MANAGING HUMAN FACTORS IN HONG KONG THROUGH A RISK-BASED APPROACH

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SUMMARY

Hong Kong is one of the most densely populated cities in the world and rail transport is indispensable to its people's quality of life. Railway operations in Hong Kong are ranked among the best for safety performance in international benchmarking. Although the railway systems in Hong Kong are highly automated, human factors do cause railway incidents from time to time. As long as people play a significant part in rail operations, human factors must be prudently managed to compensate for variations in performance.

The first part of this paper describes how we adopt a risk-based model to tackle human factor issues for the railways in Hong Kong. With this model, appropriate safeguards and inspection plans are implemented to reduce the risk arising from human factors to a level that is as low as reasonably practicable. The second part of this paper seeks to shed light on potential human issues in railway development, drawing on lessons learnt from five railway incidents that occurred between 2010 and 2012.

1. INTRODUCTION

In comparison with railway systems in the developed countries, Hong Kong's metro and railway network is relatively complex. There are altogether 84 stations and 64 light rail stops with a total track length of about 218 km. The network is heavily utilised, with an average weekday patronage in excess of 5 million. In 2012, our passenger service achieved a record-breaking ridership of 1724 million. Under the current regulatory framework, the Railways Branch of the Electrical and Mechanical Services Department (EMSD) of the Government of the Hong Kong Special Administrative Region (HKSAR) is delegated with the authority for regulating the safety of the metro and railway network operated by the Mass Transit Railway Corporation Limited (MTRCL). In this capacity, our role straddles the design, tendering, construction, operation and maintenance stages of the railway systems. We monitor the safety performance of the railways, conduct incident investigations to identity causes and recommend improvements, monitor implementation of improvement measures, and vet and approve the safety design aspects of new railway projects.

2. RISK-BASED MODEL IN MANAGING HUMAN FACTORS

Safety is an absolute pre-requisite of our railway operations. Railway incidents resulting from human error have been regarded as a high priority issue for the regulator in recent years. Figure 1 shows the number of human factor incidents happened within our heavy rail network from years 2008 to 2012 classified to have been caused by staff behaviour. We adopt a "risk-based model" in regulating railway safety and accord top priority for those cases having impact on passenger or public safety. In our risk-based model, we focus on a series of safety risk determining factors, primarily the design considerations, running capacity, patronage, frequency of train services, operation and maintenance regimes and so on. In addition, we have also developed a comprehensive database of railway incidents. This Incident Data Management System (IDMO) provides details of the findings of incident investigations, accurately identifies the causes, and explains what post-incident improvement measures have been undertaken. Every incident relating to human factors is further classified according to the type of human error involved (Figure 2) and studied to help us find the best way to avoid problems in the future.

