SUSTAINABLE DEVELOPMENT OF A ROAD SAFETY FRAMEWORK

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ABSTRACT

The road network in Singapore has shown safety records improving over the years, albeit with increases in both vehicle and human population. The number of road fatalities has decreased by 47% from 327 per annum in the 1980s to 173 per annum in the 2000s. The road fatality rate has progressively been reduced to 1.9 fatalities per 10,000 vehicles and 3.7 fatalities per 100,000 human populations.

An effective policy formulation and institutional road safety framework has contributed towards this improvement. This paper outlines how the Land Transport Authority (LTA) of Singapore has achieved in developing this road safety framework through systematic engineering strategies.

Road safety professionals are always looking for new initiatives to make the roads safer and more sustainable. While there is no one single direction that leads to best practices in road safety engineering, our efforts through three key strategies have enabled the development of a sustainable framework to improve road safety in Singapore.

This framework includes the strategy to initiate and plan accident prevention measures, the study of crash data and the execution of accident reduction measures and the management and collaboration with major stakeholders in road safety.

1. INTRODUCTION

Singapore is an urbanised city state with a land area of 710 square kilometers and a dense population of about 5 million. 12% of our total land area is taken up by roads. The road network is highly urbanised with 161 km of expressways, 627 km of arterial roads, 521 km of collector roads and 2046 km of local access roads. The road infrastructure is well developed and well maintained with lighting on every public road. Compared with many developed countries, car ownership is low with usage demand management and other controls. The vehicle fleet is modern with motorcycles taking up about 20% of all motor vehicles.

In Singapore, road traffic injuries have been seen as part of sustainable development. This sustainable development goes back to LTA's White Paper on A World Class Land Transport System in 1996. In the White Paper, we recognise that "road accidents are also costs which are not apparent to motorists but adversely affect our quality of life." Road accidents impose a substantial cost on both our economy and our people in terms of the loss of earnings, medical expenses, and pain and suffering. Hence, it makes economic sense to reduce the incidence of accidents on our roads.

However, it is a challenge for transport authorities like LTA to balance traffic efficiency while making roads safer for all. Gradually over the years, an effective and sustainable policy is grounded and formulated with an institutional road safety framework which will be

elaborated in later paragraphs. This road safety framework is developed systematically and embedded structurally through three engineering strategies. Our experience shows that for this development to be sustainable, it is important that these three engineering strategies be approached with careful balance. With encouragement, education and enforcement by major stakeholders, improvements in our road safety records have been attained.

The focus of this paper is on how LTA, the road authority in Singapore, has achieved in developing a sustainable road safety framework through systematic engineering strategies.

2. INTERNATIONAL COMPARISON

In Singapore, the number of road fatalities has decreased by 47% from 327 in the 1980s to 173 in the 2000s (see Figure 1).

