ITS of SMART

Mohd Saleh Santhiman*
Director of SMART Highway
Projek Tambatan Banjir Kuala Lumpur
73, Jalan 3/93, Taman Miharja,
Off Jalan Cheras, 55200 Kuala Lumpur
Email : saleh@llmnet.gov.my

Looi Hong Weei**
Head of M&E Department
MMC Engineering Group Berhad- Gamuda Bhd JV
Stormwater Management & Road Tunnel (SMART)
No. 67, Jalan 3/93, Taman Miharja
Off Jalan Cheras, 55200 KUALA LUMPUR

ABSTRACT

The city of Kuala Lumpur is plagued with two serious problems: flooding and traffic congestion. The SMART (Stormwater Management and Road Tunnel) project is an innovative solution to both of these problems. This paper will describe the intelligence system in terms of the various components and their functions in relation to manage the traffic. The two major components of the system for this project, namely the Traffic Management and Control System (TMCS) and Flood Detection System (FDS) play equally important roles to make the SMART efficient and fit for the purpose. The 9.7km stormwater tunnel also shares the center 3km of motorway tunnel that is unique to this project.

The Government of Malaysia decided to proceed with the project which can mitigate the flood in city center and ease of traffic at south of city, the project proponents MMC Corporation – Gamuda Berhad Joint-Venture have driven the project half-way through success.

1.0 Project Background

The Stormwater Management and Road Tunnel is a project necessitated by an urgent need to solve two major problems that have been having crippling effect in the city of Kuala Lumpur. With heightened land development resulting in increased surface runoff coupled with constrictions along the main rivers running through the city, frequent flooding had brought losses and inconvenience to the business district centre of Kuala Lumpur (refer to Figure 1). In addition, traffic congestion occurs due to the increasing numbers of vehicles on the road.

Citing from the problem of traffic congestion and flooding, SMART project is initiated with the objectives to:

- ease the traffic at the south of KL City, and
- bypass the stormwater from KL City

SMART, the 3km long motorway will run through approximately the central portion of the 9.7 km tunnel (refer Figure 2). At each end of the motorway tunnel, there is a Y-junction. One junction allow vehicle to enter/exit the tunnel via 1.5 km ingress/egress section at each end, another junction link to stormwater tunnel to mitigate the flood water. This concept of integrating a motorway within a stormwater tunnel is believed to be the first of its kind in the world and the challenge to engineer.

The tunnel design is only for light vehicles, which is not exceeding 2m height.

