EXPRESS RAIL LINK

Seamless Integration of Express Rail Link with the Mainland's High Speed Rail Network

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1.0 SUMMARY

Construction of 20,000km National High Speed Rail network (四纵四横) planned in 2008 was substantially achieved in 2016. High speed rail has drastically changed the way how people travel in the Mainland. The demand has been increasingly strong that the next phase to complete 38,000km in total by Year 2025 was announced (八纵八横). The 26km Hong Kong section of the Guangzhou-Shenzhen-Hong Kong Express Rail Link (XRL) was built entirely underground which connects with the high speed rail network underneath Shenzhen River at Mai Po and the first station at Futian of Shenzhen. In order for the trains to run smoothly across the Hong Kong / Shenzhen boundary at high speed, various electrical and mechanical systems have to be carefully designed for high degree of compatibility. This paper will discuss how Mainland system integration works with focus on train, signalling, communications & main control systems. Progress of cross boundary train testing would be updated and some challenges would be shared.

2.0 PROJECT BACKGROUND

The Express Rail Link (XRL) will connect Hong Kong with the 20,000-km National High Speed Rail Network, which is the largest high-speed rail network in the world. With improved connectivity between Hong Kong and the Mainland, the economic development in Hong Kong and cultural exchange with the Mainland will be enhanced. XRL will bring many social and economic benefits to both Hong Kong and the Mainland. Direct non-stop shuttle service from West Kowloon to Guangzhou South Station (142km) will take about 48 minutes. The services would be jointly operated using trains provided by the MTR Corporation and Guangzhou Railway Corporation. Long-haul services would be provided using trains from Mainland railway bureaus to serve at least 10 major cities. To Beijing, it would take around 9 hours. As per the estimation given by the Government of the Hong Kong Special Administrative Region (HKSAR), over a 50-year operation period, the Hong Kong Section of the XRL can save passengers about 39 million hours of travelling time per year on average.
The 11-hectare underground station is located next to the West Kowloon Cultural District (WKCD) and connected to the WKCD as well as MTR Kowloon Station and Austin Station. Provisions have been made at the immigration halls to facilitate the co-location of boundary control facilities, arrival/departure hall, VIP lounges, duty free and retail outlets. The 26-km Hong Kong section runs from West Kowloon Station to Hong Kong / Shenzhen boundary close to Mai Po. There will be no intermediate station within the Hong Kong territory. The alignment runs entirely in dedicated twin tunnels except at Shek Kong Emergency Rescue Siding (ERS) where the underground tracks are exposed to atmosphere for emergency evacuation and response to incidents.

The Express Rail Link is expected to carry about 109,200 passengers daily, and it would provide a reliable, efficient and environmental friendly alternative mode of travel to short or medium haul flights to the Mainland.

3.0 INTERFACES WITH THE MAINLAND

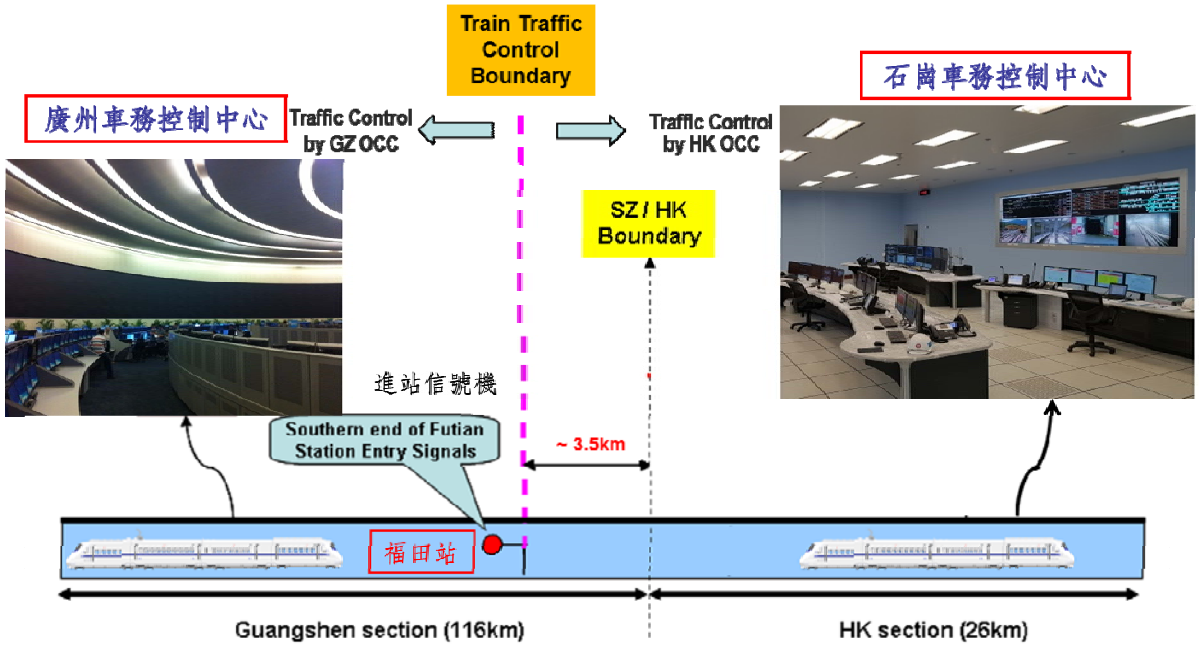
3.1 Electrical and mechanical interface design