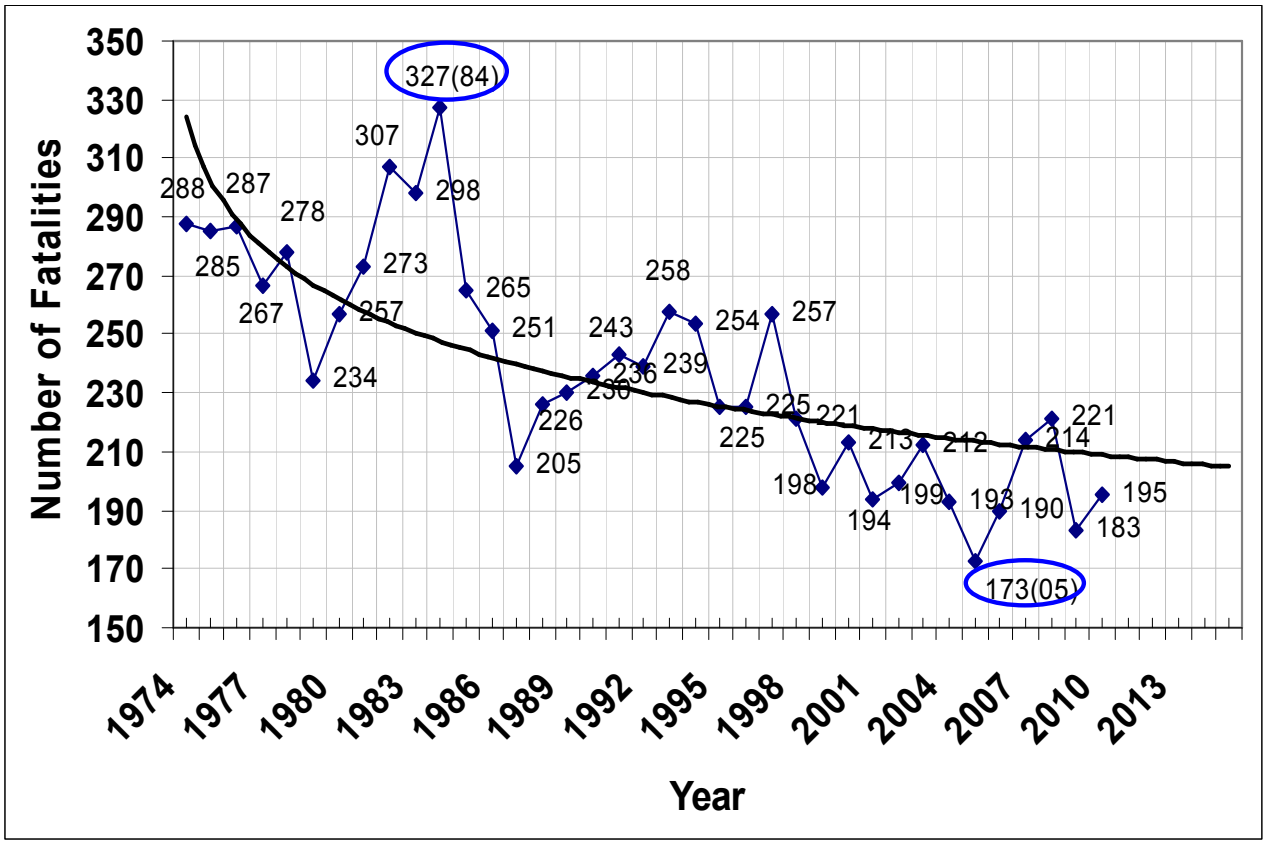

Figure 1 – Road Fatalities in Singapore (Source: http://www.spf.gov.sg/stats)

In 2010 [1], there were 195 deaths and 8,432 injuries on the roads, with accidents involving drivers driving under influence of alcohol accounted for 22 deaths. Out of the 195 fatalities, almost half or 46% involved motorcyclists/pillion riders and 28% involved pedestrians. These are the two most vulnerable groups of road users. The groups of road users that are more susceptible to fatal accidents are young motorcyclists (20-24) and elderly pedestrians (age 60 and above). A major proportion of the fatal accidents are speed-related accidents.

The road network in Singapore is among the safest in the world with the road safety records improving over the years, albeit with increase in both vehicle and human population (see Figure 2).

