港鐵東鐵綫

紅磡站列車出軌事故

技術調查報告

Technical Investigation Report on

Train Derailment Incident at

Hung Hom Station on MTR East Rail Line

事故日期：2019 年 9 月 17 日

Date of Incident : 17 September 2019

英文版

English Version

機電工程署 EMSD

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Executive Summary

On 17 September 2019, a passenger train derailed while it was entering Platform No. 1 of Hung Hom Station of the East Rail Line (EAL). This report presents the results of the Electrical and Mechanical Services Department's (EMSD) technical investigation into the causes of the incident.

The investigation of EMSD revealed that the cause of the derailment was track gauge widening[1]. The sleepers[2] at the incident location were found to have various issues including rotting and screw hole elongation, which reduced the strength of the sleepers and their ability to retain the rails in the correct position. The track gauge under dynamic loading of trains would be even wider, and this excessive gauge widening caused the train to derail at the time of incident.

After the incident, MTR Corporation Limited (MTRCL) have reviewed the timber sleeper condition across the entire EAL route and replaced the sleepers of dissatisfactory condition. MTRCL were requested to enhance the maintenance regime to closely monitor the track conditions with reference to relevant trade practices to ensure railway safety. MTRCL were also requested to install on-board real-time monitoring devices on passenger train to give greater and more timely visibility of track deficiencies and make good use of this monitoring and reporting system to improve track maintenance.

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1 Track gauge is the distance between the inner side surfaces of a pair of rails. Excessive gauge widening might cause the train to derail.

2 Rail is fixed onto the sleeper via baseplate to secure the position of the rail.

Technical Investigation Report on
Train Derailment Incident at Hung Hom Station on MTR East Rail Line on
17 September 2019

1 Objective

1.1 This report describes the technical investigation by the Electrical and Mechanical Services Department (EMSD) into the train derailment incident of 17 September 2019 on the East Rail Line (EAL). The purpose of the investigation is to find out the causes of the incident.

2 Background of Incident

2.1 At 8:29 a.m. on 17 September 2019, a derailment incident occurred on EAL when a 12-car passenger train of MTRCL was entering Platform 1 of Hung Hom Station. Upon receipt of notification from MTRCL at 8:36 a.m., EMSD immediately dispatched staff to the scene to carry out investigation. The sequence of events is listed in **Table 1**.

Table 1：Sequence of Events

Time	Description
17 September 2019	
08:29 a.m.	As train ID L094 was moving towards Platform 1 of Hung Hom Station, its 4th to 6th cars derailed, and its 4th and 5th cars were disconnected.
08:36 a.m.	EMSD was notified of the incident by MTRCL.
09:07 a.m.	EMSD staff arrived at the incident scene to carry out investigation.
09:43 a.m.	About 500 passengers were all evacuated to Hung Hom Station with assistance of MTRCL's staff.
11:40 a.m.	MTRCL commenced repair works.
18 September 2019	
06:05 a.m.	Platform 4 of Hung Hom Station resumed operation.
20 September 2019	
05:30 am	Platforms 1 and 4 of Hung Hom Station resumed operation.

2.2 At the time of the incident, the train was entering Platform 1 of Hung Hom Station. The 4th to 6th cars derailed, and the coupler connecting the 4th and 5th cars was disconnected. Eight passengers were injured. **<u>Figure 1</u>** shows the status of the train immediately after derailment.

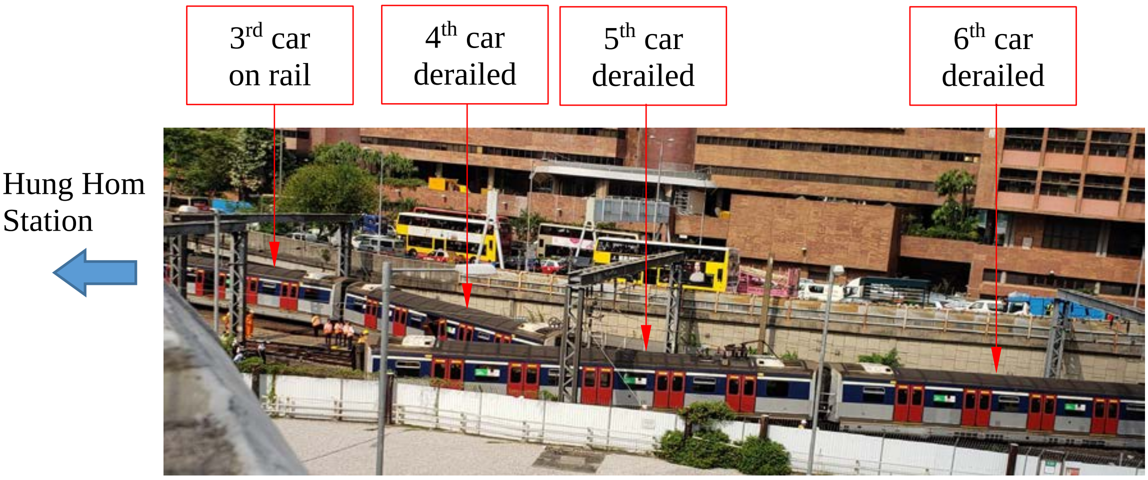

Figure 1 : Status of the incident train immediately after derailment

3 Technical Details Relating to Incident

3.1 <u>Track design of EAL</u>

EAL is a ballasted track. Sleepers are placed on the ballast and the baseplates[3] of rails are fixed onto the sleepers with screws. Rails are then placed and secured on the baseplates by clips. **<u>Figure 2 and 5</u>** show the typical ballasted track section with rail, clips, sleepers and baseplates on EAL.

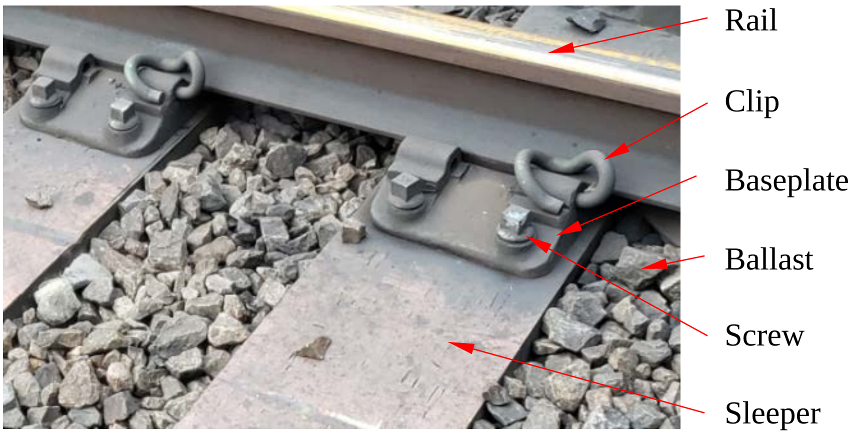

Figure 2 : Typical ballasted track section of EAL

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3 Baseplate is the component between the rail and the sleeper. In normal circumstances, the baseplate is fixed to the sleeper with screws and the rail is secured to the baseplate by clips.

3.2 Train routes at incident location

The normal routes of passenger trains passing through turnouts[4] P5116, P5114, P5111 and P5109 and turnouts P5116, P5114, P5112 and P5108 before entering Platform 1 and Platform 4 of Hung Hom Station of EAL, respectively, are shown in **Figure 3**. The incident train derailed just before entering Platform 1 at turnout P5116, which is located at a sharp curved track section on EAL. The speed limit of this section is 40 km/h. Each turnout consists of a point machine[5], switch rails[6], crossing[7] and two check rails[8]. The layout of a typical turnout is shown in **Figure 4**.

