alignment
- Vertical curve obstructs visibility of pedestrian crossing mid-block after crest
- Pedestrian overhead bridge constructed to provide safe crossing facility

Before After

Figure 4.6: Sight line over vertical curve



Source: (Guide to Road Design Part 3: Geometric Design, 2021)

Figure 4.7: Combination of Vertical and Horizontal Curves

Sight Distance

Sight distance is defined as the distance, measured along the carriageway, over which visibility occurs between a driver and an object. For the design requirements of different types of sight distance, please refer to LTA CDC Rev. A2 Cl. 10.4.2.2.

For safe and efficient traffic operation on the road, sufficient sight distance must be provided to enable drivers to perceive and react to any hazardous situation. A driver's sight distance should be as long as practicable, but it is often restricted by crest vertical curves and obstructions on horizontal curves and the designer should consider all of these elements when developing the horizontal and vertical geometry of the road.

Traffic Lanes

A traffic lane is that part of the roadway set aside for one-way movement of a single stream of vehicles. The number and width of traffic lanes have a significant influence on the safety, capacity and comfort of driving. The width of traffic lanes may also impact upon the operating speed of the road. For the design requirements of lane width, please refer to LTA CDC Rev. A2 Cl. 10.5.2.

The factors to consider for the width of traffic lanes are:

- Location (junction / mid-block)
- Speed
- Type of vehicles / traffic composition
- Alignment
- Presence of motorcycles / bicycles

When drivers perceive that a fixed hazard or object is too close to the road, they will reduce their speed or place their vehicle away from the hazard within the traffic lane. This offset within the lane is called the shy away distance.

	
Narrow lane width: • Vehicle straddling in-between two lanes • Potential side-swipe collision	Wide lane width: • Vehicles travelling side-by-side within same lane / poor lane discipline • Potential side-swipe collision

Figure 4.8: Substandard Lane widths

- Motorists tend to “shy away” from travelling too close to edge of carriageway / roadside features, e.g. safety barriers (guardrail, parapet wall, etc).
- Adequate lane width / lateral offset required to minimise encroachment onto adjacent lanes

Figure 4.9: Motorists shying away from edge of carriageway / roadside features

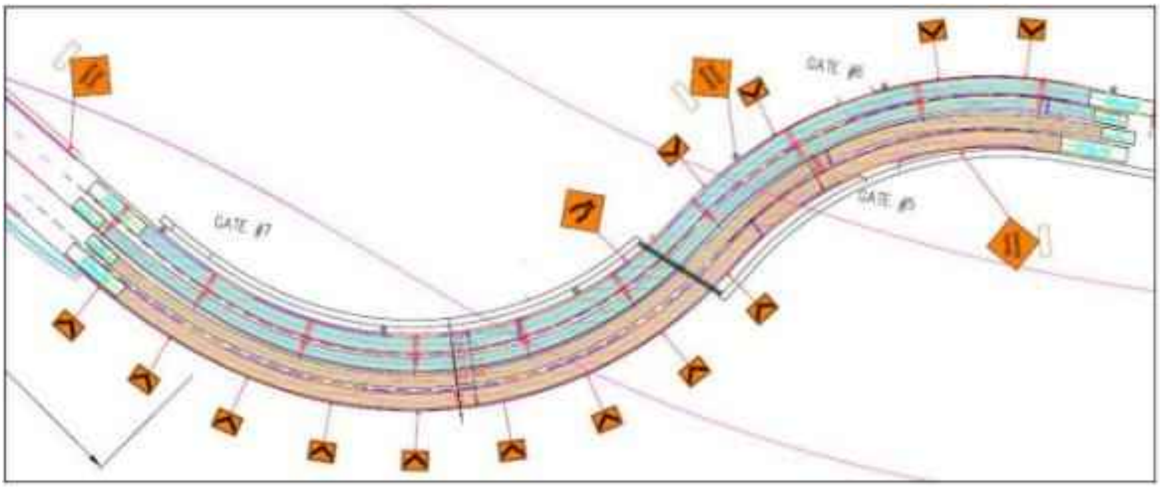


Figure 4.10: Demonstration of sufficient lane width using swept path analysis

- Conduct swept path analysis
- Analysis conducted based on type of vehicle and designed speed
- Verify that vehicles do not encroach onto adjacent lane or veer off the carriageway
- Adjust lane width, physical alignment or posted speed limit accordingly

Road Shoulder

The functions of road shoulder are to:

- Shelter breakdown vehicles
- Provide access for emergency response / maintenance
- Provide recovery area for errant vehicles

- Provide lateral offset from roadside obstacles, e.g. safety barriers (guardrail, parapet wall, etc.)
- Provide adequate Stopping Sight Distance along inner radius of road bends

For the design requirements of road shoulder, please refer to LTA CDC Rev. A2 Cl. 10.5.4.

- No shoulder / limited shoulder width
- Cameras for incident detection
- Provide advance warning through Lane Use Sign (LUS), Variable Message Sign (VMS) to warn motorist to avoid any lane with stalled vehicle ahead
- Despatch vehicle recovery crew to tow away breakdown vehicles
- Access control (close slip road if necessary)

Figure 4.11: Substandard shoulder width

- Bridge > 1.0 km, provide emergency walkway / safe refuge area behind safety barriers
- Breakdown lay-by at 600m interval
- Incident detection & management provision

Figure 4.12: Alternative provisions for bridges without shoulder

Sidetable

The functions of sidetable are to:

- Provide space for installation of road agency infrastructure and furniture such as signs, lamp posts, guide posts and road safety barriers
- Provide space to accommodate infrastructure belonging to other utilities services/agencies such as gas, electricity and water
- Provide space to accommodate commuter infrastructure such as footpath, cycling path, shared path, taxi/PUDO bay, bus bay, etc.

Figure 4.13: Sidetable with adequate width to accommodate various roadside features

Centre Divider

A centre divider is commonly provided to improve the safety and operation of roads with multiple lanes in each direction. Its main functions are to:

- Separate and reduce conflict between opposing traffic flows, effectively reducing the possibility of head-on collisions
- Prevent indiscriminate crossing and turning movements
- Shelter right-turning and crossing vehicles at intersections
- Shelter road furniture and traffic control devices, such as signs, traffic signals and street lighting
- Provide a pedestrian refuge which enables pedestrians to cross the road one carriageway at a time
- Reduce the impact of headlight glare and air turbulence from opposing streams of traffic
- Provide scope for improvement of visual amenity by landscaping
- Accommodate level differences between carriageways
- Provide safety barrier

Drainage

The main functions of drains are to:

- Collect runoff from carriageways and the adjacent cutting and embankment slopes
- Provide the means for containing and draining these waters to points of disposal

Figure 4.14: Use of a drain covered with vehicular grating behind w-beam guardrail to cater for the dynamic deflection of the guardrail when impacted

Figure 4.15: Provision of drainage inlets with gratings that are perpendicular to the direction of travel and smaller gaps in-between the gratings

Safety Audit (Roads)

To ensure road system in Singapore is designed and constructed with a high level of safety for all road users, LTA has implemented the Project Safety Review (PSR) (Safe-To-Use) process for temporary and permanent road projects under LTA's purview since 2000. It is a check-and-balance process which systematically identify and mitigate road safety hazards throughout the various stages of the project lifecycle.

The PSR (Safe-To-Use) process helps to ensure that:

- All parties involved in road development projects have adequate commitments and resources to manage safety effectively
- Projects are designed and constructed to achieve a high level of safety

The diagram below shows the overview of PSR (Safe-To-Use) process for road projects.

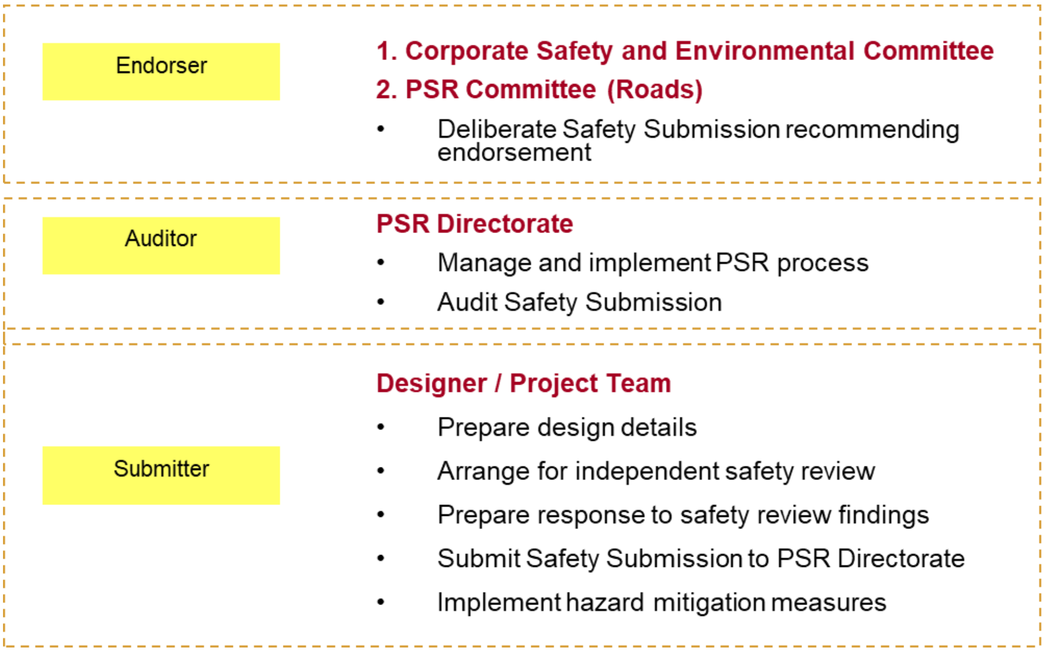


Figure 4.16: Overview of PSR (Safe-To-Use) process for road projects

Safety submissions are the main element of the PSR (Safe-To-Use) process for road projects. In these submissions, project teams must demonstrate or assert that the road project is safe to use for all road users. Safety submissions take place at key milestones in a project's life cycle:

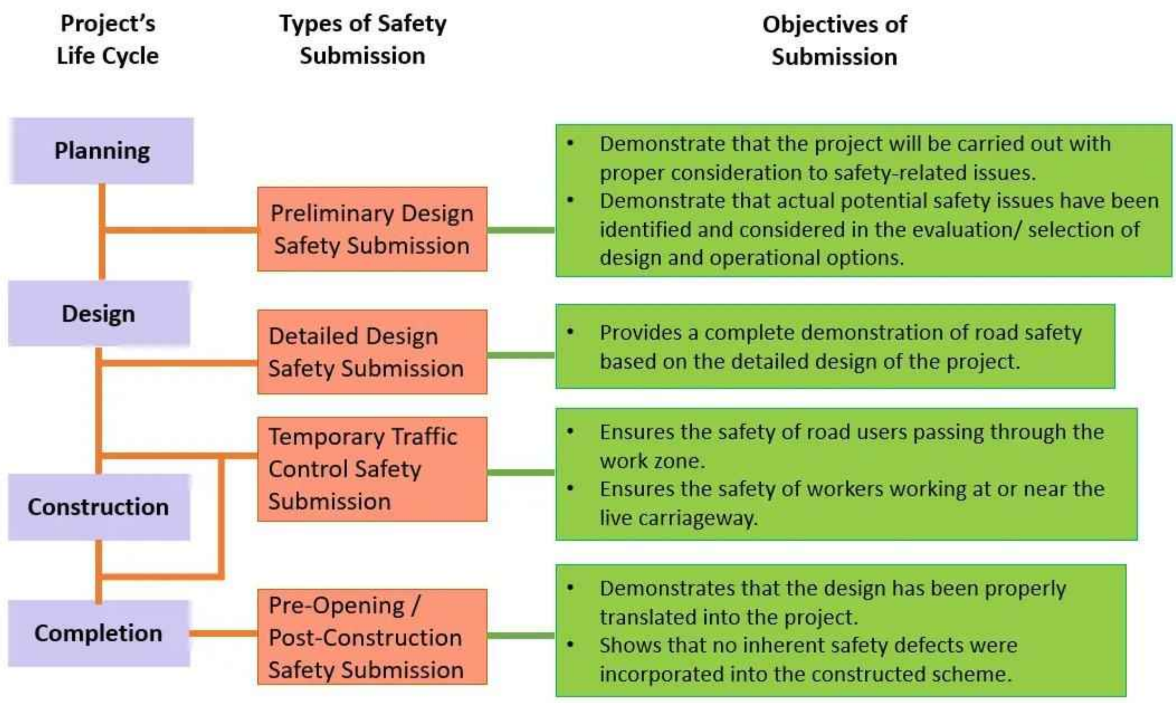


Figure 4.17: Overview of Safety Submissions in a project's life cycle

One of the key documents required for a safety submission is an Independent Safety Review Report. A Safety Review is:

- A formal hazard identification process
- To make an independent assessment of Project Team's assertion that the proposed road system is "safe to use"
- Not a design and structural integrity check

To learn more about safety review and safety submission requirements, please register for road safety training courses at LTA | Road Safety Training Courses.

After a safety submission is made, PSR Directorate from LTA will:

- Check Safety Submission to ensure completeness and compliance to requirements in PSR procedure manual for road projects
- Confirm adequacy of hazard mitigating measures to ensure that all risks identified in safety review report have been reduced to a level as low as reasonably practicable

- If required, provide audit queries to clarify response given in hazard log and/or highlight additional safety hazards

Once all the safety issues have been addressed adequately, PSR Directorate will prepare a PSR paper with a recommendation for PSR Committee (Roads) to endorse the safety submission.

Audit of Road Tunnel

The LTA Project Safety Review Directorate (PSRD) (Rapid Transit System) is responsible for the implementation and management of the PSR process for RTS and road tunnel Electrical & Mechanical (E&M) system projects. The PSRD (RTS) conducts independent audits of safety submissions to ensure that the requirements of the PSR process are fulfilled, and adequate assertions on system and operation safety have been demonstrated at the various stages of the RTS and road tunnel E&M system projects.

PSR process for Road Tunnel Projects

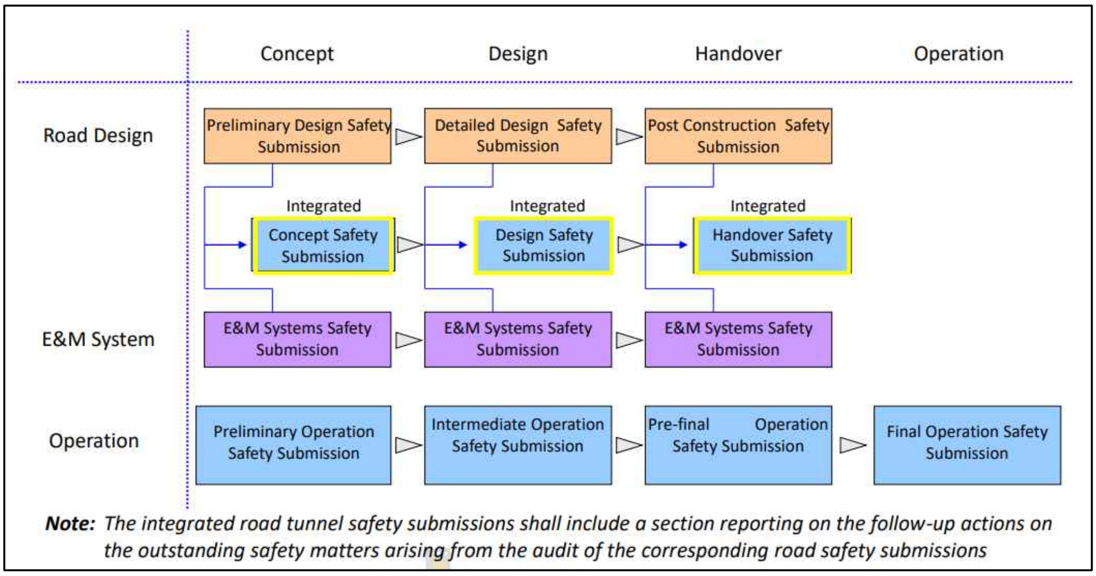


Figure 4.18: PSR process for road tunnel project

Requirement of Safety Submission for Road Tunnel

In general, new road projects (Group A projects) with tunnel sections exceeding 240 metres in length or tunnel extensions (Group B projects) with overall tunnel length exceeding 240 metres after the extension, require additional safety submissions (Road Tunnel Safety Submissions) to address the risks associated with the tunnel environment.

Conversely, if the party responsible for the project considers that the project involves considerable safety risk for commuters, the project may be recommended to the PSR Committee (Roads) for PSR implementation.

	Group A (New road projects)	Group B (Tunnel extension projects)
Safety submissions	CSS, DSS, HSS and OSS.	CSS, DSS, HSS and OSS.
Exemptions	• Projects which will be constructed / opened in stages (e.g. KPE Phase 1 & 2), the subsequent stages of the project will be exempted from CSS, Preliminary & Intermediate OSS. • The existing Operator may seek exemption for Preliminary OSS if their safety management system is still applicable to the new project.	• For road extension projects, submission of CSS, Preliminary & Intermediate OSS are exempted.

Note: Any exemption of submission shall be sought from PSR Com (Roads) in the form of a PSR paper.

Figure 4.19: Requirement of safety submission for road tunnel

<u>Objective of Road Tunnel Safety Submission</u>

No	Safety Submissions	Objective
1	Integrated Concept Safety Submission	• Demonstrate that actual and potential safety issues have been identified/analysed and that they are considered in the definition of safety requirements.
2	Integrated Design Safety Submission	• Demonstrate that the design meets the safety requirements • Hazards have been mitigated by designs
3	Integrated Handover Safety Submission	• Demonstrate that the system has been successfully built, tested and commissioned to achieve the level of safety intended at the concept and design stages and therefore can be considered safe for use.
4	Operation Safety Submission	• Demonstrate that the necessary organisational structure has been set up and processes have been established to operate and maintain the road tunnel safely, and competent staff are ready to perform their duties for the commencement of road tunnel for public use.

Figure 4.20: Objectives for different types of road tunnel safety submission

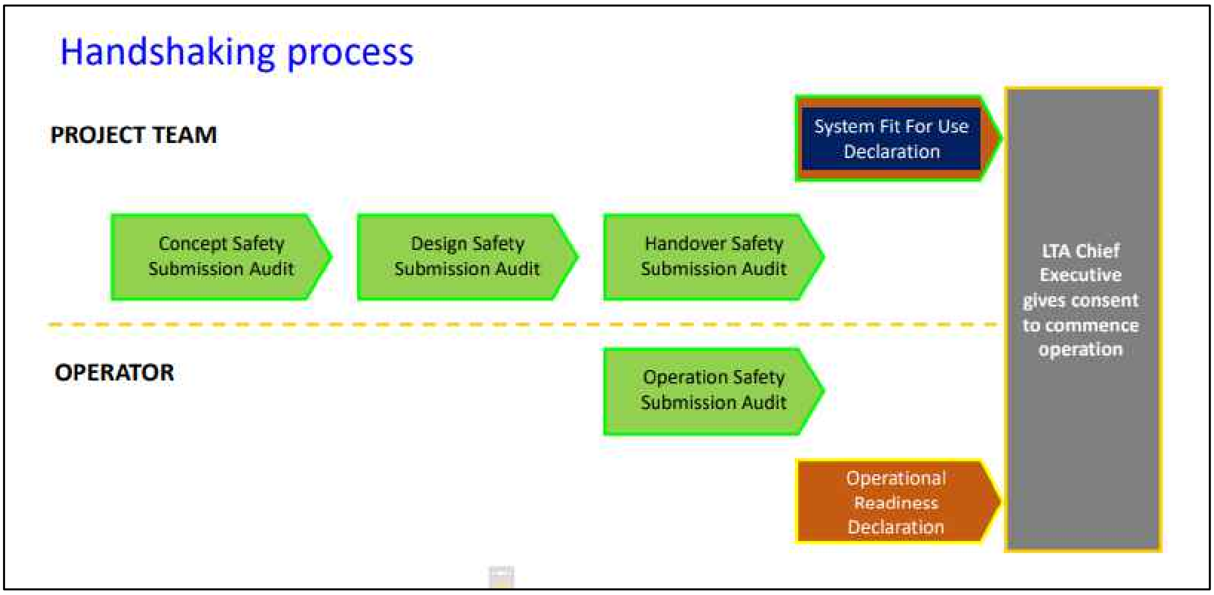


Figure 4.21: The Handshaking process

The handshaking process refers to the requirement to have both declarations which are the Fitness for Use of the System and the Operational Readiness of the Operator. Upon the declarations, the LTA Chief Executive would give consent to commence operation of the road tunnel.

4.1.2 Active Mobility Infrastructures

Active Mobility (AM) commonly refers to walking and cycling but also includes skateboarding, running and using personal mobility devices. Some jurisdictions consider active transport or active travel as modes of transport that rely on human power for propulsion, and more recently includes personal mobility devices propelled by engines/motors.

Personal Mobility Aids (PMA) refer to manual or motorized wheelchair or mobility scooters which are designed to carry an individual who is unable to walk or has walking difficulties. They are typically designed with higher, if not, the same priority as pedestrians. Personal mobility devices (PMD) include kick-scooters, electric scooters, hoverboards and unicycles, which can be non-motorised or motorized.

Active mobility has been seen to be getting popular over the past decade, especially with impact of the pandemic (COVID-19). Taking a closer look at the percentage breakdown of on-road fatalities, cyclists and their pillions take up about 10%, behind pedestrians (28%) and motorcyclists/pillions (47.8%).

Number of on-road fatalities by user type

Year	Total	Pedestrian	PMD user	Cyclist/ pillion	Motorcyclist/ pillion	Motorcar driver/ passenger	Other Vehicle driver/ passenger
2008	221	62		22	108	23	6
2009	183	45		17	92	12	17
2010	193	55		16	89	14	19
2011	195	49		15	99	15	17
2012	168	44		16	76	14	18
2013	160	43		15	73	16	13
2014	155	45		15	74	12	9
2015	151	43		17	72	7	12
2016	141	47		20	62	8	4
2017	121	41	4	15	44	9	8
2018	124	39	1	9	61	10	4
2019	118	39	2	8	64	1	4
2020	83	18	0	7	49	4	5
Total	2013	570	7	192	963	145	136
Average		28.3	0.3	9.5	47.8	7.2	6.8

Figure 4.22: Number of on-road fatalities by road user

Source: Traffic Annual 2020, Singapore Traffic Police

Introduction to Active Mobility Act

Active Mobility (AM) is observed to be getting popular in the urban landscape over the past decades. The Active Mobility Act (AMA) came into force on May 2018, providing a set of rules and code of conduct to enable safer sharing of public paths among various AM users. If you fail to adhere to the rules, you may face prosecutorial action by the Authority under the Active Mobility Act.

The active mobility devices governed under the AMA are summarised below.

