APPLICATION OF AUTOMATIC PLATFORM GATES TO REDUCE SAFETY RISKS

K.M. LEUNG

BSc(Eng), MSc, PhD, CEng, FIMechE, FHKIE, MIET

P.H. SZE

BEng, MSc, CEng, MIMechE, MHKIE

Railways Branch, Electrical and Mechanical Services Department,

Government of the Hong Kong Special Administrative Region

SUMMARY

Before 2002, Hong Kong had an average of around 20 railway suicides and attempted suicide cases every year, where individuals jumped onto a track into the path of an approaching train. Of these, over 10 cases per year were fatal. That was the time when metro stations of the Kwun Tong Line, Tsuen Wan Line and Island Line of our railway system had not been fitted with platform screen doors (PSDs) nor automatic platform gates (APGs)[1]*. Nor were these stations, commissioned in the late 1970s and early 1980s, designed for the installation of safety barriers like PSDs or APGs.

All new metro lines and railway lines built since 1998, including the Airport Express Line and Tung Chung Line, Tseung Kwan O Line, West Rail Line (WRL) and Disneyland Resort Line, have been fitted with either PSDs or APGs. As a result of initiatives by the Government and the MTR Corporation Limited (MTRCL), all 30 underground metro stations were retrofitted with PSDs by 2006 with the aim of enhancing platform conditions, and by 2011 all the eight above-ground metro stations of the Kwun Tong Line, Tsuen Wan Line and Island Line were also retrofitted with APGs. After completion, the annual average railway suicides and attempted suicide cases had dropped significantly to five cases in 2014, three of which were fatal. However, the 22 stations along the East Rail Line (EAL) and Ma On Shan Line (MOL) are still open to rail tracks today.

This paper describes how the Government of the Hong Kong Special Administrative Region and the MTRCL, Hong Kong's sole railway operator, work together to effectively overcome the challenges and reduce the number of suicide cases, including resolving the safety risks associated with platform gaps and limitations of the existing signalling system, trains and platform structure. The paper also explains how we improve railway safety by adopting advanced technologies to support the retrofitting of APGs at

[1]*Note: A platform screen door (PSD) is a full height door separating the platform and the track, while an automatic platform gate (APG) is a chest-height sliding door. Both are intended to prevent passengers from falling onto the track.

the EAL and MOL stations in tandem with the new Shatin to Central Link (SCL) project which is still under construction.

1. INTRODUCTION

The EAL, built in 1910, was constructed with curved platforms at seven of its 14 stations due to geographical constraints. The curvature leaves a relatively wide platform gap that is further exacerbated as the EAL platforms accommodate trains of different widths. When a 12-car EAL train with a car length of 23.8 m berths at the curved platform, for example, the platform gap can be as wide as 300 mm. Even if APGs are installed, these wide platform gaps will increase the risk of passengers inadvertently falling through them if the passengers' sight is obstructed by the APGs.

Figure 1: Wide platform gap at an EAL station

The Government and MTRCL decided in 2010 to carry out an in-depth study to explore if APGs can be retrofitted at these EAL stations once and for all. Four major challenges were identified, namely:

(a) The safety risk associated with the comparatively wide and curved EAL platform gaps, which were designed to accommodate the operation of different types of trains including intercity trains from Mainland China;

(b) Limitations of the existing signalling system which is of intermittent design and cannot achieve the stopping accuracy required to align the train doors with APGs;

(c) Limitations of the existing trains which are not equipped with up-to-date motoring and braking systems suitable for use with APGs; and

(d) Limitations of the existing platform structure which cannot support the extra weight of APGs and the large lateral wind loads.

The MOL, commissioned in 2004, has incorporated the necessary civil provisions for retrofitting with APGs. APG retrofitting works are currently underway at the nine MOL stations. A number of measures including the application of advanced technologies to support the retrofitting of APGs at EAL and MOL stations, adopting communications-based train control (CBTC) for moving block signalling and variable voltage variable frequency (VVVF) traction control were deployed.

2. SAFETY RISK ASSOCIATED WITH WIDE PLATFORM GAPS

There are seven EAL stations constructed with curved platforms due to land acquisition and geographical constraints. The platform gap problem gets even worse as EAL needs to cater for different types of trains operating on the EAL, including two types of passenger trains: Mid-life refurbished (MLR) trains and SP1900 trains, and intercity trains from Mainland China.