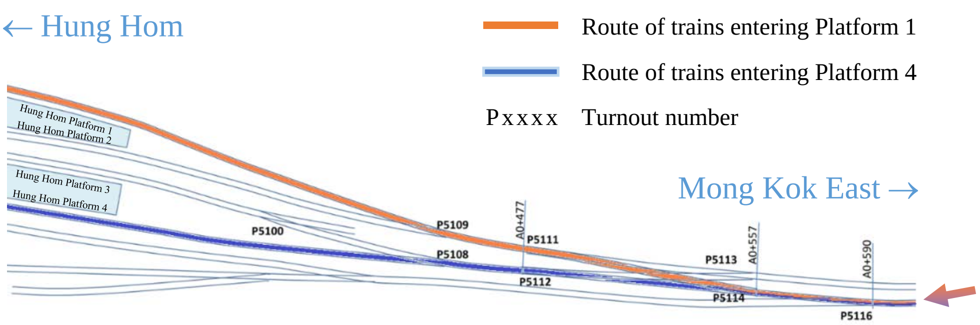

Figure 3 : Routes of trains entering Platform 1 and 4 of Hung Hom Station

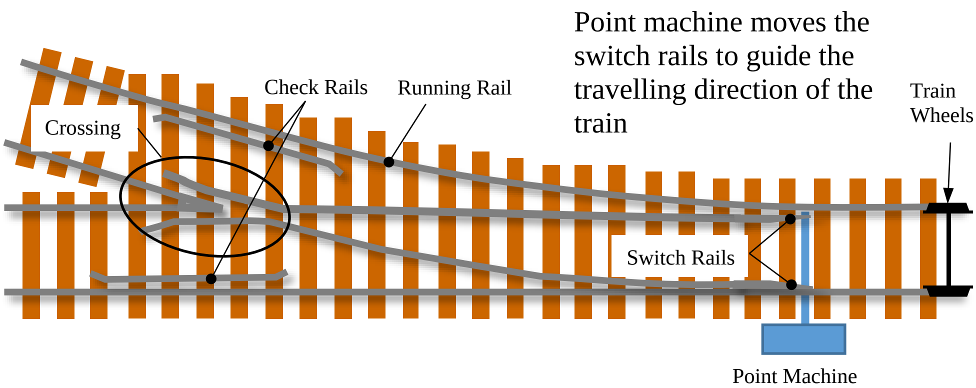

Figure 4 : Layout of a typical turnout

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4 Turnout is a mechanical device used to guide the train from one rail track to another.

5 Point machine is a power-driven device that moves the switch rails and controls the running path of train passing a turnout, often controlled by signalling system.

6 Switch rails are a pair of swinging rails that change the direction of turnouts.

7 Crossing has four rails to ensure that trains can safely pass through the turnout.

8 Check rail is an additional rail mounted alongside the inside rail of a curve or opposite of a crossing to restrict the lateral movement of wheels.

3.3 Sleepers

Sleepers of EAL are made of either concrete, timber, or synthetic[9] materials. Concrete sleepers are installed on plain tracks[10] and timber/synthetic sleepers are used at turnouts. Timber/synthetic sleepers have the flexibility of fine-tuning the position of baseplates and rails on site by drilling holes on the timber/synthetic sleepers so as to fit the curvature and profile of the route. There are over 9,800 timber/synthetic sleepers installed at turnouts of EAL. Since 2008, MTRCL have been replacing[11] timber sleepers with synthetic sleepers due to deterioration of timber sleepers. As at August 2019, MTRCL had replaced about 4,000 timber sleepers with synthetic sleepers in EAL.

3.4 Standard track gauge

Track gauge is the distance between the inner side surfaces of a pair of rails (see **Figure 5**). The standard track gauge of EAL is 1,435 mm. The gauge might exceed 1,435 mm due to a number of factors, such as lateral force exerted on the rail by running trains, wear and tear of rail, and loosening of fixing clips, etc. Excessive gauge widening might cause a train to derail. In this connection, periodic measurement and rectification of track gauge widening are of utmost importance.

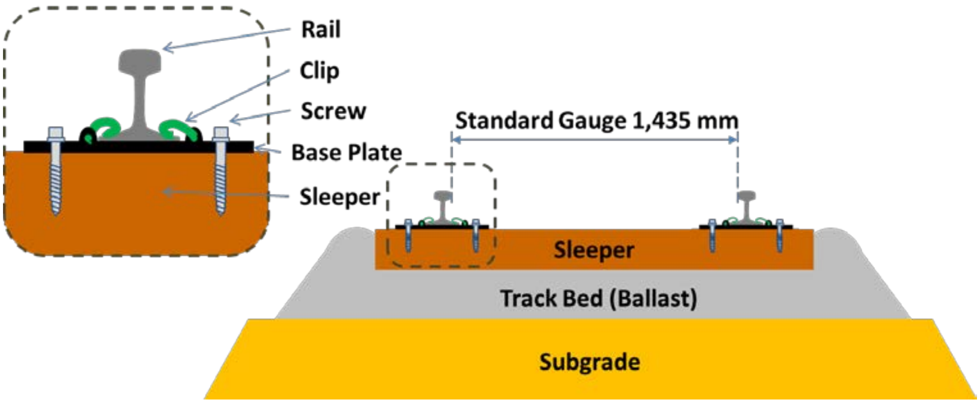

Figure 5 : Standard track gauge of EAL

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9 Synthetic sleepers used on EAL are made of fibre-reinforced foamed urethane (FFU).

10 Plain tracks are tracks without turnouts and crossings.

11 Since the supply of natural timber suitable for use in railway becomes tight, sleepers that are made of synthetic materials are used to replace timber sleepers.

3.5 Maintenance procedures for track gauge

3.5.1 MTRCL's maintenance procedures for track gauge specify the following routine preventive and corrective maintenance work for the track of EAL.

(i) Patrolling with visual inspection of track conditions including rails, clips, screws, baseplates, and sleepers once every three days with tolerance of one day

(ii) Dynamic measurement of track gauge once every 30 days with tolerance of six days by the "Track and Overhead Line Vehicle" (TOV)[12] and comparing the figure against the maintenance threshold namely L1 Threshold[13] of 1,457 mm, which is 22 mm above the standard gauge of EAL

(iii) Turnout maintenance including inspection, measurement, and maintenance of major components such as crossings, check rails, switch rails and point machines once every 90 days with tolerance of 27 days

According to MTRCL's track gauge maintenance procedures entitled "Management of Track Geometry Measurement by TOV", when the TOV measurement reveals that the track gauge of EAL has reached the L1 Threshold, corresponding follow-up on-site verification by manual static measurement[14] is required within 28 days of the TOV measurement. If the on-site verification confirms that the track gauge reaches the Safety Intervention Limit[15], which is 20 mm and 30 mm above the standard gauge of turnouts and plain tracks, respectively, the gauge widening should be rectified within 28 days from the date of TOV measurement.

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[12] The Track and Overhead Line Vehicle (TOV) is an engineering train for measuring the geometry of the track and overhead line. The TOV measurement is commonly referred to as dynamic measurement, which measures the track gauge when the track is being subject to the loading of a train passing over it.

[13] Track gauge reaching the "L1 Threshold" does not imply immediate danger for train operation. However, on-site verification and the necessary rectification should be conducted within the predefined time frame to avoid further gauge widening that might cause derailment of train.

[14] Static measurement means manual measurement of track gauge when the track is not being subject to the loading of a train passing over it.

[15] If the Safety Intervention Limit is exceeded, rectification should be carried out within a predefined time frame according to maintenance procedures of MTRCL.

These rectification works should also be registered in MTRCL's maintenance management system namely "RailASSURE" for issue of corrective maintenance jobs. Follow-up Report and Quarterly L1 Exception Summary Report should be issued for monitoring the progress of maintenance work. MTRCL's maintenance procedures for track gauge maintenance and relevant monitoring mechanism are shown in **Figure 6**.

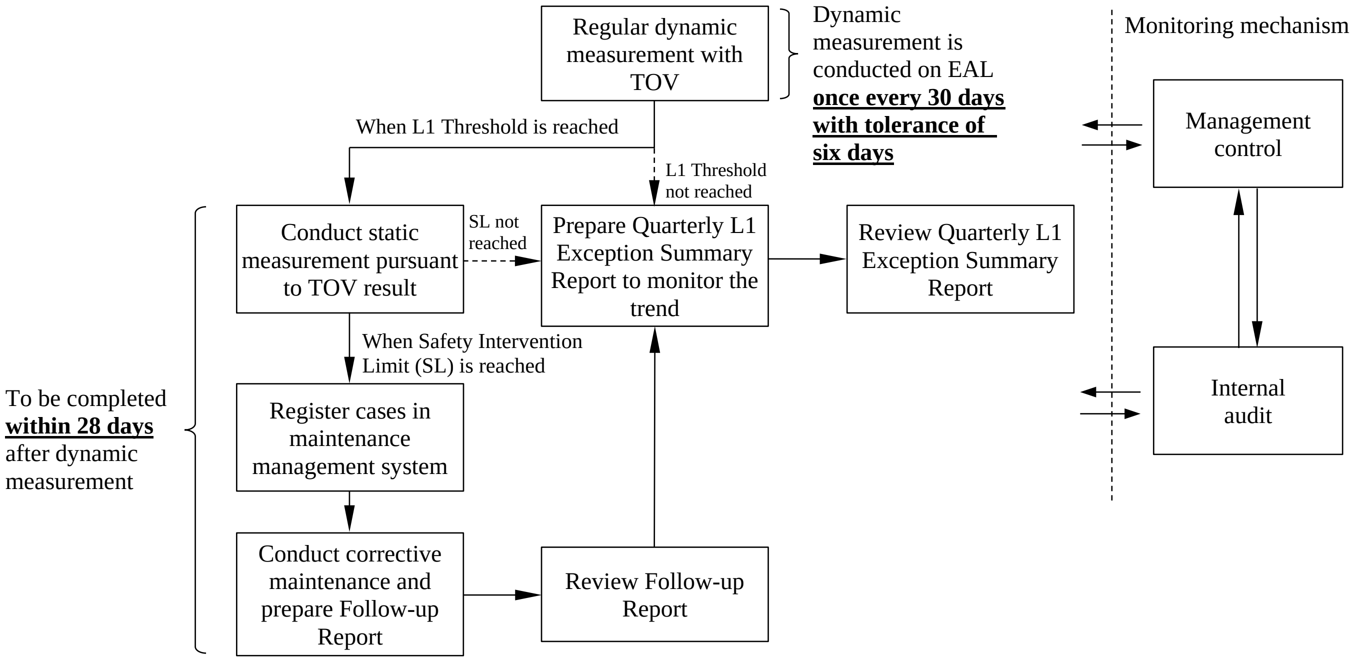


Figure 6 : MTRCL's maintenance procedures for track gauge maintenance and relevant monitoring mechanism