Term	**Meaning**
Active Mobility Act	• An act for the establishment of public paths for walking, cycling or other similar purposes, and to regulate the use of these public paths
Public path	• Means a path or path-connected open space
Pedestrian	• An individual walking with or without animals • An individual in a non-motorised wheelchair • An individual driving a motorised wheelchair or riding a mobility scooter • An individual travelling on inline skates, roller-skates or a wheeled toy

	• An individual pushing a pram, stroller or trolley, or a motorised or non-motorised wheelchair • An individual walking beside and pushing other vehicle
Personal Mobility Aid (PMA)	• A vehicle that has 3 or more wheels and a footboard supported by the wheels • Is steered by handlebars • Has a seat • Is designed to carry an individual who is unable to walk or has difficulty in walking • Is propelled by a motor that forms part of the vehicle
Bicycle	• A vehicle that has 2 wheels held one behind the other in a frame • Is steered by handlebars attached to the front wheel • Has pedals • Is built to be propelled solely by human power
Personal Mobility Device (PMD)	• A wheeled vehicle that is built to transport people only (with or without carry-on baggage) • Is propelled by an electric motor attached to the vehicle or by human power or both • Includes a skateboard, but does not include a bicycle, PAB, motor car, wheelchair, mobility scooter, pram, stroller or trolley, inline skates, roller-skates or a wheeled toy
Power Assisted Bicycle (PAB)	• A bicycle that is powered by an electric source • The motor power can only cut in when the rider starts to pedal • The motor power must be progressively reduced and finally cut off as the bicycle reaches 25km/h or sooner, if the cyclist stops pedalling.

Figure 4.23: Terminology used in AMA

The figure below summarises the types of AM devices that are allowed on the different classification of paths. For footpaths, pedestrians, PMAs and non-motorised bicycles and non-motorised PMDs are allowed, with a maximum operating speed of 10km/h. Along cycling paths or shared paths, pedestrians, all bicycles and PMDs are allowed, with a maximum operating speed of 25km/h. Along roads, only bicycles (inclusive of power assisted ones) are allowed and they shall follow the speed limit of the road speed limit.

Figure 4.24: Types of AM devices that are allowed on the different classification of paths

The AMA also provides LTA with legislative and enforcement powers to regulate the sale of PMDs, PABs and PMAs. They must comply to the various stipulated device requirements, in terms of maximum allowable weight, device width, speed limit and fire resistance requirements.

All AM devices except PMAs shall comply with the maximum weight of 20kg to reduce the risk of serious injuries and a maximum width of 70cm to allow devices to pass each other safely along the public paths. For motorised PMDs and PMAs, there is a maximum device speed limit of 25km/h and 10km/h respectively, to ensure that users do not exceed the speed limit. The motor power of PAB must be progressively reduced and cut off as the bicycle speed reaches 25km/h. There are also other associated regulations relating to user requirements such as age limit for users of certain devices, and mandatory theory tests for e-scooter and PAB users.

<u>Safe System Approach</u>

Similar to the road safety management system, a multi-pronged approach (viz. engineering, education, regulations and enforcement) is adopted to enhance safety for all AM users and other affected road users.

<u>Design of active mobility infrastructure</u>

The cycling network is around 500km long today. As part of Singapore Green Plan 2030 and the Land Transport Masterplan 2040, the Land Transport Authority together with other agencies are accelerating the construction of Islandwide Cycling Network to 1,300km by 2030 (COS, 2022), enabling greener and healthier commutes. These new cycling paths will enhance connectivity within and between towns, bringing greater convenience and improved path safety for residents.

Geometric design

General

In order to provide adequate facilities for the AM users, it is necessary to understand the characteristics and needs of the various AM users. AM infrastructure should be designed to accommodate the safe use by user groups.

Pedestrians	**PMA users**	**Cyclists**	**PMD users**	**PAB users**
Unprotected, unlike other motor vehicle users	Walking disabilities, needed device to help increase mobility	Pedalled by human power	Can be on standing or sitting position	Bulkier and heavier than conventional bicycles
Less visible – relatively small size	Sometimes accompanied by caregiver	Varied level of cycling experience (leisure, commuter, amateur, sports)	Required less manoeuvre space than cyclists	Quicker acceleration than conventional cyclists
Flexible in routes, tend to take shortest path	Lower eye level compared to standing pedestrian	Varied age group	Quicker acceleration than conventional cyclists	
Include young, elderly, people with prams, trolleys and visually/hearing challenged group, with different behaviour on the road/path	Needed door-to-door travel, step-free route	Some use off-road paths, some use roads, with different applicable rules		

Figure 4.25: Characteristics of various AM users

Path width

The typical 1.5m wide roadside footpath is able to accommodate a pedestrian and a wheelchair side by side. To provide barrier-free accessibility to PMA users, the new standard of footpath has been increased to 1.8m wide, to allow two wheelchairs to pass comfortably.

For cyclists, they need around 1m manoeuvre width. A 2m wide cycling path is provided to allow 2 cyclists to pass comfortably.

Typical footpath width: 1.5m

New footpath min width: 1.8m

(BCA's BFA requirement)

Dedicated cycling path min width: 2m

Figure 4.26: Footpath and cycling path widths

If the cycling path is located alongside existing footpath, the minimum total width required is 3.5m (1.5m footpath plus 2m cycling path). If the cycling path is physically segregated (eg. by green verge) from the footpath, the footpath needs to be widened to a minimum of 1.8m width.

A footpath is typically of concrete finishing, sometimes with tiled finishing, for example within the city area. A cycling/shared path is demarcated either by full terracotta red coating, dark grey coating (old typology) or two terracotta red/yellow lines.

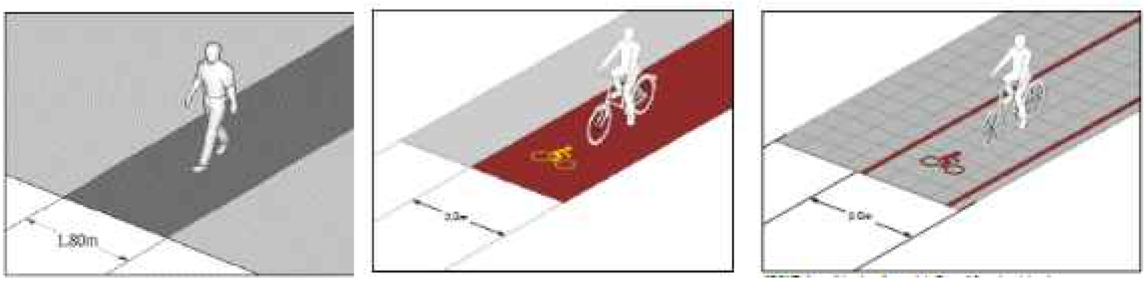


Figure 4.27: Footpath and cycling/shared path finishing

If the shelter is being provided for pedestrians, the footpath needs to be widened to a minimum of 2.4m width, with the covered linkway columns situated at the development side, instead of the shared path side, to ensure a minimum clear width of 1.8m for pedestrians.

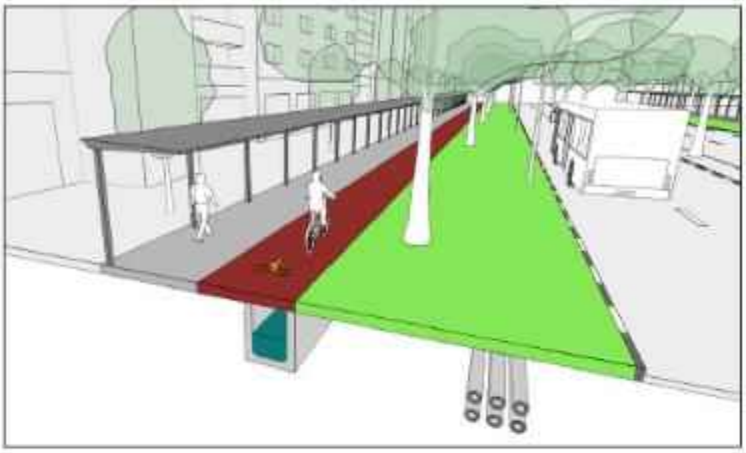


Figure 4.28: Widened footpath 2.4m (minimum) with covered linkway columns near development side

Horizontal alignment

An AM device user (eg. cyclist or PMD user) typically travels around 2 to 4 times faster than a pedestrian. Sight distance is the distance measured along the pathway / driveway / over which visibility occurs between two users in their intended direction of travel. For safety, sufficient sight distance must be provided so drivers / riders can control their vehicles to avoid collisions with other vehicles or objects on the road / path.

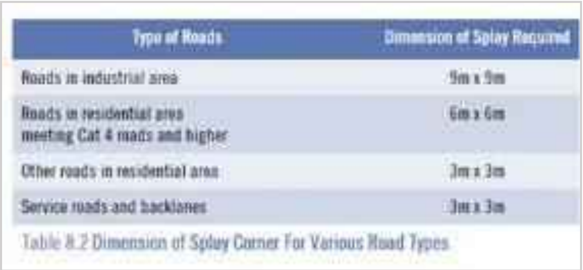
For a design speed of 15km/h and 25km/h, a minimum safe stopping sight distance of 12m and 23m is required for AM uses on the paths respectively. For comfortable riding round the bends, a minimum turning radius of 6m and 17m is required for the respective design speeds.

Path Type	**Design speed**	**Safe Stopping Distance (SSD)**	**Radius**
Footpath*	15km/h	12m	6m
Shared path	25km/h	23m	17m

**15km/h is the design speed but the maximum allowable speed on footpaths is 10km/h*

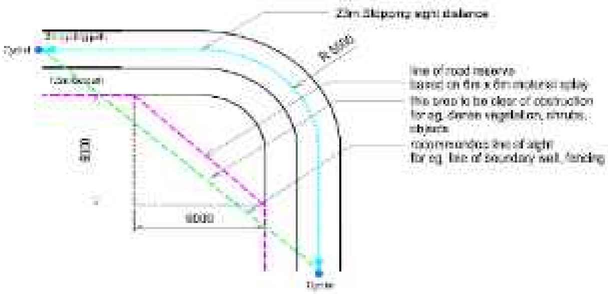
Figure 4.29: Design speed, SSD and Radius for footpath and share path

Clear sightlines shall be provided at the development's property line to ensure adequate visibility between vehicles and pedestrians on the frontage footpath. The requirements of the corner splay for pedestrian safety is typically 6m by 6m at residential area (with Cat 4 roads and higher). With cyclists on footpaths, the actual visibility triangle is often larger than the stipulated splay. Hence, it is necessary to control the design or landscaping of the development to ensure safe manoeuvre of AM users.



Type of Roads	Dimension of Splay Required
Roads in industrial area	9m x 9m
Roads in residential area meeting Cat 4 roads and higher	6m x 6m
Other roads in residential area	3m x 3m
Service roads and backlanes	3m x 3m

Table 8.2 Dimension of Splay Corner For Various Road Types



Visibility splay requirements	
	
• Tall trees/bushes at the corner blocking users’ line of sight	• Spacings between trees still allow adequate line of sight
	
• Development with landscaping obstructing the line of sight round the corner	• Establish planting restriction zone in proposed landscaping plans • Maintain regular maintenance regime

	
• Landscaping (creepers on trellis) at the corner impeding line of sight of cyclists at the junctions	• Minimum first two panels (6m) shall not be planted with creepers • Spaced out and well-maintained creepers on trellis allow good sight line
	
• Tall, opaque hoarding impedes line of sight especially round the bends	• Use of clear panels or BRC fencing round the corner of construction sites to ensure good line of sight

**Diagrams affixed with the "Danger Ahead" brown signs are designs that can be further improved.*

Figure 4.30: Visibility splay requirements

Sharp bends such as right angle have typically sight line issues if the path is wrapping around the development boundary and is difficult for cyclist to manoeuvre safely. There should be smoother tapering of the path, following the minimum turning radius at such locations.

Figure 4.31: Examples of sharp bend at path

Vertical alignment

Cyclist safety is more directly affected by minor surface deficiencies (e.g. potholes, loose gravel, poor skid resistance, unevenness surface) as compared to motor vehicles due to the small surface contact area and that cyclists are usually balancing on two wheels. A small vertical deflection along the path is a potential safety hazard that can send cyclists 'flying' off the path.

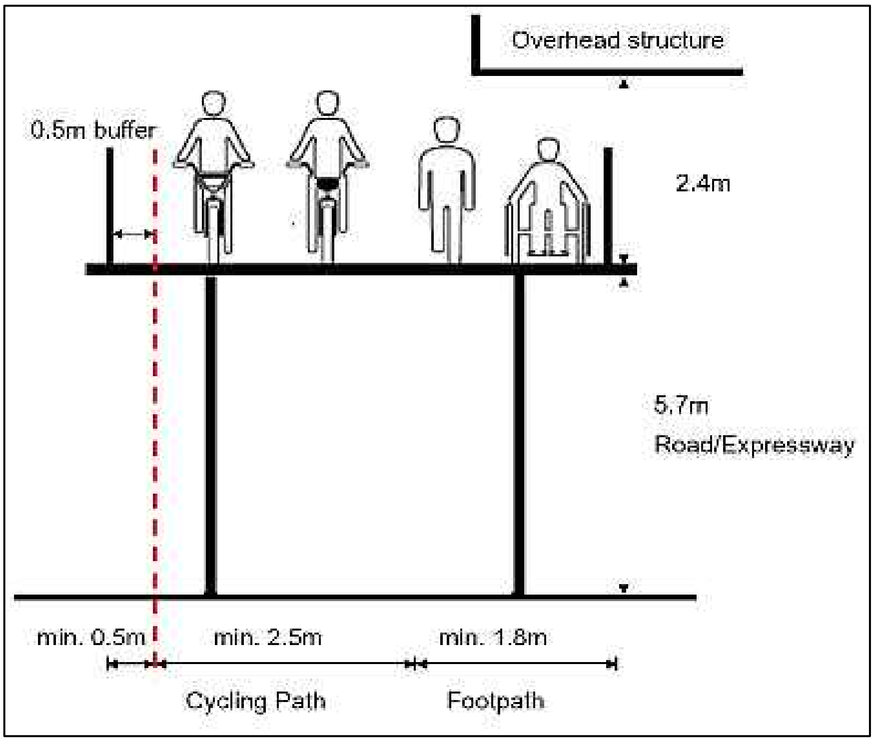
Figure 4.32: Examples of vertical alignment along the path

Hilly typography can also have an impact on the alignment of the cycling route. Designers need to overcome the impacts through design where possible, else the shared path should be diverted to flatter terrain. Where the gradients greater than 5% are used, level-resting platforms (minimum 2m length) must be introduced at regular intervals. If the path doubles up as barrier free accessibility route, it has to comply to BCA's requirement too.

Location	Maximum Grade*
General cycle facility including approach ramp to cycling bridge/underpass	4% (1:25) Unrestricted length 5% (1:20) Up to 100m 6% (1:18) Up to 100m 7% (1:14) Up to 30m 8% (1:12) BCA's Code of Accessibility

Table 4.1: Guideline to type of maximum grade

A cycling/shared path has to observe minimum vertical clearance both from overhead structures (2.4m) and above carriageway (5.7m)/ canals (5.4m). This is to ensure safe manoeuvrability of AM users on the path and motorists on the carriageway.



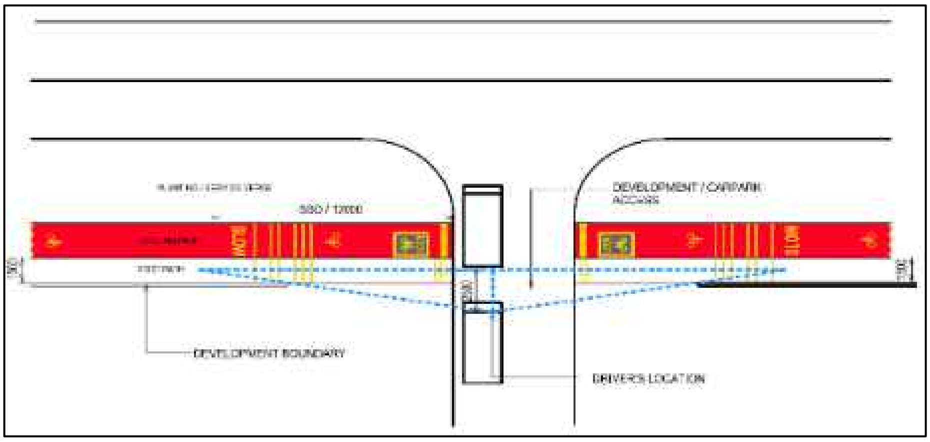
The minimum widths of the paths in the diagram above applied to elevated cycling paths.

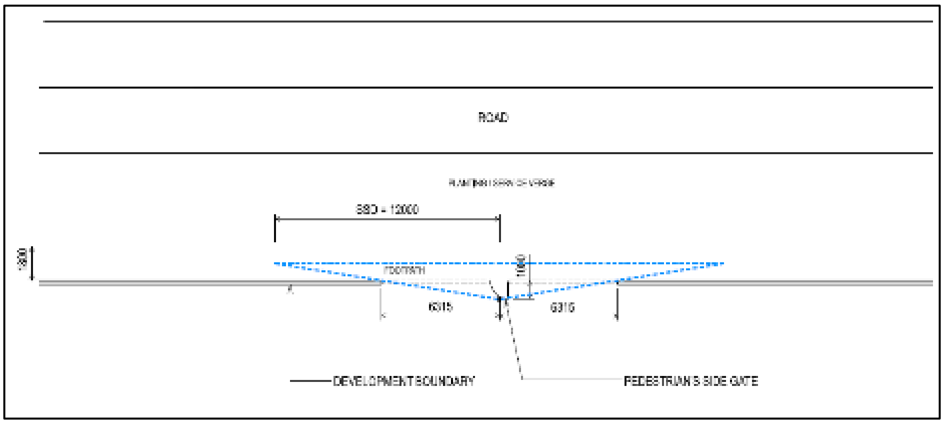
Figure 4.33: Minimum vertical clearance for overhead structures/above-carriageways/canals

Sight distance

Conflicts can occur between AM users and vehicles where the path intersects the driveway. To prevent crashes, motorists on driveways must be able to see approaching path users before their vehicles encroach onto paths. This is the first precautionary barrier to preventing a crash. Where motorists' sight lines are obscured, path user reactions become the only precautionary barrier to a crash. In this situation, faster path users (including runners, cyclists and other personal mobility device users) and path users with slower reaction times (e.g. elderly and children) are at greater risk, because they require more time to react and slow down to avoid the crash. Where sight lines are compromised, both parties may be in a position where they have insufficient reaction time to avoid a crash from occurring.

A minimum of 12m Safe Stopping sight Distance (SSD) is required along the path, assuming that the motorists are slowing down (usually impeded by the gantry or hump) before reaching the path and when there is traffic calming measures (e.g. "SLOW" markings and speed regulating strips) along the path. Where there is no traffic calming measures, a minimum of 23m SSD should be provided instead. No hard structures or dense/tall vegetation should be allowed within the visibility splay area (blue triangle) to ensure safety of all users.





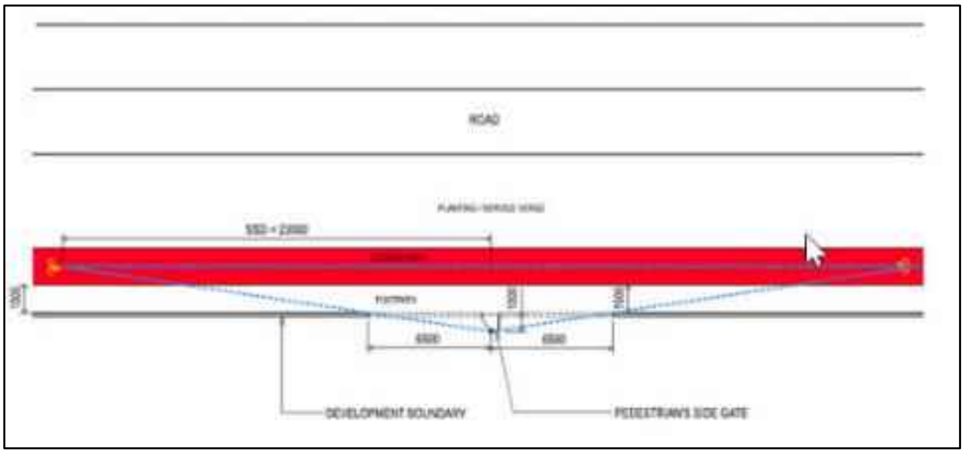


Figure 4.34: Safe Stopping Sight Distance along the path

Development accesses	
	
• Line of sight of motorists coming up from basement carpark ramp of the development is blocked by the walls/ planter box on both sides.	• Chamfered walls on both sides of vehicular ramp before reaching pedestrian crossing enhance sight visibility

	
• Line of sight of motorists coming out from the development, blocked by development fencing on both sides with thick landscaping	• Development fencing setback with low landscaping allow un-obstructed line of sight for motorists coming out from the development vehicular access
	
• Walls/fencing of development pedestrian access gate impeding line of sight of pedestrians coming out from the gate. Right-angle collisions with oncoming pedestrians/cyclists along footpath may occur.	• Development using porous gate (e.g. BRC fencing) or set back with low planters to provide good sight visibility to users.

Figure 4.35: Line of sight from development access

Intersection

Where there are connecting shared paths, the crossing should be widened by at least an additional 2m, to accommodate the AM device users, so that there are less conflicts among pedestrians and AM device users. Small traffic island and holding space before the crossing should be reviewed to see if adequate standing space is provided. Measures to widen or remove the traffic island should be considered in the design process.

Figure 4.36: Connecting shared paths at intersection

All new mid-block crossing should be implemented with a minimum 3m wide bicycle crossing alongside, sharing the same pedestrian signal phase. The bicycle crossing markings are wider and comes with the “Bicycle Look” box to help AM device users to position away from the pedestrians before crossing, to minimise conflicts among the users.

Figure 4.37: New mid-block crossing with bicycle crossing beside pedestrian crossing

Signalised junction	
	
• Inadequate standing space before crossing	• Wide standing space to accommodate users
	
• Small traffic island unable to accommodate users	• Small traffic island removed to create bigger standing space for AM users at the junction

Figure 4.38: Examples of standing space and traffic island size at signalised junction

Drainage

Maintaining a good skid resistance surface is paramount especially for wheeled device users. Proper drainage grating is also important both along the paths and roads where cyclists will ride. Concrete-infill gratings with the same minimum skid resistance as the path surface are typically used along the path. For roadside drop inlet chambers, the gratings should be perpendicular to the road carriageway to prevent cyclists' narrow wheels to be trapped between the gratings.

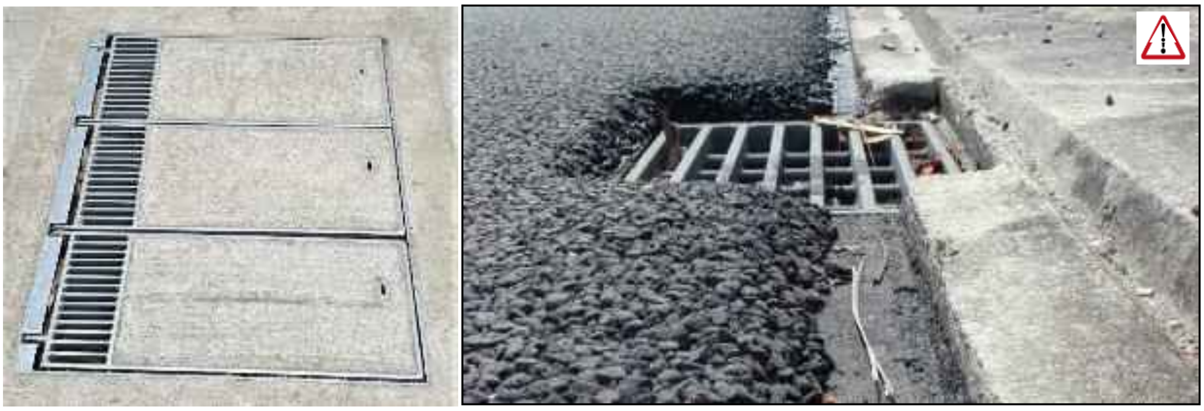


Figure 4.39: Good and poor example of drain grating

Poor drainage or soil retaining structure may cause water ponding and soil erosion which decrease the skid resistance of the path. This may likely cause AM users to slip and skid.