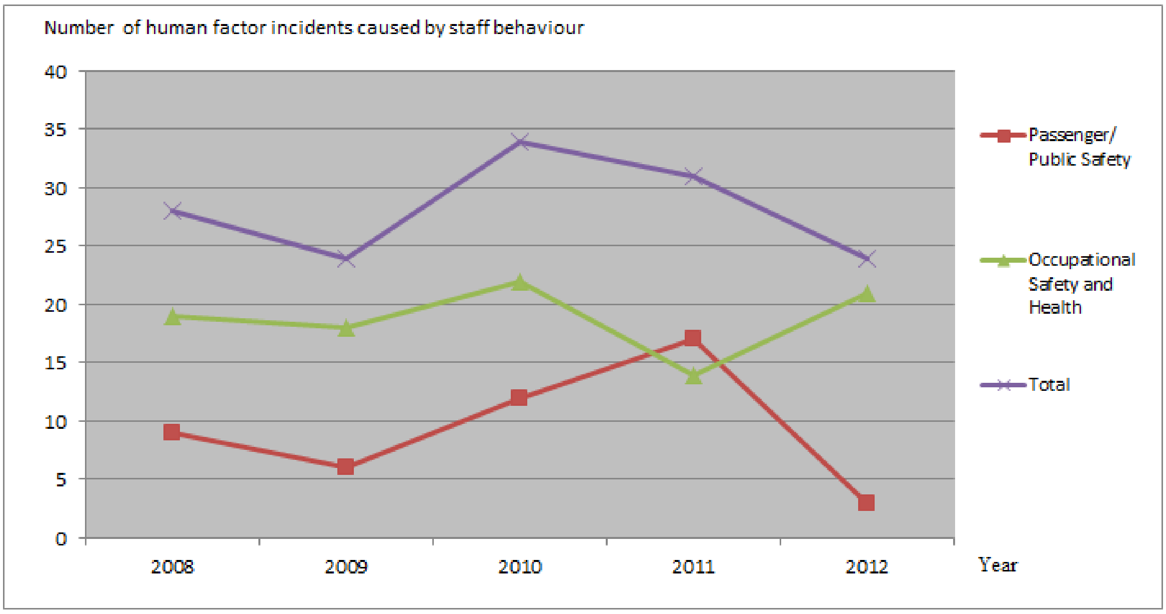

Figure 1: Number of human factor incidents caused by staff behaviour (Years 2008 – 2012)

Similar to conventional risk management models, our risk-based model (shown in Figure 3) involves classifying incidents, identifying hazards, assessing the likelihood, consequence and risk levels, and proposing mitigation measures. Mitigation measures may include enhancing the human-machine-interface, design control procedures or operation control procedures, and providing training and continuous education (to modify staff and stakeholders' behaviour). These measures may even extend to public education and publicity (to influence passengers' behaviour).

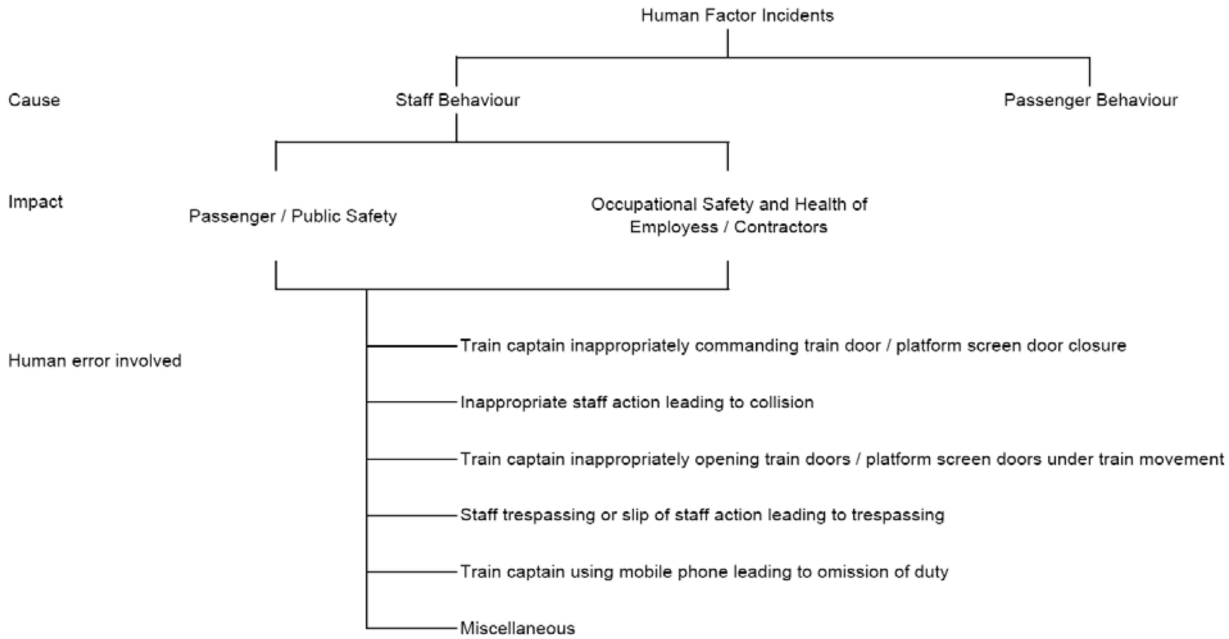

Figure 2: Classification of Human Factor Incidents

Risk assessment is based on a traditional risk matrix that evaluates consequence and likelihood and assigns risk level. To ensure that the risk is being assessed in an objective and systematic manner, we categorise the risk according to seven consequence levels and 10 levels of likelihood of occurrence [1], as shown in Figure 4.