4 Incident Investigation

4.1 Approach of investigation

EMSD conducted an in-depth and comprehensive investigation into the causes of the incident. EMSD also appointed three railway safety experts, namely Technical Programme Delivery Limited (TPD)[16], Prof. Alan Lau[17]

[16] Technical Programme Delivery Limited is a UK railway safety consultancy company that employs experts with more than 40 years of experience in train derailment investigation.

[17] Prof. Alan Lau is an expert in failure analysis of materials and is the Pro Vice-Chancellor of the Swinburne University of Technology in Australia.

of Swinburne University of Technology, Australia, and Dr Eric C H Lim[18] of Safety Accident and Failure Expert Limited. The investigation included-

(a) examination of track gauge and sleeper conditions;
(b) examination of rail cracks, broken rails, and broken check rail;
(c) examination of point machines;
(d) examination of the incident train as well as the five trains immediately prior to the incident train;
(e) interviews with 34 relevant personnel of MTRCL, including train captains and permanent way maintenance staff;
(f) review of over 140 documents and records, mainly on maintenance and operation log for track, trains and point machines;
(g) review of the CCTV footage of the incident train entering Platform 1;
(h) seizing 50 items including the rails, sleepers and point machines from the incident site;
(i) joint site inspections with experts;
(j) joint inspection of the incident site and the incident train with the Hong Kong Police Force to identify any foreign objects; and
(k) laboratory tests on the material strength of sleepers.

4.2 Observations at Incident Location

The incident location revealed the following.

(a) The incident train was scheduled to enter Platform 1 of Hung Hom Station. During the incident, the 4th to 6th cars derailed, and the coupler connecting the 4th and 5th cars was disconnected. The first three cars and the last six cars remained on the track rail. There were eight turnouts at the incident location to control train movement to and from different platforms at Hung Hom Station. The status of the incident train after derailment and the damage to the nearby railway facilities are shown in **Figure 7**. Photos of wheel flange marks, broken rails, rail cracks, and damaged point machines are shown at **Appendix I**.

[18] Safety Accident and Failure Expert Limited is a local consulting firm. Dr Eric C H Lim is a material testing expert of the firm with extensive experience in failure analysis.

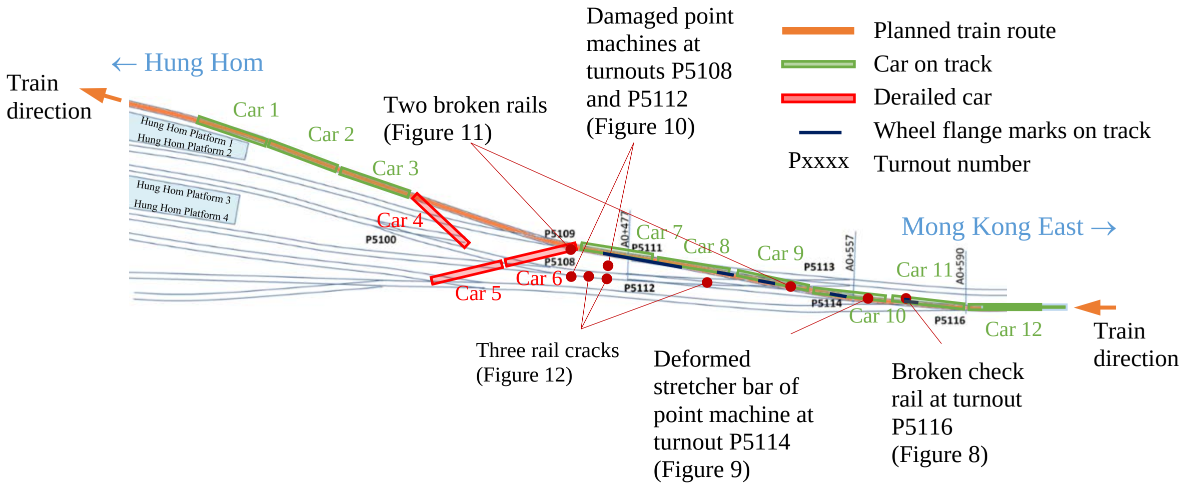


Figure 7 : Status of incident train after derailment and damage to nearby railway facilities

(b) The check rail at turnout P5116 towards Hung Hom Station was found broken (see **<u>Figure 8</u>**). The length of the broken section was measured to be 325 mm.

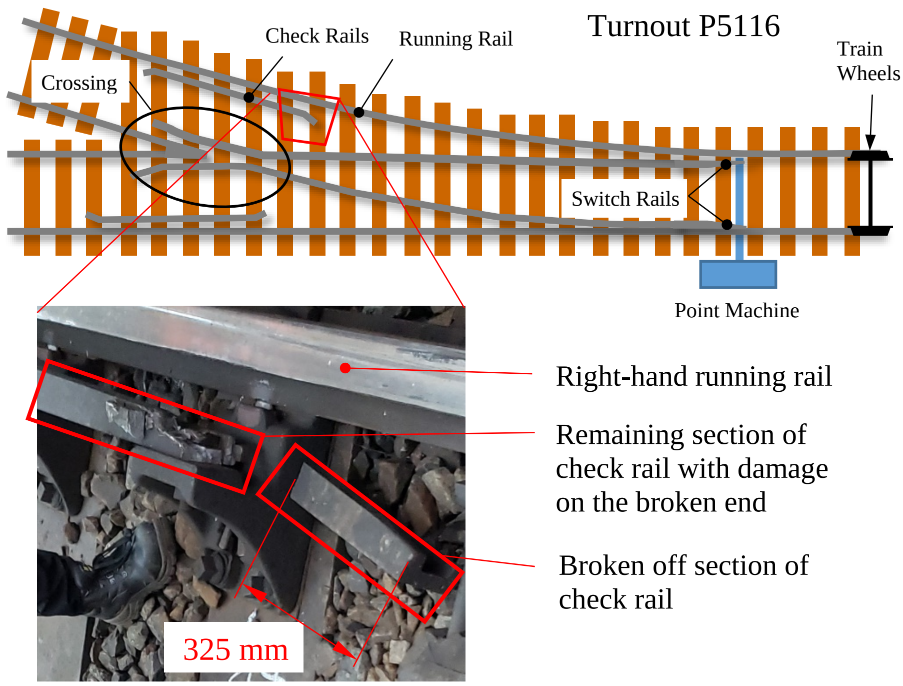


Figure 8 : Broken check rail at turnout P5116

(c) At turnout P5114, the components of the point machine[19] were deformed and damaged as shown in **Figure 9**. The motor drive of point machines of turnouts P5108 and P5112 were also damaged as shown in **Figure 10**.

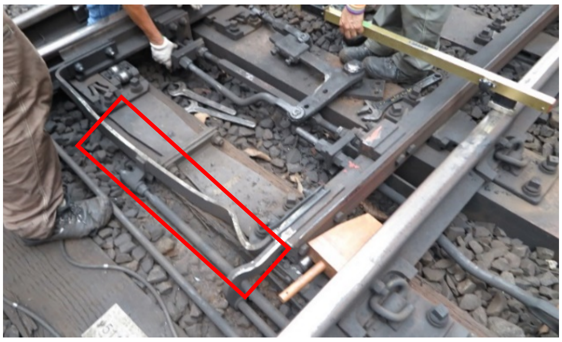


Figure 9 : Deformed stretcher bar of point machine at turnout P5114

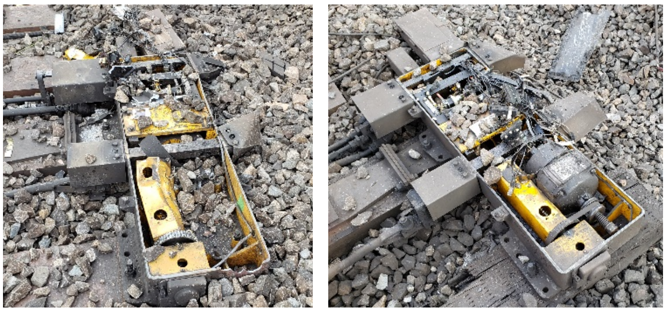


Figure 10 : Damaged motor drives of point machine at turnouts P5108 (left) and P5112 (right)

(d) Two broken rails (see **Figure 11**) and three rail cracks (see **Figure 12**) were found at the incident location.