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Looi Hong Weei, MALAYSIA

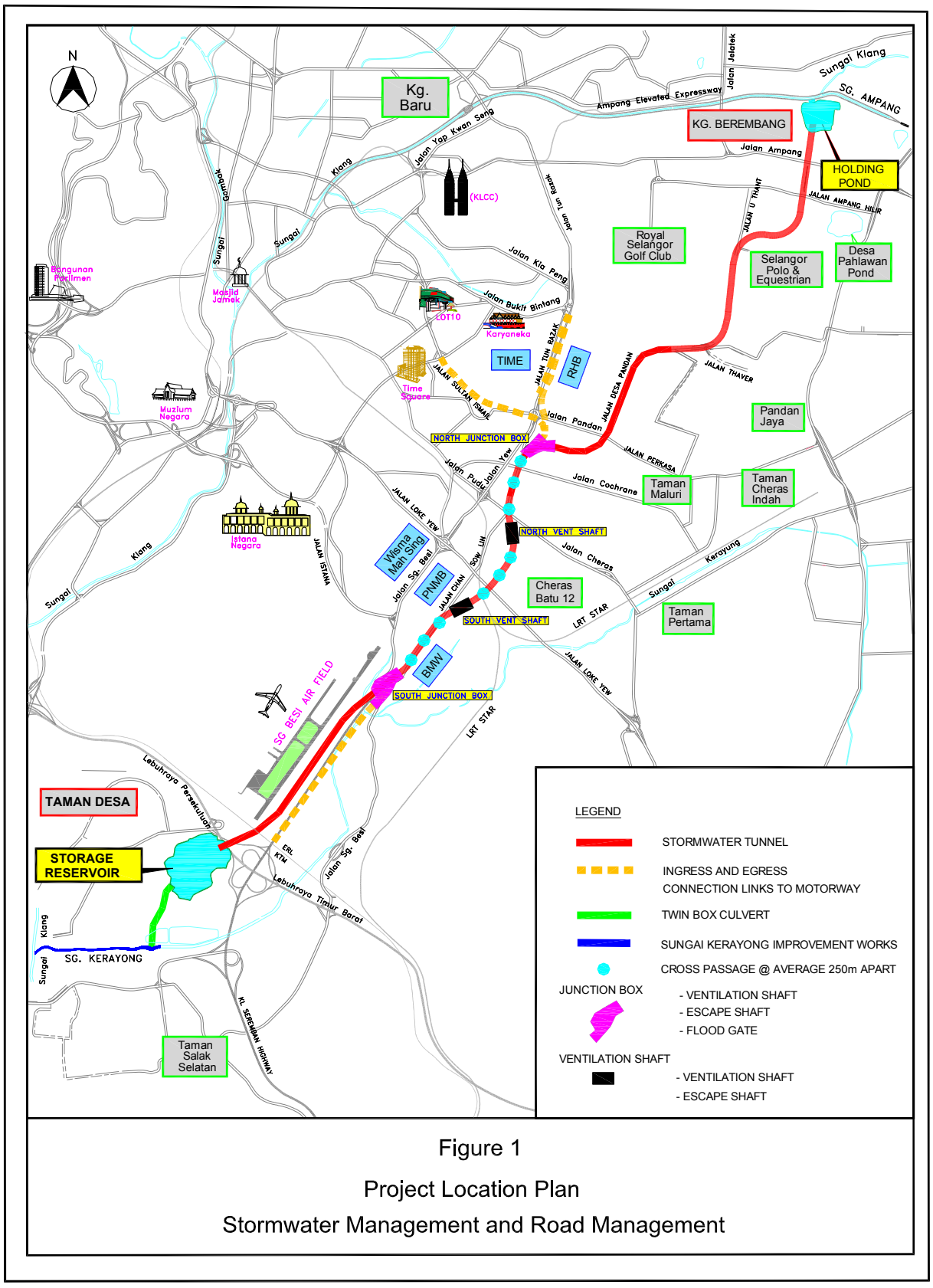

Figure 1

Project Location Plan

Stormwater Management and Road Management

Figure 1 : Project Location Plan of SMART

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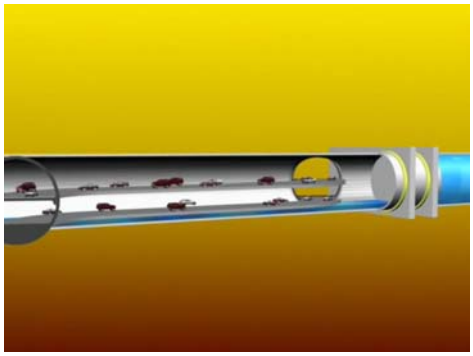
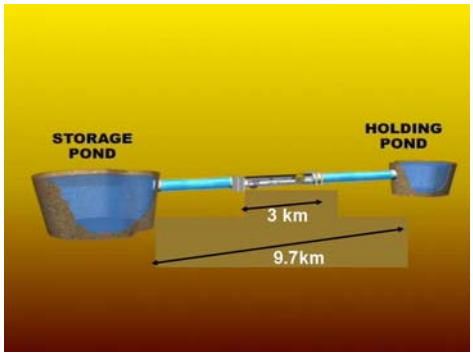
Looi Hong Weei, MALAYSIA

Two (2) major components to make this tunnel 'smart', there are Flood Detection System (FDS), and Traffic Management & Control System (TMCS).

FDS is used for forecast and detect the rainfall and river water at upstream and downstream, it will decide and confirm to close and open the tunnel for flood to bypass. On the other hand, the TMCS is an intelligent system to manage, monitor and control the traffic of the ingress/egress and tunnel.



Schematic view of the motorway



Schematic view of the stormwater system

Figure 2 : Schematic of the SMART – Motorway and Stormwater

2.0 The 3 Modes of Operation

The operation of the motorway in the SMART works on three- principles mode depends on the flood condition at the upstream of Klang River/ Ampang River confluence, as well as the operation status of the motorway tunnel.

2.1 Mode 1, with no storm or low rainfall. No flood water will be diverted into the SMART. Motorway tunnel operates under normal condition.

2.2 Mode 2, SMART system will be activated. The stormwater from moderate rainfall is diverted into the bypass tunnel at the invert level (lowest segment) of the motorway tunnel. It is worth to note that during the mode 2, the motorway section on the upper and lower decks are still open to traffic, while the invert level of the tunnel is filled with water.