Figure 4.40: Poor drainage causing water ponding at path

Restraint

Proper restraining structures should be provided to prevent AM users from falling over height where there is level difference or steep slope alongside the paths. The railing height should be at least 1.2m height and where there is a higher chance of angle collisions (e.g. along steep slope of the path or at bends), a higher railing of 1.4m should be used.

Vehicular impact guardrails used along roads pose potential safety concerns to AM users if they are installed next to the paths. The sharp edges of the posts and top beam can easily cause injury to the AM users if they collided into them. Hence, it is recommended to site the guardrails with at least a 0.5m lateral distance away from the paths.

Figure 4.41: Examples of poor restraint structures

Cycle safety audit

The safety of active mobility users on the cycling path has been an important focus in the design considerations of the cycling network. Safety review on cycling infrastructure or Cycle Safety Audit (CSA) becomes necessary in addition to the road safety review, as it takes on a targeted safety assessment from the perspective of the cyclists, AM users and pedestrians. This safety review is important as it provides opportunities to identify pedestrian and cyclist safety issues that may have resulted from changes in land use and mode choice over time. Cycle Safety Audit (CSA) is commonly implemented in cycling advanced cities like those in Denmark and USA (FHWA, 2012). It should complement road safety review to gain the benefits for the road and cycle path network. CSA attempts to pick up potential hazards on top of the regular maintenance regime, to prevent such occurrence of accidents.

The key aspects of a cycle safety audit focus on the following:

- Sufficient visibility – can the different parties see one another and do they have time to react to avoid a potential collision?
- Space for cyclists – is there adequate space to cope with the demand and allow safe manoeuvre between AM users
- Speeds control – do road and AM users have enough time to stop before points of conflict
- Conflict points – the interaction of cyclists, with other on road users (e.g crossing points, property access/egress, side gates etc)

Educational efforts

Apart from engineering measures, educational efforts are also part of the safe system approach to further enhance safety. There are also various publicity campaigns and programmes launched to create awareness on active mobility rules/regulations and promote gracious behaviour. Outreach to schools and the community were also regularly conducted to engage the public.

Regulatory efforts

Since 2015, Active Mobility Advisory Panel consisting of key active mobility stakeholder groups was set up to deliberate on AM rules, regulations and policy. Since 1 Jan 2019, E-scooters are required to be registered. This aims to deter reckless riding, encourage greater rider responsibility and facilitate enforcement efforts against errant rider. Further in April 2020, all e-scooters are required to undergo mandatory inspection to check for UL2272 certification, maximum width, weight and device speed compliance. An import control regime was established in June 2021 for all motorised PMDs and PABs, to ensure that imported devices meet LTA's device criteria and technical requirements to improve public path and fire safety. In addition, all e-scooter and PAB riders have to undergo mandatory theory test with effect from 1 January 2022.

Enforcement efforts

To assist enforcement efforts, Active Mobility Enforcement Officers are deployed to conduct patrols at hotspots islandwide to deter errant riding behaviour and non-compliant devices on public paths.

Through engineering, education, regulations and enforcement, a safer AM landscape can be provided and maintained for harmonious co-existence of all AM users and other road/path users.

4.1.3 International and Local Standards governing the road / path design

The followings are some of the roads and cycling infrastructures design standards /guidelines developed by the international authorities and agencies over the world.

International Standards:

Australia

Document	**Publisher**
ACT design standards for urban infrastructure, DS03 Road Design	Australian Capital Territory (ACT)
Adelaide Design Manual	Adelaide City Council
Guide to Road Design (Part 1 to Part 7)	Austroads
NSW bicycle guidelines	Roads and Traffic Authority of New South Wales (NSW)
Planning and designing for pedestrians: guidelines	Main Roads Western Australia
Road planning and design manual	Queensland Department of Transport and Main roads
Streets for people	Government of South Australia
VicRoads Supplement to the Austroads Guide to Road Design (AGRD) Part 2 – Design considerations	VicRoads
VicRoads Supplement to the Austroads AGRD, Part 3 – Geometric Design	VicRoads
Cycling Aspects of Austroads Guides	Austroads

Table 4.2: Road Standards in Australia

United States of America

Document	Publisher
A policy on Geometric Design of Highways and Streets	American Association of State Highway and Transportation Officials (AASHTO)
Highway Capacity Manual	Transportation & Research Board (TRB)
Connecticut Highway Design Manual	Connecticut Department of Transportation
Street Design Manual	New York City, Department of Transportation
AASHTO Roadside Design Guide	US Department of Transportation, Federal Highway Administration (FHWA)
Model Streets Design Manual	Los Angeles County
Separated bike lanes Planning and Design Guide	FHWA
Urban Street Design Guide	National Association of City Transportation Officials (NACTO)
Urban Bikeway Design Guide	NACTO

Table 4.3: Road Standards in United States of America

United Kingdom

Document	Publisher
Design Manual for Roads and Bridges (DMRB)	National Highways
Local Transport Note 2-08: Cycle Infrastructure Design	Department for Transport (DfT)
Traffic signs manual	Department for Transport (DfT)
Designing for cycle traffic: International principles and practice	Institution of Civil Engineers (ICE)
Cycle Traffic and the Strategic Road Network, Interim Advice Note 195/16	National Highways

Table 4.4: Road Standards in United Kingdom

Singapore

The LTA is responsible for planning, operating, and maintaining Singapore’s land transport infrastructure and systems. LTA has the following Code of Practice, design Standards & Specifications and guidelines.

❖ **Code of Practice**

- **Code of Practice on Street Works Proposals relating to Development Works (Version 2.0, Apr 2019)** introduces the technical requirements, standards and specifications to aid the design of development layout with regards to proposed street works, as well as the engineering design and construction of proposed street works.
- **Code of Practice for Works on Public Streets** outlines the procedures and requirements for carrying out works on public streets
- **Code of Practice for Traffic Control at Work Zone** provides a comprehensive guide on the planning and operations of temporary traffic control in a work zone.

❖ **Standards & Specifications:**

- **Standard Details of Road Elements** - sets standards and guidelines for common road elements such as drains, kerbs and pavements as a reference for road construction
- **Civil Design Criteria** contains the requirements for the design and detailing of all Civil Engineering Works for the Land Transport Authority
- **Materials and Workmanship Specifications for Civil and Structural Works** sets out the basic standard for the quality of materials and workmanship for Civil and Structural Works required by the Land Transport Authority.

- **Architectural Design Criteria** defined the criteria and parameters for the architectural design, layout and construction of land transport facilities.
- **Design Guidelines Manual** defines wayfinding signage parameters for the public transit systems and commuter facilities
- **Architectural Materials and Workmanship Specifications** discusses the basic standards for the quality of materials and workmanship required by LTA.
- **Architectural Design Criteria for Covered Linkways** assists consultants in the design and submission of proposals for covered linkways.

❖ **<u>Guides</u>**

Walking and Cycling Design Guide sets out inter-agency aligned guidelines to design for active mobility infrastructure. It is a one-stop guide that documents key design principles and guidelines for active mobility related infrastructure.

4.1.4 Traffic Management Strategies

Introduction

Traffic management strategies are necessary to improve the overall traffic flows, condition, and safety of the existing as well as new planned/improved road. The main objective is to minimise the existing traffic congestion by managing the traffic more efficiently. The safety aspects of the road shall also be maintained at all times to protect all road users.

In general, traffic management strategies can be classified into different categories:

1. Traffic Impact Assessment (TIA)

   TIA study is generally used to manage and control the existing road network's capacity and performance to be able to accommodate the expected additional traffic from the new and proposed redevelopments in the vicinity. In the TIA study, the existing and future conditions are analysed and compared to assess the potential impacts arising from the additional traffic.

   Measures and improvements shall be proposed wherever necessary to ensure that the road network has sufficient and adequate capacity to perform well.

2. Traffic Calming/Management Measures

   In order to minimise traffic impacts that may arise from road works/diversion, public feedback of the existing road condition, or any other safety concerns, it is necessary to always identify the issue and propose suitable measures to alleviate or to minimise the impacts.

   For example, speed regulating strips/speed hump could be proposed to slow down vehicle's speed especially along the road where the number of pedestrians is relatively high or at the area where there is a sight visibility issue/other safety concern.

   Intelligent traffic signals may also be installed and implemented at the busy road junctions to help reduce the total time that is spent by motorists on the signalised intersections. Intelligent traffic signal able to sense the traffic conditions (whether congested or not) and adjust the waiting time on the intersection accordingly. With this, the efficiency of a traffic signal can be enhanced and further improve the overall traffic condition and flows within the area.

3. Design Review/Road Safety Audit

   Swept path analysis is a tool that can be used to check the design adequacy of a road geometry or layout. Swept path analysis calculates the movement of different parts of a vehicle, especially when it makes a turn. This tool is very useful especially during the planning stage of a road diversion as well as a building layout.

In addition to the checking during planning stage, site visit is also essential to observe and examine the implemented diversion/newly constructed infrastructure to improve the overall safety performance of the road

4.1.5 Traffic Impact Assessment and Studies (using Traffic Simulation Tools such as SIDRA, VISSIM, VISSUM)

<u>Transport Impact Analysis</u>

Introduction

With the constant growth in new developments and/or expansion of the existing developments, there is a need to also ensure that the surrounding road network has the sufficient capacity to cater for the additional traffic generated by the proposal. Traffic Impact Analysis (TIA) is a tool that widely used worldwide to assess the impacts to the road network. In Singapore, LTA has developed a set of Guidelines to assist in the TIA preparation as well as its submission process.

In general, the main objective of the TIA is to identify the potential traffic impacts on the surrounding road network and propose necessary measures to alleviate those impacts. Additionally, TIA study also helps to assess the overall design of the development to ensure that the proposed design is adequate to meet the demand and allow for smooth manoeuvring within the development itself.

Based on LTA's Transport Impact Assessment Guidelines for Developments (2019 edition), a TIA submission is only required for proposed development that meets the criteria (in terms of type and size) as stipulated in the guidelines. The type and size of a development is likely to affect the additional trip generated by the development which subsequently distributed to the road network in the vicinity. Developers and Consultants shall approach LTA to discuss and review the expected work scope before proceeding with the necessary study.

In Singapore, TIA submission and approval is part of the requirements for the development to obtain the Development Clearance (DC) during the initial design stage before moving onto the subsequent stage.

<u>TIA Classification</u>

Based on LTA's Transport Impact Assessment Guidelines for Developments (Addendum, January 2020), TIA study is classified into three different types depending on the complexity and nature of the proposed development. The TIA classification, for Developers' and Consultants' reference is shown in Table 4.5 below.

TIA Classification	**Description**
Type 1	• ≤ 5 junctions • Junction analysis with SIDRA software • Typically for single development TIA • Generally, 3 months to prepare and submit TIA report • Target generally around 3 reviews or 3 months to close the TIA
Type 2	• > 5 junctions. Generally, not exceeding 12 junctions • Junction analysis with SIDRA software and/or with micro-simulation • Single development or district level development TIA • Generally, 3 months to prepare and submit TIA report • Target generally around 4 reviews or 4 months to close the TIA
Type 3	• > 12 junctions • Junction analysis with SIDRA software, with high-level demand modelling and/or with micro-simulation • Typically for large district level or Masterplan TIA • Generally, 6 months to prepare and submit TIA report • Target generally around 4 reviews or 6 months to close the TIA

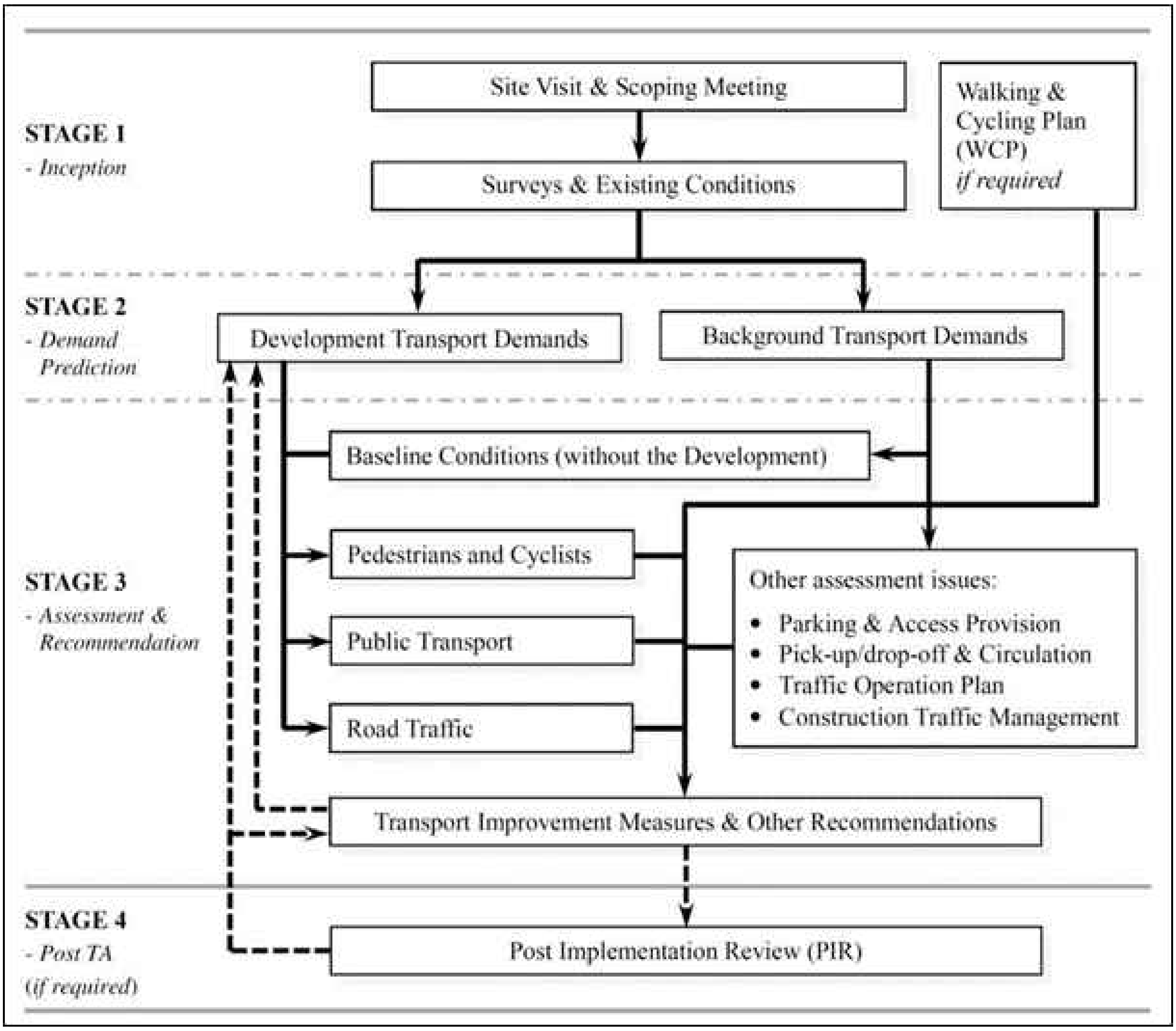
Source: LTA's Transport Impact Assessment Guidelines for Developments – Addendum, January 2020

Table 4.5: Traffic Impact Assessment Classification

The above classification shall be used as a reference for both Developers and Consultants while preparing for the programme schedule and timeline for other Authorities' submission and approval.

TIA Process

Typical TIA process has three stages from the commencement of the study until the acceptance of the report by LTA, as shown in Figure 4.42 below. Additional stage 4, Post Implementation Review (PIR), may be activated if it is deemed to be necessary during the scoping meeting with LTA.



Source: LTA's Transport Impact Assessment Guidelines for Developments – 2019 Edition

Figure 4.42: Traffic Impact Assessment Process

- Stage 1
  a. Pre-Consultation with LTA
  Consultants to provide pre-scoping checklist with the necessary information for LTA's preliminary assessment. Consultants to also check with LTA on any future planned transport improvements in the vicinity that may affect the study. The submission and arrangement of scoping meeting shall be done via email.

b. Scoping Meeting
   Discussion between Consultants and LTA to confirm the scope of works which mainly includes the following:

   - ➔ Study junctions
   - ➔ Study timing and period
   - ➔ Assessment years
   - ➔ Software to be used
   - ➔ Similar developments to forecast the additional traffic
   - ➔ Other additional requirements from LTA as well as any planned improvements works in the study junctions

   For projects which require micro-simulation, Consultants shall submit an inception report which covers all the methodology and assumptions used in building the model for LTA's review and acceptance, before proceed with the necessary analysis.

   As part of the TIA process, LTA may also require a Walking and Cycling Plan (WCP) submission for certain developments. The WCP report shall be prepared by the Consultant and the Qualified Person (Architect) and submitted together with the TIA.

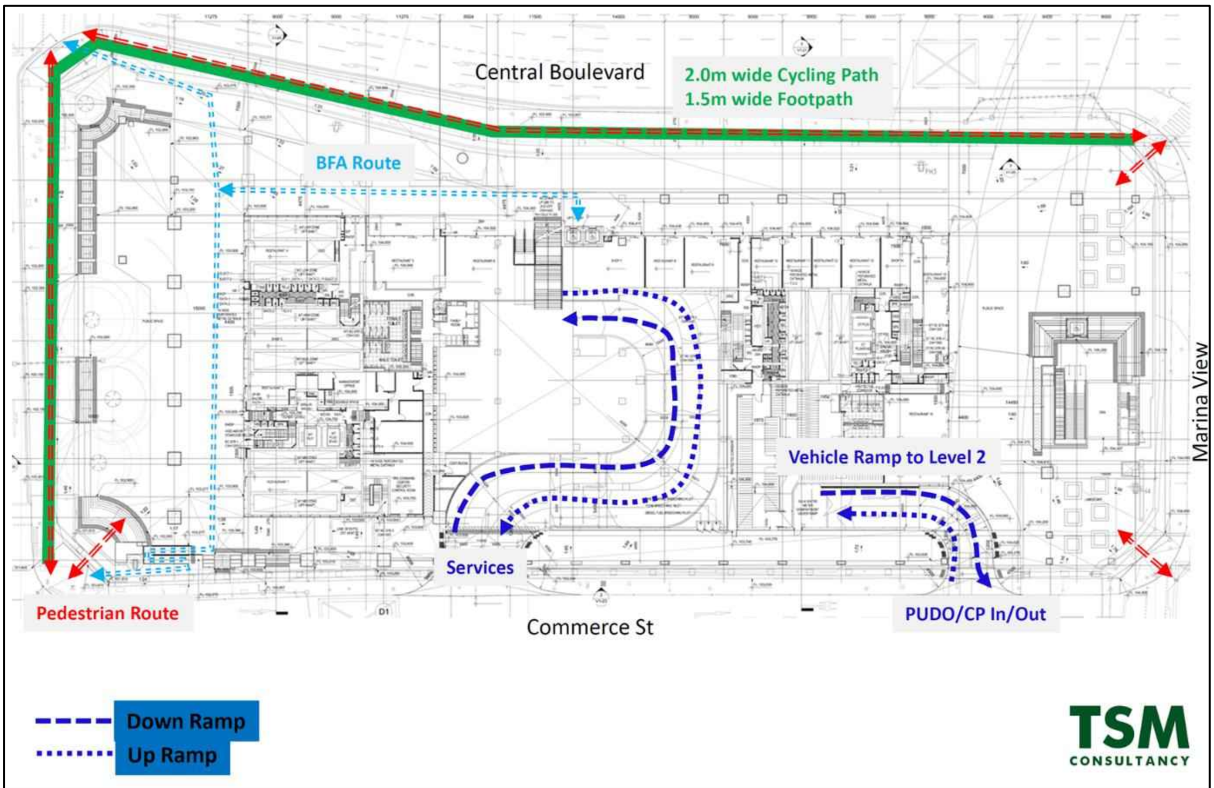


Figure 4.43: Walking and Cycling Plan sample 1

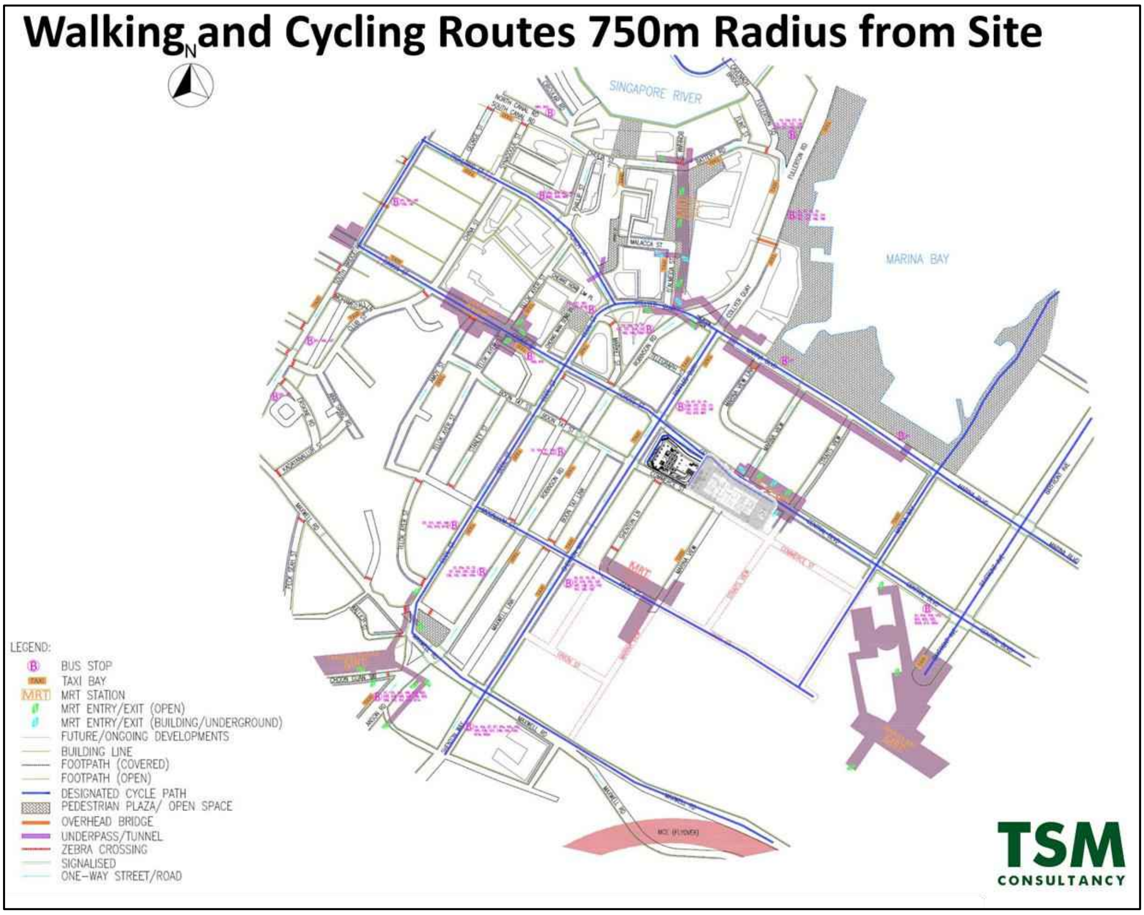


Figure 4.44: Walking and Cycling Plan sample 2

c. On Site Survey
   After confirmation of the scope of works, Consultants to carry out the traffic survey at the agreed study junctions as well as at the similar development (as discussed and agreed with LTA). The survey results will then be collated and send to LTA for confirmation.