Figure 11 : Two broken rails

[19] Point machine consists of an electric motor and movable mechanical linkages to move and lock the switch rails in the turnout so as to control the moving path of the train. A point machine is controlled by the signalling system.

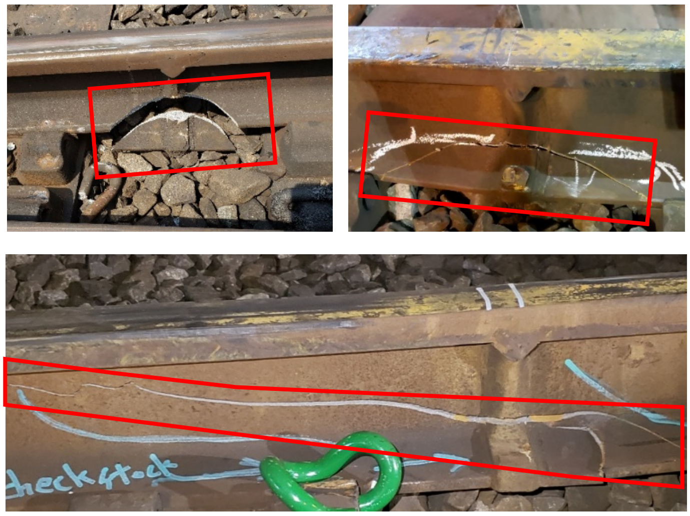


Figure 12 : Three rail cracks at the incident location

(e) During investigation at turnout P5116, some fastening screws for fixing the baseplates to the sleepers were found to have been taken out and put aside. MTRCL confirmed that these fastening screws were found loosened and removed by their staff without the use of any tools after the incident (see **<u>Figure 13</u>**). Some clips for retaining the rail on the baseplates at the inside of the right-hand rail near the broken check rail were missing.

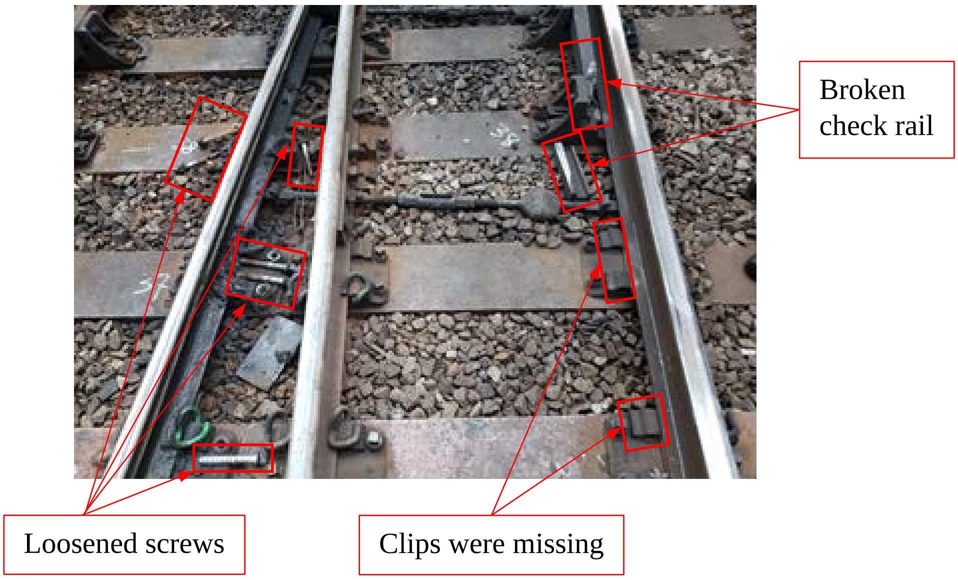


Figure 13 : Loosened fastening screws, missing clips, and broken check rail at turnout P5116

(f) Wheel flange marks, as caused by the wheel flanges[20], were observed on rail foot and sleepers along the tracks at the incident location. An example of wheel flange mark found on the running rail near 36th sleeper of turnout P5116 is shown in **Figure 14**.

(g) The track gauge of the running rails at turnout P5116 was measured after the incident and found exceeding the Safety Intervention Limit of 1,455 mm.

(h) The train operation log showed the train speed was 39 km/h at the time of derailment.

(i) No external object that was not part of the railway system was found at the incident location and nearby areas during site investigation with the Hong Kong Police Force.

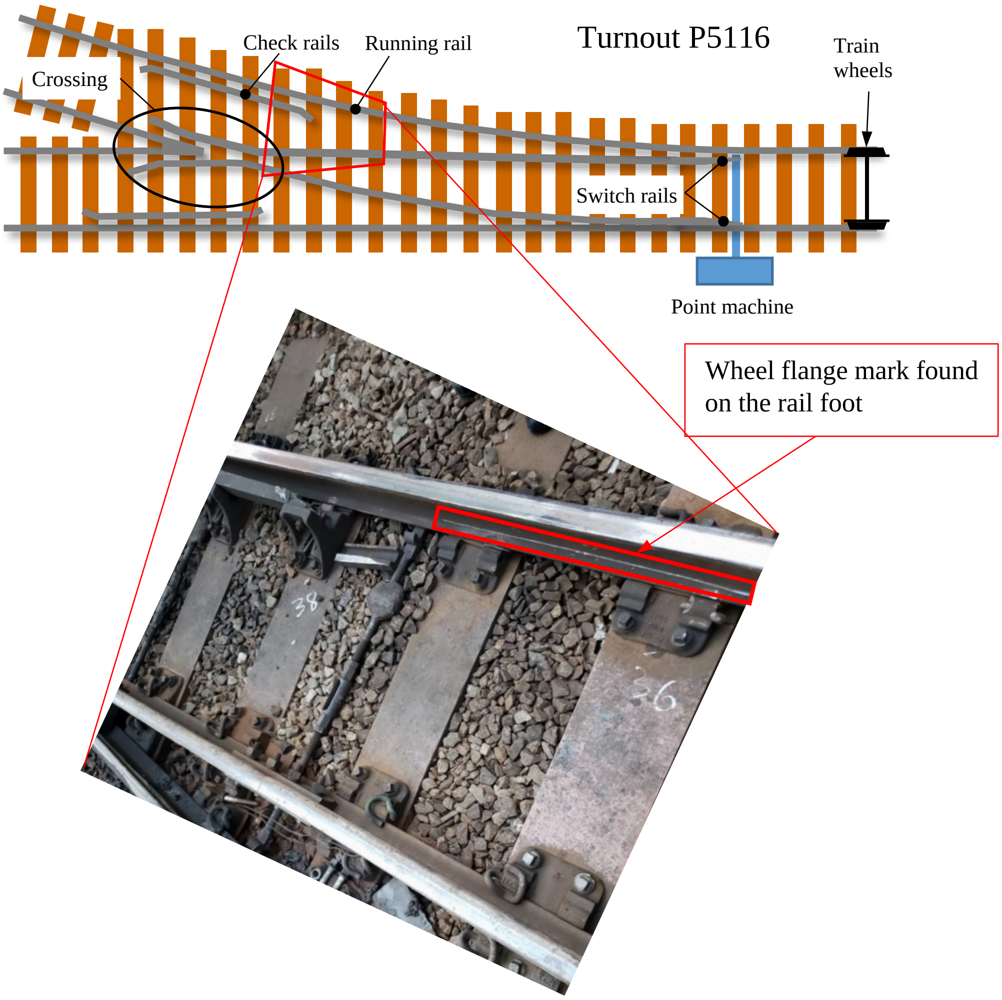


Figure 14 : Wheel flange marks on the rail foot

[20] Wheel flange is the extended portion of a rail wheel that provides it with direction guidance.