2.3 Mode 3, the motorway will be closed to traffic. Full bore of the tunnel will be used to mitigate the stormwater. Once the FDS system confirm the need to activate the mode 3 operation. Sufficient time will be allocated to allow the closure of tunnel from traffic, evacuate all passenger vehicles before the automated water gates are activated to occupy the flood water. The anticipated duration of switching to from mode 2 to mode 3 is estimated to be about one hour. After the flood recede, the targeted duration for tunnel reopening is minimum of two days to enable for flood dewatering, cleaning and reinstatement the TMCS.

The mode of operation can be referred to the diagram in Figure 3.

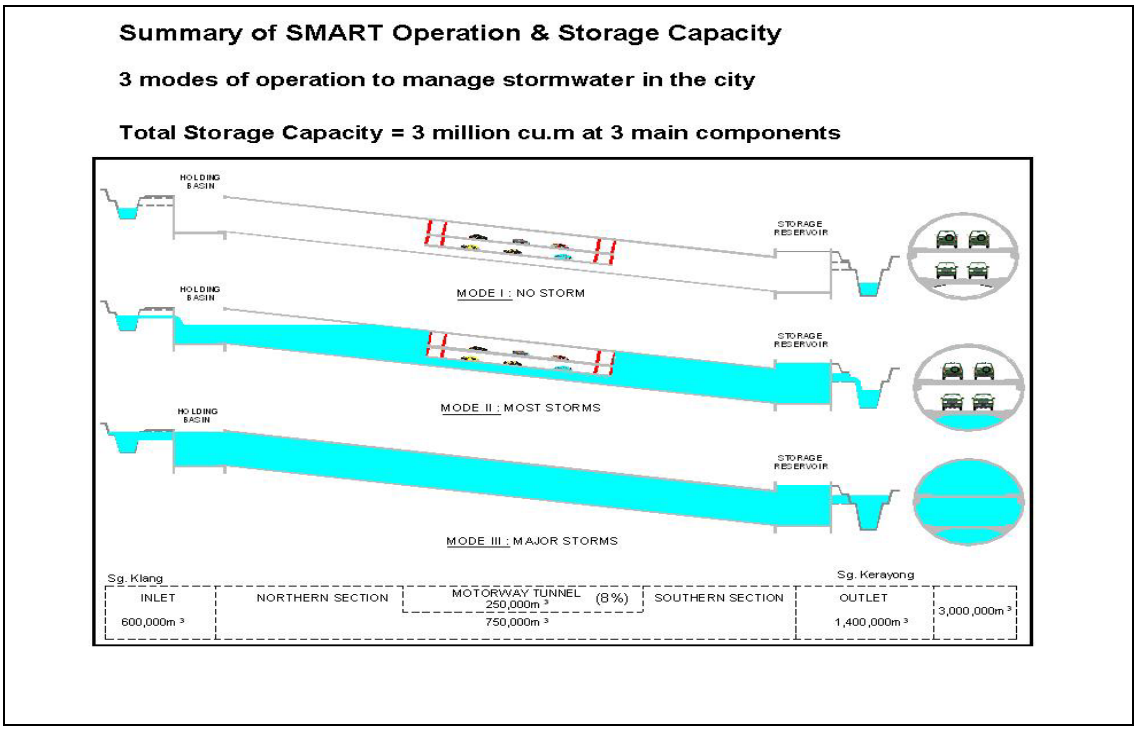


Figure 3 : Mode of Operation

During operations, the upstream monitoring facilities and the retention capacities of the two holding ponds together with the tunnel retention capacity provides the system operators at least an hour of warning for the need to close the motorway to traffic and avail it for flood water diversion. Emptying the road tunnel from traffic user will only take between one hour including closing of the gates and cross passage doors, conducting a walkthrough check and opening the flood tunnel barrier.

2.0 Stormwater Components

2.1 Flood Detection System and Operation.

The major components of the FDS are:

- Catchment Monitoring System – rainfall, water level, river flow and etc.
- Tunnel Sensor Monitoring – ultrasonic and gas purge
- Modeling System – Hydrological and Hydrodynamic
- Warning & CCTV Surveillance System
- Radio Transmission Repeater Stations
- Radar System (future)

Operation of the flood mitigation scheme based on automatic reception of data coming in from remote monitoring stations and gauges installed along the Sg Klang, Sg Ampang and Sg Bunus, their tributaries and catchments. This information is monitored and processed by the SCADA system and flood forecasting software. With this system, a prediction of the hydrograph is generated and displayed at the Stormwater Control Centre.