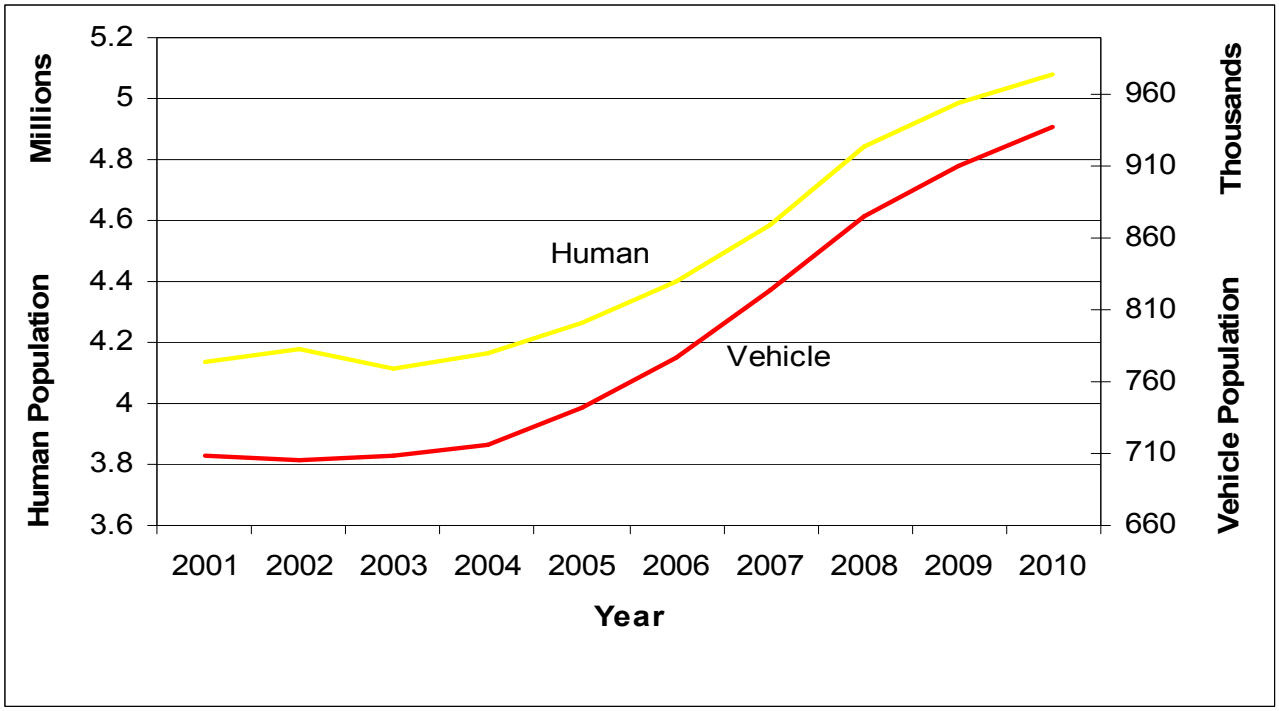

Figure 2 – Vehicle and human population in Singapore (Source: LTA)

With a sustainable road safety framework, our road safety records gradually show good improvement over the years. Our road safety professionals continue to explore ways to prevent and reduce road accidents. The road fatality rates have progressively been reduced to 3.8 fatalities per 100,000 human population, 2.1 fatalities per 10,000 vehicles and 0.8 fatalities per 100 million vehicle kilometers travelled. Our roads are recognised to be among the safest in the region. However, there is still room for improvement when compared with the world's best standard in developed countries such as USA, UK and Japan.

3. ROAD SAFETY FRAMEWORK

There are two government agencies in Singapore responsible for managing road safety and formulating policy. They are the Land Transport Authority (LTA) and the Traffic Police (TP). LTA is responsible for the provision of a safe physical road network for road users. Enforcement of the traffic regulations and public education efforts are carried out by TP. LTA and TP collaborate with other non-government organizations such as the National Safety Council and the Singapore Road Safety Council to promote and improve road safety.

In August 1998, LTA set up a dedicated Road Safety Engineering Unit with a mission to implement the best practices for road safety management and deliver safe roads to the public. This is achieved through the planning, implementation and management of various road safety initiatives. Processes and techniques such as black spot programme, crash

site investigation, road safety assessment and remedial treatment programmes are well established best practices being used.

Adopting a systematic approach to applying these principles and essential tools across the road network has the potential not only to facilitate the achievement of targeted safety outcomes but also to realise a sustainable safety management process [2]. Over the years, we have developed an effective road safety framework centered around three strategies (See Figure 3). Our efforts through these three key strategies have enabled the development of a sustainable framework to improve road safety in Singapore.