   Consultants shall also propose methodology on how the additional traffic shall be distributed to the study junctions with consideration of the shortest travel time to/from the development.

Figure 4.45: Traffic survey

- <u>Stage 2</u>
  Once LTA confirmed the traffic survey data as well as the proposed trip distribution and generation, LTA will provide background growth rate, which takes into consideration all the future development in the vicinity, to be used to forecast the future traffic of the nearby road network.

- <u>Stage 3</u>
  With the confirmation of all the necessary parameters, Consultants may proceed to carry on the detailed analysis using the agreed software (i.e. SIDRA analysis or VISSIM micro-simulation).

  The assessment shall include the following:
  a. Internal development layout to ensure the development is designed efficiently to minimise the impact and likelihood of any spill over to the public road.

     ➔ Parking & Access provision
     ➔ Overall traffic and pedestrian circulation
     ➔ Pick-Up/Drop-Off provision

  b. External road junctions to ensure the existing junctions have sufficient capacity to take the additional traffic added into the road network. If necessary, improvements (both soft measures or physical measures) may be proposed to improve the overall junction's capacity and performance.

  Based on LTA's Transport Impact Assessment Guidelines, the performance of an individual signalised junction may be considered acceptable if:

  a. All the vehicular traffic turning movements are able to clear the individual junction within three (3) traffic light cycles.
  b. The additional development traffic does not increase the individual junction's delay by 1 or more traffic light cycles.

  For unsignalized junction, LTA will advise the appropriate standard to assess the traffic performance (i.e. acceptable average delay for vehicles on opposed traffic turning movements).

- <u>Stage 4</u>
  Depending on the scale and complexity of the project, LTA may require the Developer to carry out a Post Implementation Review (PIR). The main objective of a PIR is to review the actual transport situation and evaluate the implementation and effectiveness of the improvement measures as well as explore further measures if necessary.

  Consultants/Developers shall discuss and seek agreement with LTA on the exact scope and requirements before commencing the works.

Analysis Software

Some commonly used software to analyse the road network capacity and performance are as follows:

- SIDRA Intersection and SIDRA Network

SIDRA is a micro-analytical software used to analyse the design of a single intersection as well as a network of intersections for both unsignalized and signalised intersection. SIDRA allows modelling of different Movement Classes (Light Vehicles, Heavy Vehicles, Buses, Bicycle, and other user classes) to model the unique design of the road or lane arrangement. These movements can be allocated to different lanes, lane segments as well as signal phases which is helpful to model bus lanes and bus only signal for example.

SIDRA evaluation includes the estimate of capacity and performance statistics (include delay, queue length, stop rate, etc.) which are essential to determine the adequacy of an intersection. Signal timing optimisation is also one of SIDRA's features to aid in further optimising the overall capacity for an individual junction as well as for a number of intersections which are operating under a single signal controller.

SIDRA Intersection can be used to analyse different type of intersections as listed below:

- Signalised intersections Signalised and unsignalized pedestrian crossings
- Roundabouts (unsignalized and with metering signals)
- Fully-signalised roundabouts
- Two-way stop sign and give-way/yield sign control
- All-way stop sign control
- Freeway diamond interchanges
- Other alternative intersections and interchanges

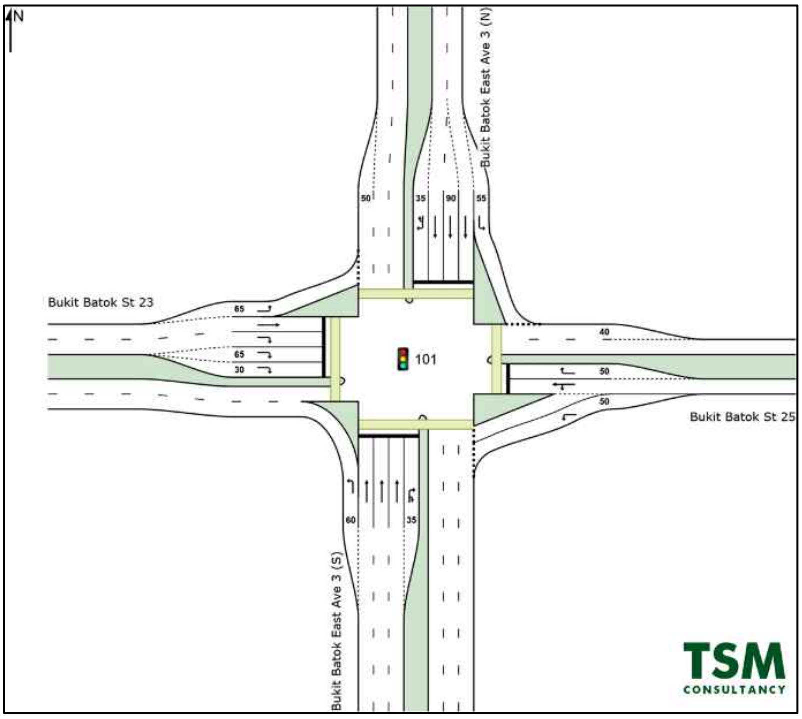


Figure 4.46: Example of SIDRA Intersection Layout

Based on SIDRA Intersection User Guide, SIDRA Intersection and SIDRA Network are defined as below.

<u>SIDRA Intersection</u>

"SIDRA Intersection employs lane-by-lane and vehicle path (drive-cycle) models couple with an iterative approximation method. The evaluation includes the estimate of capacity and performance statistics (include delay, queue length, stop rate, etc.) which are essential to determine the adequacy of an intersection. All input and output data as well as the modelling is based on Origin-Destination movements."

SIDRA Network

"SIDRA Network can help to determine the backward spread of congestion as queues on downstream lanes block upstream lanes (queue spillback), and applies capacity constraint to oversaturates upstream lanes, thus limiting the flows entering downstream lanes. These two elements are highly interactive with opposing effects. A network-wide iterative process is used to find a solution that balances these opposing effects."

SIDRA can analyse any network with up to 50 sites including roundabout corridors, a mixture of signalised intersections, roundabouts and sign control, etc.

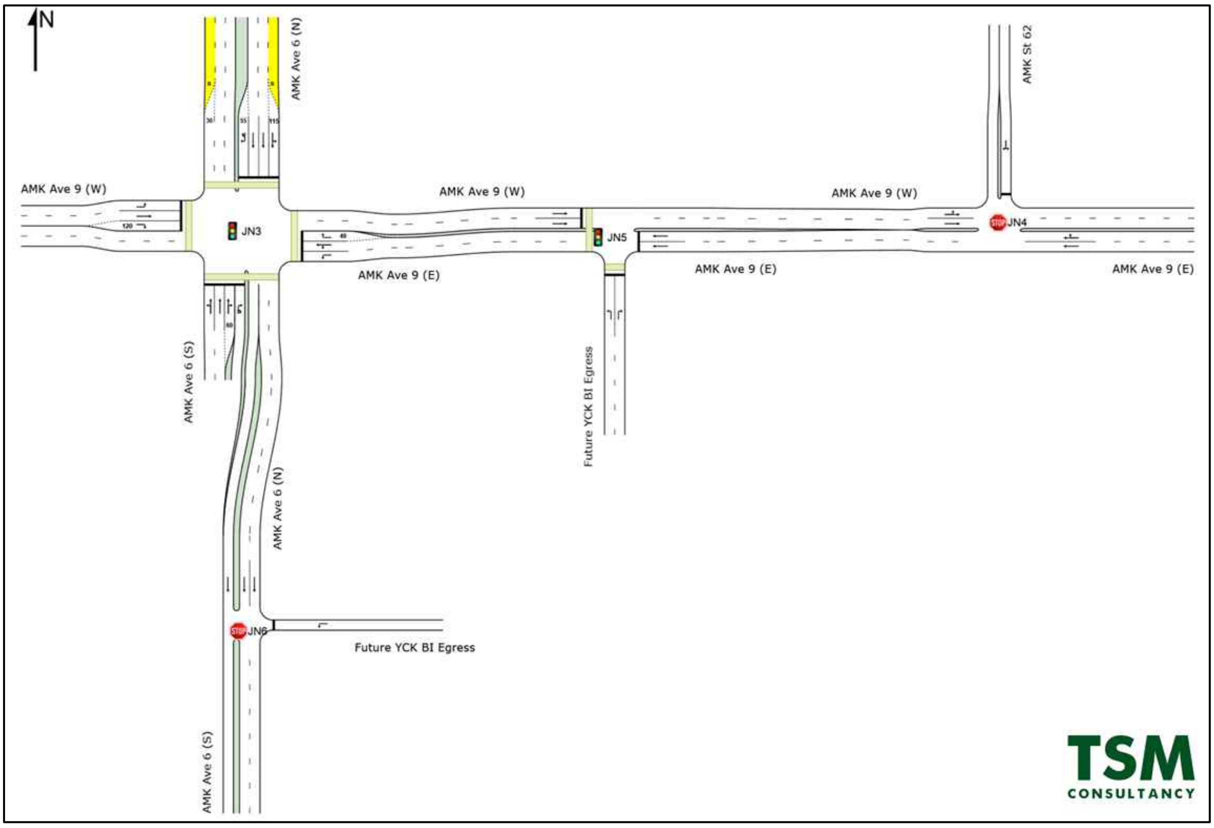


Figure 4.47: Example of SIDRA Network Model

SIDRA Intersection is generally used for most of the TIA study as it has user-friendly features without the need to change most of its default parameters. Necessary input that are required from the users are as follows:

1. Junction geometry and layout (i.e. number of lanes, lane configuration)
2. Traffic and pedestrian volume
3. Signal phasing and timing

Once all the data entered into the SIDRA model, SIDRA will run the model to assess the junction's capacity based on the given data. Figure 4.48 shows the movement summary result generated by SIDRA which includes the average delay, queue length as well as average number of cycles for traffic to clear the signalised junction. With this set of result, user then can determine should there is a need to further improve the junction's capacity by either providing additional lanes or change the signal phasing and timing

MOVEMENT SUMMARY

Site: 101 [J1 [Existing 2021, AM] (Site Folder: Junction 1)]

TSM CONSULTANCY

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 143 seconds (Site User-Given Phase Times)

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Bukit Batok East Ave 3 (S)														
1	L2	935	0.0	984	0.0	0.530	5.7	LOS A	0.0	0.0	0.00	0.53	0.00	52.4
2	T1	549	0.0	578	0.0	0.396	35.5	LOS D	14.2	99.5	0.77	0.65	0.77	36.3
3	R2	230	0.0	242	0.0	* 0.618	34.5	LOS C	9.9	69.0	0.94	0.81	0.94	38.3
3u	U	3	0.0	3	0.0	0.618	35.9	LOS D	9.9	69.0	0.94	0.81	0.94	29.4
Approach		1717	0.0	1807	0.0	0.618	19.1	LOS B	14.2	99.5	0.37	0.60	0.37	42.7
East: Bukit Batok St 25														
4	L2	558	0.0	587	0.0	0.525	21.6	LOS C	18.8	131.6	0.63	0.76	0.63	44.4
5	T1	173	0.0	182	0.0	* 0.525	54.9	LOS D	13.7	95.6	0.93	0.83	0.93	33.0
6	R2	14	0.0	15	0.0	0.057	63.0	LOS E	0.9	6.2	0.90	0.69	0.90	33.8
Approach		745	0.0	784	0.0	0.525	30.1	LOS C	18.8	131.6	0.71	0.78	0.71	40.7
North: Bukit Batok East Ave 3 (N)														
7	L2	13	0.0	14	0.0	0.014	18.2	LOS B	0.4	2.6	0.44	0.62	0.44	48.9
8	T1	829	0.0	873	0.0	* 0.732	55.7	LOS E	20.9	146.5	0.97	0.84	1.00	29.6
9	R2	135	0.0	142	0.0	* 0.958	95.8	LOS F	12.8	89.6	1.00	1.01	1.42	22.9
9u	U	13	0.0	14	0.0	0.958	97.2	LOS F	12.8	89.6	1.00	1.01	1.42	25.8
Approach		990	0.0	1042	0.0	0.958	61.2	LOS E	20.9	146.5	0.97	0.87	1.06	28.6
West: Bukit Batok St 23														
10	L2	98	0.0	103	0.0	0.083	8.2	LOS A	1.2	8.2	0.22	0.61	0.22	52.4
11	T1	66	0.0	69	0.0	0.159	48.2	LOS D	3.9	27.1	0.84	0.66	0.84	35.4
12	R2	649	0.0	683	0.0	* 1.108	138.0	LOS F	28.3	197.9	1.00	1.14	1.65	13.0
Approach		813	0.0	856	0.0	1.108	115.1	LOS F	28.3	197.9	0.89	1.03	1.42	16.2
All Vehicles		4265	0.0	4489	0.0	1.108	49.1	LOS D	28.3	197.9	0.67	0.78	0.79	30.5

Site Level of Service (LOS) Method: Delay & v/c (HCM 2010). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 2010).
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

Figure 4.48: Example of SIDRA Movement Summary Result

However, SIDRA Intersection also has its limitation which unable the users to model specific motorists' behaviour (i.e. lane changing, reduced speed, etc) which may affect the overall traffic situation. Hence, SIDRA is mostly used to analyse the intersection's capacity rather than the effectivity of a road network. Should the need arise to analyse a more complex road network (with multiple interactions in close proximity), microsimulation modelling is usually preferred.

PTV VISSIM / VISWALK / VISUM

PTV VISSIM

PTV VISSIM is an advanced traffic simulation software commonly used to simulate complex vehicle interactions realistically on a microscopic level. It also enables the modellers to model the infrastructure and motorists' behaviour in detail which gives a realistic representation on the existing traffic situation. In addition to the default vehicular simulation, VISSIM also allows modellers to perform a pedestrian simulation by modelling the human walking behaviour realistically to simulate and analyse pedestrian flows, both indoors and outdoors.

When the impact goes beyond a single junction and covers a few junctions that forms a small road network, LTA may request the use of VISSIM to simulate the network, and then iteratively test scenarios to find a suitable scenario for implementation. Transport for London's guidelines (see Traffic Modelling) also gives advice on when to use VISSIM for operation

Based on VISSIM's Guidelines, the traffic flow model is based on a car-following model (for the modelling of driving in a stream on a single lane) and on a lane changing model. For multi-lane roadways, a driver in the VISSIM model takes into account not only the vehicles ahead, but also the vehicles in the two adjacent lanes. In addition, a signal control for about 100 meters before reaching the stop line leads to increased attention of the driver.

VISSIM simulates the traffic flow by moving **driver-vehicle-units** through a network. Every driver with specific behaviour characteristics is assigned to a specific vehicle. As a consequence, the driving behaviour corresponds to the technical capabilities of the vehicle

In VISSIM, users would have to model the junction/road network configuration manually, different from SIDRA which generates the configuration automatically based on the given inputs. Users would also require to provide input on different driving behaviour such as, reduced speed area, conflict areas, priority rules, etc, which will affect the model's performance. Hence, with a more complex input, VISSIM generally able to provide a more realistic road network's performance for a more detailed planning.

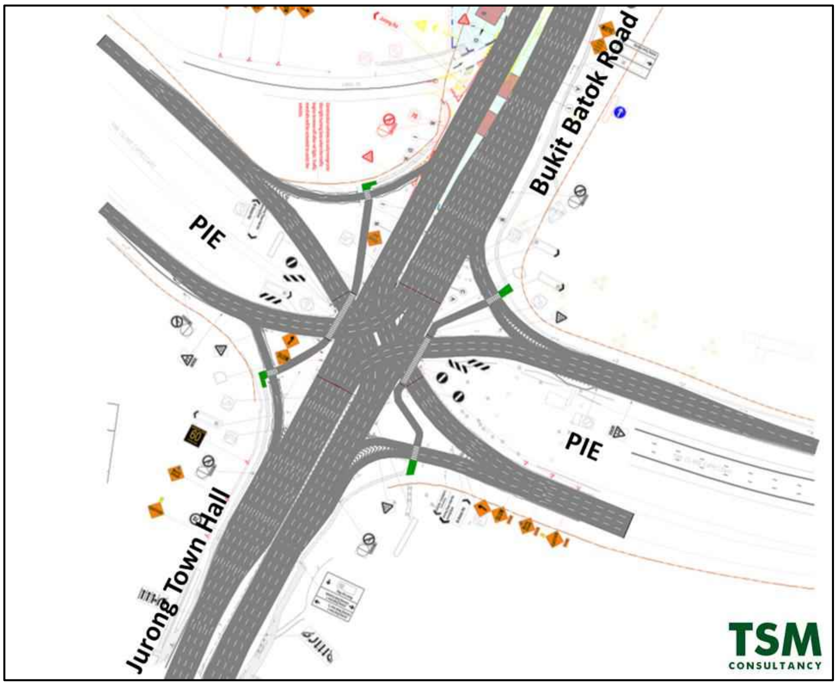


Figure 4.49 Example of VISSIM Model (1)

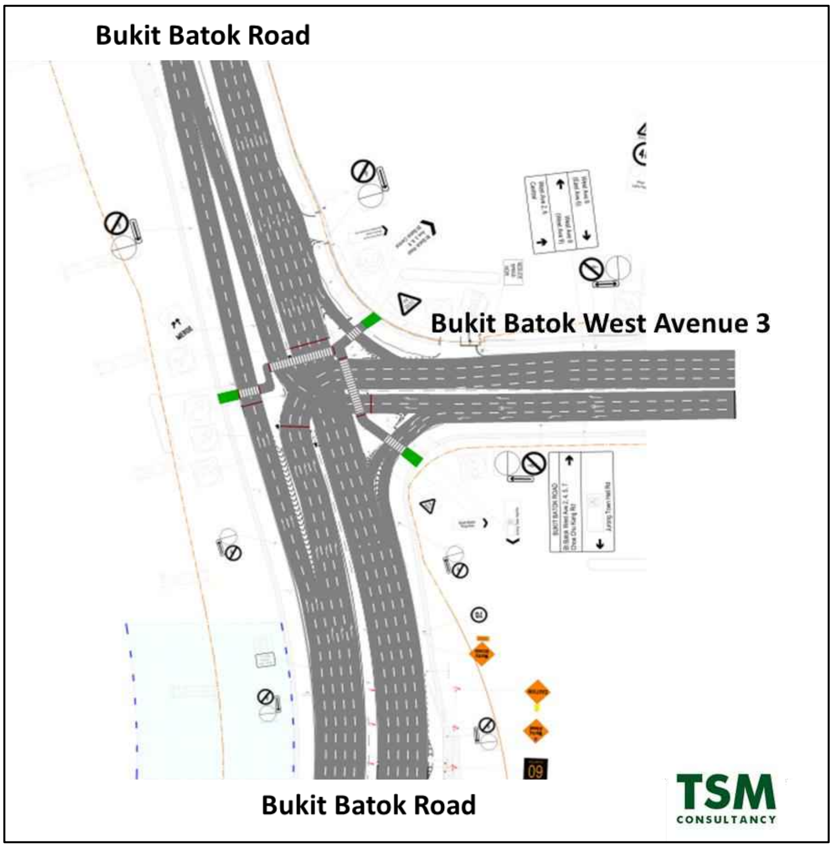


Figure 4.50: Example of VISSIM Model (2)

Once the model has been built with its corresponding input, VISSIM will run its analysis and provide road's performance such as average delays, average and maximum vehicular queue lengths (which are used as quantitative measures to describe the operational procedure). While network objects such as speed decisions, conflict areas and dwell time are coded in the network to simulate existing condition. With the results, the modellers can proceed to determine any necessary measures to improve the overall road's capacity and performance.

For a more realistic scenario of actual ground condition, usually a 15-minutes 'warm-up' and 'cool-down' periods were added into the simulation run to ensure realistic congestion/delay is replicated at the beginning of the defined modelled hour.

In order to ensure the model is simulated closely to the base scenarios, observed existing and modelled vehicular flows are used to calibrate the models. The proposed acceptability guideline for calibration and validation is that at least 80% of simulated maximum queue and simulated traffic flows have GEH < 5.0. The GEH statistic is used to calibrate observed and forecasted flows with modelled traffic flows, as well as to validate observed queues and modelled vehicular queue length. GEH Statistic is defined as follow:

$$GEH = \sqrt{\frac{2(M-C)^2}{(M+C)}}$$

where, $M = \text{modelled flow/queue}$

$C = \text{observed/forecasted flow/queue}$

VISSIM able to generate a video to simulate the junction/road network's performance that is simulated in the model. This will provide a better understanding for people who is not in engineering background, for better decision making.

PTV VISWALK

PTV develops a special software for professional pedestrian simulation, which can be used as a stand-alone or in combination with VISSIM. The dynamic model allows pedestrians to walk independently to their destination, without a network model predefining their trajectories. While a simple pedestrian simulation, based on directed routes (instead of areas), is included in VISSIM and based on the car following model as per the vehicle simulation.

PTV VISUM

PTV VISUM is a macroscopic planning software designed for Transport Planners to carry out the holistic overview of the traffic situation as well as to forecast and measure effects of development planning.

4.1.6 Traffic Modelling

Introduction

Based on UK's Transport for London (TfL) Traffic Modelling Guidelines, there is a user provision hierarchy to be considered while creating a traffic model. This is to ensure that the model is built accordingly and can represents the actual priority on the road.

Consider first	Pedestrians
	Cyclists
	Public transport users
	Specialist service vehicles (e.g. emergency services, waste, etc.)
Consider last	Other motor vehicles

Quoted from UK's Transport for London (TfL), *"traffic models present a simulated environment in which numerous design solutions can be tested and appraised with the aim of achieving the optimum balance of benefits and value for money. Modelling also enables users to understand any potential traffic impacts as well as develop strategies to mitigate adverse impacts."*

Figure 4:51: UK's Transport for London Hierarchy of User Provision

The reasons why traffic modelling is necessary and useful, especially for overall road network planning, are as follows:

1. **Design**
   Traffic model can be used to test and refine a road design until it achieves the desired and optimal performance.

2. **Balance**
   In modelling the traffic model, modellers would need to consider the need and demand of all road users. It is necessary to balance out the demand to ensure that the road network able to accommodate all road users. On top of assessing the existing scenario, the simulated model can also be used to assess the needs of future users to maximise the benefits of a particular scheme.

3. **Prediction**
   Models can help to quantify the impacts of a scheme. Highlight should there be any issues arising from the design and follow up with proposed mitigation measures

4. **Communication**
   The results of modelling which is the predicted effects will be communicated to give stakeholders some idea of how it will look after implementation. Use the visual output to clearly convey technical data to a non-technical audience.

5. **Demand**
   Models to be used to explore implications of alternative demand resulting from in travel behaviour.

Basic Modelling Process

1. **Replicating the Current Situation**

   For any traffic modelling, the first step is to build a model that replicates the current traffic conditions when the data used to build the model was collected. This model is called Base Model which is going to be used as a baseline for comparison with any other scenarios. Usually, base model includes the weekday AM and PM peak periods. Other time periods (i.e. mid-day) may be modelled if deemed necessary.

   Base models shall be developed and calibrated using the actual data collected from the site. The data is required to validate the model and demonstrate that the models have adequately represented the current conditions, within the acceptable level of accuracy, and are suitable for comparison when assessing other scenarios. Based on UK's Tfl, one of the examples for validation parameter is degree of saturation (the percentage of capacity) at a stopline and journey times between two points.

2. **Assessing Future Scenarios**

   One of the purposes of a traffic modelling exercise is to assess and forecast the operational performance of a future traffic proposal/scheme. The future model shall be built/developed based on the Base model which has been calibrated. Should there are any other input that are not available during the model development (for example, road user behaviour), necessary assumptions shall be made based on a logical approach of the available survey data or observation wherever possible and available.