With the alert of extreme flood conditions, high river flow at the confluence of Sg Ampang and Sg Klang will be diverted by a diversion weir into the holding basin at Kampung Berembang. From the holding basin the flood water flows into the tunnel and discharge to the Taman Desa storage reservoir at the other end of the tunnel. Flood water will then be released in stages into Sg Kerayong, which is a tributary of Sg Klang.

2.2 Gates

The motorway section of the tunnel is fitted with water gates at either end (North Junction Box and South Junction Box) to separate the motorway from the stormwater tunnel for the safety of the motorway users. The flood gates at both ends of the motorway will remain closed at all times during traffic operation and opened only when the tilting road gates in the ingress and egress are closed.

As added safety precaution, the opening of flood control gates is not possible without first closing the road gates. Likewise no possibility of opening the road gates without first closing the flood control gates The two are deliberately interlocked as part of the fail safe / defect-proof operation. The interlock enabled the dual purpose operations to be combined safely in a single but dual purpose structure.

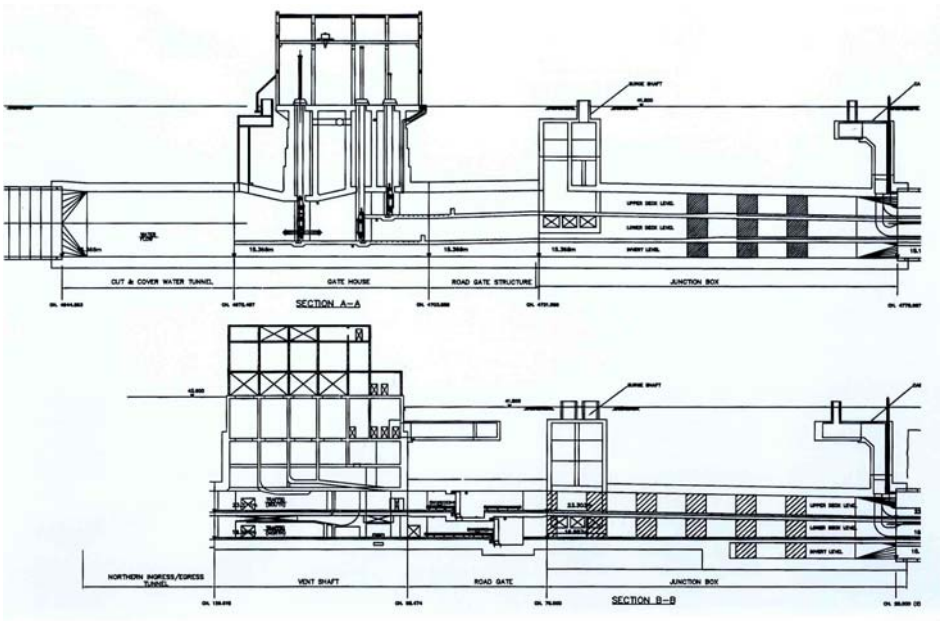


Figure 4 : Gates Arrangement at North Junction Box and South Junction Box

3.0 Motorway

The motorway traffic is uni-directional, consist of a double decks structure, each carrying two (2) traffic lanes and one emergency lane, situated one above another (refer Figure 5). The motorway tunnel is link to ingress and egress tunnel for vehicle entry and exit. Thus, the entire length for the motorway tunnel is about 4.5km (included ingress/egress cut and cover tunnel).

The motorway has all the fittings and safety features in compliance with international and local standard. However, some special requirements are unique to SMART, the entire fitting and road furniture in the motorway is designed to cater for the dual-purpose function of the tunnel. The design philosophy adapted for the road tunnel fixtures and fitting within the motorway is sufficiently robust to withstand and maintain its integrity during the operation of flood mitigation. As well as provide a conducive environment for traffic commuter, effective monitoring and efficient control of motorway tunnel operation during normal operations after flood recede.

All the system such as lightings, linear head detection loop, CCTV cameras, radio rebroadcast cable, power cable and road signage's are being design to withstand water tightness of 2.5 bars hydrostatic pressure and continuous submergence for at least 24 hours. The bracket design shall withstand the water flow of 5.5 m/s.

Figure 5 : An artist's impression of the motorway

3.1 Tunnel Ventilation System

The purpose of the tunnel ventilation system is to control the air quality within the tunnel during normal and congested traffic operation and the movement of smoke in the event of a fire.