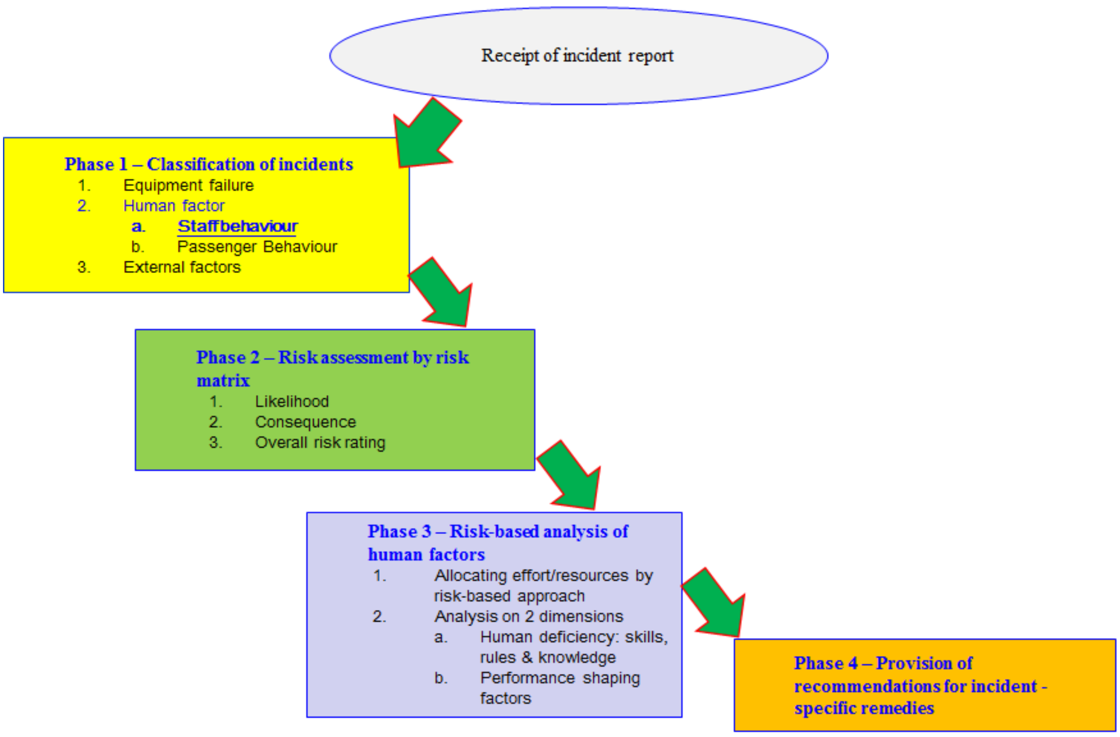

Figure 3: Risk-based Model

				CONSEQUENCE						
				7	6	5	4	3	2	1
				Trivial	Negligible	Marginal	Serious	Critical	Catastrophic	Disastrous
		Passenger / Public Safety	Fatality					<5	5-50	51-500
			Major Injury				<5	5-50	51-500	501-5000
			Minor Injury			<5	5-50	51-500	501-5000	>5000
		Service	Disruption		<8 min	8 – 30 min	31 - 180 min	181 - 240 min	>4hr – 1 day	>1 day
LIKELIHOOD	1	Few time/week or more	≥100 per year	OR3	OR1	OR1	OR1	OR1	OR1	OR1
	2	Few times/month	≥10 - <100 per year	OR4	OR1	OR1	OR1	OR1	OR1	OR1
	3	Few times/year	≥1 - <10 per year	OR4	OR2	OR1	OR1	OR1	OR1	OR1
	4	Few times/10 years	≥0.1 - <1 per year	OR4	OR3	OR2	OR1	OR1	OR1	OR1
	5	Once since operation	≥1E-2 - <1E-1 per year	OR4	OR3	OR3	OR2	OR1	OR1	OR1
	6	Unlikely to occur	≥1E-3 - <1E-2 per year	OR4	OR4	OR3	OR3	OR2	OR1	OR1
	7	Very unlikely to occur	≥1E-4 - <1E-3 per year	OR4	OR4	OR4	OR3	OR3	OR2	OR1
	8	Remote	≥1E-5 - <1E-4 per year	OR4	OR4	OR4	OR4	OR3	OR3	OR2
	9	Improbable	≥1E-6 - <1E-5 per year	OR4	OR4	OR4	OR4	OR4	OR3	OR3
	10	Incredible	<1E-6 per year	OR4	OR4	OR4	OR4	OR4	OR4	OR3

Figure 4: Risk Matrix

Likelihood is defined as the chance of occurrence and is determined by the number of occurrences in the past. Consequence is related to the severity of impacts on passenger and public safety or to service disruption. Severity of consequence is measured by the number of fatalities and injuries. With regard to pivotal events near-miss precursors of accident, we identify any potential safety hazard and cast a consequence rating as if there were actual casualties. For service disruption incidents, the consequence is evaluated based on the duration of service interruption. For an incident with both service and safety aspects, we accord the higher of the two severity ratings to the consequence. The resulting risk is then termed the Overall Risk (OR), with classifications varying from OR1 to OR4, as follows:

- OR1 - the overall risk level is unacceptable and shall be eliminated
- OR2 - the overall risk level is undesirable and shall be reduced by practicable control measures
- OR3 - the overall risk level is tolerable but shall be further reduced if possible
- OR4 - the overall risk level is negligible

As far as the management of human factor is concerned, we are prioritising our resources and efforts to tackle OR1 and OR2 human factor incidents. To better control the risk of recurrence, we constantly review the processes of the Safety Management System (SMS) operated by MTRCL to ensure that every incident is systematically analysed under a well-established risk management process embedded within the SMS.