Figure 3 – Framework of road safety measures in Singapore

4. ACCIDENT REDUCTION MEASURES

The strategy on Accident Reduction Measures (ARM) aims to treat locations where accidents have occurred, and remedy existing problems contributing to accidents. This is to reduce the number and severity of future accidents.

4.1 Crash Site Investigation

Crash Site Investigation (CSI) is our first step in executing the ARM strategy in the early years of road safety engineering work in Singapore. The CSI work focuses on the investigation of fatal accidents. Fatal accidents which are comparatively more costly than others are treated with higher priorities. Fatal accident reports are obtained from Traffic Police. On average, about 180 fatal cases a year are reviewed. Cases of fatal accidents that we do not investigate include likely heart attack and accidents involving drivers under the influence of alcohol. The common CSI schemes implemented include improving lighting level, and installing pedestrian barriers like railings to discourage jaywalking.

4.2 Crash data and Traffic Accident Analysis Management (TAAM) system

LTA recognizes that it is important to develop, and establish excellent crash database for the proper study and execution of ARM strategy. This database can also serve in the exploration on Accident Prevention Measures (APM) strategy. To develop a reliable and useful crash database, LTA invests in developing a comprehensive, multi-functional analysis, and GIS map-based tool called Traffic Accident Analysis Management (TAAM) system. LTA has been working hand-in-hand with TP on developing this TAAM programme by collating the accident details in a suitable database format, marking the accident locations on a pre-developed road map. TAAM enables road safety engineers to analyse the accident trends, understand the contributory factors leading to accidents at specific locations, and identify black spot locations.

4.3 Black Spot Program

The Black Spot Programme (BSP) first started out as a simple CSI programme. Officers are sent down to the accident scenes to investigate and put up necessary remedial treatments whenever a fatal accident occurred. With no established accident analysis tool and limited experience at that time, this was our initial fundamental approach into accident reduction work. With the development of TAAM, LTA strategically maps out a programme with different phases to treat black spots in the road network. Our BSP is now well established as an important road safety engineering strategy. It is used to systematically identify and treat accident-prone locations based on predefined criteria and target. BSP aims to reduce the accident numbers if not the severity of the accidents through various black spot treatments. As Singapore has a dense urban road network, many of the targeted locations are signalised intersections.

With the support of TAAM, road safety engineers are able to discern a high percentage of junction accidents involve right turning vehicles. Treatments such as exclusive right turn arrows have been installed to control right turns. The results have been encouraging with the number of accidents dropping by as much as 80% over 12 months. BSP analysis show that many accidents involving motorcyclists losing control on expressways when the road surface is wet. BSP countermeasures include resurfacing some sections of the expressways with better quality and higher skid-resistant material. Before-after studies reveal a substantial reduction in the number of such accidents.

Since 2005, other cost-effective BSP treatments have been implemented with the aim to reduce the number if not the severity of the accidents that happen at these black spots. These BSP treatments include installing Red Light Cameras, targeted publicity and education for road users.

The Black Spot Programme (BSP) is carried out through five key stages:

Stage I: Develop a good accident database and accident analysis system
This is the first and most important stage in the BSP. Getting a good accident database is pertinent for accurate analysis of the problem in subsequent stages. TAAM system is able to contain all the necessary data such as accident database and several accident related factors such as traffic volume. It is integrated with a multi-query builder, a map interface and an analyzer. With the aid of detailed and reliable textual records together with the display of accident locations, TAAM enables users to have a quick visualization of accident concentration and generate areas of concern. Pre-specified criteria for choosing the black spots include black spot size, years of accident data considered and accident type. The system is also able to generate reports related to the black spot site for meaningful analysis.