4.3 Examination of trains at MTRCL Ho Tung Lau Depot

4.3.1 EMSD examined the incident train (train ID L094, referred to as "Train A" in this report) and the five trains that arrived at Hung Hom Station immediately before the incident train (train ID M092, C090, M088, L086 and M084, referred to as "Train B" to "Train F" in this report) at MTRCL Ho Tung Lau Depot on 20 and 22 September 2019. **Table 2** shows Train A to Train E with hit marks found on the right-hand wheels and their respective arrival schedule at Hung Hom Station. No hit mark was observed on the wheels of Train F. **Figure 15** shows the record of hit marks on wheels.

Table 2：Trains with hit marks observed on right-hand wheels

Schedule of arrival at Hung Hom Station *	Train No.	Ref. No.	Platform	Hit mark on wheels	Remarks
08:12	M084	Train F	4	No	
08:14	L086	Train E	1	Yes	First hit mark observed on 8th car
08:17	M088	Train D	4	Yes	
08:19	C090	Train C	1	Yes	
08:22	M092	Train B	4	Yes	
08:24	L094	Train A	1	Yes	Incident train

* Actual train arrival time might be different from the scheduled arrival time

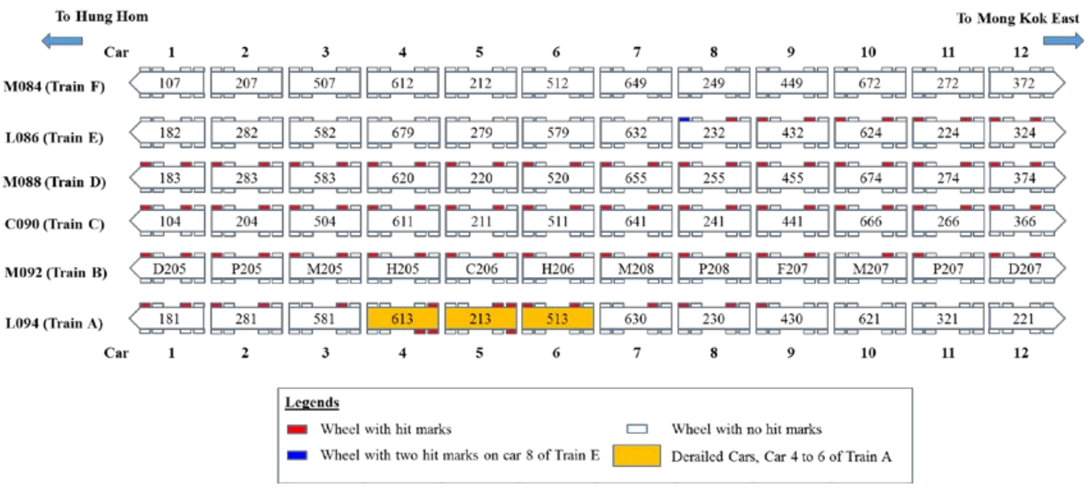


Figure 15 : Record of hit marks found on wheels of Train A to Train F

4.3.2 EMSD examined and found two hit marks with a separation of 325 mm (see **Figure 16**) on the first right-hand wheel on the first bogie of the 8th car of Train E. The separation distance of these two hit marks matched with the length of the broken check rail at turnout P5116. As no hit mark was found on the wheels of the 1st to 7th cars of Train E, it was evident that the 8th car was the first to have hit and broken the front end of the check rail of turnout P5116.

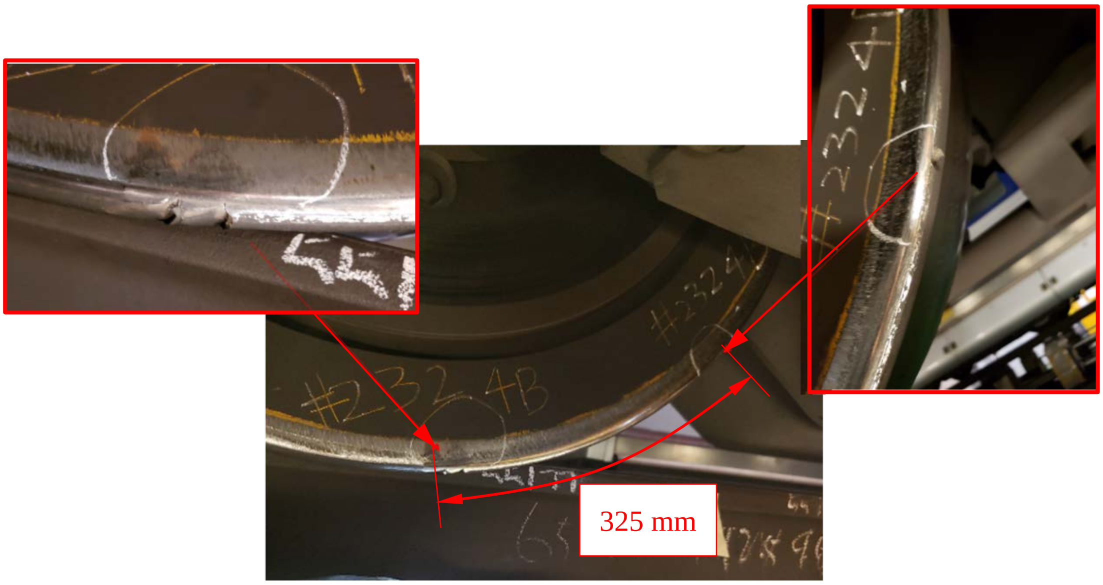


Figure 16 : Two hit marks separated by 325 mm on the first right-hand wheel of the 8th car of Train E

4.3.3 Hit marks were also found on the right-hand wheels of Train A to Train E. It was evident that these hit marks were caused by hitting the remaining section of the broken check rail at turnout P5116.

4.3.4 Examination of Train A included (a) measurement of the distance between the pairs of wheels, (b) measurement of the profile of wheels, (c) measurement of thickness of the brake discs, (d) functional test of the braking system, and (e) the conditions of the Automatic Train Protection system. All the above systems were found in normal working conditions. There was no evidence that the derailment was due to the condition of the incident train.

4.4 Examination of seized exhibits

4.4.1 Broken check rail

The check rail of turnout P5116 towards Hung Hom Station was found broken. The purpose of the check rail was to restrict lateral movement of wheels to ensure that trains take the correct route through the crossing. The detached section of the broken check rail was of length 325 mm (see **Figure 17**). From the hit mark at the upper front edge of the check rail and the hit marks on the wheels of the 8th car of Train E, it was evident that the breakage was due to fracture failure from collision with the wheel of the 8th car of Train E, instead of material fatigue.

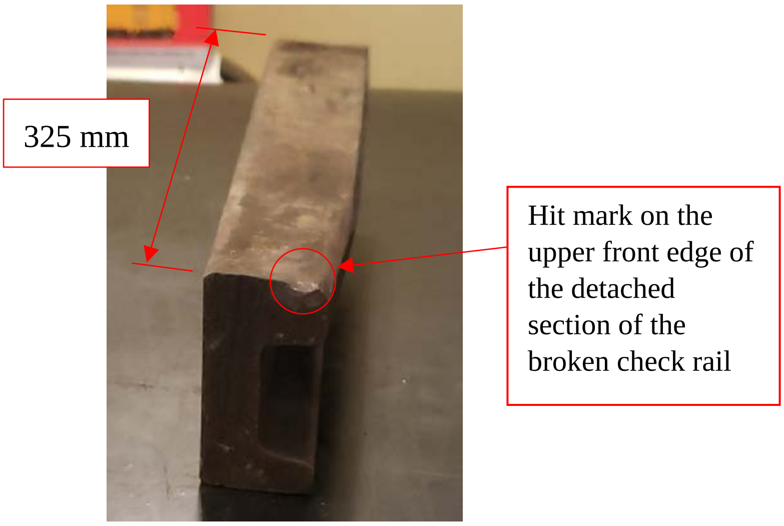


Figure 17 : Front view of detached section of broken check rail

Three smaller pieces of broken metal were found near the broken check rail on the track. The shape of the metal pieces, when putting together, matched with that of the fractured surface of the remaining section of the broken check rail (see **Figure 18**). It was evident that these metal pieces were shattered off from the fractured surface as a result of being hit by wheels of subsequent Train E to Train A.