The objective is to perform "plan, do, check and act" functions to allow MTRCL's staff to continuously enhance their human performance under different operating environments.

Our analysis has two main dimensions: human performance, in respect of skills, rules and knowledge; and performance shaping factors, which include task design, interface design, competence management, procedures, person, and environment [2]. Putting these two dimensions together, we can pinpoint the human factor loop-holes.

Apart from applying this risk-based approach, we also devote effort to preventive measures. Under our scheduled annual inspection plan, we conduct inspections and audits of safety critical items and systems (SCIs and SCSs) to ensure that the railway operator exercises effective steps to eliminate human errors in its operation and maintenance processes. In Hong Kong, we commonly commission independent safety checkers to help tackle human error issues.

3. HUMAN FACTOR INCIDENTS

Broadly speaking, the "human factor" in any incident can be interpreted as someone not doing the right thing at the right time, which directly or indirectly leads to an incident. We now present five human factor railway incidents to illustrate the results of human factors analysis and the recommended remedial measures by applying the risk-based model. These incidents all occurred in Hong Kong between 2010 and 2012.

3.1 Failure of data transmission network at East Rail Line

On 21 January 2010, the data transmission network at the East Rail Line Operations Control Centre (OCC) failed. This meant that the train controllers at OCC could not track the locations of trains, communicate by radio with train captains or make public announcements, although the signaling system was operating normally, with the Automatic Train Protection (ATP) system continuing to keep trains a safe distance apart. Train services on the whole line were suspended for one hour, and about 30,000 passengers were stranded during the incident. Figure 5 shows the OCC under normal operating conditions.

Our investigation revealed that the incident occurred when a third-party supplier's computer engineer was conducting a regular software audit to ensure the integrity of the data network. He erroneously executed an off-line software optimisation program before leaving for his dinner break, overloading the data network with junk data and causing the failure.