Stage II: Identify accident prone locations

The next step is how to make full use of the information to select the most worthy (accident-prone) candidates in a systematic manner for safety improvement. Appropriate road engineering solutions can then be used to treat, evaluate and monitor the accident locations more effectively with positive results. The following are five simple steps to define what to treat:

a) Consider the number of years of accident history
A period of 3 years would be considered as practical since a period less than that cannot achieve statistical stability and a period more than that would be most likely to be affected by traffic and environmental changes.

b) Define the location/accident type to treat
There are four basic strategies to adopt in the different phases of a BSP: single site treatment, route action plan, mass action plan and area wide schemes.

c) Decide on the selection method
The number of accidents over the selected number of years is by far the simplest to compute. If data is available, the number of accidents can be normalized with related accident variables (accident rate) such as vehicle population or human population.

d) Consider organization target, available manpower and budget
It is important for the management to set a realistic accident or casualty reduction target where sufficient manpower and budget are allocated for this programme to work well.

e) Set a threshold
Every country has its own way of defining accident black spots/lengths depending on its own unique land size and traffic characteristics, organisation target (realistic), available manpower and funds allocation. Singapore set her black spot threshold at 15 accidents over 3 years. This is comparable with some countries such as UK.

Stage III: Diagnose the problem

The next step is to understand the root of the problem(s) at each location. This is essential to ensure that correct treatment is being selected. A desktop analysis of all information collated prior to a site check is mandatory. After which, the initial site check should pick up features of the road, environment and road user characteristics. There should also be follow-up site investigations to observe driver behaviour and traffic flow in different conditions and to take detailed site measurements and photographs.

Stage IV: Implement remedial measures

For a countermeasure to be effective, it must be applied to a particular problem which it is known to affect. There is no 'silver bullet' to select the 'correct' countermeasure(s) in roadway safety. One countermeasure seldom provides a total solution to a safety problem. Engineers should remain open to all possible options, and be prepared to use the strategies flexibly to meet community's unique circumstances.

Stage V: Monitor the effectiveness of remedial measures

Monitoring is most effectively carried out through before-after studies. In Singapore, we have a scheduled program to monitor the accidents at these 'treated' black spots at 6 months interval (till 3 years) after implementing measures.

5. ACCIDENT PREVENTION MEASURES

The Accident Prevention Measures (APM) strategy aims to treat locations before they become black spots. Accident prevention requires checking to ensure safety of road users is adequately addressed in planning, design and construction of new works, road improvements, traffic management schemes and maintenance works. There are three important accident prevention measures i.e. conducting road safety assessments, managing hazardous road locations and road safety initiatives.

5.1 Road Safety Assessment (RSA)

Since 1999, LTA has been conducting RSA as a proactive engineering tool to examine Singapore's roads and assess their accident potential and safety performance. Day and night road safety assessments are carried out by trained and qualified road safety engineers. RSA of all expressways was completed in year 2000. This was followed by RSA of arterial roads from year 2002 onwards. Potential road safety concerns of roads are identified and countermeasures are implemented within six months. The entire length of each arterial road is assessed (by driving & walking) in both directions both by day and night by the RSA team which comprises three suitably qualified reviewers. The RSA team examines all junctions in detail. Both general as well as site-specific observations are reported.

Project Safety Review (PSR) is a formal process of assuring the safety of road projects throughout their life cycle. PSR aims to ensure that the project developer or designer has adequate commitments and resources to manage safety effectively and that the project is designed and constructed to achieve a high level of safety. For existing roads, the road safety engineers in LTA conduct the RSA progressively. To date, about 400km of arterial roads have been assessed. RSA reports are regularly endorsed by the senior management in LTA.

The priority of the RSA programme is based on the risk of accidents. These roads are sorted in descending order according to the past accident records, and the roads to be assessed are clustered according to proximity/continuity.