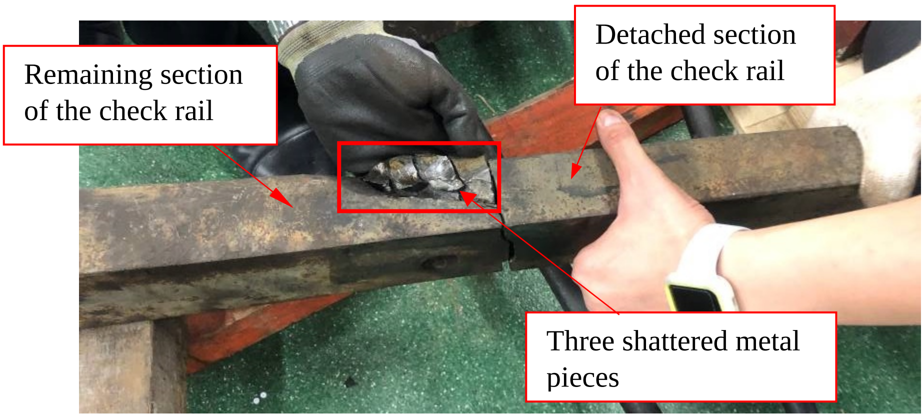


Figure 18 ：Broken check rail and shattered metal pieces

4.4.2 Examination of sleepers

Both timber and synthetic sleepers were used at the incident location. Some of the timber sleepers were found to have rotted (see **Figure 19**). EMSD seized some sleepers from the derailment location.

Figure 19 : Rotten timber sleeper

Elongated and enlarged screw holes were found on all the seized sleepers (**Figure 20**). These screw holes would not have been able to secure the positions of baseplates on the sleepers, thus failing to maintain the standard track gauge.

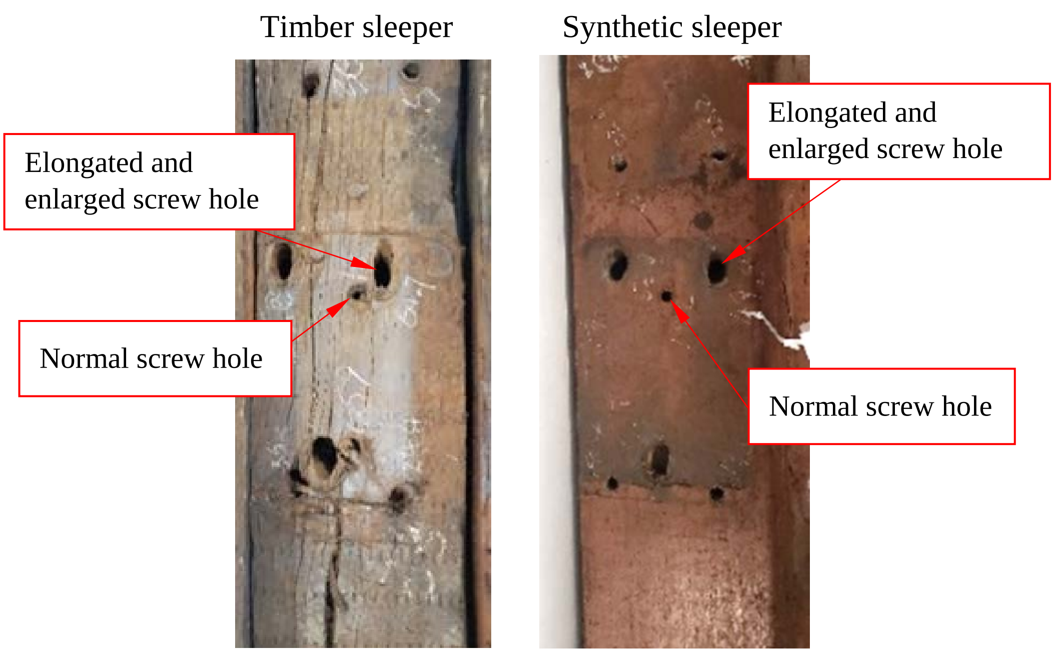


Figure 20 : Sleepers with elongated and enlarged screw holes

More than one set of screw holes underneath the baseplate were observed on some seized sleepers. During track maintenance, a loosened baseplate may be fixed by shifting and re-orientating the baseplate and mounting it with a new set of screw holes on the existing sleeper. The new screw hole should be separated from existing screw holes with sufficient distance to ensure the integrity of the new screw hole. Three sets of screw holes were found underneath the baseplate of left hand rail of the incident route on the 32nd sleepers of turnout P5116 (see **Figure 21 and Figure 22**). Some screw holes were very close to each other, which would weaken the timber and its restraint of the baseplate.

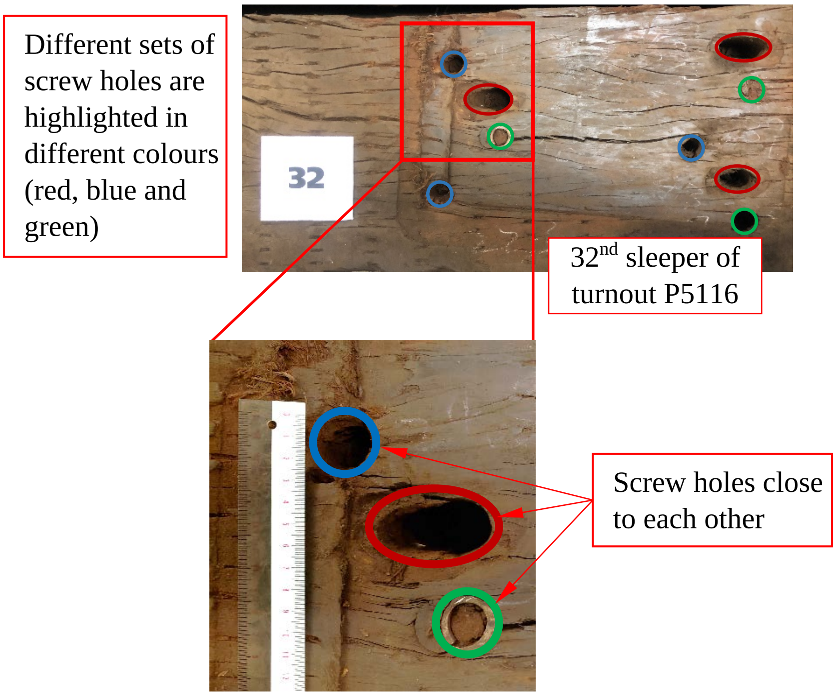


Figure 21 : Screw holes underneath the baseplate of left hand rail of the incident route on the 32nd sleeper of turnout P5116

4.5 Examination of signalling system

4.5.1 Signalling system

EMSD examined the operation records of the signalling system and associated field equipment. There was no abnormality or equipment fault of the signalling system in the course of the incident.

4.5.2 Cyber-attack

EMSD examined MTRCL's security event analysis report and confirmed no network security breach of MTRCL's corporate networks on 17 September 2019. EMSD also verified the design of the signalling system of EAL and confirmed that it was a closed system and was not connected to the internet or any other networks of MTRCL.

4.6 <u>Material testing of synthetic sleepers used in EAL</u>

Material testing of sampled synthetic sleepers was conducted to confirm their compliance with the standard JIS E 1203:2007[21]. There was no evidence that the derailment was due to any inferior mechanical properties of the synthetic sleepers.

5 EMSD's Findings

5.1 <u>Point of derailment</u>

EMSD's investigation team, including the appointed experts, conducted detailed inspections at the incident location to determine the point of derailment. Given the travelling direction of trains, the investigation team found that the wheel flange mark first appeared on the rail foot between the 35th and 36th sleepers of turnout P5116. Considering the train speed and the time taken for the wheel to fall and touch the rail foot, it was evident that the point of derailment was between the 33rd and 34th sleepers of turnout P5116. **<u>Figure 22</u>** shows the location of the point of derailment at turnout P5116.