The smoke control and air pollutant control during fire and congested vehicle emission respectively demand extensive understanding of fluid, emergency escape operation and profile of vehicle movements. These parameters are fed into Computational Fluid Dynamic (CFD) to perform detailed analysis. The CFD analyze and determine the critical air flow velocities required from the ventilation system performance.

Ventilation system is a critical feature for safe, efficient and effective operation of tunnel emergencies such as fire. A longitudinal ventilation system is employed with fresh air supply through Saccardo nozzle and a tunnel extract located together at each four (4) ventilation buildings. The system is supplemented by jet fans located at the ingress egress tunnels. The motorway consists of four ventilation buildings, each containing 12 number of axial ventilation fans (6 supply and 6 exhaust) and two (2) number of axial pressurized fans for the stairway and lift shaft. The staircase of the buildings will also act as escape route from the tunnel to ground level.

The tunnel ventilation system will generally need to be operated for pollution control only during periods of traffic congestion. Under normal traffic conditions with traffic flowing freely, the 'piston effect' generated by the traffic movement will ensure that there is sufficient airflow in the direction of the traffic movement to keep pollution concentration below acceptable level.

Should a fire occur under normal traffic operations, then the tunnel ventilation system will be used to blow the smoke in the direction of traffic movement. Extraction from the tunnel will occur at the adjacent ventilation shaft downstream of the fire. This will ensure fresh air upstream (behind the car accident) of the fire site and allow safe public egress and emergency intervention.

The ventilation system is integrated with air quality monitoring system and linear heat detection system. The information from these systems is feedback via SCADA supervisory and controls the fans serving respective zones to provide a safe and conducive environment for road users.

3.2 Tunnel Lighting System

Intelligent tunnel lighting systems were designed for the Smart tunnels, incorporating multi-stage lighting levels to provide visual comfort for road users. The intelligence build into the systems include a continuous feedback measurement on light intensity at the tunnel portals, backup scheduler. The information is then process using Programmable Logic Control (PLC) and the lighting levels is then adjusted accordingly.

The light fittings within the tunnel uniquely design to withstand water tightness rating of Ingress Protection 68 (IP68). This specially improvised IP68 lighting are made so that all light fittings can remain in the tunnel, thus facilitate the speedy switch from road usage to flood mitigation. Two years of conscientious effort on the research and development of the lighting fitting by the SMART's engineer together with manufacturer and university to ensure that a fail-safe lighting system is incorporated for the SMART tunnel project.

3.3 Tunnel Heat Detection System

Fiber Optic Linear Heat Detector system is adopted because of its ability to perform programmable zoning and the fast response time of less than 10 second even the signal comes from the further zone. The linear heat detector system is considered as primary heat detection system. Linear heat detection system is integrated with the CCTV located along the bored tunnel. Signal detected by the fiber optic cable, the corresponding CCTV camera serving the same zone as the loop will be displayed and alert the operator at Motorway Control Center. This integration enabled the speedy identification and reconfirmation of fire or false alarm thus allows the quick activation of fire fighting and rescue operation to be carried out.

3.4 Tunnel Redundant Electrical System

Despite the fact that the tunnel is supply by two (2) separate national power grid, diesel power generator sets is capable to support all the essential electrical loading of the equipments inside the tunnel. In addition, comprehensive uninterruptible power supply (UPS) provides continuity of power supply to essential loads at all times even in the event of mains supply interruptions and during switching over from one source to other. The power switching is pre-programmed and managed by TMCS.

If the permanent power supplies fail, the system will start the diesel generators and perform the power switching. The whole switching process only takes a few seconds to complete and is perform automatically. The TMCS only receives and acknowledges the switching signal.

3.4 Tunnel Fire & Emergency Telephone System

These facilities are located at the emergency escape shaft and cross passages to facilitate the communication in accident or emergency situations. The entrance door is interlocked with CCTV located within the escape shafts and cross passages. The CCTV will be displayed once the door is open and the operator will be alerted on the visitor. After the operator were informed on the needs of the visitor or emergency situation, the operator can turn on the pre-programmed voice recording to all the emergency telephones. The pre-programmed voice recording will provide short but useful instruction or inform that the situation is being addressed.