Our comprehensive RSA programme has seen much progress over the years In addition, all new roads are reviewed at various stages for safety concerns. Some RSA safety concerns include improving safety at the gore area for vehicles exiting from the main expressway to slip roads. These gore areas are hard and unforgiving. RSA schemes include installing *crash cushions* to reduce the accident severity of errant drivers and implementing *hazard markers* at these gore areas to warn motorists. Research shows that crash cushions can save lives and reduce injury to motorists by absorbing the impact of the crash. More than 100 crash cushions have been installed and there has been no more road fatality at these gore areas installed with crash cushions.

Other cost-effective RSA schemes include having *high entry angle treatment* for slip roads, proper *end treatment* of vehicle impact guardrails (ramp down), *covering of drains* where necessary to minimize the risk of being injured or killed if one drove or fell into the drain and *shifting stop line* outwards to improve motorist's sight distance of side roads.

5.2 Hazardous Road Locations

The Hazardous Road Locations (HRL) work is initiated to complement RSA as our road safety engineers look out for potential hazards on the roads. Potential dangerous locations can be identified from road users' feedback and information on frequently hit locations. These data include locations of damaged crash cushions, vehicular impact guardrails, street lamp posts, scratched walls, damaged wall claddings and traffic light posts. Examples of HRL treatments can be simple, cost-effective treatments such as floodlights for zebra crossings, road markings and signs to prohibit unsafe driving such as overtaking, parking and speeding.

5.3 Road Safety Initiatives

Road Safety Initiatives (RSI) is a major core area under the APM approach. Road safety professionals are always looking for new initiatives to make the roads safer and more sustainable. In line with that, we are also exploring continual improvement by encouraging innovations for new road safety initiatives. Where necessary, trials are carried out with technologies from overseas best practices to adapt to the local environment. In this way, we are able to update ourselves with the latest innovation in road safety and ensure sustainability in our road system. International best practices and lessons are explored and evaluated for island wide application especially for the vulnerable road users.

5.3.1 Motorcyclists

About 50% of road fatalities in Singapore involve motorcyclists or their pillion riders. While education and enforcement continue to be undertaken to enhance road safety, engineering measures are also intensified. Road surfaces at accident-prone locations are treated with high skid-resistance material to give better control for all road users, particularly motorcyclists. Exclusive right turns are used to regulate the right turning movements at some traffic light junctions. Due to the inconspicuousness of the motorcyclists on the road, this measure helps to reduce the chances of motorcyclists involved in accidents due to misjudgement from either right-turning or on-coming vehicles.

5.3.2 Pedestrians

To make our roads more pedestrian-friendly, we provide pedestrians with barrier-free accessibility by ramping down parts of the sidewalks and kerbs. This also assists the elderly to get off the roads and onto the footpaths easily and safely. Elderly-friendly features such as at-grade crossings are provided in areas where the elderly frequent if traffic situation allows. Railings can be installed along centre medians to deter pedestrians from jaywalking by putting up railings.

At zebra crossings, motorists are given advance warnings through safety features like signboards, zigzag lines and flashing beacons with black/yellow poles. However, some motorists have been observed not to give way to pedestrians that are located after a bend. For such locations, Pedestrian Crossing Ahead Markings in the form of a pair of white triangular road markings are painted before zebra crossing. This is to pre-warn motorists that there is a zebra crossing ahead, and be aware and give way to pedestrians. The blue pedestrian crossing signs attached to the flashing beacon poles indicate to pedestrians and motorists the position of a designated crossing. This enhances the visibility and alert motorists of the approaching zebra crossings. Flashing beacon poles are now placed lower for better visibility. All flashing beacons with halogen bulbs have been replaced with LEDs for better brightness and reduced needs for maintenance. This ensures that these warning lights go not get blacked-out. And where lighting at the pedestrian crossings is insufficient, floodlights are provided. This helps to enhance the lighting level at zebra crossings so as to draw attention of motorists to watch out for pedestrians at night.