3. **Interpretation and Presentation of Modelling Results**

   Base model results shall be used to:
   - Demonstrate that the model adequately represents the existing situation
   - Provide the reader with a detailed assessment of the existing situation

   While, Future model should demonstrate:
   - The effect of the scheme on the road network. Based on the future model analysis, modellers to propose any measures to be implemented to improve the overall road/traffic condition
   - Results from the future modelling should be presented and compared with the base model or with a future year base model (without any scheme) for better comparison

4.1.7 Types of Traffic and Directional Signs

<u>Providing Information to Motorists</u>

Motorists need guidance on how to use the road network and specific instructions on traffic movement to maintain road safety. These require the use of traffic signs at the appropriate locations to advise them on what they can and cannot do. A well-thought out and clear methodology of sign installation is a pre-requisite to good traffic management. These signs make the driving task less ambiguous, less tiring and less hazardous.

There are five types of signs.

a) Warning signs - alert motorists of potential hazardous or unusual conditions ahead. They are used for forewarning so that the motorist is not caught unaware by an unfamiliar situation. All warning signs are indicated in a red triangle. The following are some examples of warning signs.

 **Double Bend Ahead, First To The Left**	• This sign indicates that the road ahead has a double bend with the first bend to the left/right • To inform motorists to Keep left and slow down. Do not overtake, make a U-turn, stop or park your vehicle.	It may be used with a supplementary plate.

 **Road Hump Ahead**	• This sign warns of a road hump or humps ahead. • To inform motorists to slow down, keep left and do not overtake.	It may be accompanied by a 'SLOW' plate to advise motorists to slow down.
 **Elderly or Handicapped Pedestrians Ahead**	• This sign warns of elderly pedestrian ahead • To inform motorists to slow down and beware of elderly people crossing the road.	

Figure 4:52: Warning Signs

b) Mandatory signs - tell motorists what he/she must do. For examples, "Turn right" or "Stop" signs fall into this category. Most of the signs are circular with blue background and a white border. The following are some examples of warning signs.

 **Turn Right Only**	• The sign indicates vehicles are obliged to proceed in the direction indicated by the arrow. • To instruct motorists to turn right only.	

 **Keep Left**	• The sign indicates vehicles shall proceed on the left of some permanent or temporary obstruction. • To instruct motorists to keep left	The sign may be used as part of traffic bollards on islands or refuges

Figure 4:53: Mandatory signs

c) Prohibitory signs - tell motorists what not to do. Examples are “No Entry” and “No Right/Left Turn” signs. Prohibitory signs are mostly circular in shape with a red border.

 **No Entry**	• The sign indicates that vehicles are not permitted to enter unless indicated otherwise by a supplementary plate.	
 **No Right Turn**  **No Left Turn**	• The sign prohibits vehicles from turning right/left.	The sign may be used with traffic signals or may be qualified with supplementary plates.

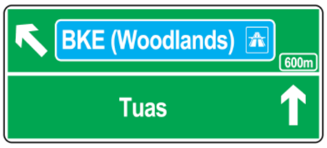
Figure 4:54: Prohibitory signs

d) Information signs - tell motorists driver what is available. The signs are used to convey messages concerning thing that is of interest and importance to motorists. Information signs have a blue background with white letter headings

 **Red Light Camera**	• To remind motorists to slow down and prepare to stop at the junction ahead. • Approval/Installation of Red-Light Camera is under the Traffic Police.	
 **Rain Shelter**	• To inform motorcyclist of the nearest rain shelter ahead along the expressway.	

Figure 4:55: Information signs

e) Directional signs - give information on road names and destinations so that motorists can find their way around. There are four main directional signs, namely, advance, intermediate, confirmatory and gantry signs.

 **Advance Directional Sign**	• To show the destination that exit will lead to as well as the destinations in other directions. • It also contains the exit distance between the sign and the exit.
 **Intermediate Directional Sign**	• To reinforce the message to motorists about the exit, and where it leads to. • It contains the destinations the next exit leads to, the exit number and exit distance. • Intermediate signs are only used on expressways

 **Confirmatory Directional Sign**	• Confirmatory signs for expressways indicate the locations of the exit, and those along arterial roads point towards the directions to which motorists must turn to get to the indicated destinations. • It contains the exit destinations and exit number.
 **Gantry Directional Sign**	• To guide motorists to keep to the appropriate lane of their intended destination in advance. • Gantry signs are usually placed on expressways at locations much further ahead of the exits than the normal advance directional signs

Figure 4:56: Directional signs

Information and directional signs are very important as a hesitant motorist can hold up traffic flow and may cause accidents at the worst. However, indiscriminate use of signs can result in a clutter, misinformation and end up with motorists disregarding them. The golden rule is that signs should only be installed if they are relevant and can assist motorists. More details of the signs can be found in LTA's Civil Design Criteria and Standard Details of Road Elements.

4.1.8 Temporary Traffic Control and Diversion Plans

Introduction

Temporary traffic control is developed to manage the traffic condition efficiently and safely to minimise the impacts to the road users. The road alignment shall be designed according to the prevailing standards based on LTA's Civil Design Criteria. Other than the road alignment, traffic control also regulates the use of signages and other traffic control devices (i.e. Truck Mounted Attenuator) in accordance with LTA's Code of Practice for Traffic Control at Work Zone to provide adequate warning and clear information to motorists on the upcoming road works.

Traffic control at work zone starts from the first advance warning sign and ends at the last traffic device where traffic returns to normal. There are five phases involved in the execution of temporary traffic control for works on road.

1. Planning Phase
   During planning phase, Consultant/Contractor shall identify and include traffic control requirements in the contract specification, works program and method of construction. Details of the traffic control design will be further developed in the subsequent Design Phase.

2. Design Phase
   The main purpose of Traffic Control Plan (TCP) is to support the preferred works program as well as construction sequences and methodology. Hence, based on those consideration, Consultant shall develop the detailed design of the temporary control plan. The TCP would have to be submitted to LTA for review and approval. Should there be a need to propose any lane closure, additional study may be required to ensure that the remaining road capacity can still meet the demand. Otherwise, further improvements works are to be proposed to ensure minimal impacts to the other road users.

   The submission and approval process of TCP generally consists of a few rounds of review before LTA formally endorse and approve the plan for implementation.

3. Implementation Phase
   Contractor shall install all temporary traffic control devices safely as well as implement the proposed road alignment in accordance with the approved TCP and make adjustments if necessary, according to site conditions and/or required by the Authority. Site inspection to check the implemented scheme to be conducted within 10 days of the implementation to ensure that the scheme is implemented accordingly.

4. Operation and Maintenance Phase
   Contractor/Consultant shall inspect the implemented traffic scheme and devices regularly by day and night to ensure that they are effective and safe. Additional measures to be provided if the need arises.

5. Close Out Phase
   Once, the temporary road works are completed, Contractor shall remove all the traffic control devices safely and reinstate the permanent/original traffic scheme.

Preparation and provision of proper traffic control shall comply with the prevailing Street Works Act and Street Works (Works on Public Streets) Regulations and other relevant legislative requirements of other authorities, such as the Workplace Safety and Health Act, Workplace Safety and Health (Construction) Regulations, Road Traffic Act, Road Traffic (Traffic Signs) Rules etc.

General Guidelines/Design Considerations for Traffic Control

Design shall start after the preferred temporary traffic control scheme has been selected for each stage of the work. As described in LTA's Code of Practice for Traffic Control at Work Zone, important design consideration shall include the following and summarized in Table 4.6 below.

S/No	Type	Differentiation	Characteristic

1.	Work Duration	Long Term	• Long term means stationary works which occupy lane(s) for extended period continuously.
			• Require to change the alignment of the road and/or maintain the same number of the existing lane
			• Require use of portable and elaborate devices e.g. use of high containment road safety barrier for the safety of road users and workers
			• Require relocation of traffic signals and/or traffic furniture
			• Detailed TCP/traffic diversion plan and comply with the LTA Civil Design Criteria, Road Safety Guidebook and approved by LTA
			• Examples include but are not limited to:
			    • Tunnel shaft construction
			    • Deep excavation
			    • Rigid pavement construction
			    • Road widening

		Short Term	• Short term means stationary works which occupy lane(s) temporarily and can be removed quickly
			• Required use of portable devices
			• Examples include but are not limited to:
			    • Connection works for utility supply
			    • Trial trench
			    • Trenching for utility laying
			    • Manhole maintenance

		Mobile	• Continuously moving works with intermittent stops
			• Portable device
			• Examples include but are not limited to:
			    • Signs washing
			    • Road marking

2.	Road Speed	Design speed for diversion shall not fall below more than 10 km/h of the existing permanent gazette speed limit Road geometry for diversion shall comply with LTA Civil Design Criteria	• Horizontal alignment • Vertical profile • Cross-section • Sight distance • Taper length • Safety buffer • Sign spacing
3.	Road Type	Expressway Arterial Primary Access Local Access	• Legal speed • Access control • Shoulder • Stopping/waiting • Parking/driveway

4.	Road Location	Rural area Urban area Public housing Private housing CBD Industrial area School zone	• Local traffic • Pedestrian • Local business • Bus stop • Parking • Driveway • Stopping
5.	Work Location	Outside/near carriageway Shoulder lane Slow/left lane Intermediate lane Fast lane Multi lanes Median Junction/interchange	• Road encroachment • Work access • Work traffic • Speed gradient • Fast/right lane is hazardous • Special attention on fast lane
6.	Traffic Condition	CONDITION I: Demand always < road capacity CONDITION II: Demand at peak > road capacity	• Long term lane closure may be allowed for Condition I Lane closure will not be allowed on peak hours. Temporary widening or traffic diversion required for long term work
7.	Type of Work	TYPE I: Can be removed quickly TYPE II: Cannot be removed easily	• Simple planning would suffice for Type I • Detailed planning needed for Type II for unforeseen delays
8.	Mode of Operation	MODE I: Workmen are always in attendance MODE II: Work left unattended	• Use simple and portable devices for Mode I • Use robust devices and keep clear of passing vehicles

Table 4.6: Summary of Design Considerations

Design of Traffic Control Plan

In general, the work zone is typically divided into four zones as indicated in Figure 4.56 below. The required lateral safety buffer and taper length are determined based on the current speed limit of the area. This is to ensure that motorists will have sufficient time and safe distance to react and stop in time before hitting the work area.

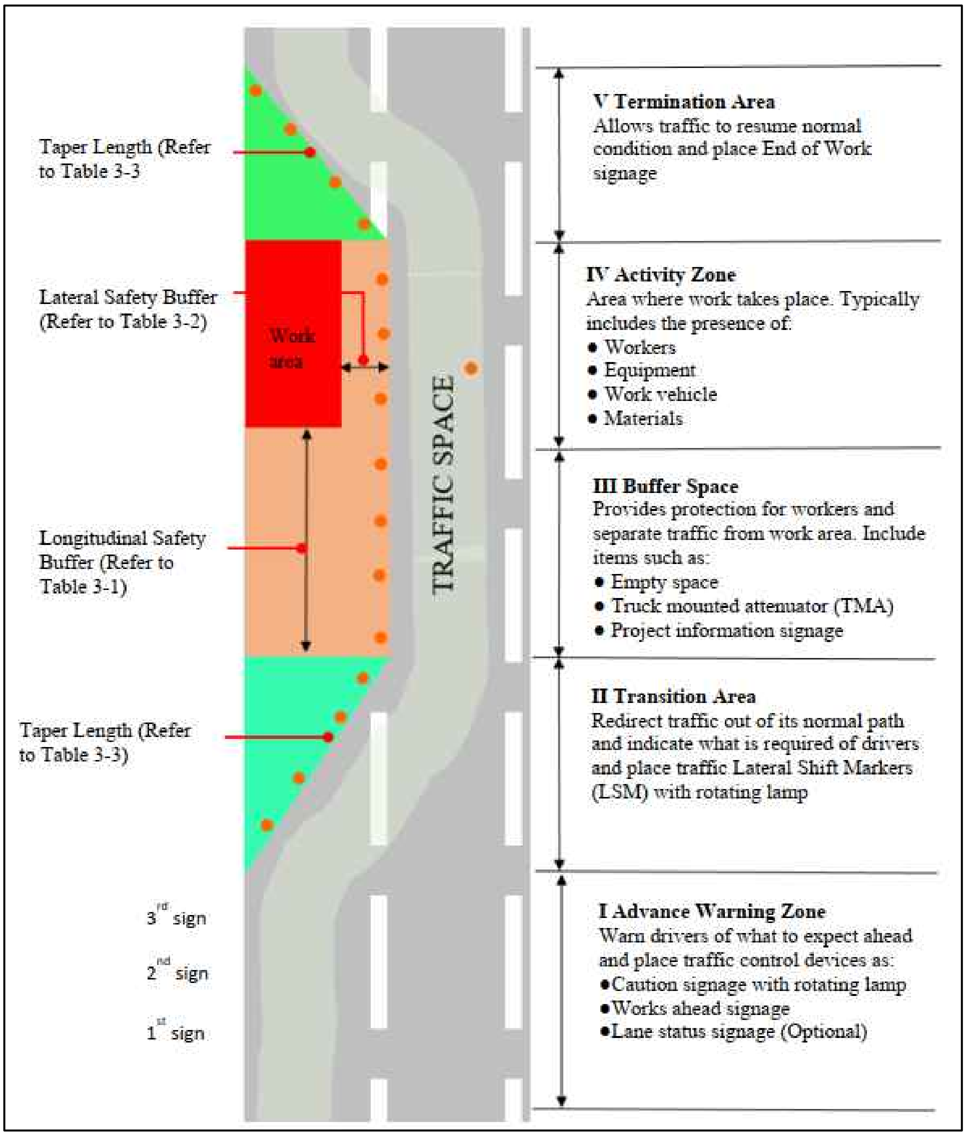


Figure 4:57: Component of an Activity Zone

Table 4.7 to Table 4.9 below shows the recommended longitudinal safety buffer, lateral safety buffer as well as taper length respectively based on the current speed limit of the road. Type of taper within the diversion area are shown in Figure 4.57.

Speed (km/hr)	Length (m)
=> 80	60
70	30
60	20
50	10
40	10

Table 4.7: Recommended Longitudinal Safety Buffer

Speed (km/hr)	Minimum Width (m)	
	Desirable	Absolute
=> 80	1.2	0.6
70	0.9	0.6
60	0.5	0.3
50	0.5	0.3
40	0.5	0.3

Table 4.8: Recommended Lateral Safety Buffer

Speed (km/hr)	90	80	70	60	50	40
Merging	200	150	120	80	40	20
Shifting	100	80	60	40	20	10
Shoulder	20	20	NA	NA	NA	NA

Table 4.9: Recommended Length for Taper (m)

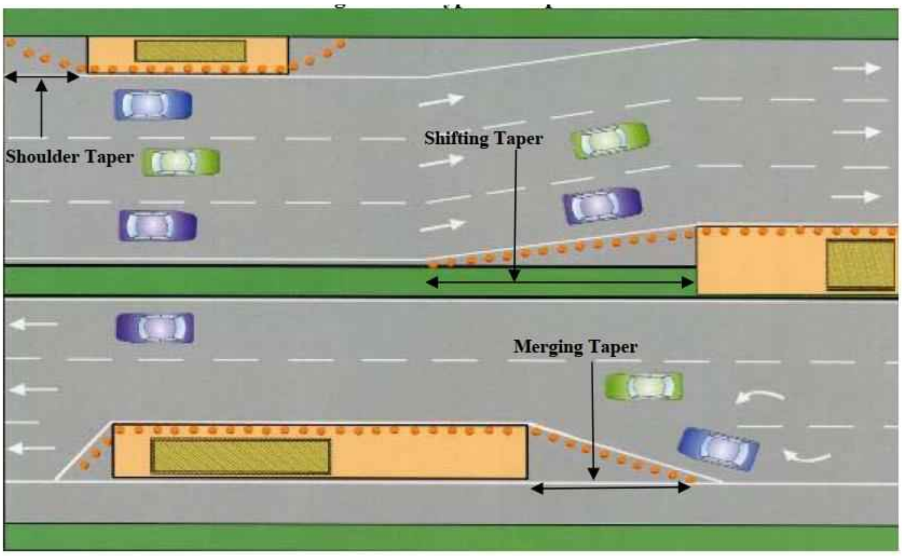


Figure 4.58: Type of Tapers

In general, two Temporary Advance Warning signs shall be provided at every approach to work site on all public roads (including expressway). The third sign usually installed to inform motorists on the nature of road works ahead (i.e. lane closure, lane diversion, etc). Example of the Advance Warning signs are shown in Table 4.10 below. Minimum distance of each of the Temporary signage placing is determined based on the road speed limit as shown in Table 4.11.

1st Sign	To alert and command road user's attention to work zone. Typical visibility of 1st sign = minimum stopping sight distance	
2nd Sign	To notify road users of the general nature of the work ahead. Logo identifies the organisation carrying out the work.	
3rd Sign	To guide road users of the action to be taken (i.e. merge to middle lane, slow, bend ahead etc)	

Table 4.10: Example of Advance Warning Signs

Distance from taper starts	90/80 km/h	70 km/h	60 km/h	50 km/h	40 km/h and below
3rd sign	240 m	200 m	160 m	120 m	60 m
2nd sign	360 m	300 m	240 m	180 m	90 m
1st sign	480 m	400 m	320 m	240 m	120 m

Table 4.11: Minimum Distances of Temporary Signs

At the termination zone, interface between the work zone and the unaffected road portion, the design considerations are as follows:

1. A taper of 1:10 or at least 30m shall be provided to ease traffic back to its normal path for expressway, major arterial, distributor, and 1:1 for other roads.
2. End of Work Zone sign (Figure 4.54) shall be used at the end of the work zone of long-term work to inform and thank road users for their understanding and co-operation.

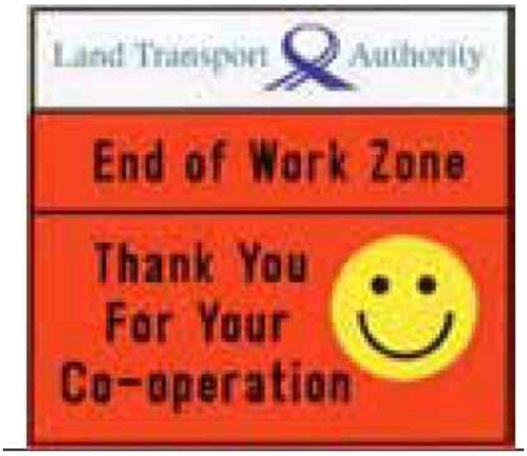


Figure 4.59: End of Work Zone Sign

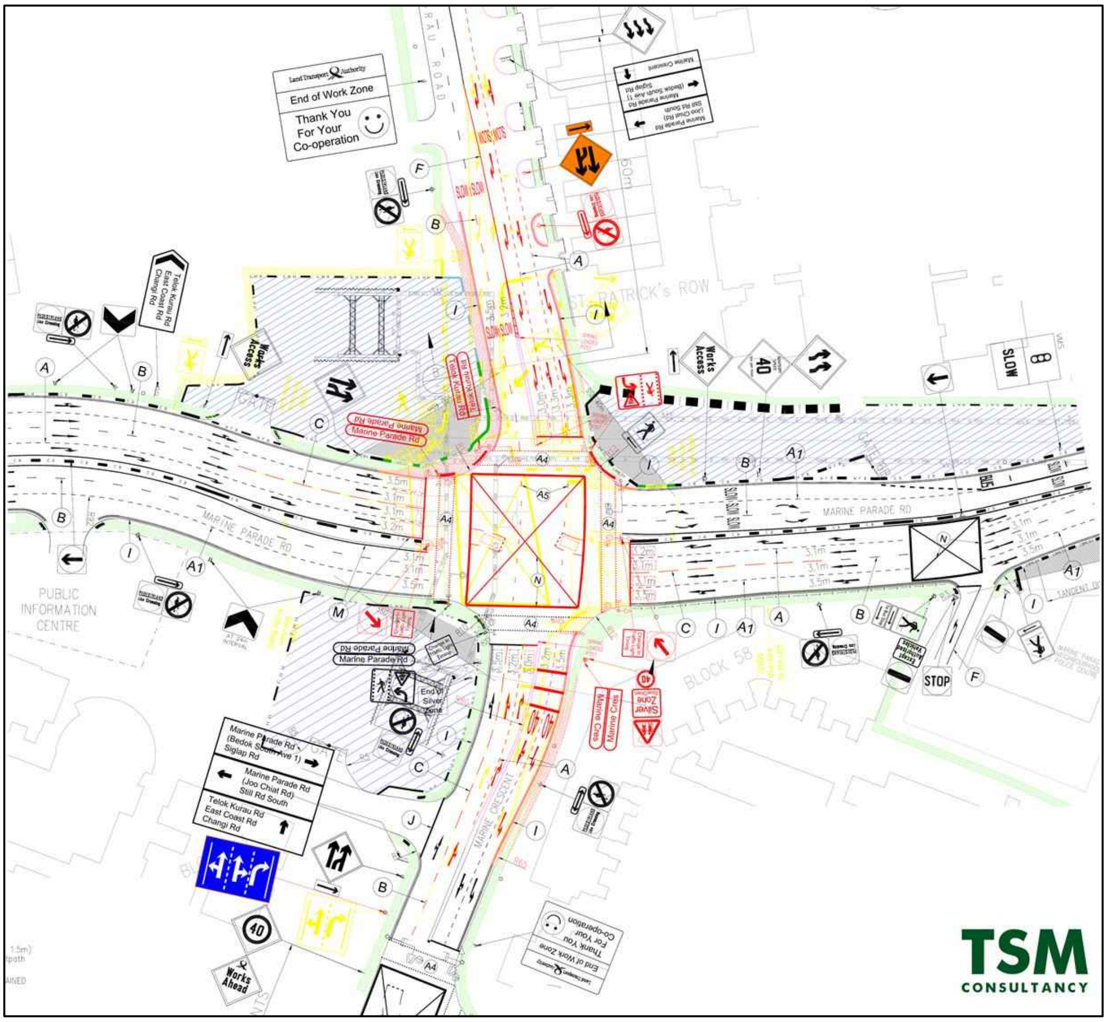


Figure 4.60: Example of Traffic Control Plan

Other Consideration

In general, it is preferred to design the temporary road diversion to comply with all the requirements for permanent road, in terms of lane width, turning radius, for example. However, in some cases, it is not always feasible to fully comply with the requirements due to tight site constraints, the presence of existing developments, and other considerations. Hence, some measures such as reducing the speed limit, narrowing the lane width, may be proposed to ensure that the allocated work zone is sufficient for the Contractor to carry the works.

However, it is necessary to ensure and demonstrate that the proposed design is adequate and safe for motorists. Swept Path Analysis is one tool that is widely used to check the road design and ensure the expected road users are able to manoeuvre along the diverted road alignment.