Figure 2: Curved platform at an EAL station

Local Passenger Train		**Intercity Trains from Mainland China**
MLR	SP 1900	DF11 Diesel Locomotive
		
Carbody width = 3,100mm	Carbody width = 3,100mm	Carbody width = 3,304mm

Figure 3: Carbody widths of different train types on EAL

With a view to resolving the EAL platform gap issue, the former EAL operator, KCRC, carried out a series of trials, one of which was the installation of extendable mechanical gap fillers (MGF) at the Lo Wu Station, one of the EAL terminals. The trial aimed to test the effectiveness of MGFs in real life passenger service. The trial commenced in mid-2008 and was completed in October 2009, with details as follows:

(a) Phase 1: A 7-day test on two MGFs under manual control at the south ends of Platforms 3 and 4, completed in August 2008.

(b) Phase 2: A 6-week test on 10 MGFs under automatic control at Platforms 3 and 4, completed in May 2009.

(c) Phase 3: An 8-week test on 98 MGFs under automatic control at all four platforms with wide platform gaps, completed in October 2009.

Figure 4: Mechanical gap fillers at EAL Lo Wu Station

Results of the trial indicated that the MGF system was not reliable during typhoon and inclement weather, and some MGFs were jammed during heavy rain by debris washed by rain water into the MGF mechanism. Results from data collected during the good weather days were also not too promising for reasons below:

(a) Poor availability: The availability of the MGF system was 99.83% only, which was lower than MTRCL's target of 99.99%. A total of 17 failures were found in 10,000 operating cycles.

(b) Poor reliability: The reliability of the MGF system was found to be 30 times below target. The actual result was a fault every 9,601 cycles, compared to MTRCL's target of once every 300,000 cycles.

(c) High failure rate: During the trial, 6.1 failures occurred each day. In addition, there were 42 cases of MGF faults requiring resetting/adjusting of MGF by staff, 34 cases of man-machine interface faults requiring staff attention, and 187 cases of signalling/train interface faults.

As the Railways Inspectorate of the Hong Kong Government, we conducted inspections during the MGF trials and assessed the results. We found that with the adoption of MGF, each station was required to incur an extra 15 seconds for each cycle of train door opening and closing due to limitations of the existing EAL signalling system. The impact was equivalent to a reduction of two train journeys per hour per direction during peak hours. The MGFs would also pose potential safety hazard to regular passengers who might step into the platform gap when they failed. This is because passengers would expect the MGF to be available and hence pay no attention to the platform gap, especially when their sightline of the platform gap was blocked by the APGs.

The trial was considered not successful as the MGF system was proved unreliable with prolonged platform dwell time and negative impact on service. MTRCL would therefore explore better solutions to mitigate the platform gap risk.

3. LIMITATIONS OF THE EXISTING SIGNALLING SYSTEM

The main limitation of the EAL signalling system is that it cannot process the operation of any new equipment efficiently, leading to longer station dwell time and journey time as well as reduced service level of EAL. MTRCL revealed that an extra seven seconds would be required to cater for the additional dwell time due to the operation of APGs under the existing EAL signalling system. The maximum additional dwell time incurred for a station with both MGFs and APGs would amount to about 22 seconds. The impact is equivalent to a reduction of three train journeys per hour per direction during peak hours.

Trains currently stop at a lower degree of accuracy at open EAL platforms. Passengers can board or alight safely as long as the full length of a train is berthed within the platform area. However, with the installation of MGFs and APGs, trains are required to stop at more precise stopping positions to ensure that train doors are aligned with MGFs and APGs. The existing EAL signalling system is not designed for such accuracy, which means that when trains miss their designated stopping marks, they will have to be moved backward or forward to the correct position before doors can be opened for boarding.

The urban lines (URL) with PSDs currently achieve a minimum doorway clearance of 1,200 mm. MTRCL conducted a site survey of train stopping accuracy on EAL in 2010 and indicated that the current train stopping accuracy was 99.5% at ± 500 mm and 90.0% at ± 300 mm. As the door pitch of existing EAL trains is shorter than that of the URL trains, if APGs are to be installed in EAL stations for operation with existing trains, the new APG door width would be about 1,600 mm, and the resulting minimum doorway clearance would be 1,000 mm only with the train stopping accuracy of 99.5% at ± 500 mm.

Figure 5: Stopping accuracy of an EAL train

Furthermore, if an APG is opened or an APG-platform edge gap is found intruded by an external object before a train enters a platform, the existing signalling system cannot automatically stop the train from entering the platform, which may pose potential hazard to passengers.