To ensure full compatibility of the train-track systems with the Mainland, the 4th Design and Survey Institute (4DI) in Wuhan was appointed as the design consultant for the Mainland interfaces who was also responsible for designing Guangzhou-Shenzhen section. In line with the MTR Corporation design management practice, interface requirement specifications clearly spelt out the physical, logical & technical interfaces during design phase. The roles and responsibilities of all the interfacing contractors were well-defined without ambiguity. The subsystems built by different contractors would then be integrated without much difficulty to ensure seamless operation across the boundary.

Regular interface meeting between Mainland and Hong Kong contractors were held to fine-tune and produce detailed interface specification, detailed interface test plan and interface test specification for signature by both contractors. The Mainland / Hong Kong interface designs were approved by China Railway Corporation (CR) in 2012. In addition, the communication links from the Mainland to Hong Kong was approved by Ministry of Industry and Information Technology. System modification on various systems of the operational Guangzhou-Shenzhen Line included traction power, overhead line, backbone optical fibre communication, GSM-R radio network, train control & signalling, earthing & bonding, tunnel ventilation, passenger services management, ticketing and main control system. The construction contracts in the Mainland were executed by the Guang-Shen-Gang Dedicated Passenger Line Co., Ltd. (廣深港客運專線有限公司) who is also the asset owner of the Mainland section of XRL.

3.2 Operations Control Centre

In the original design, train traffic control of the entire Guang-Shen-Gang Express Rail Link was monitored and controlled by Guangzhou Operations Control Centre and the MTR Corporation would have staff on duty there. However, as a result of the national policy to implement Regional Control in China Railway, every Railway Bureau should bear its responsibilities to take care of the train traffic control within its territories. A separate OCC was thus required in Hong Kong Shek Kong Stabling Sidings (SSS) in 2012 and the dedicated OCC building was completed in 2015. Hong Kong OCC controls all train traffic from West Kowloon Station to the southern entry signals of Futian Station, 3.5km north of the Hong Kong / Shenzhen boundary. Once a southbound train departs from Futian Station, the traffic control would be passed from Guangzhou OCC to Hong Kong OCC. Any northbound train entering Futian Station would have to be governed by command from Guangzhou OCC. The XRL overview display at Hong Kong OCC will not only monitor all trains within its control boundary, but also traffic as far as Guangzhou South Station. Train information such as location, speed, train number, signalling CTCS-3 / CTCS-2 mode, punctuality can all be displayed at OCC.



3.3 Cross Boundary Tunnel connection with the Mainland

The cross boundary tunnels were constructed by tunnel boring machine (TBM). The 8.7m diameter tunnel boring machine started construction from Huanggang Park Ventilation Building (HPV) shaft in Shenzhen towards Mai Po Ventilation Building (MPV) shaft in Hong Kong. Tunnel length is 3.8km in which 2.3km is within Shenzhen and 1.5km within Hong Kong. The twin tunnels were constructed with cross passage at 250m interval for emergency escape. Evacuation walkway along the tunnels was built to match the train floor height for side de-trainment.

The cross passage doors were specified to be fire-rated for 4 hours in order to meet the fire safety strategy approved by various government authorities in Hong Kong. They are normally locked and centrally monitored at the OCC in Hong Kong, including cross passage doors in the cross boundary tunnel north of the boundary because of the demarcation of the train traffic control. In case of emergency, they would be unlocked remotely by OCC upon suspension of train movement in the adjacent tunnel. Mechanical manual override switch is also provided for operation by trained staff in cse the electrical unlocking function fails.