3.5 Tunnel Radio Communication and Cellular System

The SMART tunnel is equipped with leaky cables for radio communication system that facilitate communication for the Malaysian Fire Department, Police and Ambulance and tunnel operator. During normal operation, the selected radio services will remain intact when the listener is entering the tunnel. During emergencies, the radio communication network will be interrupted and the broadcast will be disseminated from control center. This feature is important to enable all the rescue teams remain communicated on

latest action or development during emergency operations within the motorway control center.
Cellular communication network also provides the driver an uninterrupted communication while passing through the tunnel.

3.6 Closed Circuit Television (CCTV)

The Closed Circuit Television (CCTV) System is installed along the entire length of the tunnel. In order to facilitate efficient monitoring and effective operation of the tunnel, approximately 200 nos. of CCTV installed along the tunnel provides full coverage on the traffic lane, cross passages and escape entrance. The CCTV enclosure is designed to Ingress Protection 68 (IP68) to withstand 2.5 bar of water pressure and water flow velocity of 5.5 m/s. During mode 3 operation, these CCTV remained in the tunnel.

The CCTV selected for SMART tunnel also equip with state of the art of Automatic Incident Detection System (AID). The system is able to perform as below: -

- Measurement of traffic flow speed
- Measurement of zone occupancy or the number of vehicle passing through a particular location
- Detection of speed drop - if the speed in the particular lane suddenly drops with a significant percentage, this can indicate the trouble in front of the vehicles
- Detection of stop vehicles – if the vehicle remains idle position over a certain period of time, will alert the operator.
- Detection of inverse direction – if the vehicle move in the wrong direction, alarm will be triggered.
- Detection of smoke – when there is sudden drop in term of video quality and this situation persist for a certain period, a smoke alarm will be generated

The function of AID together with the vision offers early detection of problem, and quick identification and reconfirmation of emergency situation.

3.7 Traffic Management and Control System (TMCS)

The status of the primary and essential electrical and mechanical equipments inside the tunnel is continuously monitored, processed and controlled by SCADA.

It is of extreme importance that the tunnel has a smooth traffic flow and the mechanisms to quickly respond to any emergency events. This is achieved partly through an information system that automatically collects traffic data such and speed and density of traffic. This information is relayed to a safety and control office to allow quick and effective control of vehicles entering, inside and exiting the tunnel. The tunnel features about 200 cameras for the instantaneous detection of non-moving vehicles to supplement the fire alarms,

air quality detectors and other traffic management systems that usually determine incidents and intervention response.

Emergency info will be disseminated via variable message sign at the ingress / egress of tunnel. Along the motorway tunnel, arrow signs/boards featuring a highly visible LED display provides very effective traffic direction. The portable signal board can be mounted on the trailer or permanently installed to allow the traffic patrolman to divert the traffic.

Closed Circuit Television (CCTV)-Automatic Incident Detection (AID) cameras are installed along the ingress / egress as well as tunnel to acquire the speed, density and flow of traffic in each lane and transmit the data to a central computer. The processed information can be displayed to other Variable Message Signs (VMS) on the ingress/egress highway. The VMSs provides continually updated to advise motorists of road conditions and traffic movements ahead. The information from Traffic Management and Control System is also useful to estimate number of motorist within the tunnel during emergencies.