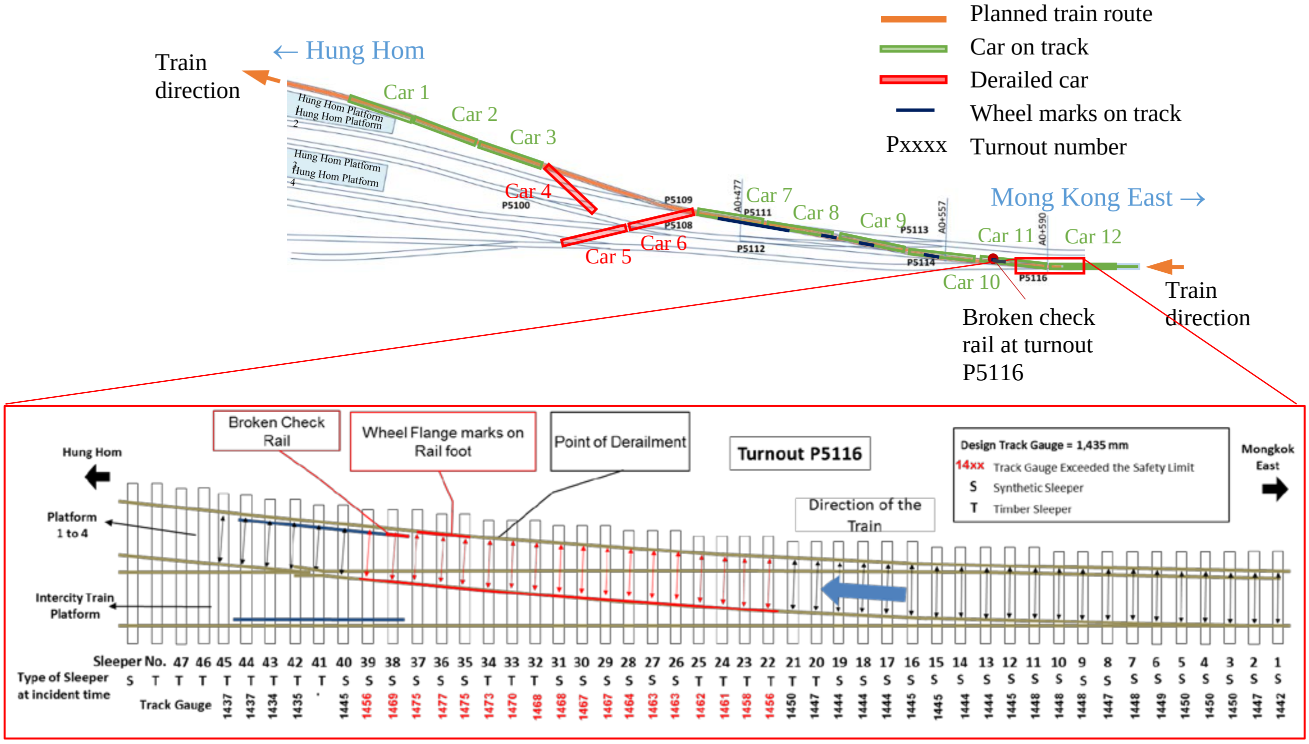


Figure 22 : Point of derailment and track gauge at turnout P5116

[21] JIS E 1203:2007 – "Synthetic sleepers – Made from fiber reinforced foamed urethane" is the standard on synthetic sleepers for use on the permanent way.

Wheel flange marks were found on the top of the check rail at turnout P5116 (**Figure 23**). It was evident that some wheels of Train A to Train E had hit the check rail and climbed onto the top of the check rail.

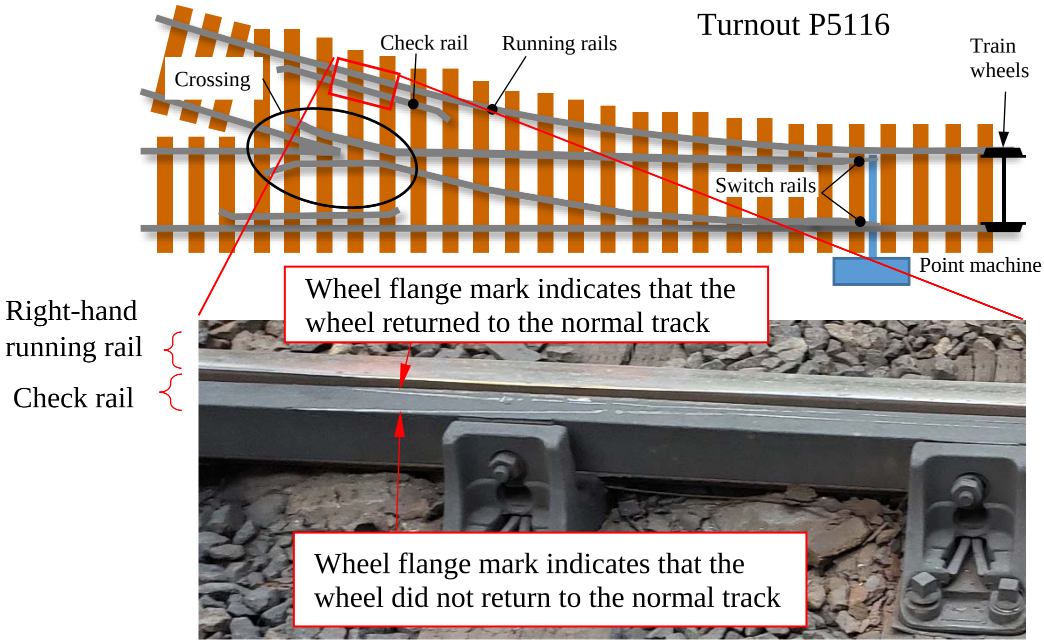


Figure 23 ：Wheel flange marks on top of the check rail

Two broken rails and three rail cracks were found at five different locations around the incident location. All points of fracture were located at welded joints. All broken points and cracks were recent fracture, instead of fatigue failure. It was evident that these fractures and cracks were caused by the derailed wheel flange striking the protruding part of the weld collar (see **Figure 24**), which were not uncommon in train derailment incidents.

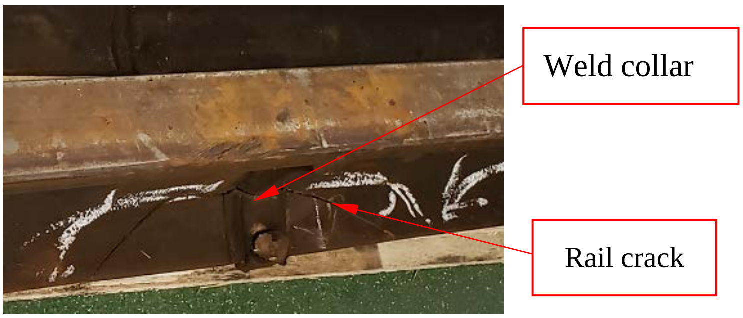


Figure 24 : Wheel flange mark on the weld collar of a cracked rail

5.2 Deterioration of sleepers

The investigation team examined the sleepers that were seized from site at or near the point of derailment. Many of the timber sleepers were found to have rotted internally. Longitudinal surface cracks and splitting were noted on some timber sleepers. The type of surface cracks present was evidence of internal rotting of timber. Deterioration of the integrity of the timber due to rotting reduces the ability of the screws to hold the baseplate firmly in place on the sleeper, resulting in gauge widening. **Figure 25** shows the condition of a rotten timber sleeper with longitudinal surface crack and splitting.

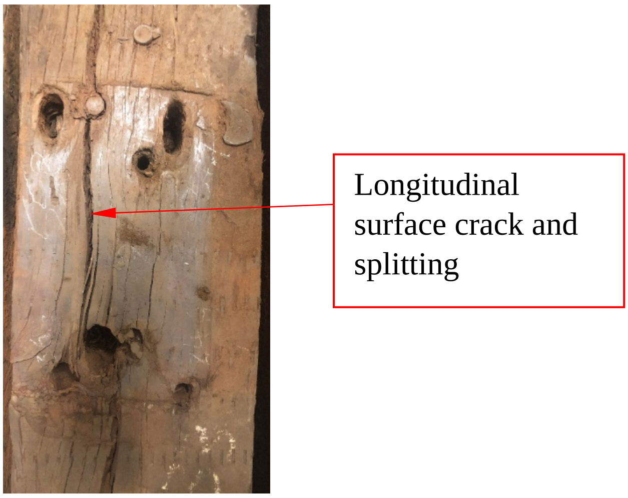


Figure 25 : Rotten timber sleeper

Elongated and enlarged screw holes were found on all the seized sleepers. The enlarged screw holes were unable to securely retain the screws of the baseplates in position on the sleepers. Some of the screws at the incident location were loosened as mentioned in paragraph 4.2(e) and shown in **Figure 13**. When the trains travelled on the curved section of track rail, the lateral force exerted by the train on the rail would cause the outer rail to move or rotate outwards, resulting in the gauge widening. To avoid excessive gauge widening, proper monitoring and maintenance of track gauge were essential to ensure railway safety.

5.3 Gauge widening

According to the static gauge measurement immediately after the incident, the gauge of the track section between the 22nd and 39th sleepers of turnout P5116 were all measured to have exceeded the Safety Intervention Limit of 1,455 mm as marked in red at **Figure 22**. The track gauge at the point of derailment at the 34th sleeper at turnout P5116 was 1,473 mm, which was 38 mm wider than the standard gauge of 1,435 mm. In view of the rotted condition of sleepers, the track gauge under dynamic loading of trains would be even wider, and this excessive gauge widening had caused the train to derail at the time of incident. The investigation team concluded that the cause of the derailment was excessive gauge widening.