Figure 5: The OCC

Subsequent to the incident, the following improvement measures were implemented:

(i) Tighter working procedures were put in place for all outside experts within the MTR system (including closer monitoring of audits by assigning designated staff to communicate with the third-party experts to ensure the on-line system would not be affected);

(ii) A policy of avoiding carrying out audits during peak hours or, where possible, during operating hours was established;

(iii) A new interlocking switch was installed to prohibit uploading of new software patches to on-line operating systems during traffic hours to mitigate the risk; and

(iv) A standby workstation was permanently installed at the OCC to allow the OCC to continue its central monitoring function in case of network failure.

3.2 Breakage of overhead line on the Tsuen Wan Line

The overhead line between Prince Edward Station and Yau Ma Tei Station was burnt out as a result of repeated short-circuit faults in the morning of 21 October 2010. The Tsuen Wan Line train service at Yau Ma Tei Station was suspended for three hours and 100,000 passengers were affected during morning peak hours. Figures 6 and 7 show the schematic of the electric circuits and the congestion at Yau Ma Tei Station during the incident.

Our investigation found that a small carbon chip had broken off from a carbon brush inside the DC traction drive motor, causing an electrical short-circuit fault. The magnitude of the fault current exceeded the rupture capacity of the train-borne circuit breaker and the circuit breaker was damaged. The overhead line traction supply circuit breaker was also tripped. While train T48 was stopped at the Yau Ma Tei Station with its pantographs raised, train T49 traveled through the two traction supply sections behind it (i.e. Section 641 and 642) and swept through the section insulator resulting in two more short-circuit faults.

Figure 6: ***Schematic showing the electric circuits***

Figure 7: ***Congestion on the Tsuen Wan Line platform at Yau Ma Tei Station***

The traffic controller at the Operation Control Centre (OCC) asked the captain of train T48 to lower the pantograph to isolate the fault. The train captain did not press the pantograph-down button thoroughly as instructed (and thought that the pantograph had been lowered). Based on the train captain's incorrect report on the pantograph status, the traffic controller then instructed the power system controller to reclose the DC Circuit Breaker (DCCB) to resume the traction supply. Of course, the traction DCCB then tripped again. Without further checking, the power system controller made a second attempt to close another DCCB a few seconds later, but failed. As a result of five consecutive electric short-circuit faults, the overhead line overheated and burnt out. It then took a further 2.5 hours to re-connect the overhead line.

At least two human errors occurred during this incident. The first was that the train captain did not correctly report the pantograph status to the traffic controller. The second was that the power system controller made a second attempt to reclose the traction DCCB before asking the platform supervisor to check the pantograph situation on site.

The mitigation measures we agreed with MTRCL were as follows:

(i) Replace the train-borne circuit breakers with new ones of higher current rupture capacity;

(ii) Install a visual indicator in the driving cab to confirm to the train captain the position of the pantographs; and

(iii) Review and revise the operation control procedure for closing traction supply circuit breakers to provide clear steps for operators to follow.

3.3 Rail breakage incidents on the East Rail Line and the Tsuen Wan Line

Two rail breakage incidents occurred with a month of each other in early 2011: the first on the East Rail Line in the morning of 13 January and the second on the Tsuen Wan Line in the morning of 10 February. The train services were severely affected as trains travelled in “restricted manual mode” at 20kph near the affected rail sections. In each case, steel fish plates were immediately applied as a temporary emergency repair and the broken rail section was subsequently replaced after normal operating hours.

In the East Rail Line incident, it was found that a bolt of smaller diameter had been temporarily installed to fix an insulated rail joint (IRJ). When trains passed over the IRJ, the stresses concentrated at the smaller diameter bolt and its bolt hole, ultimately propagating a crack and breaking the rail. The incident would have been avoided if a suitable size bolt was used in the first place. The entire rail network was subsequently checked and seven IRJs with a smaller bolt were identified and replaced.