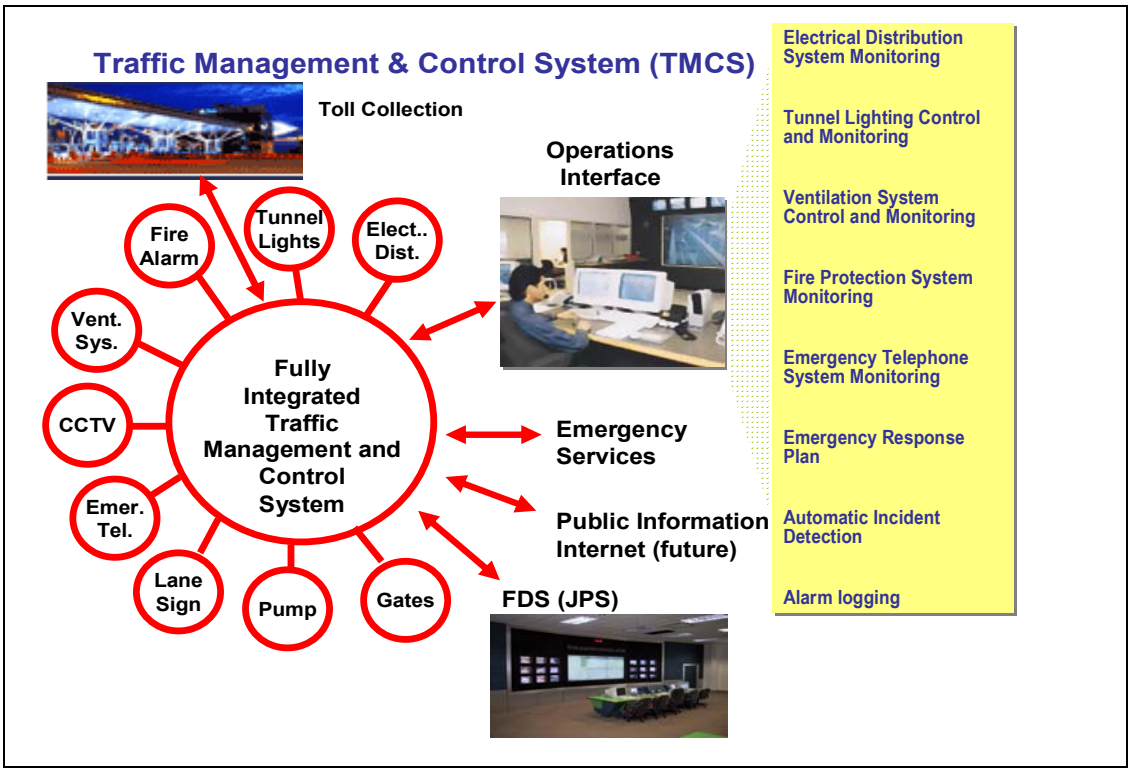


Figure 6 : Traffic Management and Control System (TMCS)

4.0 Demonstration

Demo 1 : Tunnel Closure from Mode 2 to Mode 3

Scenario: The KL City is experiencing a extraordinary storm season. Remote monitoring and gauging stations of Sg Klang and Sg Ampang collect the hydrological data on river flow velocity, river level, rainfall data and feed to

state of the art Flood Detection System. The system shows a strong trend that mode 3 is expected within 1 hour. Stormwater Control Center will decide to activate mode 3.

All the hydrological information is continuously transmitted to SMART through wireless broadband services. Similarly, the selected information from SMART will also feed to Stormwater Control Center continuously for JPS to understand the situation in SMART such that an inform decision can be made.

Upon receiving of the directive, the following list the mode 3 switching operations in a sequential manner: -

- Send the signal to VMS located at each Ingress/Egress portal that the tunnel needs to close down for traffic in order to mitigate the stormwater. Traffic will be diverted at ingress/egress before entering to tunnel.
- The toll booth will be close and no new entry of vehicle or pedestrian are allow into the tunnel.
- The Traffic Management and Control System provides the data on traffic velocity, vehicle count and estimated time that the traffic can be completely disseminated.
- Radio broadcasting will be interrupted and explain the need of such diversion in order to prevent heavy flood in KL City. Meanwhile, the drivers can inform of the possible delay of the schedule to their friends and family due to the diversion via their cellular phone
- After the last vehicle exit the tunnel, controller verifies the vehicle count using Traffic Management and Control System.
- Patrolman check to ensure each cross passages is empty and closes the entrance door to ensure no persons stayed in the tunnel.
- The controller at Motorway Control Center can monitor via CCTV and confirm the status of the door is closed.
- Control System will then switch off all the drainage pumps and ventilation fan located along the bore tunnel using SCADA.
- Meanwhile, the Stormwater Control Center regulates the diversion weir to increase water level in Kg Berembang holding basin. The water level in the basin is monitored and the volume of water intake from diversion weir is modulated.
- Motorway Control Center controller will initiate the road gate closing sequence. Then, open the flood gates. All the positions of the gates are monitored by TMCS.
- SMART will confirm to JPS on the completion of tunnel closing and ready for stormwater to pass through.
- Stormwater Control Center will allow more water to flow into the tunnel.
- Water level within the tunnel is monitored at the information from sensors located at various location is collected and compared.

Demo 2: Traffic Accident

Scenario: The KL City is full of traffic. The horrendous jam had been 2 hours and motorist is eager to head home. Without hesitation, motorist drives into SMART tunnel to relive from traffic jam and enjoy the smooth driving experience. The motorist drive fast and exceed the pre-determine speed limit. Two vehicle clashes and the passenger suffer a minor injury, but the traffic behind the accident is blocked and piling up quickly. The sequences of traffic diversion from one lane to another lane need to be initiated.