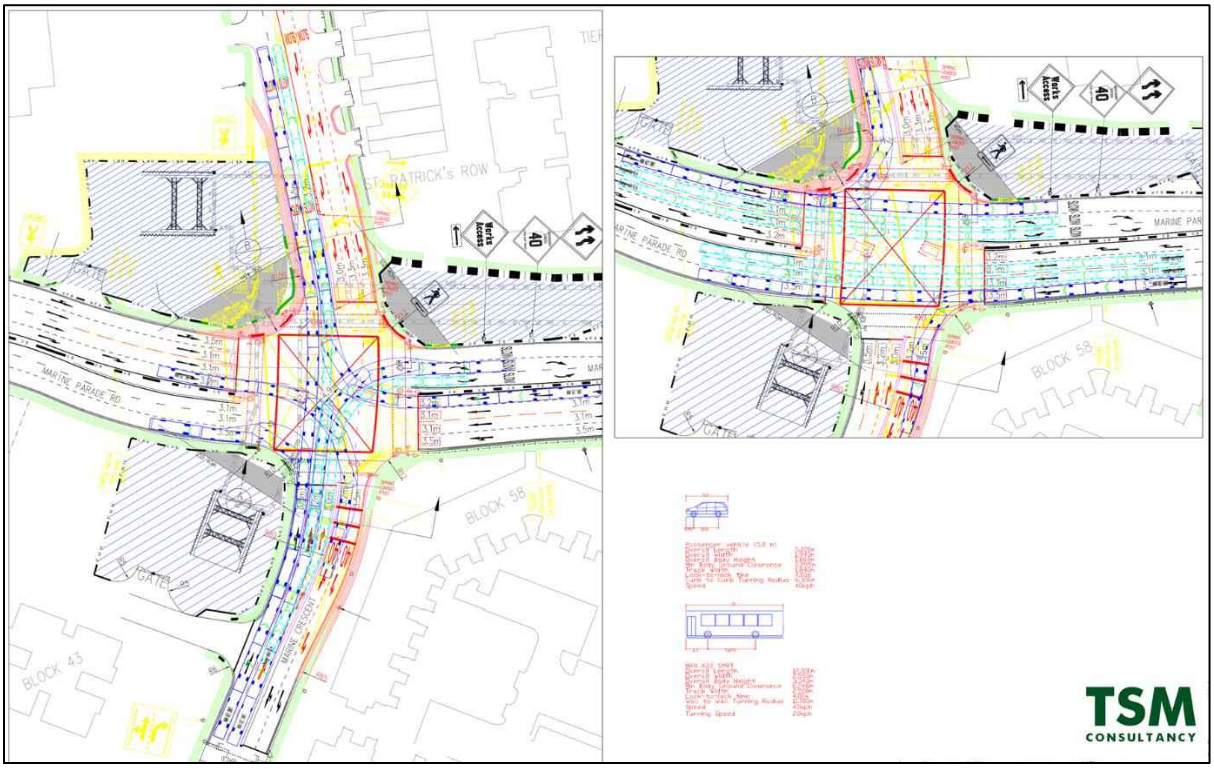


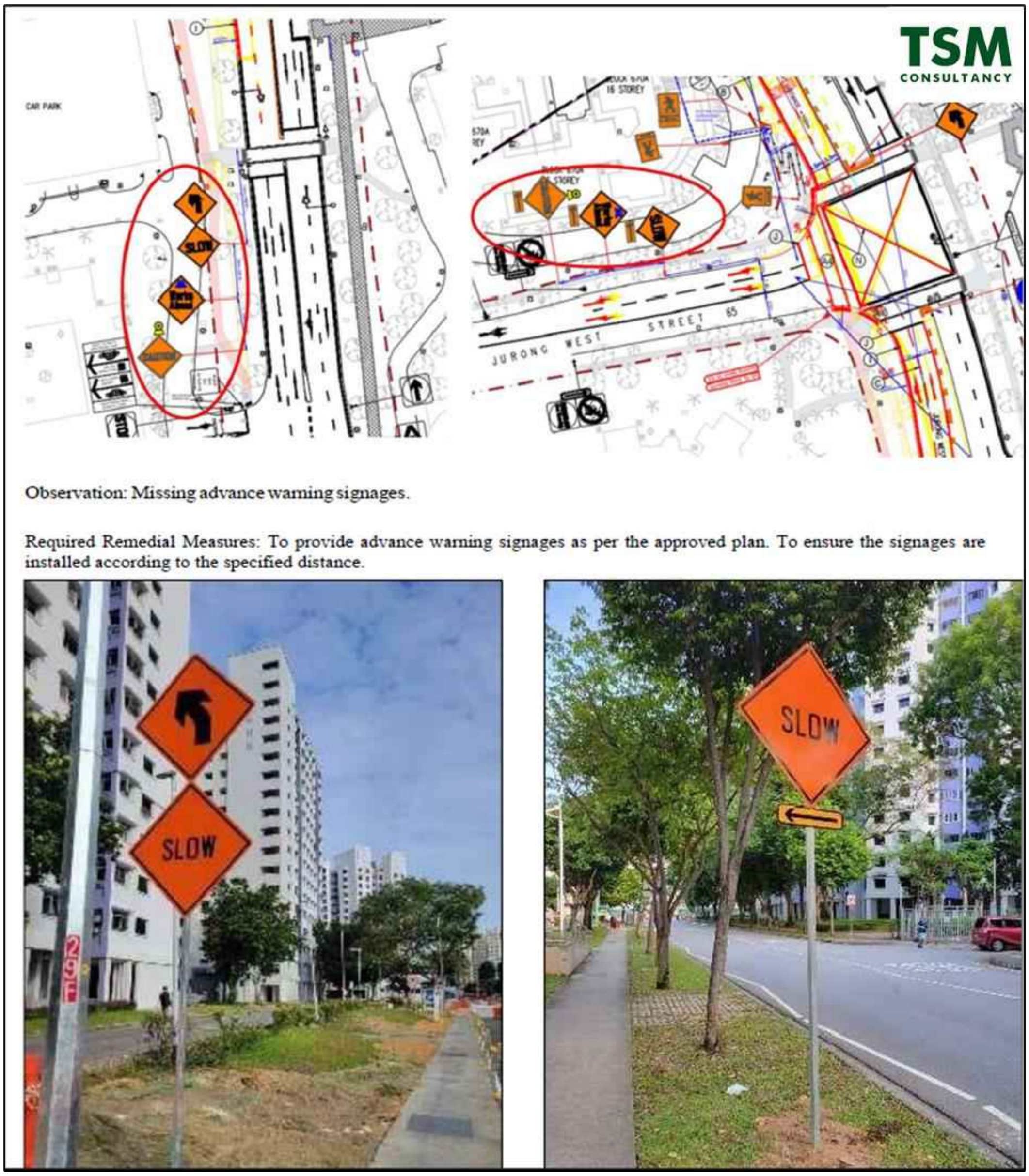
Figure 4.61: Example of Swept Path Analysis

Some other traffic management measures such as signages and road calming measures (i.e. speed regulating strips, Variable Message Signs [VMS]) could be proposed to further alert motorists on the upcoming road works/diversion.

Figure 4.62: Signs/Other Road Calming Measures

Post Implementation Review (PIR)

For all road diversion, it is necessary to carry out a Post Implementation Review (PIR) within 10 days of the implementation date. During the site inspection, Consultants shall inspect and check the implemented diversion/scheme and ensure that it has been implemented according to the approved plan. A checklist, which will document all potential hazards, non-compliance as well as future improvement works, to be submitted for Contractor’s necessary action. Contractor then would need to carry out the necessary remedial measures.



Observation: Missing advance warning signages.

Required Remedial Measures: To provide advance warning signages as per the approved plan. To ensure the signages are installed according to the specified distance.

Figure 4.63: Examples of PIR Document

4.2 Operation

4.2.1 Overview of Road Operations and Regulations

LTA has set up the various divisions to manage and regulate the safe operation of the roads under their jurisdiction.

Intelligent Transport System Operations (ITSO)

Figure 4.64: ITS OCC & Incident Management Team

The Intelligent Transport Systems Operations Control Centre (ITS OCC) works around the clock to monitor traffic and manage incidents on our expressways and road tunnels using the i-Transport and various ITS.

The 24/7 real time Traffic Operations Control Centres leverage on Intelligent Transport Systems to monitor and manage real-time traffic on the roads and in tunnels. Support may then be given by the Operations Planning teams who analyse traffic impact of planned events, prepare operation plans, and manage ITS operational parameters to ensure seamless execution by OCC, as well as Incident Management Team who manages a fleet of incident management resources for swift incident response and recovery.

Site deployment of mobile cameras to monitor the traffic around the event locations e.g., General Election nomination centres / National Day Parade. The ITSO staff would patrol specific areas and liaised with the Operation Control Centre (OCC) to ensure smooth traffic and bus movements.

Road Works Regulations and Licensing (RWRL)

Figure 4.65: Road works

The Road Works Regulations and Licensing (RWRL) division's main role is to ensure road works by third parties (e.g. PUB) are carried out such that the roads and road structures are safeguarded, occupation of the roads for engineering works are carried out safely and pose minimum disruptions to traffic flow.

They also perform enforcement actions against offences such as obstructions on public streets, skips placement that pose safety or traffic issues.

Figure 4.66: Obstructions on public street blocking pedestrian movement

Active Mobility Enforcement (AMEF)

Figure 4.67: AM Enforcement

Active Mobility Enforcement Section was formed in May 2016 to handle Active Mobility violations under the Active Mobility Act. Since 1 May 2018, Active Mobility Enforcement Officers (AMEOs) are able to take enforcement actions against non-compliant Personal Mobility Devices (PMDs), Power Assisted Bicycles (PABs) and all other AM devices.

The intention is to inculcate and mould a gracious path-sharing culture for the safety of all path users through public engagements, reinforcement of regulations and strategic enforcement, to achieve a liveable and sustainable city through LTA's vision of Walk Cycle Ride SG.

Vehicle Enforcement (VEF)

Figure 4.68: Vehicle Enforcement

The LTA Vehicle Enforcement Team was formalised in 2012 and their main duties are enforcing regulatory, technical and licensing offences under Road Traffic Act Rules and subsidiary legislation.

4.2.2 Road Tunnel Operations and Safety

- Safety Features in Road Tunnel

Singapore has in place electrical and mechanical systems to keep our road tunnels safe such as the Uninterrupted Power Supply System and Generator where critical equipment such as the communication, lighting, traffic control and monitoring systems are supported by Uninterrupted Power Supply (UPS) in the event of major power failure to prevent disruption to operations.

Ventilation system in the tunnel

Overhead water sprinkler system in tunnels

Figure 4.69: Ventilation system and overhead water sprinkler system in tunnel

The ventilation and fire protection systems, and equipment, help to keep the temperature in the tunnels acceptable and provide support in case of fire.

The ventilation system measures parameters such as visibility, carbon dioxide quality, temperature and velocity of air travel. If these markers exceed certain values, jet fans fitted along the tunnel will be activated to improve the air quality and keep the environment appropriate for motorists. In the event of fire, the ventilation system will push smoke out of the tunnel.

Tunnels are equipped for fire protection with heat detector systems that trigger an alarm to the OCC when the temperature indicates the presence of fire, and other fire-fighting equipment such as fire extinguishers, and hydrant pillars.

The drainage system comprises the storm water system, which collects rainwater, and wastewater drainage system which discharges water arising from tunnel washing and fire-fighting activities.

Being built around a densely developed urban environment, our road tunnels need to cater for high traffic volume, peak hour congestion and multiple entrances and exits. These pose challenges to traffic and incident management including tunnel emergencies and planned and unplanned tunnel closures.

Traffic control and monitoring systems, together with signs and barriers, enable supervision of traffic flow in tunnels and guide motorists along the way. Automatic Incident Detection (AID) is used to detect incidents and collect traffic data. Closed Circuit Television (CCTV) also provides 100% surveillance coverage in the tunnels.

Lane Use Signs (LUS) and Variable Message Signs (VMS) are placed along and before tunnel entrances to guide motorists and inform them about traffic conditions within the tunnel. To facilitate the closure of tunnel slip roads during maintenance or emergencies, certain tunnels are also equipped with drop down barriers and traffic lights at tunnel entry points.

- Safe Driving in Road Tunnels

Figure 4.70: Examples of safe driving messages

Safe driving is important at all times; perhaps even more so in a confined space within a tunnel. In addition to the usual safety rules and road etiquette, practice these tunnel safety habits and be mindful of what to do in an emergency:

- ✓ Turn on your headlights and tune your radio to a local FM channel
- ✓ Observe the speed limit
- ✓ Follow the overhead lane use signs. If you see a red "X" above a particular lane, avoid using it
- ✓ If all lanes are marked "X", do not proceed further. Stop the car, turn off the ignition and head towards the nearest emergency escape route on foot. Stay vigilant for traffic and other road users. Look for the red-and-white or green panelled emergency exits
- ✓ If you are approaching the tunnel and see lanes marked with a red "X", do not enter the tunnel and look for an alternative route
- ✓ Pay attention to the messages on the electronic signboards, and tune in to local radio stations as the OCC will broadcast emergency messages, if any
- ✓ In case of emergencies, you can also find help phones located at escape staircases and fire niche cabinets along the tunnel for you to contact the OCC and emergencies services such as the Singapore Police Force, Traffic Police or Singapore Civil Defence Force.

- Lane Use Signs

When inside the road tunnels, follow the lane use signs above each traffic lane. They show if the lane ahead can be used.

Figure 4.71: Overhead Lane use signs

In the event of any major obstruction or emergency, red crosses may be lit across all lanes. This indicates that you should not proceed any further.

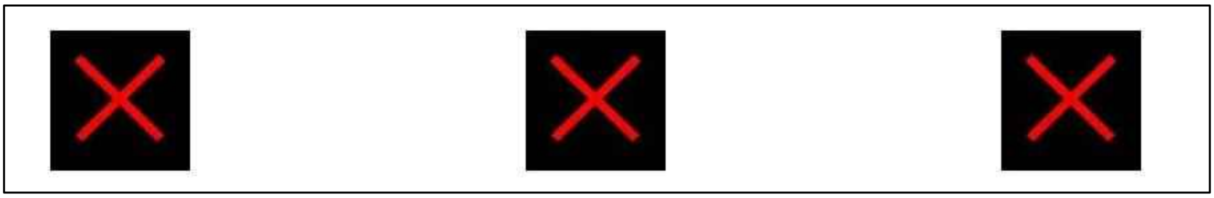


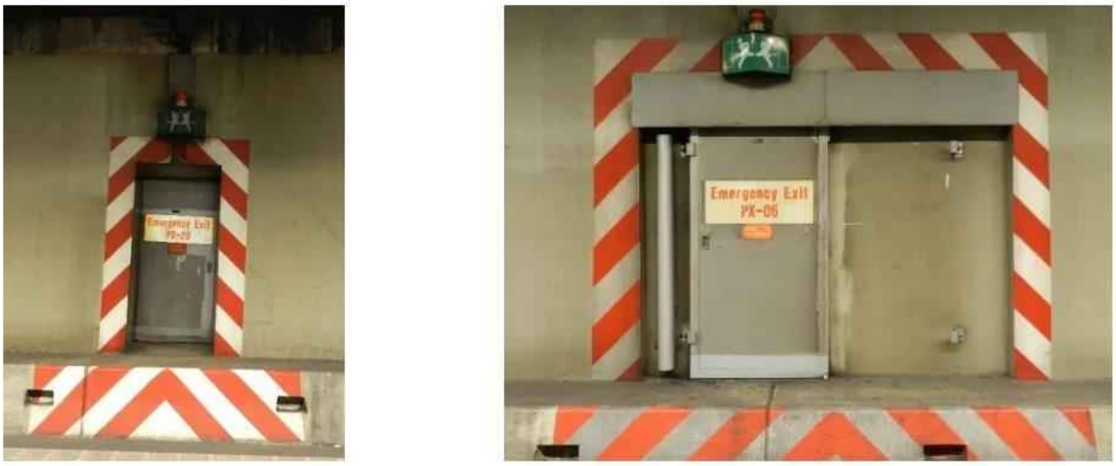
Figure 4.72: Red crosses on Overhead Lane use sign

When red crosses are lit across all lanes, do not proceed further.

- Emergency Exits

If you have to evacuate the tunnel on foot:

- ✓ For Woodsville Tunnel and Fort Canning Tunnel, head for the tunnel's entrance, away from the incident or smoke.
- ✓ For CTE, KPE, MCE tunnels and Sentosa Gateway Tunnel, head for the nearest Emergency escape staircase, which is located every 500m in the tunnel next to the slow lane. The stairs lead to street level; or Pedestrian cross passage door, which is located every 100m in the CTE, KPE and MCE tunnels next to the fast lane. Doors lead to the opposite bound tunnel.
- ✓ For CTE Tunnel, escape staircases and pedestrian cross passage doors are identified by red-and-white stripes and flashing orange lights.



Escape staircase
(every 500m, next to slow lane)

Pedestrian cross passage door
(every 100m, next to fast lane)

Figure 4.73: Escape staircase and pedestrian cross passage door at CTE tunnel

For KPE, MCE and Sentosa Gateway Tunnel, escape staircases and pedestrian cross passage doors (KPE and MCE) are identified by green panels and flashing bluish-white lights.

Escape staircase
(every 500m, next to slow lane)

Pedestrian cross passage door
(every 100m, next to fast lane)

Figure 4.74: Escape staircase and pedestrian cross passage door at KPE, MCE and Sentosa Gateway tunnel

- Fire Service Cabinets

Fire hose and extinguishers in fire service cabinets are located every 50m next to the slow lane inside all our road tunnels. Inside these cabinets, you can find:

- ✓ A fire hose reel
- ✓ Fire extinguishers
- ✓ A fire break-glass unit which can be activated to sound an alarm

- ✓ Emergency SOS phones located every 100m inside alternate fire service cabinets. They connect directly to the LTA Operations Control Centre and can be used to call for help.

Figure 4.75: Fire Service cabinet equipment

4.2.3 Incident Management

LTA Incident Management Team manages a fleet of incident management resources for swift incident response and recovery.

To improve roadworks and incident management, a quick overview of traffic status of all ongoing Incident

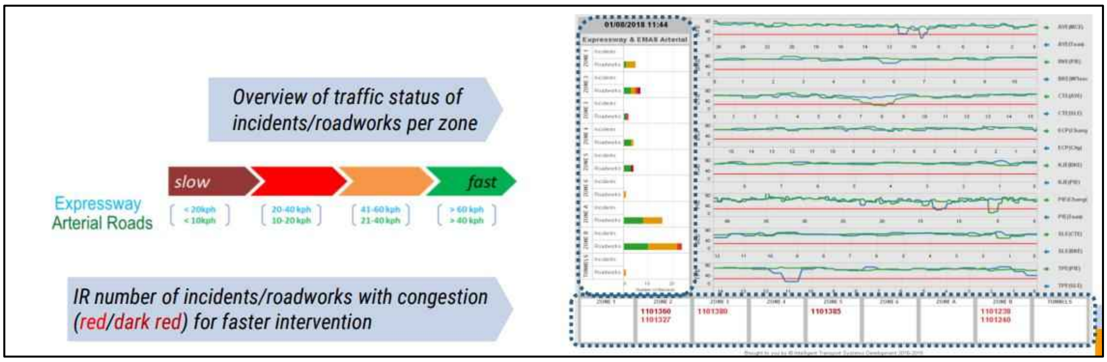


Figure 4.76: Overview of traffic status and colour-coded

Records can be colour-coded based on average speed upstream of incident/roadwork for faster intervention (red/dark red refers to incidents/roadworks with congestion).

Expressway Monitoring Advisory System

Figure 4.77: Expressway Monitoring Advisory System (EMAS)

Smooth, safe and swift accident response is made possible through the Expressway Monitoring Advisory System (EMAS), an intelligent incident management tool that manages traffic along our expressways. EMAS detects accidents, vehicle breakdown and other incidents promptly, ensuring fast response to restore normal traffic flow. It also provides travel time information on signboards before entering and along the expressways.

To help motorists determine the best routes to take, electronic signboards along the expressways and adjacent major roads display messages, graphics and colour-coded information on the traffic situation ahead. It also provides real-time information on travel time on electronic signboards located just before and along the expressways. Traffic information is also disseminated on OneMotoring, MyTransport.SG mobile app and @LTATrafficNews on Twitter, and sent to TrafficWatch (MediaCorp Radio) for broadcast.

EMAS also serves 10 major arterial road corridors. This brings about better information dissemination and improves traffic flow on the road network island wide.

Response to Traffic Incidents

When a traffic incident is detected, the EMAS vehicle recovery tow truck and LTA Traffic Marshal work together to clear an accident and bring traffic flow back to normal as quickly as possible.

Any stalled vehicles are towed to the nearest designated carpark free of charge. With effect from 18 January 2006, it is an offence if a vehicle owner refuses to allow his vehicle to be towed away by the recovery crew, even if the owner is waiting for his own tow truck service that has yet to arrive. This minimises congestion and inconvenience to other motorists.

LTA Traffic Marshals also carry out on-scene management duties like traffic control and evidence preservation for accidents involving minor injuries to improve the accident clearance time, especially for minor accidents. The Traffic Police handles all accidents involving injuries and fatalities and enforces traffic offences.

Enforcement Operations Centre (ENFOC)

ENFOC was launched on 8 March 2019 by LTA. The launch of ENFOC mark the start of LTA transformation journey to move into a more technologically embracing workforce. Integrating information from all sources to provide a coalesced ground situation picture with incident management tools to support enforcement operations with enhanced Ic5l capabilities.

Figure 4.78: Mobile Solution for Violation & Enforcement (MOVE)

Project MOVE serves to streamline and digitalise the submission of violation reports across Active Mobility Enforcement (AMEF) division, Vehicle Enforcement (VEF) division, Road Works Regulation and Licensing (RWRL) division and Development and Building Control (DBC) division.

Figure 4.79: Active Mobility Enforcement Detection System (AMEDS)

The AMEDS is a mobile CCTV enforcement system which can be deployed at various locations. AMEDS will allow for quick and agile deployment of CCTVs to enforce active mobility hotspots and provide 24/7 deterrence of behavioural Active Mobility offences. This will help to augment the existing deployment of Auxiliary Police Officers manpower.

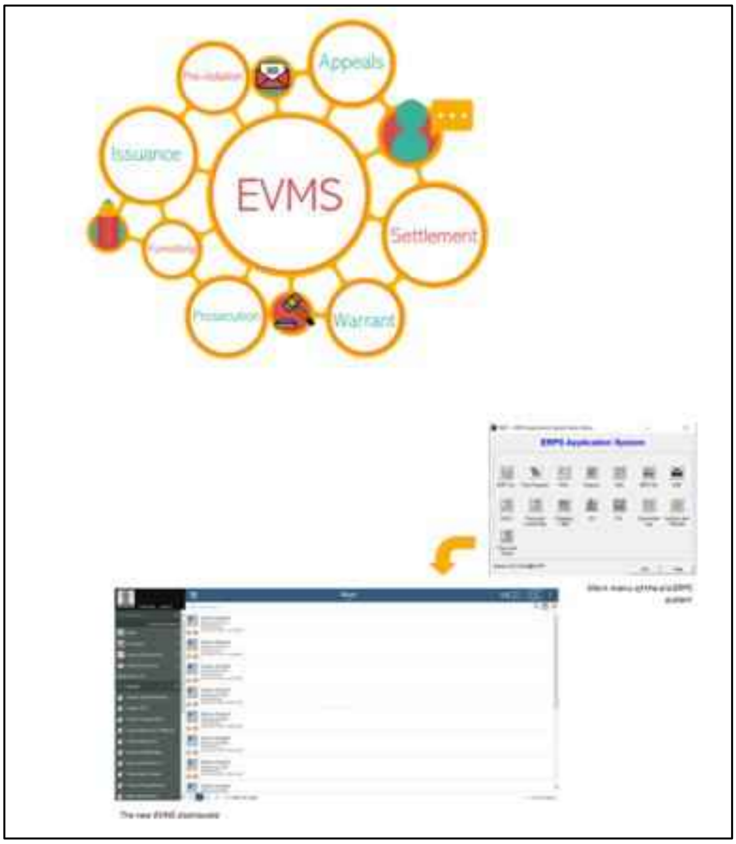


Figure 4.80: Enterprise Violation Management System (EVMS)

Commissioned on 2 September 2021, EVMS serves as a consolidated platform to manage the violation lifecycle of offences administered by LTA under the various legislations. It establishes interfaces with various internal and external systems for exchanging of information for processing of violation till its closure.