The EAL signalling system is of intermittent design and has little capacity to interface smoothly with APGs. The technical solution would be to replace the signalling system. Intermittent design of signalling systems is still widely used in mainline railway systems worldwide, but such design does not suit the future operational requirements of a metro line with APGs. It is possible to upgrade the signalling system from intermittent design to continuous design to sustain a high level of safety for APG operation, but it will involve substantial replacement of the majority of system software and hardware. Total replacement of the signalling system for retrofitting of APGs is regarded as a more sensible and cost effective approach.

4. LIMITATIONS OF EXISTING TRAINS

There are two types of trains running on the EAL, namely the MLR trains manufactured by Metro Cammell (now Alstom) which were first put into service between 1982 and 1992 and refurbished in mid-1990s, and SP1900 trains manufactured by Itochu/Kinki Sharyo/Kawasaki (IKK) Consortium which have been in service since 2001.

Figure 6: MLR (right) and SP1900 (left) trains

As neither MLR nor SP1900 trains provide selective non-opening of train doors or APGs, passengers face a high risk of stepping inadvertently into the platform gap when an MGF fails to extend for the approaching train, as passengers would expect the MGF to be available and hence pay no attention to the platform gap. The operation of APGs will also require trains to stop more accurately at platforms. While a more sophisticated signalling system will be required, a more advanced train motoring and braking system will also be necessary. However, the motoring and braking systems of the existing MLR trains are still of an outdated design. Currently, MLR trains use an electro-pneumatic braking unit with a 7-step discrete control, while their existing motoring system uses a notch and discrete control, with four notches for different level of tractive efforts. This means that acceleration is relatively low at 0.5 m/s^2. To enable the trains to stop more accurately at EAL stations, the Automatic Train Operation (ATO) system should require the brake performance to be of linear characteristics with consistency, but the current MLR braking system cannot meet these requirements.

Furthermore, upgrading of the existing MLR train fleet for selective non-opening of train doors is not technically feasible due to constraints of the limited number of control wires in the existing trains. Existing MLR trains are also not equipped with advanced motoring and braking systems. Even if more advanced motoring and braking system were installed, they would impose additional stresses and reduce the structural integrity of the train cars and eventually their asset life. Further structural enhancements may be possible, but will induce a risk of structural failure. As the current MLR train fleet has an estimated useful life of only 10 to 20 years, MTRCL opined that replacing the entire fleet of 29 MLR trains would be the most cost effective measure.

5. LIMITATIONS OF PLATFORM STRUCTURE

The EAL platforms are about 100 years old. The EAL platform structure has to be strengthened before APGs can be installed in order to be able to support their extra weight and the corresponding wind load. One set of APG together with tempered glass panels weighs around 500 kg, and 45 sets of APGs will have to be retrofitted at each platform, totalling 22.5 tonnes of extra weight.

As most of the EAL stations are located above ground with open platforms, the platforms and APGs must withstand the large lateral wind loads as well as the loading of passengers. The platform structures are not capable of withstanding the additional weights and wind loads, and therefore must be reinforced.

Figure 7: Construction works for platform at EAL stations

Figure 8: Platform level at EAL stations

The necessary strengthening works will mainly involve the installation of steel bars and brackets at the platforms. Work procedures include removing the coping stones and concrete surfaces, as well as saw-cutting platform edges. Furthermore, owing to normal wear and ageing, irregularities have been found at the edges of some EAL station platforms. To enhance the platform environment, the platform floor should be laid with new floor tiles with floor markings, so as to provide a more comfortable travelling environment for passengers.

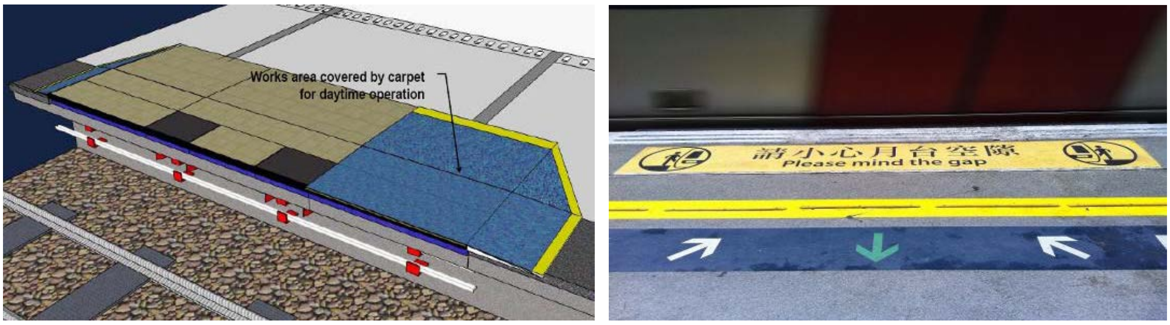

Figure 9: Enhancement of platform leveling with new floor tiles and floor markings

There are also other difficulties in construction works within the operating railways environment. Most of the platform modification works can only be carried out during non-traffic hours, typically from 2:00am to 4:30am. This limited time slot severely restricts the amount of work that can be done each night. In order to conduct the platform modification works, application for special access is required but this can only be allocated three times a week per station. To follow stringent operation railway requirements, works have to be well protected and inspected before the platform and train service are resumed for public use every morning. At the same time, Hong Kong's construction industry is now in the midst of manpower shortage, with competition for skilled workers reaching new levels, leading to concerns about adequate manpower supply for platform modification works.