4.0 HIGH SPEED TRAIN

4.1 Trains procured by the Hong Kong Section of the XRL

9 sets of 8-car trains were manufactured by CRRC Qingdao Sifang (中車青島四方) under Contract 840 which are based on CRH380A technology platform for maximum operational speed of 350 km/h. The interior / exterior aesthetic outlook were re-vamped with a flying dragon like pattern which resembles the logo of Hong Kong. It can carry 579 passengers with 2 wheel chair space. Due to the underground alignment, the maximum train operating speed in Hong Kong section is limited to 200 km/h to reduce drag and energy consumption. The maximum operating speed on the Mainland side is 300km/h on viaducts beyond Shenzhen North station. The train has undergone a series of high speed type testing in the Hangzhou-Changsha (杭州~長沙段) section of Huku Line (滬昆線) in 2014 upto test speed of 380km/h. Reliability of CRH380A type is excellent since the CRH380A family trains have accumulated mileage of 770million km since its introduction in 2010 with a fleet of exceeding 400 trains.

4.2 Trains provided by the Mainland

Apart from the 9 trains procured by the Hong Kong section of the XRL, GRC would deploy some trains for shuttle and long haul services. Many train types, namely CRH1A/1B/1E, CRH1A-A, CRH2A/2B/2E, CRH3C, CRH380A/AL, CRH380B/BL, CR400AF /BF might be deployed by China Railway to serve XRL from the Mainland. Their car body has different width and the XRL infrastructures have to cater for all these different structural gauges and kinematic envelopes. A universal kinematic envelop was developed and endorsed by the Mainland Expert Review Panel for use in Hong Kong section which is suitable to accommodate the high level emergency walkway & some critical / specific localized areas like depot maintenance platform where clearance is carefully controlled to avoid wide gap for operational safety reason.

To enable the various Mainland Train types to operate in Hong Kong section, third party train certificate framework was agreed with the stakeholders, based on the current ordinary speed Inter-City through-trains (直通車) operating between Guangzhou East and Hunghom Station in Kowloon. The certification process involved 3 major stages:

- Preparation Stage to identify the verification items, review technical documentation, prepare test procedure
- Verification Stage to perform inspection and testing in the Mainland and Hong Kong
- Approval Stage to compile technical assessment report and obtain approval from the regulatory authority

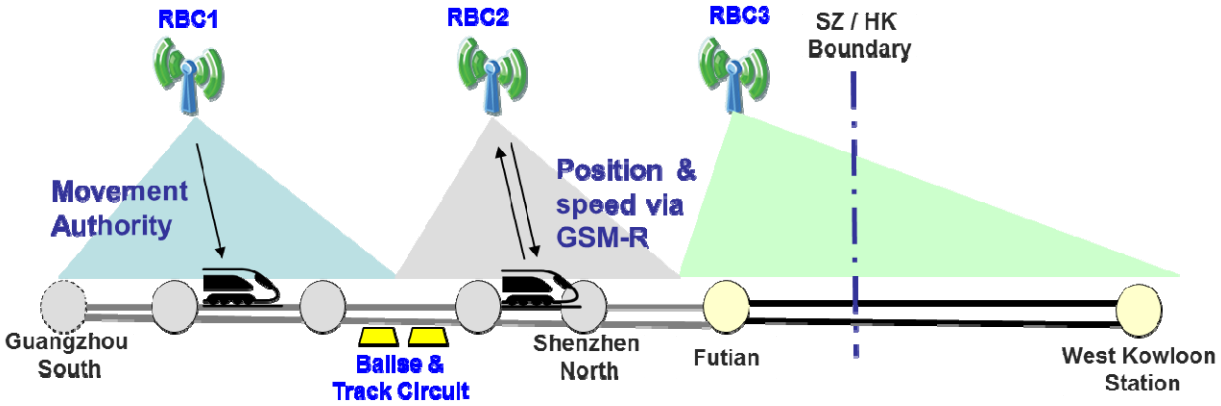
Technical information to be verified & tested on site includes traction & braking characteristics, emergency facilities & communication, bogie, door, rescue coupler, driver alert and other safety related features, etc.