4.2.4 Road Opening Permit via PROMPT

Introduction

Works on public streets are inevitable. Depending on the nature of the works, Contractor may require to occupy the public roads to carry out the works. It is necessary to manage all works on public streets to ensure the structural integrity and function of the road can be maintained for public use. All road features located within the road reserve belongs to LTA and under LTA's maintenance. Hence, any works that affects anything within the road reserve, would need to obtain approval from LTA.

Based on LTA's Guidelines on the Permit to Work on Public Streets, there are five general types of works as follows:

1. Excavation/boring/pipe-jacking to lay or repair utility services
2. Soil investigation
3. Activities occupying traffic lane (hoisting, painting)
4. External works of developments
5. Any other construction related works that affect public streets

On top of the above, the work is also classified into three categories based on the urgency of the project, as below:

1. Planned
2. Ad-hoc (connection/development)
3. Emergency (unscheduled work for immediate repair, for example burst water pipe, road cave-in)

Under the Street Works Act, LTA has the power to control and regulate works on public streets. Contractors and Consultants shall refer to LTA's Code of Practice for Works on Public Streets and LTA's Code of Practice for Traffic Control at Work Zone to ensure the design and plan are according to the standard to minimise the impacts to public. In planning of the works on public roads, some of the key requirements are as follows:

1. Lane to lane replacement shall be implemented wherever possible. Use of alternative method such as jacking, steel decking, traffic diversion is preferred.

2. Should lane closure be inevitable, lane closure shall be carried out during off peak hour only. Consultants/Contractors shall refer to the detailed lists in LTA Prompt (Permit for Road Occupation Portal) Website. Generally, the peak hour is between 0730 to 0930 hours in the morning and between 1700 to 2000 hours in the evening. Only one lane can be closed at any one time.

3. For newly resurfaced road as well as newly constructed road, no works are allowed for 1 year and 2 years respectively. No works are also allowed on expressway.

Process

In general, the process of applying road application permit is summarized below:

1. **Consultation**
   Consultants/Contractors shall prepare the necessary plan/drawing showing the proposed road works that complies with LTA's Code of Practice. Consultants/Contractors to approach the corresponding LTA's officer in charge of the area via email for consultation.

   For any traffic diversion (with or without lane closure), Consultants/Contractors are required to obtain approval from LTA's Traffic Analysis & Project (TA&P) Division before proceeding to apply for formal application via LTA Prompt website (https://prompt.lta.gov.sg/webUIPWAS/Account/Login).

2. **Submission**
   Submission shall be done via LTA Prompt website. Consultants/Contractors to fill in the online form and submit all the necessary documents (i.e. site plan, approved traffic control plan, photographs of the existing condition, method statement – if applicable).

   Average processing time for any applications is 14 working days. Should the works considered as emergency works, which need immediate approval, the Consultants/Contractors shall notify the LTA's officer in charge for assistance.

   Only registered Professional Engineer (PE), Contractor, Supervisor and Officer from Utility Agencies can register the works via LTA Prompt. Register commencement date shall be within 28 days from the date of application. Applicants would need to make a payment of $165 for the processing fee (without any lane closure). For any works which involve lane closure, lane closure fee will be imposed. The fee payable is depending on the proposed length of closure, duration as well as period of works. More details can be found on LTA Prompt website.

   Once approved, LTA will issue the written permit for Contractor's record and other use such as Auxiliary Police's engagement, which usually requires for any lane/road closure.

Reinstatement

After the road work is completed, Contractor to reinstate the road back to its original arrangement. The reinstatement process is divided into two stages:

- Stage 1: Temporary Reinstatement
  To be done immediately upon completion of work and before opening the road to the peak hour traffic.
- Stage 2: Permanent Reinstatement
  To be done within three weeks of temporary reinstatement and shall be as per original condition.

Contractor to apply for initial handover through LTA Prompt and attend to any feedback arises during the Defect Liability Period (DLP). After the DLP is completed, Contractor shall apply for final handover through LTA Prompt where LTA will issue the handover letter for formal closure.

Extension of Time

Should the Contractor be unable to complete the works during the approved time period, they can submit an extension of time application via LTA Prompt website to extend the validity of the road opening permit.

4.2.5 Audit of Existing Roads in Operation

During the operational phase of the road system, road safety audit (RSA) is conducted to ensure the safety for road users. The roads identified for assessment were prioritized based on speed limit and accident occurrences. Arterial roads with higher speed limit and accident occurrences are assessed first.

During RSA, the auditors walk or drive through the roads as pedestrians and motorists in both directions during day and night to identify the potential hazards. Both general and site–specific observations were reported with recommending measures. The recommended measures are then implemented or addressed with alternate measures if the recommended measures are unable to be implemented due to site constraints.

4.3 Maintenance

4.3.1 Overview of Roads, Bridges, Tunnels and Facilities Maintenance

LTA has the various divisions involved in the maintenance of the roads, bridges, tunnels and commuter facilities.

Roads and Road Facilities Management (RRFM)

Figure 4.81 Road Surfacing

The Roads and Road Facilities Management Division manages and maintains roads and road related facilities through continual upgrading/asset replacement to ensure that they are functional, safe to use and meet the quality and service level for all road users.

Bridges and Tunnel Management (B&TM)

Figure 4.82: Bridge

The Bridges and Tunnel Management Division manages and maintains bridges, flyover, vehicular underpasses, and road tunnels including upgrading and asset replacement, to ensure they are safe for use at all times and meet the quality and service level for motorists through efficient operations management and maintenance planning.

Commuter Facilities Management (CFM)

Figure 4.83: Commuter Facilities (Bus shelter)

The Commuter Facilities Management Division manages & maintains commuter facilities (eg. footpaths, covered linkways, cycling paths, Pedestrian Overhead Bridge (POB)s, Pedestrian Underpasses (PUP)s, footbridges etc), including upgrading & asset replacement. It also regulates and license the use of public road facilities, manages bus shelters and kiosks and many active mobility initiatives.

Traffic, Street and Commuter Facilities Lighting (TSCF)

Figure 4.84: Traffic, Street and Commuter Facilities Lighting

The Traffic, Street and Commuter Facilities Lighting Division manages and maintains traffic lights, public street lighting and lighting for Commuter Facilities including covered linkways, footpaths, cycling paths, bus and taxi shelters, pedestrian overhead bridges and underpasses to ensure they are safe, functional and available for road users and commuters

Vertical Transport and Tunnel E&M (VTT)

Figure 4.85: Electrical and mechanical systems

The Vertical Transport and Tunnel E&M Division manages and maintains the electrical and mechanical systems of road tunnels and vertical transport systems supporting commuter facilities to ensure a safe environment for road users and commuters.

4.3.2 Maintenance Inspection and Rectification Regime

Regular Inspection & Maintenance of Roads and Road-related Facilities

LTA has in place a regular inspection regime of roads and road-related facilities. The regular inspection helps to ensure that rectification works are followed up timely so that all the road infrastructures are operational and safe for use at all times. This approach helps to ensure functionality and meet public expectations with lower safety risks to road users. The scope of the inspection includes identifying issues and defects through walking (functional inspection) on footpath and driving (safety inspection) on the major / minor roads and expressways at various intervals.

Routine road inspections and maintenance works are outsourced to road-related facilities inspection term consultants and term contractors respectively.

Figure 4.86: Safety Inspection Vehicle for inspection on roads

Figure 4.87: Walking inspection on footpath

The Authority's officers will conduct an audit check randomly to ensure the work quality by consultant is satisfactory.

<u>Maintenance Strategies</u>

Two broad maintenance strategies

a) Preventive Maintenance Regime

- Planned resurfacing works

b) Corrective Maintenance Regime

- Corrective works carried out to prolong the life of pavement until preventive maintenance
- Corrective works from inspections, feedback, etc.

Regular Inspection and Maintenance of Road Tunnels

Visual inspection at close range is performed to assess the condition of tunnel structures, following which rectification maintenance and repairs are carried out on the areas being reported on. Principal inspections are carried out to identify and provide inspection reports of any defects. Maintenance Inspections and Safety Inspections are carried out by trained technical inspector. Maintenance inspections is conducted annually, whereas safety inspection is conducted weekly.

Developing a Prototype Hardware System Capable of Conducting Automated Footpath Inspection

LTA has collaborated with LightHaus Photonics Pte. Ltd. through Enterprise Singapore (ESG), in a pilot project on the use of Artificial Intelligence (AI) in the automation of the routine footpath inspection. The pilot trial involved the development of a software that would autonomously detect defects along the footpath through the photos taken by the camera system mounted on the project prototype (bicycle). The trial is currently in progress with actual field testing. The project prototype is already up and running and the Machine Learning of the software's AI is already in progress.

Achievements

- Successfully designed a prototype with distortion correction capability and 3D images stitching algorithm to provide a 360-degree view
- Images captured goes through process of machine learning algorithm for the identification of defects categories, which is processed in a software module- Graphic Users Interface (GUI) to generate defect reports for intervention
- Phase 1 trial completed with a crack detection rate of 80% and Phase 2 trial is in progress to enhance the pavement inspection system with increase detection accuracy and wider coverage of different defect categories

Figure 4.88: Camera mounted on bicycle for taking photos of the footpath

Automated Footpath Inspection bike using a 360-degree camera plus pavement module cameras to capture defects on concrete pavement such as cracks, defective tactile tiles.

Artificial Intelligence–Enabled Automated Road Marking Inspection

To automate the laborious manual measurements of road marking wear index and to support maintenance program more objectively, high speed cameras and Global Positioning System (GPS) are used to capture raw data of road marking without lane closure. The set-up provides map-based results and network overview conditions.

Figure 4.89: Three high-speed camera-mounted van

Section 5

Safety Initiatives Implemented by LTA

Authors:

Road Safety Engineering Division	Land Transport Authority
Traffic Schemes Design and Development Division	Land Transport Authority

5. Safety features implemented by LTA

5.1 Silver Zone

The Silver Zone initiative is a national project to enhance road safety for seniors. This initiative was announced by A/P Muhammad Faishal Ibrahim, Parliamentary Secretary at the Ministry of Health and the Ministry of Transport in the Committee of Supply (COS) March 2014.

Silver Zones are areas with enhanced road safety measures which make it safer and more convenient for senior pedestrians to cross the roads. These features include distinctive signs, road features and markings which help to lower vehicle speeds and guide pedestrians to designated crossing points.

Silver Zones are found in selected housing estates with a higher population of seniors and relatively higher accident rates involving seniors, as well as areas near amenities which seniors frequent.

The speed limit in Silver Zones, where it is feasible to lower the speed limit, is generally 40km/h. Some traffic calming features that can be seen in Silver Zone are:

<u>Silver Zone Gateway</u>

The Silver Zone Gateway includes prominent signs and road markings that indicate the start of a Silver Zone. At the gateway, one can find bright fluorescent yellow-green signs and yellow rumble strips that alert motorists that they are entering a Silver Zone.

Figure 5.1: Example of a Silver Zone Gateway

Chicane

Chicane is a series of narrowings or kerb extension that alternate from one side of the road to the other, forming S-shaped curves to encourage motorists to drive at a slower speed.

Figure 5.2: Example of a road chicane

Low-height centre divider

Low-height centre dividers reduce lane widths and encourage motorists to drive slower. In an emergency, emergency vehicles can still drive over them safely.

Figure 5.3: Example of a low-height centre divider

5.2 School Zone

In the late 1990s, there was concern regarding the safety of young school children, especially those in primary education. This spurred the discussion to enhance road safety along primary school frontages. In 2000, the LTA introduced the concept of School Zone. The intent was to slow down motorists on school days during the start and end times of primary school sessions where there were activities along the school frontage. School zone signs and their operation timings are displayed at the start and end of school zone.

Figure 5.4: School Zone signs

In 2004 saw the introduction of the Enhanced School Zone. This came along with two patches of red asphalt pavements and “SLOW DOWN” markings on the road for better visibility. The School Zone signs have been modified to make it easier for motorists to read while maintaining the purpose, which is to slow them down. The red asphalt pavement texture is meant to be highly conspicuous to alert motorists through a visual and vibratory effect that they are travelling within a School Zone, thus prompting them to slow down. Similarly, the “SLOW DOWN” markings were also implemented at the start of a School Zone to achieve the same goal.

Figure 5.5: Two patches of red asphalt pavements at School Zone

The latest enhancement in 2014 introduced the “40 km/h When Lights Flash” sign. It displays a pair of amber aspects that flash alternately during school peak hours. During this time, drivers are to keep within the reduced speed limit of 40 km/h as there will potentially be a heavier student pedestrian volume.

Figure 5.6: Example of a “40km/h When Lights Flash” sign

5.3 Speed Calming Measures

Speed calming measures are commonly, physically placed, such as road hump and speed regulating strips. These are effective in reducing motorists' speed but may be unpopular with residents or motorists as these vertical deflections generate increased noise (to residents) and discomfort (to passengers) when vehicles travelled over them. On high trafficked roads, physical calming measures can have an impact on the road capacity, leading to congestion.

Non-physical speed calming measures make use of perceptive markings on the road to influence motorists driving behaviour and overcome some of all these difficulties, while still retaining the capability of reducing vehicle speeds. Some types of the perceptive measures on our road are listed as follow:

<u>Traffic Calming Markings (TrCM)</u>

TrCM is a form of non-physical traffic calming measure. It aims to manipulate the appearance of the traffic lane to a driver by reducing the perceived lateral clearance, so as to influence his/her behaviour and travelling speed to suit the road condition. This reduction of lane width is achieved by painting of two parallel sets of white triangular markings on the side of road to create a visually narrower lane. TrCM aims to trigger motorists' awareness of a proceeding hazard and the need to reduce their speed.

Figure 5.7: Example of Traffic Calming Markings (TrCM)

Advance Stop Markings

Advance Stop Markings follow some similarities to TrCM with its intention to influence motorists' behaviour by narrowing the lane width with two sets of parallel markings. The difference is the markings are painted with horizontal markings at varying widths, becoming longer as it approaches the stop line. It aims to create a "funnelling" effect on the motorists by reducing the lane width as the driver approaches the stop line, hence reduce their speed before the junction. This is mainly used at non-signalised junction in local or access roads in residential estate.

Figure 5.8: Example of Advance Stop Markings

Broader Alignment Lane Markings (BALM)

BALM is another form of traffic calming measure that is applied along expressways and major arterial roads. It comprises broader lane markings spaced in closer intervals from one another compared to standard lane markings. It guides motorists to be aligned to their lanes better and serve as a visual cue to perceptually narrow down the travel lanes to encourage motorists to travel at lower speeds.

Figure 5.9: Example of Broader Alignment Lane marking

5.4 Rain Shelter

Rain shelter is a bay built under structures along expressways to allow motorcyclists to take shelter during wet weather. In the past, the motorcyclists used to stop on the shoulder lane of the expressways when it rains. The rain shelter enables the motorcyclists to wait within the bay, protected from exposure to oncoming traffic along these high-speed roads. There are unique Umbrella signs along the expressways, that symbolise these rain shelters, indicating their locations.

Figure 5.10: Umbrella sign indicating the location of the rain shelter

Figure 5.11: View of the rain shelter waiting bay for the motorcycles and the riders

Figure 5.12: Rain shelter at exit portal of road tunnel

5.5 Safety Features for Enhancing Pedestrians’ Safety

Pedestrians are considered as one of the vulnerable road users on our road network. To ensure their route is safe and seamless, different forms of crossing facilities are provided for pedestrians to start and complete their journey safely. Crossing features like overhead bridge, signalised crossing and zebra crossing are commonly found on our road network and serve the pedestrians well. There are also some unique safety measures, not as common but is progressively rolled out at locations to enhance its safety level. Here are some listed below.

- “LOOK” markings

“LOOK” markings are painted at zebra crossings to remind pedestrians, especially young children and the elderly, to look out for oncoming traffic before crossing the road. The ‘O’s resemble a pair of eyes for a more salient design to catch pedestrians’ attention. The markings complement the “Kerb Drill” taught in all primary schools to remind the juniors to look out for traffic before crossing the road. It also complements the current safety features (which comprises flashing beacons, pedestrian crossing signs and zigzag lines), that are more targeted at motorists at the zebra crossing.

Figure 5.13: Example of “LOOK” Markings at raised zebra crossing

- Pedestrian Crossing Ahead Markings (PCAM)

The Pedestrian Crossing Ahead Markings consist of a triangle road marking that alerts motorists to a zebra crossing ahead. These markings are installed ahead of zebra crossings that motorists are unable to see from afar. (e.g. due to the crossing being located around a bend).

Figure 5.14: Example of Pedestrian Crossing Ahead Markings (PCAM)

- “Give Way to Pedestrians” sign

At selected signalized junctions where motorists make a right turn across the junction, "Give Way to Pedestrians" signs are mounted on top of the traffic light pole to remind motorists to look out for and give way to pedestrians.

Figure 5.15: Example of “Give Way to Pedestrians” sign at a traffic junction

- Green Man +

The Green Man Plus (Green Man +) allocates a longer green man time for the elderly and Persons with Disabilities (PWD). They simply need to tap their CEPAS-compliant senior citizen concession card or PWD concession card on the reader mounted above the standard push-button on the traffic light pole to extend green man time by between 3 and 13 seconds, depending on the width of the crossings.

Figure 5.16: Green Man+

5.6 Red-Amber-Green (RAG) signal-controlled Right-Turn at Junction

5.6.1 Enhancing safety at traffic junctions with Red-Amber-Green (RAG) arrows

Red-Amber-Green (RAG) arrow signals aims to improve the safety of pedestrians and motorists by replacing discretionary right-turns with controlled right-turns. LTA targets to have RAG arrows at 1,200 traffic junctions in Singapore.

First introduced in December 1999, controlled right turn using RAG arrows were implemented at junctions where motorists' visibility was obstructed. Controlled right turn using RAG arrows separates the concurrent movements of opposing traffic and pedestrian crossings to the drivers' right.

From April 2018, LTA started to implement controlled right turns at signalized junctions where feasible. At locations where the introduction of RAG arrows is not suited, other safety measures will be implemented to further enhance junction safety. Currently, RAG arrow signals at more than 400 junctions have been installed.

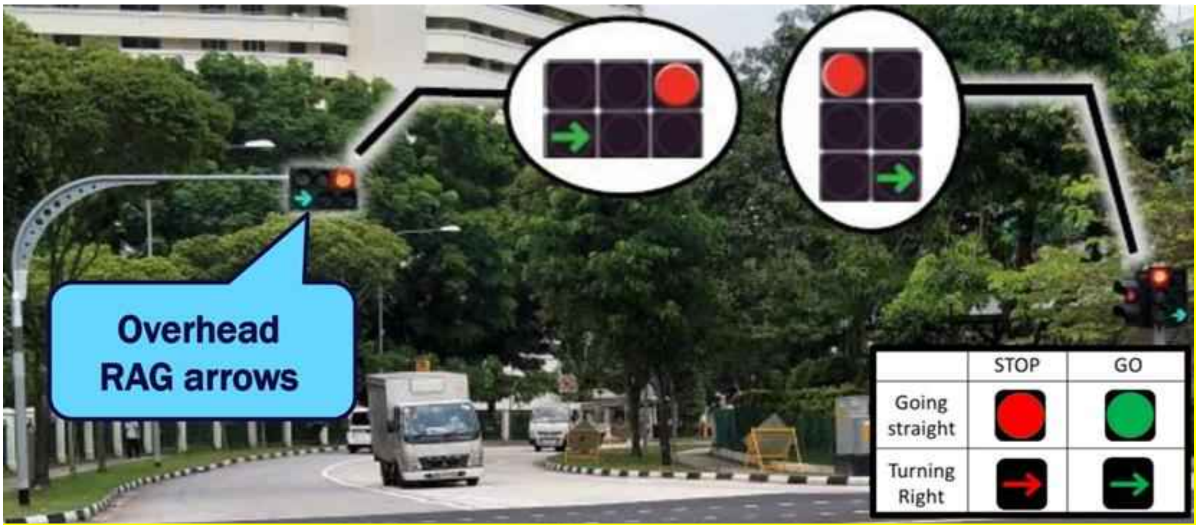


Figure 5.17: RAG arrow signals

With the RAG arrow signals, motorists can only turn right when the green arrow appears. Concurrent movements of opposing traffic and pedestrians' crossing to the right is eliminated. Overhead RAG arrows have been introduced recently at junctions where there are space constraints of installing ground traffic aspects on the centre median. "Change in Traffic Light Timing" information signs are also placed in advance of date of implementation to alert motorists who have become accustomed to the previous traffic signal arrangement.

RAG signal installation process

1. Study and design stage
    - Detailed site survey and measurements of traffic flows.
    - Traffic simulation to establish traffic impact and improvement measures required;
    - Preparation of traffic scheme drawings incorporating modification to traffic light signals, centre median and other necessary changes.

2. Site installation stage
    - Preparation, installation and modification of traffic light components;
    - Modification of traffic light phases and timings;
    - Factory and site testing of operational parameters;
    - Civil works to adjust kerbs and lane markings.

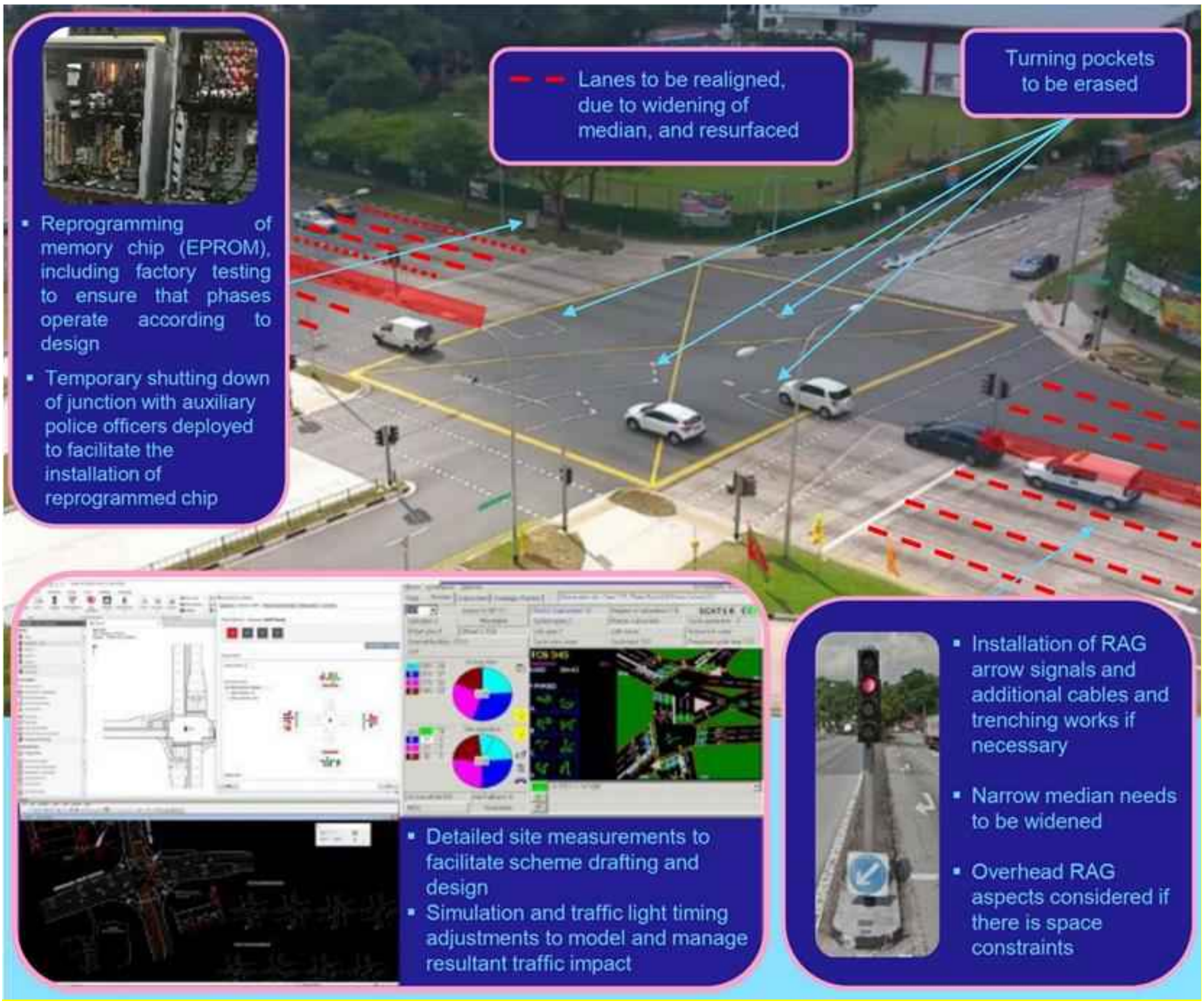


Figure 5.18: RAG signal installation process

Asides above engineering measures, road users should also remain vigilant, observe traffic rules, exercise patience and care, to ensure their own and other road users' safety.