At signalised pedestrian crossings, dashed pedestrian crossing lines gradually replace the continuous white lines. and enable drivers to easily distinguish the “stop” line from the pedestrian crossing. Wired blinking LED road studs flushed to the ground or Intelligent Road Studs are used to warn turning motorists to watch out and give way to pedestrians crossing alongside. To help the visually handicapped safely cross the road, Pedestrian Audio Signal is provided at some traffic lights. Green-man countdown timers are installed at many places to show the time left in the pedestrian crossing phase. Green Man Plus uses Radio Frequency Identification (RFID) technology to detect elderly pedestrians crossing the road. RFID readers are mounted on the traffic light poles to detect the RFID cards held by elderly pedestrians who wish to cross the roads. Once detected, the system will extend the 'green man' timing to allow them more time to make their way across the roads. At locations where the traffic volumes do not warrant for a proper crossing, centre dividers are constructed to provide central refuge and assist the pedestrians to cross the road in 2 stages. "Pedestrian Ahead" warning signs are also put up to increase the awareness of motorists.

5.3.3 *Pedal cyclists*

To enhance safety between cyclist and pedestrian, LTA plans to provide *dedicated cycling paths* in 5 Towns for a start. In terms of engineering measures to enhance safety, appropriate signs and markings are provided at critical points where pedestrian and cyclists would come into conflicts. In addition, LTA looks into the need to widen specific crossing points or provide segregated bicycle crossing traffic signals.

5.3.4 Motorcar drivers and passengers

Electronic “Your Speed” Signs (YSS) are installed at specified stretches of some roads to display real-time speeds of speeding motorists who have exceeded the speed limit. This vehicle-activated speed display sign increases motorist’s awareness and encourages motorists to reduce vehicle speeds and obey the speed limit. YSS are currently used to

treat black spot sites with speed-related accidents. Traffic Calming Marking (TrCM) is a psychological traffic calming measure to slow down motorists. TrCM creates a visual effect of traffic lanes narrowing with two rows of white triangles. Our studies show that TrCM is effective in helping motorists observe and moderate their speeds.

To make our roads more forgiving, various devices are used such as spring-loaded posts with better retro-reflectivity at centre dividers to replace the conventional delineator posts. flexible posts with yellow and black stripes are implemented on road pavement to help improve conspicuity of the gore areas with crash cushions. Flashing Advanced Warning Light (AWL) is used to alert motorists to slow down for the red traffic lights ahead. When approaching a concealed signalised junction (usually at bend or after a crest), motorists will see the AWL warning motorists in advance to a red traffic signal and that they need to prepare to stop. At sharp bends on the roads, we provide curve alignment markers, which are made of highly reflective yellow/black material to guide motorists in negotiating these bends safely. Vibraline markings that are installed along expressways are used to alert fatigued drivers who may have swayed from their traffic lane.

5.3.5 Public transport road users

Since 1999, safety bollards have been progressively installed at every bus stop to protect bus commuters from direct impact of errant vehicles. We also paint a yellow band near the edge of every bus stop to guide bus commuters to stay away from the bus bay.

5.3.6 School children

The enhanced school zone scheme is a road safety improvement at primary schools to increase the visibility of school zones, and raise motorist awareness of small children crossing in the area. The scheme includes two simple easy-to-read signs demarcating the boundary of the school zone as well as red-pigmented stretches of pavement along the approach roads in the school vicinity. The schools also engage parents to be trained as traffic wardens to guide young children crossing the roads. Favourable public feedback has been received concerning this scheme.

6. COLLABORATION AND CONSULTATION (CAC)

The CAC strategy focuses on managing sustainable collaboration and consultation efforts with major stakeholders in road safety. The earlier two strategies (ARM and APM) adopt a systematic approach by applying road safety engineering principles and essential tools. This has helped to achieve targeted road safety outcomes with a sustainable road safety management process.