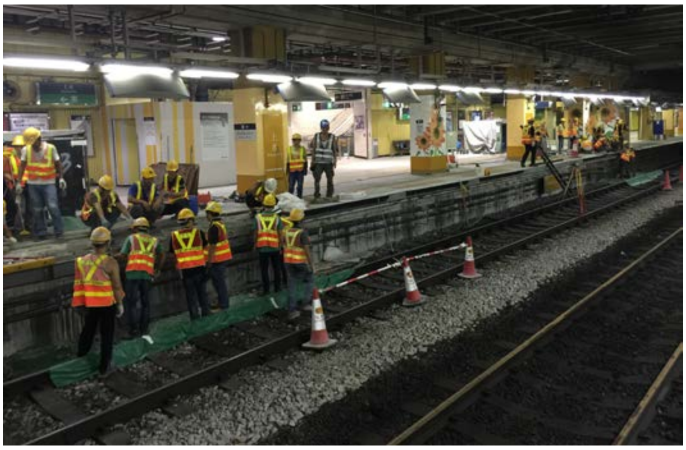

Figure 10: Platform modification works at non-traffic hours

6. TECHNICAL SOLUTIONS

The SCL is a strategic railway corridor that will run through the north and south as well as the east and west of the New Territories in Hong Kong. The East West Corridor, with new railways and stations, will connect the existing MOL to the WRL through East Kowloon. The North South Corridor will connect the existing EAL to Hong Kong Island via the fourth cross-harbour railway underneath Victoria Harbour.

Given its interface with the EAL and MOL, the SCL provides an excellent opportunity to implement a range of technical solutions that will resolve the challenges at EAL and MOL discussed above in one go.

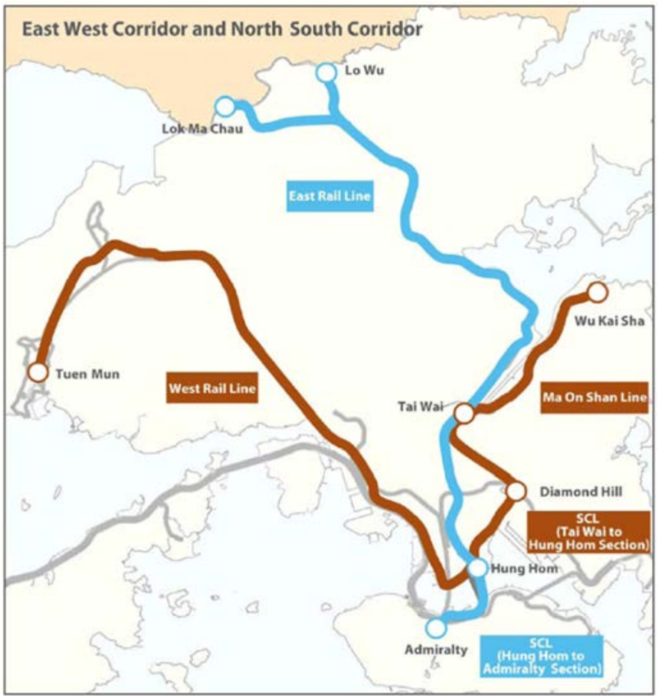

Figure 11: The new SCL will connect the existing EAL, MOL and WRL

6.1 Narrowing platform gaps

As there are different types of trains running on the EAL, including intercity trains from Mainland China, the gap at the curved platforms poses a technical and safety issue. Retrofitting APGs at these platforms would block the passengers' view of the platform gap, thus creating significant safety risks. The problem of wide platform gaps must be first resolved before retrofitting APGs. As the new 9-car trains of SCL will replace the existing 12-car trains of EAL, the new trains can then berth at the straight parts of the EAL platforms when SCL begins service. The wider-body new trains at 3,220 mm wide will also reduce considerably the platform gaps.