- Through AID, the controller in the control room immediately alert by the TMCS on the vehicles stays in the idle positions for period exceeding pre-determine threshold. The CCTV of the zone pop up to notify the controller on the incident.
- Controller direct patrolman to the incident area, and inform police, bomba and hospital as necessary.
- Controller send signal to VMS located at the ingress/egress to inform of the accident and switch all the traffic sign downstream of the accident to red.
- Radio broadcasting will be interrupted and inform the motorist on the accident. Otherwise the motorist can continue to enjoy their radio broadcasting from service provider. Tunnel motorist can inform of the possible delay of the schedule due to the congestion via the personal cellular phone.
- The air quality monitoring equipment begins to detect high level of pollutant and activated the ventilation fan to supply the fresh air.
- A motorist helping the injuries can seek emergency phone to communicate with the tunnel operator. If the number of emergency telephone used is more than what the controller can handle. The controller can choose to switch on the automatic voice recording to inform the situation or provide some guide. Then answer to each visitor selectively.
- The controller can also use the public address system to broadcast the situation or switch on the recorded message.

Demo 3: If fire developed

Scenario: Two or three cars crashed and cause the fire inside the tunnel.

- Air Quality Monitoring Equipment register unusually high pollutant level and notify the controller. Controller notice a smoldering fire begins to develop from the accidents car. Linear heat detectors system alert on the temperature rise and corresponding CCTV will pop up to alert the controller. The controller switches the ventilation fan to fire mode via SCADA. Depending on the location of fire, ventilation fan and jet fans located at the corresponding locations will be running to achieve critical

velocity along the tunnel such that upwind of the incident is smokes free. This smoke free area offers an escape route for evacuees.

- The patrolmen direct all the motorists upstream of the accident to evacuate to nearest cross passages. Then evacuate to ground floor of nearest escape shaft for assembly. Once the door at escape shaft or cross passage door is open, the CCTV is activated to monitor the activities of the visitor. The evacuation process is being monitored and assists by controller via Public Address System to ensure all evacuees are evacuating according to directive given.
- Vehicle at downstream of the accident will be dispersed from more congested exit to less congested exit. Radio broadcasting will be interrupted and explain the need of such diversion as part of self rescue operation during emergencies. Tunnel motorist can inform of the possible delay of the schedule due to the diversion via the cellular phone.
- Meanwhile, the controller send the signal to VMS located at each Ingress/Egress portal that the tunnel needs to close down for traffic. Traffic will be diverted at ingress/egress before entering the booth.
- The toll booth will be closed and no new entry of vehicle or pedestrian are allow into the tunnel.
- The Tunnel Monitoring System provides the data on traffic velocity, vehicle count and estimated time that the traffic can be completely disseminated. This data help the rescue team to plan for the rescue operation.
- Rescue and fire fighting team enter the tunnel from non-incident deck, access to incident deck via cross passage upstream of the accident. The non incidental deck is pressurized to maintain a positive pressure from incident deck.The controller can monitor the status of all equipments such as fire pump, drainage pump near the incident, ventilation fans, lighting, air quality are function properly.

The rescue, fire fighting, evacuation, traffic diversion, operation of the equipments and communication to public and rescue team are integrated. Thus greatly enhance the efficiency and effectiveness of the operations.

5.0 Progress to date and Conclusion

The civil works for motorway tunnel is just completed and handed over to mechanical and electrical. Thus, the installations of works are in progress now. It is expected the works will be completed and ready for usage by early of 2007. The stormwater components will be ready by mid of 2007.

Through the utilization of the latest intelligence technology of these two (2) systems, namely Traffic Management and Control System (TMCS) and Flood Detection System (FDS) are the key successful factor of SMART operations. The amount of redundancy built in for safety and security to ensure the operation with minimum interruption.

By introducing the state of the art of TMCS and FDS in SMART, it is able to ease of traffic congestion and flood mitigation of KL business district center.

FOR MORE INFORMATION ON THE PROJECT, PLEASE VISIT OUT WEBSITE AT: WWW.SMARTTUNNEL.COM.MY

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* Mohd Saleh Santhiman is the Director of SMART Highway. He is assigned by Malaysian Highway Authority to supervise the construction of the motorway component of SMART project. He graduated from ITM with civil engineering (1983), then obtained M. Sc. in Transportation Planning from UTM in 1996. He is a member of IEM and BEM.

** Looi Hong Weei is the Head of M&E Department of MMC-Gamuda JV. He graduated from UTM with Electrical Engineering and obtained his MBA from UPM. He is a Chartered Engineer of UK and Member of IET, UK.