Section 6

Road Safety Education and Enforcement in Singapore

Authors:

Traffic Police

Singapore Road Safety Council

6. Road Safety Education and Enforcement in Singapore

6.1 Road Safety Education

- Launch of Singapore Road Safety Month (SRSM) 2021 Campaign

The Traffic Police (TP) and Singapore Road Safety Council (SRSC), with support from Land Transport Authority (LTA), Ministry of Education (MOE), People's Association (PA) and Automobile Association of Singapore (AAS) launched the Singapore Road Safety Month 2021 campaign. The Guest-of-Honour for the event was Associate Professor Muhammad Faishal, Minister of State for the Ministry of Home Affairs and Ministry of National Development. The theme of the month-long campaign is "Road Safety for All". The campaign will focus on raising awareness on red light running and speeding offences.

Figure 6.1: Launch of SRSM 2021 campaign

Two road safety videos were produced as part of public education outreach efforts to educate motorists on the correct driving behaviours. The videos highlight the seriousness and negative consequences of red light running and speeding, and what must be done to avoid speeding, and what must be done to avoid these accidents arising from the offences. The videos were published on SRSC's Facebook and YouTube pages to engage and educate road users on road safety tips.

As part of the Road Safety Month campaign, Traffic Police also launched a month long "Spot the Safe Motorist' programme to raise the awareness level on the importance of safe driving and looking out for other motorists while driving on the road. During the period of 28 May 2021 and 27 June 2021, motorists who were spotted by TP patrol officers displaying safe driving behaviour or performing a courteous act on the roads, would be rewarded with a COVID-19 care park. In total, 190 motorists were recognised during the engagement period.

Figure 6.2: Drivers rewarded with a Covid-19 care pack by TP patrol officers

- Launch of Anti-Drink Drive Campaign 2021

On 9 December 2021, a collaboration between TP and SRSC launched the Anti-Drink Drive Campaign (ADD) 2021. Mr Desmond Tan, Minister of State for the Ministry of Home Affairs and Ministry of Sustainability & the Environment graced the event as Guest-of-Honour.

Figure 6.3: Launch of Anti-Drink Drive (ADD) campaign 2021

The tagline used for this campaign is “Drink or Drive, You Decide” and aimed to send a timely reminder to all motorists during the festive period not to drive after consuming alcohol but make use of alternative means of transport to return home. At the same time, TP also aimed to raise awareness on the dangers of drink-driving and encourage road users to be responsible. ADD posters were distributed to various entertainment outlets located in the city area. A road safety video titled “What really happened when you are caught for drink-driving” was also produced.

Figure 6.4: Anti-Drink Drive poster

- Launch of Singapore Ride Safe 2021 Campaign

Among the motorised road users, motorcyclists are considered a vulnerable group of road user as they are more exposed to live traffic than drivers on the road. On 29 October 2021, TP and SRSC with the support from LTA launched the Singapore Ride Safe (SRS) 2021. The event was graced by Guest-of-Honour, Mr Desmond Tan, Minister of State for the Ministry of Home Affairs and Ministry of Sustainability & the Environment.

The theme for 2021 was “Gear Up. Ride Safe”. A road safety video was produced with the theme in mind to encourage motorcyclists to don protective riding gears, ride safely and responsibly so that they can arrive home to their loved ones at the end of the day.

Figure 6.5: A safety video clip and poster for “Gear Up. Ride Safe” campaign

Road safety banners were erected at targeted accident-prone locations and hotspots by TP and LTA to remind motorcyclists to practice safe riding habits. Safety messages were also displayed on expressway electronic signboards as a reminder to motorcyclists to ride safely.

- Safety Promotion and Publicity for Vulnerable Road Users

With an ageing population in Singapore, the safety of the seniors had become an important consideration at areas residing with high elderly population. Silver Zones had been progressively rolled out since Oct 2014 to provide our senior road users a safer and conducive environment to travel around.

In June 2021, TP together with Ministry of Home Affairs (MHA) publicise on the enhanced penalties for irresponsible driving in Silver Zones. In a Facebook video, Associate Professor Muhammad Faishal highlighted the rise in the number of elderly pedestrian casualties form road traffic between 2015 and 2019. Hence there is a need for enhanced penalties to deter irresponsible driving within Silver Zone. Starting from 1 July 2021, motorists who commit offences that endanger pedestrians at Sliver Zone will incur 2 additional demerit points, and composition sums for offences were raised by $100.

In July 2021, an event called Road Safety for Seniors 2021 was jointly organised by TP and SRSC, and support from LTA and Lions Befrienders, to run an online programme comprising a road safety talk, sharing session on eye care for seniors, quizzes and give out gift bags with souvenirs bearing safety reminders for senior citizens. Road safety banners were also erected at neighbourhoods island-wide to remind seniors to cross safely by using designated pedestrian crossings.

Figure 6.6: Road safety banner and gift bag for Road Safety for Seniors 2021

In the first quarter of 2021, TP, SRSC and MOE set out to install road safety banners at 180 primary schools in Singapore. The road safety banners sought to remind motorists to watch out for pedestrians, especially young children as they approach School Zones, and also remind pedestrians to observe road safety and keep a look out for other road users.

Figure 6.7: Safety banners to remind motorists of young children at School Zone

Primary school children can also learn road safety rules in the form of a fun and interactive way either as a pedestrain, cyclist, or motorists in a go-kart at the annual Shell Traffic Games held at the Road Safety Community Park.

Figure 6.8: Winner of the 40th Shell Traffic Games

Cycling had gained a huge popularity in recent years with many recreational and sport cyclists seen on our roads. Other cyclists include those working as food deliverer or simply using it as the first and last mile commute between home and work.

In February 2021, TP went out to produce road safety banners for cyclists and installed them at 10 identified park connector locations around Singapore. These safety banners sought to remind cyclists to be alert, practise safe cycling and look out for other road users along the path that they are sharing with.

Figure 6.9: Safety banners for cyclists at park connector locations

In addition, TP and SRSC also unveiled the cycling safety banners at six locations with support from respective grassroot leaders and Singapore Cycling Federation. They took this opportunity to engage cyclists and residents on practising safe cycling habits and to observe traffic rules if they are cycling on the roads.

There were numerous collaborations between TP and LTA Active Mobility on initiatives to remind cyclists to adhere to traffic and cycling rules, such as no riding of bicycles or power-assisted bicycles on expressways. TP Patrol unit also partnered with LTA throughout the year to conduct joint enforcement actions against errant cyclists at multiple locations around Singapore. Apart from enforcement, the officers also took the opportunity to engage and educate the cyclists and power-assisted bicycles to observe traffic rules and practise road safety.

Figure 6.10: TP Patrol unit and LTA officers conducting enforcement actions against errant cyclists

Singapore Road Safety Council - Road Safety campaigns

- Launch of Singapore Road Safety Month 2021 Campaign

In June 2020, the Singapore Road Safety Council (SRSC) and Traffic Police (TP), together with support from LTA, MOE, PA and AAS launched the 8^{th} Singapore Road Safety Month (SRSM) as an online safety campaign.

The theme for the month-long campaign was “Road Safety for All” (poster below refers) with various collaterals, such as posters on selected trains and bus shelters put up progressively nationwide to promote the efforts from SRSC and TP to enhance the safety of our roads, as well as making the roads safer for all road users. These posters highlight different scenarios on the road and provide advisories on good safety practices for road users such as pedestrians and motorists. Lamp post banners were also placed at various locations to remind all road users the importance of road safety, to look out for one another, and to keep the roads safe for the community.

Figure 6.11: Publicity poster for “Road Safety for All” campaign 2021

6.2 Testing and Licensing Regime in Singapore

<u>Background</u>

The Traffic Police (TP) of the Singapore Police Force (SPF) oversees the testing and licensing of motorists in Singapore. Learner motorists who wish to attain a driving licence in Singapore can either enrol in one of the 3 driving schools in Singapore or enrol with a qualified private driving instructor for their training. Upon completion of their practical training curriculum as well as relevant theory tests, the learner motorists may book a practical test slot at the driving schools. Testers from the Traffic Police are responsible for the conduct and grading of the test and will decide if the learner motorist is qualified to hold a Singapore Driving Licence.

While TP does not directly oversee the training of learners, TP regulates the training curriculum, training fees, driving instructors and driving schools. The candidates have to take an eyesight test at the respective driving schools before they apply for their provisional driving licence. The eyesight test is a legal requirement under the Road Traffic (Motor Vehicles, Driving Licences) Rules (https://sso.agc.gov.sg/SL/RTA1961-R27).

<u>Driving Licence Classes</u>

In Singapore, motorists are only allowed to drive or ride certain types of motor vehicles that correspond to the class of driving licence they possess. The different classes of licence are detailed below:

Class	**Type of vehicle**	**Tests Required**
Class 2B	Motorcycles not exceeding 200 cc, or power rated at 15kW and below	• Basic Theory Test • Riding Theory Test • Practical Riding Test

Class 2A	Motorcycles that are 200 cc – 400 cc, or power rated exceeding 15kW but not exceeding 25kW	• Practical Riding Test • (Class 2B is pre-requisite)
Class 2	Motorcycles exceeding 400 cc, or power rated exceeding 25kW	• Practical Riding Test • (Class 2A is pre-requisite)
Class 3	- Motor cars of unladen weight not exceeding 3,000kg with not more than 7 passengers, excluding the driver; and - Motor tractors and other motor vehicles of unladen weight not exceeding 2,500kg - Ambulances and Medical transport vehicles of unladen weight not exceeding 3,000kg with not more than 7 passengers excluding the driver.	• Basic Theory Test • Final Theory Test • Practical Driving Test
Class 3A (For all automatic Class 3 vehicles without a gear shifter)	- Motor cars **without clutch pedals** of unladen weight not exceeding 3,000kg with not more than 7 passengers, excluding the driver; and - Motor tractors and other motor vehicles without clutch pedals of unladen weight not exceeding 2,500kg - Ambulances and Medical transport vehicles of unladen weight not exceeding 3,000kg with not more than 7 passengers excluding the driver.	• Basic Theory Test • Final Theory Test • Practical Driving Test
Class 3C (For work permit and S Pass holders who hold an equivalent foreign driving licence)	Except for Light Goods Vehicles, Mini Vans, and Small Buses: - Motor cars of unladen weight not exceeding 3,000kg with not more than 7 passengers, excluding the driver; and	• Basic Theory Test
Class 3CA (For work permit and S Pass holders	Except for Light Goods Vehicles, Mini Vans, and Small Buses: - Motor cars **without clutch pedals** of unladen weight not exceeding	• Basic Theory Test

who hold an equivalent automatic foreign driving licence except Light Goods Vehicles, Mini Vans and Small buses)	3,000kg with not more than 7 passengers, excluding the driver.	
Class 4A	Omnibus	• Practical Driving Test • Class 3 or 3C is pre-requisite)
Class 4	Heavy motor vehicles of unladen weight exceeding 2,500kg which are constructed to carry load or passengers	• Practical Driving Test • (Class 3 or 3C is pre-requisite)
Class 5	Heavy motor vehicles not constructed to carry any load and the unladen weight exceeds 7,250kg	• Practical Driving Test • (Class 4 is pre-requisite)

Table 6.1: Different classes of licence

Theory Tests

All new learner motorists are required to undergo the Basic Theory Test (BTT). Upon successful completion of the BTT, the learner motorist can apply for the provisional driving licence, which will allow him to drive/ride while under instruction. Depending on the class of licence that they are applying for, learner motorists will also need to complete the Final Theory Test (for Class 3/3A learners) and the Riding Theory Test (for Class 2B learners) as well as complete a simulator training course before booking their Practical Driving Test.

The contents of the theory tests are based on the Basic and Final Theory Handbooks. Learner motorists may book a test slot with the driving schools once they are ready to take their theory tests.

All theory tests are administered at the driving schools. Each session can accommodate up to 40 candidates. Each candidate will be assigned with a designated computer where he/she will take the test. The multiple-choice test questions are randomly selected out of a pool of around 1500 questions so that no two candidates would get the same questions. The scores are automatically tabulated at the end of the tests and candidates are informed of the results before they leave the room. TP regularly reviews the questions to ensure that the questions remain relevant.

Simulator Training

With effect from 16 December 2019, all Class 2, 2A, 2B, 3 or 3A learner motorists are required to complete their driving or riding simulator training before they are allowed to book their Practical Driving/Riding Tests. Learner motorists can book the simulator training at any of the three driving schools after completing at least 5 practical lessons to obtain an adequate level of competency in handling the simulator machine. The scenario-based simulator training is based on Singapore's top 10 causes of accidents and aims to provide learner motorists with the opportunity to practice defensive driving or riding in a safe and controlled environment. The training comprises 3 modules, with each module taking around 15 to 20 minutes to complete.

Conversion of Foreign Driving Licence

All foreigners on social visit pass are allowed to drive in Singapore for a period of up to 12 months (from the date of entry into Singapore) using a driving licence issued by their home country. Foreigners are required to convert their foreign driving licence to a valid Singapore Driving Licence if:

- they reside in Singapore for more than 12 months (refer to (a) for details); or
- they are Work Permit & S-Pass holders residing in Singapore and employed as a driver (refer to (b) for details).

(a) For foreigners residing in Singapore for more than 12 months, they are to pass the Basic Theory Test for driving in Singapore. Upon passing, they may apply for the conversion in person at the Traffic Police and submit the following during the application:

- Original and photocopy of passport
- Entry permits & re-entry permits/employment pass/dependent pass/work permit/student pass/long term pass
- Original and photocopy of valid foreign driving licence
- A fee of S$50 for the application paid via cashless modes
- One matte finish passport-sized photograph with white background, eyes looking straight and both ears and eyebrows visible in the photograph. No headgear should be worn unless normally worn for religious purposes. Spectacles or glasses worn should not be tinted
  Proof of stay in the overseas country where the driving licence was obtained.

(b) For work permit & S-Pass holders residing in Singapore and employed as a driver, they are to complete similar steps stated in (a) within 6 months from the date of issuance of the work permit or S-Pass, and would be granted a class 3C licence, which will allow them to drive all Class 3 vehicles except: Light goods vehicles, mini vans, and small buses. If the work pass holder is required to drive these types of vehicles, they are required to obtain the full Class 3 licence by passing the Basic Theory Test, Final Theory Test as well as the Practical Driving Test. The issuance of a Singapore Class 3C driving licence to a work pass driver does not invalidate his foreign driving licence within the first six months of the issuance of his work pass.

6.3 Traffic Management and Enforcement by Traffic Police

Background

The Traffic Police (TP) adopts a multi-pronged approach of education, engagement and enforcement, and works with its stakeholders to improve road safety.

a. Education

Road safety education and driver licensing initiatives aim to equip road users with the relevant road safety knowledge and the competency to operate vehicles safely. This is done through the regulation of driving schools, and the conduct of tests, the instilling of good road behaviours at early stages, and providing re-education to motorists to refresh them on good driving habits.

b. Engagement

TP's engagement efforts aim to bring about a positive mind set, attitudinal and behavioural change among road users, thus making a safer road environment and culture for all. This is done though regular road safety engagement efforts such as talks, visits to workplaces, engagement with the community on localised issues, and creating platforms for dialogues and discussions on road safety.

c. Enforcement

To deal with errant road users who continue to flout the traffic rules and cause danger to other road users, TP conducts regular patrols & establishes presence, mounts dedicated operations against errant motorists and investigate into offences and accidents and take action against offenders.

Over the years, TP's overall enforcement strategy evolved from being enforcement-centric to being transparent and risk-based. Today, locations of TP's enforcement cameras are deployed based on accident statistics and are publicly available on the SPF website. Numerous measures have also been put in place to alert motorists before entering enforcement camera zones. TP envisages that this approach will be more effective in shaping motorists' behaviours to be more cautious at these accident-prone locations, thereby reducing the likelihood of them committing traffic violations or being involved in traffic accidents.

Notwithstanding, TP recognises that there will always be errant motorists who are not deterred by TP's enforcement efforts and will persist in their egregious road behaviours. Hence, there is a need for TP to adopt a targeted approach to enforce against such motorists so as to send a strong message that TP will not hesitate to take stern action against them for the safety of other road users.

Traffic Enforcement Cameras

TP has always been at the forefront in leveraging technology as a force multiplier to overcome the challenges of limited strategic resources, whilst ensuring continued effectiveness in round-the-clock traffic enforcement.

Table 6.2 lists the different types of existing traffic enforcement cameras, including the Average Speed Camera, which have been operationalised since 17 December 2018, and their functions.

Types of Traffic Enforcement Camera	**Description**
Average Speed Camera (ASC)	The ASC allows for speed enforcement over a section of road known as an “average speed enforcement zone”. While regular fixed speed cameras capture the speed of vehicles at a specific point, the ASC detects the speeds of a vehicle as it enters and leaves the zone and computes the corresponding average speed. This average speed will be used to determine if a vehicle had committed a speeding offence. ASCs have been operationalised along Tanah Merah Coast Road since 17 December 2018. **Mode of operation**: The ASC measures the average speed of a vehicle over a zone. Photographic record of evidence with Automated Number Plate Recognition (ANPR) technology is captured by the cameras.
Red-Light Camera (RLC)	The RLC, deployed at certain road junctions, detects vehicles which commit red-light running offences. As of December 2021, a total of 250 RLCs have been deployed island-wide. The locations of these RLCs may be found on the SPF website. **Mode of Operation.** The RLC uses induction loops to detect offending vehicles. Captured violation images are transmitted via 4G mobile network to backend for officers’ verification
Fixed Speed Camera (FSC)	The FSC possesses enhanced capabilities to identify speeding vehicles from afar. Currently, there are a total of 20 FSCs

	deployed island-wide. The locations of these FSCs may be found on the SPF website. On top of the 20 FSCs, there are also 10 speed cameras owned by LTA deployed along KPE and MCE. In addition, there are six speed cameras deployed in Jurong Island. **Mode of operation**: The FSC uses radar technology for detection. Captured violation images are transmitted via 4G mobile network to backend for officers' verification
Mobile Speed Camera (MSC)	The MSC is a mobile digital speed enforcement camera, which transmits images of speed violations wirelessly back to TP for processing. As its name suggests, the MSC is mobile and can be redeployed to another speeding-prone location within short notice. As of 31 December 2021, MSCs are deployed at the following five locations: 1. Buangkok East Drive; 2. Lim Chu Kang Road; 3. Seletar Link; 4. Sengkang West Way; and 5. Yishun Avenue 1. **Mode of operation**: The MSC uses radar technology for detection. Captured violation images are transmitted via 4G mobile network to backend for officers' verification.
Police Speed Laser Camera (PSLC)	The PSLC is a portable speed laser gun that may be carried by TP's two-wheelers and be readily deployed for ad-hoc anti-speeding operations. The PSLC is capable of identifying and tracking speeding vehicles from afar. It is also capable of recording photos and videos to better identify offending vehicles. It is equipped with infra-red detection capabilities, allowing the PSLC to be deployed during hours of darkness. The locations where PSLC may be deployed are listed on the SPF website.

Police Radar Speed Camera (PRSC)	The PRSC, installed on the dashboard of TP's Expressway Patrol (EP) cars, allow officers to record videos of speeding vehicles during mobile vehicular patrol. The PRSC are installed in all Expressway Patrol (EP) cars.

Table 6.2: Existing Traffic Enforcement Cameras

Mitigating Measures

Apart from being seen as the 'enforcers' of the roads, TP believes that preventing accidents is the most effective way to make the roads safer. Therefore, by being transparent about the locations of the enforcement cameras and implementing measures to alert motorists of such enforcement zones, TP believes that motorists will be more careful at the high-risk accident-prone locations, thereby reducing the likelihood of accidents. It is with this intention that TP has implemented the following measures:

a. Highly Visible Traffic Enforcement Cameras

TP's enforcement cameras have been painted in orange and white stripes. These bright colours will draw motorists' attention of the enforcement cameras from a far distance and serve as a visual reminder to drive or ride safely.

b. Traffic Enforcement Camera Signage

The 'Traffic Police Camera Zone' warning signage are strategically placed at locations preceding an enforcement zone. This serves to alert motorists in advance of the enforcement zone or camera ahead.

c. Wide and varied publicity on the locations of Traffic Enforcement Cameras

Specific locations of TP's enforcement cameras have been published on the SPF website. This allows individuals and commercial entities to utilise the data, subject to approval by SPF. In June 2020, TP partnered "Motorist", a local automotive platform, to launch a module called "Co-driver in the "Motorist" mobile application. The new audio integration feature provides real time audio alert on the enforcement cameras as well as reminders to drive safely and graciously. Other measures to increase awareness of TP's enforcement cameras include working with stakeholders such as LTA on the potential use of ERP2 On-Board Unit. To increase the outreach efforts, TP also continuously leverages Social Media Platforms such as SPF Facebook, Twitter and Instagram, to promulgate the locations of the enforcement cameras.

d. Advance Warning Blinker Trial

The Advance Warning Blinkers (AWB) are the blue blinkers installed on the ‘Traffic Police Camera Zone’ warning signage preceding a speed or red-light enforcement camera. The AWB serves to enhance the visibility of warning signage, giving motorists advance warning to slow down.

<u>Other Enforcement Operations</u>

Other than leveraging technology to conduct general enforcement operations, TP takes a targeted approach to enforce against errant motorists who persist in their reckless road behaviour. TP conducts covert enforcement operations using ‘stealth’ or unmarked motorcars and motorcycles to clamp down on these errant motorists who commit traffic violations, ranging from using communication devices while driving and failure to keep left, to more egregious offences such as illegal racing, dangerous driving and red-light running. TP also frequently conduct roadblock operations to deter and detect drink driving and other serious criminal offences.

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