6.2 Replacing the signalling system

The existing EAL signalling system also poses several problems, i.e., trains stopping with insufficient accuracy to align the train doors with APGs, and safety risk as it cannot detect APGs that have not closed properly. The current signalling system will be replaced before retrofitting APGs along the EAL, in order to ensure the safe operation of the APGs and trains. A new CBTC signalling system will be installed under the SCL project.

6.3 New rolling stock

Existing EAL trains are not equipped with suitable motoring and braking systems. For the new SCL project, new trains with VVVF control have been procured to replace the existing EAL train fleet.

Figure 12: New rolling stock for the SCL

6.4 Strengthening the platform structure

Extensive strengthening of the existing platforms will be required:

(a) Local strengthening to support the cantilevered portion of the platform edge that the APGs, when installed, will sit on; and

(b) Global strengthening to address the lack of reinforcement in the platform slab. It involves the installation of steel bars and brackets at platforms. Work procedures include removing the coping stones and concrete surface, as well as saw-cutting the platform edge, etc.

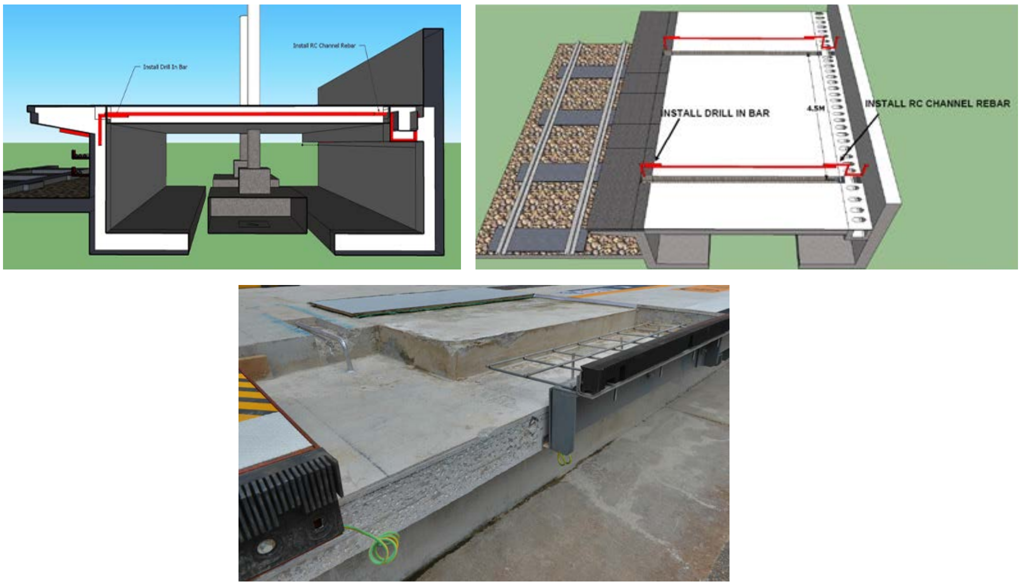

Figure 13: Global strengthening of a side platform on EAL

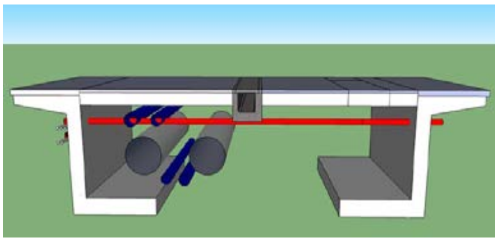

Figure 14: Global strengthening of an island platform on EAL

Out of the 14 stations along the EAL, five stations will require local strengthening and six stations will require global strengthening.

Retrofitting APGs along an operating railway is also highly challenging. Once installed during non-operating hours at night, APGs must be tested immediately so as to ensure their operation is accurately aligned with that of the train doors. Apart from the construction time and workforce constraints, it is also important to minimise the impact of construction noise due to night works. A "mobile sound insulation booth" has been deployed on site to reduce noise level by around 20 dBA.

Figure 15: Mobile sound insulation booth

7. CONCLUSION

We have thoroughly assessed the installation methodologies of APGs in tandem with the SCL project, taking into account the limitations of the MLR trains which are approaching the end of their serviceable life, limitations of the existing signalling system which must be replaced to sustain the current high level of railway safety, and the limited time window per day for the installation and construction works. We opined that the installation of APGs in tandem with the SCL project is the most reasonable and sensible solution, taking into account the synergy that will be created as detailed in the above assessment. Through effective two-way communication with passengers and nearby communities, we aim to optimise the construction works arrangement so that the retrofitting works can be completed on time, while noise and nuisance to the environment will be minimised.