5.0 RAILWAY SYSTEMS

5.1 Signalling System

Chinese Train Control System (CTCS) is adopted for XRL signalling to ensure interoperability with Mainland high speed trains and infrastructure. Trains designed to operate at 350km/h are equipped with two signalling systems namely, CTCS-2 and CTCS-3. CTCS-2 is based on European Train Control System (ETCS) Level 1 while CTCS-3 is based on ETCS Level 2. CTCS-2 relies on train-track communication via audio coded track circuits & balise installed along the track, suitable for 200~250km/h line speed. The more advanced CTCS-3 utilizes wireless GSM-R radio network to provide train-track communication. If GSM-R communication failed or CTCS-3 equipment does not work, CTCS-2 would provide the backup function and still allow trains to run at full speed in Hong Kong section.

For CTCS-3 operation, the same Radio Block Centre (RBC3) serving Futian station would also cover the Hong Kong section to allow seamless train control at high speed across the boundary. RBC processes the real time train information received, e.g. position, speed, track alignment, route setting, temporary speed restriction and issues Movement Authority command to trains, via GSM-R network. The On-Board signalling computer would analyse all the information available to calculate the target operation speed for the train driver to follow. In case the train speed exceeds the target speed for whatever reason, automatic braking would be activated to bring the train to a halt.



5.2 Communication Systems

5.2.1 Backbone Transmission Network

The dedicated optical fibre Transmission System provides a common platform to transmit data among West Kowloon Station, ventilation buildings, SSS and the Mainland transmission system for various E&M systems, including communications, signalling, main control, and ticketing system, etc.

It consists of two optical fibre cables, optical add-drop multiplexers and other network equipment to form a high speed Synchronous Digital Hierarchy (SDH) network to provide multi-service data transmission for Ethernet, standard E1 and voice interface, etc. Dark fibres are also provided to Signaling, Main Control System, Ticketing and other systems.

To provide cable route diversity, the two optical fibre cables are separately laid in different tunnels from West Kowloon Station and terminated at Hong Kong / Shenzhen boundary.

A STM-64 (10G) transmission node and a STM-16 (2.5G) node are provided at West Kowloon Station for connection to the Mainland transmission system. The 10G and 2.5G network paths are configured as dual protected paths for resilience to prevent loss of data due to single path failure. Under such configuration, a reliable fast automatic protection switching can be achieved.

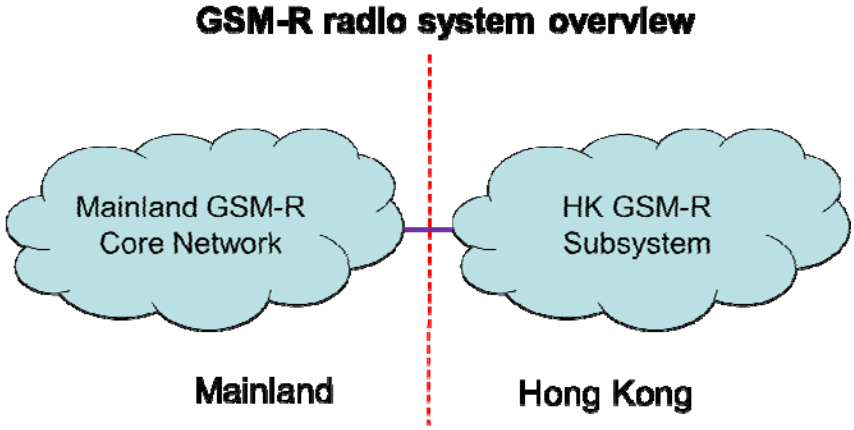
In addition, there are 3 local transmission rings. Ring 1 and Ring 2 are networks dedicated for data connection among GSM-R base stations. Both rings are formed by STM-4 nodes. Ring 3 is dedicated for local traffic including CCTV, telephone, other data networks.

5.2.2 GSM-R Radio Network

2-way Train Track communication for CTCS-3 at high speed was seamlessly supported by GSM-R which was built on the same technology platform of GSM mobile phone for railway application.

GSM-R system in Hong Kong section is fully integrated with Mainland GSM-R system and provides radio coverage in tunnel, ventilation buildings, SSS area and platforms of West Kowloon Station. It facilitates train control and signaling data transmission (CTCS-3) and voice communication between train drivers and traffic controller at OCC. Voice call function works similar to hand portable radio. The GPRS data channel transmits messages of train number, despatch instruction, route setting information between OCC and Cab Integrated Radio (CIR) inside driving cab. Train operating data and information is also transmitted through GPRS Interfacing Server for maintenance purpose.