The Tsuen Wan Line incident was caused by an aluminothermic weld defect that track maintenance staff had failed to detect through their usual non-destructing testing methods. According to MTRCL track inspection procedures, each section of the track is visually inspected once every three days and subject to by ultrasonic testing once every two weeks. An expert consultant was commissioned by MTRCL to review their rail inspection and maintenance regime. In short, this consultant recommended adopting the EN14730 standard to improve the site aluminothermic welding procedure and qualification of welding personnel. In addition, he suggested MTRCL to adopt the ISO9712 standard for independent examination and certification of non-destructive testing personnel.

3.4 Train inadvertently moved by the train captain with doors open on the East Rail Line

On 17 April 2011, the Passenger Alarm Device (PAD) of a train serving the East Rail Line was activated by a pregnant woman seeking assistance. With the PAD activated, the train's safety function prevented it from starting and alerted the train captain. After the passenger in need of assistance had been helped to disembark, the train captain reset the PAD to re-start the train. However, he mistakenly pressed the door-open button instead of the train-start button. As the train was within the door-enabling zone, the train doors opened as the train started to move slowly away from the platform. The fail-safe design was then activated to stop the slow-moving train.

Investigation revealed that the train captain did not follow operational procedures. To eliminate the risk of the train moving away from the platform with open doors, a 20-second delay was introduced into the train door control system. It prevents the train doors from opening within 20 seconds of the train-start button being activated. After 20 seconds, the train should have left the door-enabling zone and accelerated above 5kph, in which case the doors cannot open. Nevertheless, the reliability of human operation was identified as the fundamental issue in this situation. As such, a special training course was arranged for the train captain involved to ensure that the door-open buttons would not be pressed unless the train was absolutely stationary. The lesson learnt from this case was also incorporated into the refresher training materials for all train captains to avoid recurrence of a similar incident.

3.5 Train doors opened when the train did not stop in the correct position

On 8 January 2012, a portion of a passenger train on the East Rail Line stopped short of the platform stopping mark and yet the train doors were opened. Although the incident caused no passenger injury, we investigated the near-miss in view of the potential safety threat.

It is not uncommon for trains to stop in an inaccurate position. As a general rule, however, the train doors will not be opened until the train captain has confirmed that the train is in the correct position. To activate the door by-pass switch in the case of any emergency, the authorisation of the operation control centre (OCC) is required. In this incident, the train captain did not identify the train stopping position and used the door by-pass switch without authorization.

Figure 8: Vertical stopping mark on the East Rail Line

Figure 9: Vertical stopping mark at Hung Hom Station

Following this incident, a refresher training programme was specifically developed to remind train captains to be vigilant in identifying the train stopping position and to reinforce the correct procedure for operating the door by-pass switch. We also recognized that the environment and human-machine-interface were the performance shaping factors in this incident. To facilitate the checking of proper train position, a vertical stopping mark was installed at each platform end (as can be seen in Figures 8 and 9) and a reminder label was also posted near each train's door by-pass switch. Furthermore, the door by-pass switch was relocated to a new position in the cab console so that it was not so easily assessable to the train captain, thus helping to avoid inadvertent operation.

4. CONCLUSION

The risk-based model has proved to be an effective tool in managing railway incidents due to human error in Hong Kong. The number of human factor incidents has been contained and we are now seeing a steadily declining trend. As a result of improvement measures implemented to date, we have avoided the repetition of similar human errors. However, further observation is required.

Secondly, the deployment of the risk-based model has allowed us to focus our manpower resources more efficiently on our identified high-risk scenarios and to devise very targeted safeguard measures and inspection programmes in order to reduce the risk arising from human factors to a level as low as reasonably practicable.

5. REFERENCES

[1] Lai I, Controlling Operational Safety Risks from Design through to Operation, Operations Insight, October 2001

[2] Gibson WH, Mills AM, Smith S and Kirwan BK, Railway Action Reliability Assessment, A Railway-Specific Approach to Human Error Quantification, Rail Human Factors, CRC Press, 2013