6.1 National Collaboration Efforts

6.1.1 Collaborating with local stakeholders

In February 2005, the Road Safety Action Plan (RSAP) was officially launched at the National Road Safety Exhibition and Rally. The RSAP is the result of a strategic collaboration between various government agencies, non-governmental organisations and the private sector. It aims to set common targets on road safety strategies, and is specifically tailored to the particular needs of Singapore. The RSAP leads to greater emphasis and commitment on road safety issues and spurs more road safety initiatives. It is a timely effort by the various government agencies to come up with concrete initiatives to improve road safety. In particular, there is a need for a concerted effort by both road users and the relevant government agencies to reduce the number of accidents.

Besides engineering measures for road safety, the Action Plan also focuses on other non-engineering aspects, predominantly education and enforcement. Emergency preparedness is another aspect mentioned in the Action Plan as an important element. Lives can be saved with adequate and correct emergency response in handling accident victims. LTA works closely with major stakeholders like the Traffic Police, and non-governmental organizations (NGOs) like the National Safety Council and Singapore Road Safety Council to make the roads safer for all. We also collaborate with other NGOs like Singapore Action Group for the Elders to promote safety or our ageing people. By working together with an ever strong commitment to road safety, LTA takes on a holistic approach towards managing and enhancing road safety in Singapore to offer the best possible practices for our roads. The enhancement measures identified in the Action Plan have been implemented progressively.

In addition, LTA works with the communities to enhance road safety by fostering sustainable partnership with community leaders, and supporting the community's involvement in transport issues including road safety. From our experience with the communities, we learn that all the road safety features design will not be effective if the road user is not educated to use them correctly. Besides designing the roads to be equipped with safety features, LTA reaches out to the communities to educate them and to listen to their concerns. LTA develops educational collaterals such as brochures, leaflets and posters, as well as interactive games for motorists and pedestrians to educate them on the safe use of the road facilities. These people-centred initiatives compliment the efforts in public education in road safety by the Traffic Police.

6.2 International Collaboration Efforts

With strong support, close collaboration and research in road safety, we are able to have the opportunity to share and exchange road safety knowledge and experience with others. Besides national strategic partners such as the Traffic Police, we collaborate with international road safety organizations like the Global Road Safety Partnership (GRSP) and the World Health Organisation (WHO). Our regional road safety partners include counterparts and road safety experts from Association of Southeast Asian Nations (ASEAN), Asia-Pacific Economic Cooperation (APEC), and United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). Some outcome of this successful international collaboration includes the United Nations Global Road Safety Week and Road Safety Conference held in 2007, Singapore. Another outcome is the GRSP Asia Road Safety Seminar held in 2009, Singapore together with the launching of Decade of Action for Road Safety 2011-2020. These international road safety events are supported by the Ministry of Transport, and attended by road safety experts and professionals from many countries.

6.3 Consultation

LTA provides consultancy in the areas of road safety engineering such as road safety assessment, road safety programmes for vulnerable road users and black spot programme. We also conduct road safety engineering training courses to share our experiences in road safety engineering and management with many countries. Road safety activities, programs and training carried out by LTA include providing practical expertise to encourage capacity building and knowledge transfer.

6.4 Road Safety Award

In December 2007, LTA together with the Traffic Police was bestowed the prestigious Prince Michael International Road Safety Award for road safety management on Singapore for its efforts to improve safety. The Award recognised that Singapore's best practice in road safety could be adopted in other countries.

CONCLUSION

This paper has showcased how LTA, the road authority in Singapore, has successfully achieved sustainable development of a road safety framework through strategic road safety system approach. By putting road safety knowledge into practice, LTA has shared several practical road safety engineering measures in making the roads safer for road users and road workers. However, it remains a challenge for land transport authorities like the LTA to balance road safety and traffic efficiency. Despite the various infrastructural provisions, road safety is a shared responsibility and requires the close co-operation of all road users.

REFERENCES

1. Straits Times Press Release (27 January 2011). Singapore
2. Peter Croft (2005). Sustainable Road Safety Engineering. Association for European Transport and contributors, pp 1.