The same frequency bands are used at 885~889MHz Uplink and 930~934MHz Downlink as GSM network. The GSM-R base station subsystem in Hong Kong section is connected with the Mainland GSM-R core network via optical fibre network. The radio signal distribution is achieved through leaky coaxial cable system and antenna network in station, ancillary buildings and tunnel along the XRL alignment.



6.0 MAIN CONTROL SYSTEM

Hong Kong Main Control System (MCS) interfaces with 3 sub-systems on the Mainland namely, (i) Fire Alarm System (FAS) for Futian Station and trackside services along the cross boundary tunnel, (ii) Building Automation System (BAS) for E&M equipment such as tunnel lighting, exit signs, cross passage door, sump pumps and coordinated operating mode of tunnel ventilation fans; (iii) PSCADA for 25kV Traction Power and Overhead Line equipment.

As a result of Hong Kong OCC controlling train traffic in the cross boundary interface tunnel, trackside services in this tunnel section can be monitored and controlled by Hong Kong OCC, including cross passage doors with exit sign, tunnel lighting and sump pumps. Control priority of equipment can be set by BAS for control under Hong Kong OCC or Futian station.

Tunnel ventilation fans on both side of the boundary are controlled through MCS/BAS interface. When BAS receives signal of tunnel ventilation fan operating mode-in-progress from Hong Kong, it will operate the corresponding tunnel ventilation fans at Huanggang Park Ventilation Building according to the pre-defined operating mode table.

The MCS/PSCADA interface provides monitoring function across the boundary but without control. MCS monitors 25kV circuit breakers at Mainland Hao Gang (好港) Traction Substation near Shenzhen North station. By the same token, PSCADA montors 25kV circuit breakers at Mai Po Track Switch Cabin (TSC).

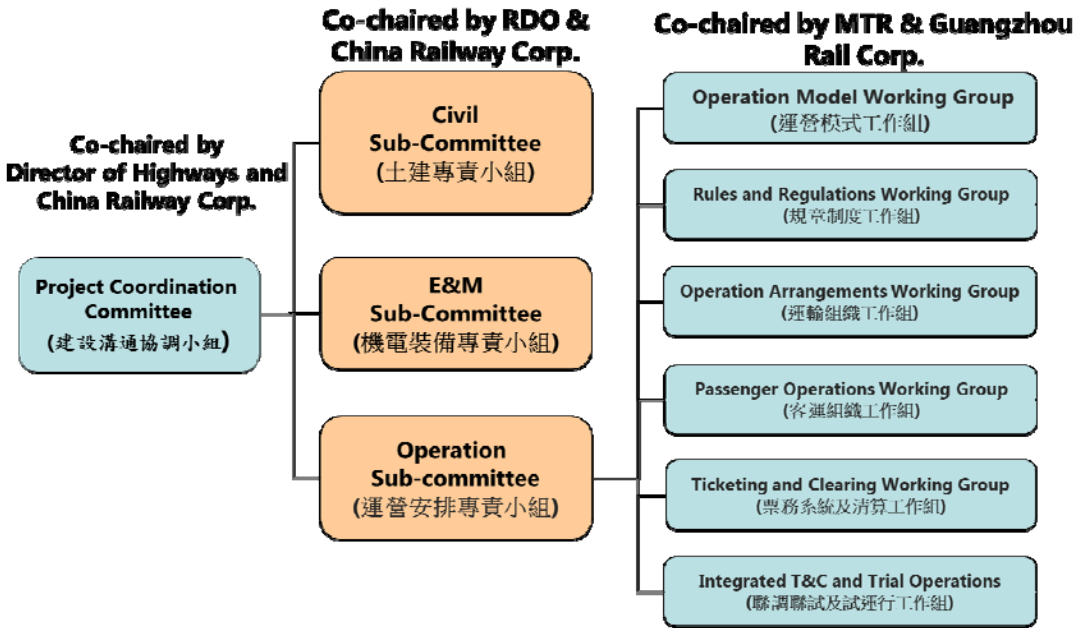
7.0 KEY CHALLENGES

7.1 Knowing the complex nature of high speed railway construction and testing, the MTR Corporation has set up a dedicated system integration team to manage this critical Mainland Interface since the beginning of the XRL project. There are many stakeholders involved :