6 Conclusions

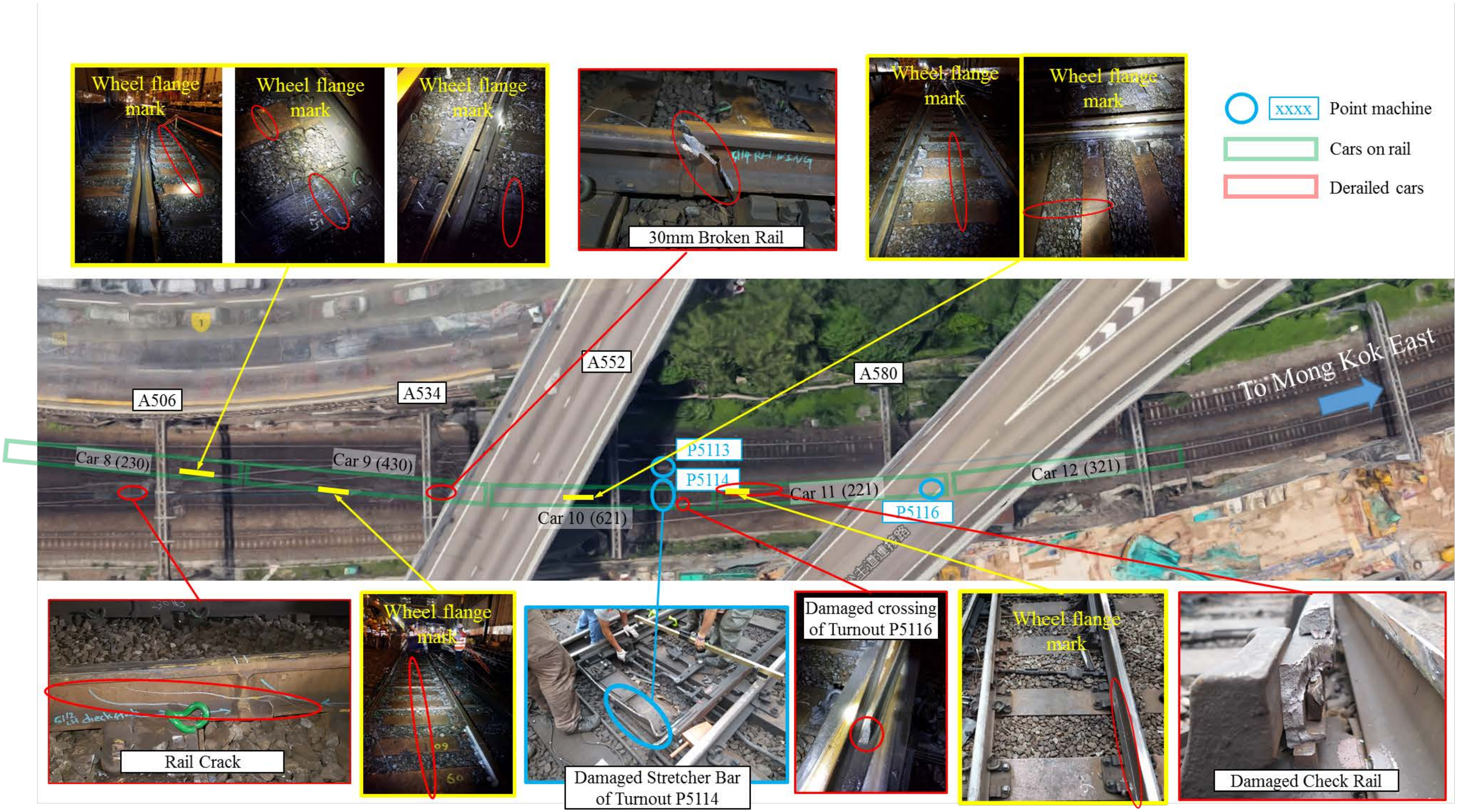
6.1 The investigation of EMSD revealed that the cause of the derailment was track gauge widening. The sleepers at the incident location were found to have various issues including rotting and screw hole elongation, which reduced the strength of the sleepers and their ability to retain the rails in the correct position. The track gauge under dynamic loading of trains would be even wider, and this excessive gauge widening caused the train to derail at the time of incident.

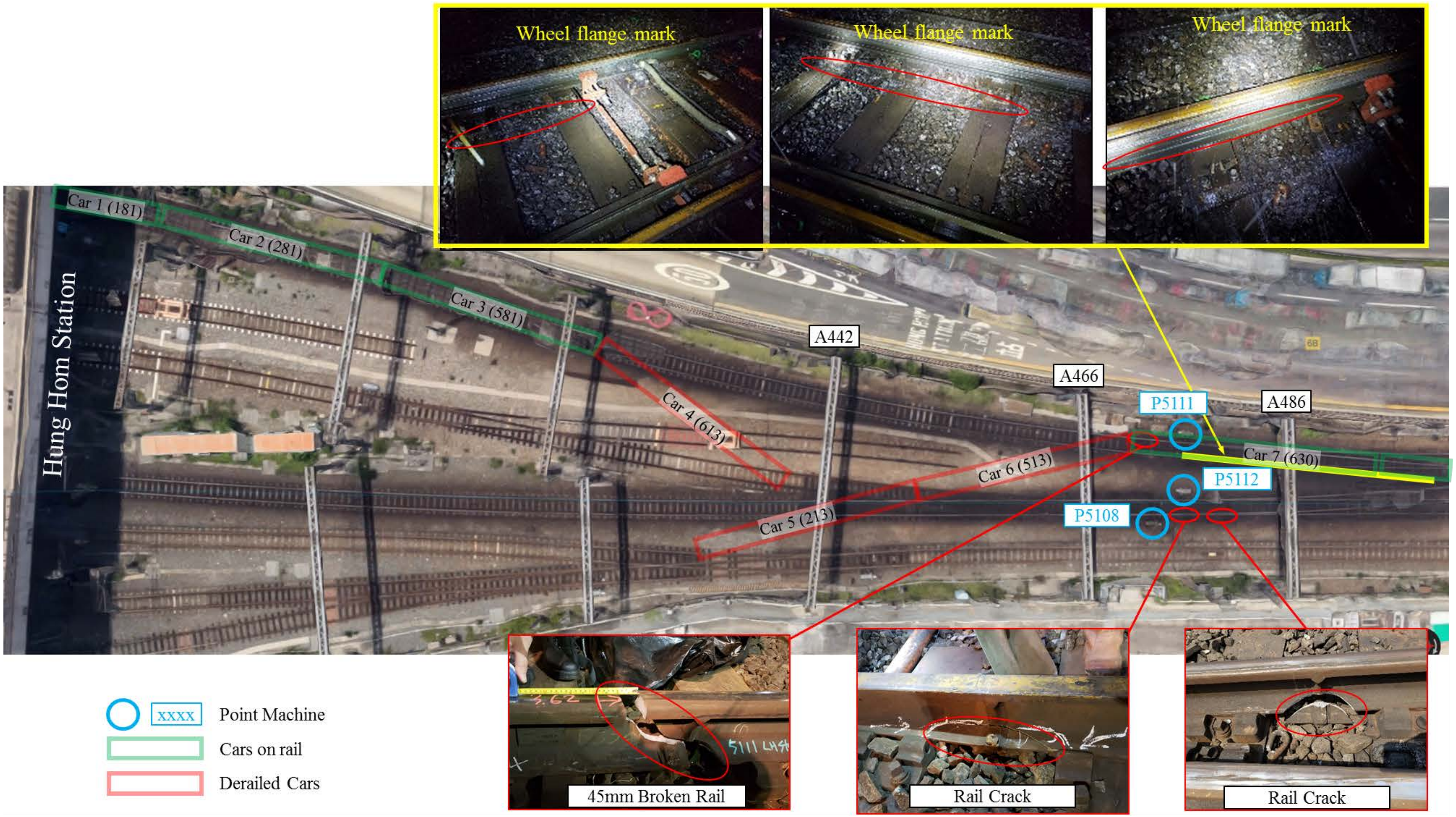
7 Measures Taken after Incident

7.1 MTRCL have reviewed the timber sleeper condition across the entire EAL route and replaced the sleepers of dissatisfactory condition. MTRCL were requested to enhance the maintenance regime to closely monitor the track conditions with reference to relevant trade practices to ensure railway safety.

7.2 MTRCL were also requested to install on-board real-time monitoring devices on passenger train to give greater and more timely visibility of track deficiencies and make good use of this monitoring and reporting system to improve track maintenance.

Appendix I – Photos of Wheel Flange Marks, Broken Rails, Rail Cracks and Damaged Point Machines On-Site





Wheel flange mark
Wheel flange mark
Wheel flange mark
Hung Hom Station
Car 1 (181)
Car 2 (281)
Car 3 (581)
Car 4 (613)
Car 5 (213)
Car 6 (513)
Car 7 (630)
A442
A466
A486
P5111
P5112
P5108
45mm Broken Rail
Rail Crack
Rail Crack
xxxx
Point Machine
Cars on rail
Derailed Cars