- China Railway Corporation : Mother company of all rail operators
- Guangzhou Rail Corporation : Operator for Guangzhou and other southern provinces
- Guang-Shen-Gang Dedicated Passenger Line Co., Ltd : Project Manager and asset owner of XRL Guang-Shen section
- The 4th Design and Survey Institute : Systems and Trackwork/OHL Designer
- China Academy of Railway Sciences (CARS) : Research institute for Mainland integrated testing & commissioning of high speed line

- China Railway of Travel and Trip Co., Ltd : Implementation of the Mainland railway ticketing system
- The Government of the HKSAR : Transport and Housing Bureau, Highways Department, Railway Development Office, Railway Branch of Electrical & Mechanical Service Department

To effectively communicate with the above organizations, a hierarchy of Project Coordination Committee, Sub-Committees and Working Groups was established to systematically discuss issues at various levels. Regular meetings were held in Beijing, Guangzhou, Shenzhen and Hong Kong from time to time to resolve problems for smooth execution of interface installation, testing & commissioning. During peak dynamic testing period, a dedicated T&C Command Centre was set up in Guangzhou to enhance communication. Key parties are represented and accommodated in a hotel to deal with the day to day matters promptly. Three routine meetings were held daily to make decisions on test schedule, test method & arrangement, train path and track possession, etc. In the congested Guang-Shen high speed line, any hiccups and delays in T&C activities would cause interruption to passenger services. All train / signalling dynamic testing north of Futian Station can only be conducted during non-traffic hours. This has to be well coordinated with other remedial repair and maintenance work. Scheduled activities may be cancelled due to unforeseen circumstances in operating lines, posing risk to timely completion of T&C. For reliability run of the XRL trains, it has been agreed for the trains to accumulate mileage from West Kowloon to Changsha South station, far beyond the operating zone of the XRL train.



8.0 PROGRESS OF INTEGRATED T&C WITH THE MAINLAND

8.1 At present, Backbone Transmission System, GSM-R network and signalling system in Hong Kong have been interconnected with the corresponding systems in the Mainland. GSM-R radio is functional and fully covers all track areas and ventilation buildings. The operational Guangzhou OCC and Hong Kong OCC are also fully integrated after completing all the relevant static and dynamic testing in July 2017. Train operational information & status between Guangzhou and Futian can also be displayed in Hong Kong OCC. Track and Overhead Line are energized and verified up to test speed of around 220km/h by the Comprehensive Integration Train from the Mainland following the tests by the Dong-Feng 11 (東風11) Inspection vehicle. 9 sets of CRH380A high-speed trains were delivered to Hong Kong, of which 7 trains were driven from Qingdao factory by rail at 300km/h to Hong Kong. Type testing of XRL trains was completed to prove that the aerodynamic, ride comfort, acoustic,

traction & brake, harmonics, EMC, energy efficient performance are complying to specifications. Reliability run would follow in Q4/2017. Signalling CTCS-2 and CTCS-3 System Acceptance Test using XRL trains were also carried out.

Independent signalling dynamic testing by CARS are being conducted in Oct 2017, followed by Signalling compatibility test with different trainborne models on Mainland CRH trains to verify compatibility of signalling trackside equipment in Hong Kong section. It is anticipated that all cross boundary dynamic testing associated with high speed train and signalling systems would be completed within Q1/2018 for Trial Operations by the Operator to be appointed by the Government of HKSAR.

9.0 CONCLUSION

9.1 Seamless integration of a complex high speed railway on a busy operational line across the boundary requires careful design and planning for compatibility. This has been done through deployment of the same system designers and adoption relevant Mainland standards and specifications for railway related systems, train, signalling, track, OHL, communications, MCS, ticketing systems. Customizations to suit local practices and norms are made to enhance operational efficiency. Hong Kong OCC controls train traffic from West Kowloon up to Futian Station, some 3.5km into the Mainland. Trackside services and equipment like cross passage doors, tunnel lighting, exit signs, sump pumps are controlled and monitored by Hong Kong OCC. One of the challenges was to overcome barrier in effective communication amongst all stakeholders through a hierarchy of committees, working groups and T&C Command Centre. Current progress of cross boundary dynamic testing & commissioning has been satisfactory. Test trains have been travelling at maximum speed of 300km/h from West Kowloon to Guangzhou South Station. Reliability run was scheduled to complete by December 2017. The Hong Kong section of the XRL is targeted to complete in Q3/2018 and will be seamlessly integrated into the Mainland high-speed rail in a safe and reliable manner.