Released Final Report on TMRT Train Collision with Foreign Object Occurrence at Feng-le Park Station

Press release

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On May 10, 2023, a Taichung Mass Rapid Transit Corporation (hereinafter TMRT) train departed from Beitun Main Station and headed south to High Speed Rail Taichung Station. This train consists of two cars, numbered 03 and 04, carrying 1 train attendant and 47 passengers. At about 1227 hours, the train, running on the southbound track between Feng-le Park Station and Daqing Station, collided with the truss of a tower crane that had invaded the track area and caused damage to the train cab and doors on the right side of the train's operating direction to fall off. The occurrence resulted in the death of 1 passenger and injuries to 15 people (including 1 train attendant and 14 passengers), as shown in Figure 1.

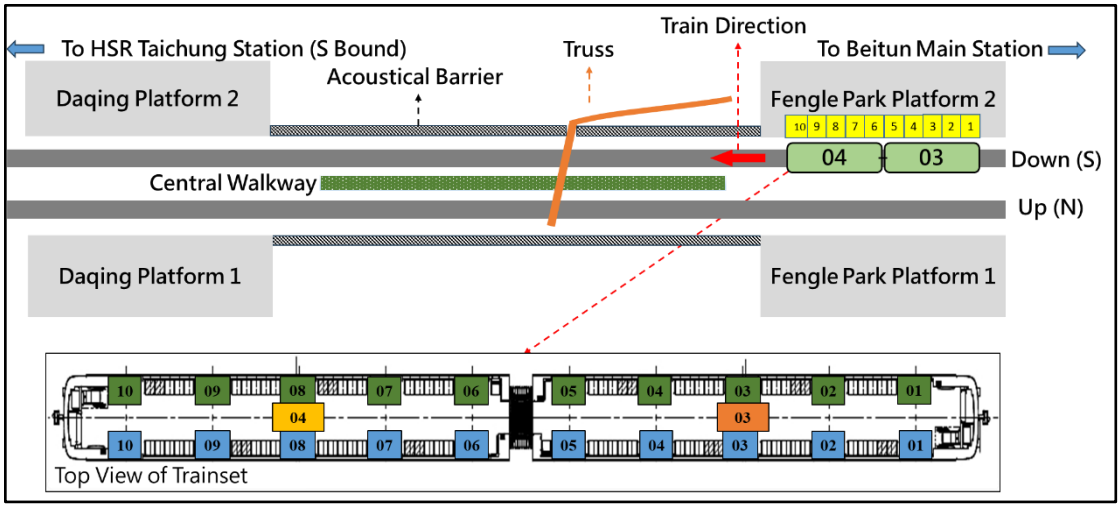

Figure 1 Train doors, station platforms, track configuration and position of fallen truss (schematic diagram)

On the day of the occurrence, operators from United Machinery International Enterprise Co., Ltd. (hereinafter United Machinery) and Chia Yuan Construction Engineering (hereinafter Chia Yuan) had been dismantling the construction tower crane (hereinafter the tower crane) by

using the dismantling tower crane (hereinafter dismantling crane) on the roof of the building built by Highwealth Construction (hereinafter referred to as Highwealth) next to the TMRT.

During the dismantling of the tower crane truss and the rotating base, Chia Yuan operators removed the latch between the root of the truss and the lug plate of the rotating base. Then they placed a ratchet wrench in the latch hole to temporarily hold it in place. Because the handle size of the ratchet wrench is smaller than the diameter of the latch hole, the root of the truss rose slightly, failing to remain parallel to the lug plate and therefore could not be loosened (see Figure 2). Chia Yuan operator then directed United Machinery operator to adjust the position of the tower crane truss by rotating the dismantling crane. During the process, the United Machinery operator may have lifted the tower crane truss diagonally (see Figure 3), causing the hoisting steel cable of the dismantling crane and the lifting point of the tower crane truss to form an angle and exceed the critical angle. Multiple rods of the dismantling crane truss were subjected to a pressure sufficient to bend or buckle, thus causing buckling and fracture. The tower crane truss fell onto Wenxin South Road after losing the hanging force of the dismantling crane, with a portion falling into the TMRT track area at 1227:03.

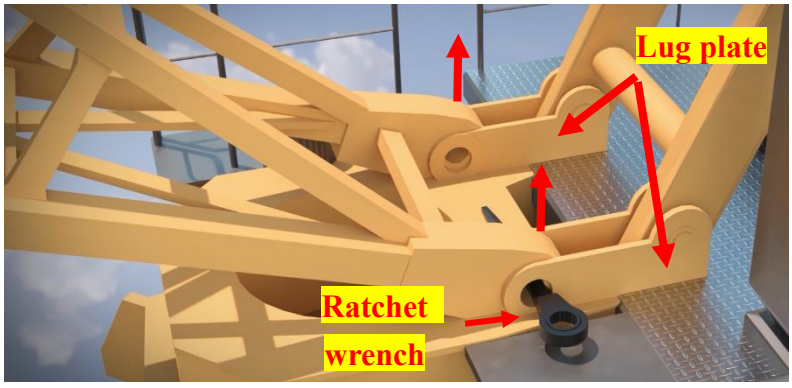

Figure 2 Rise of tower crane truss root (schematic diagram)

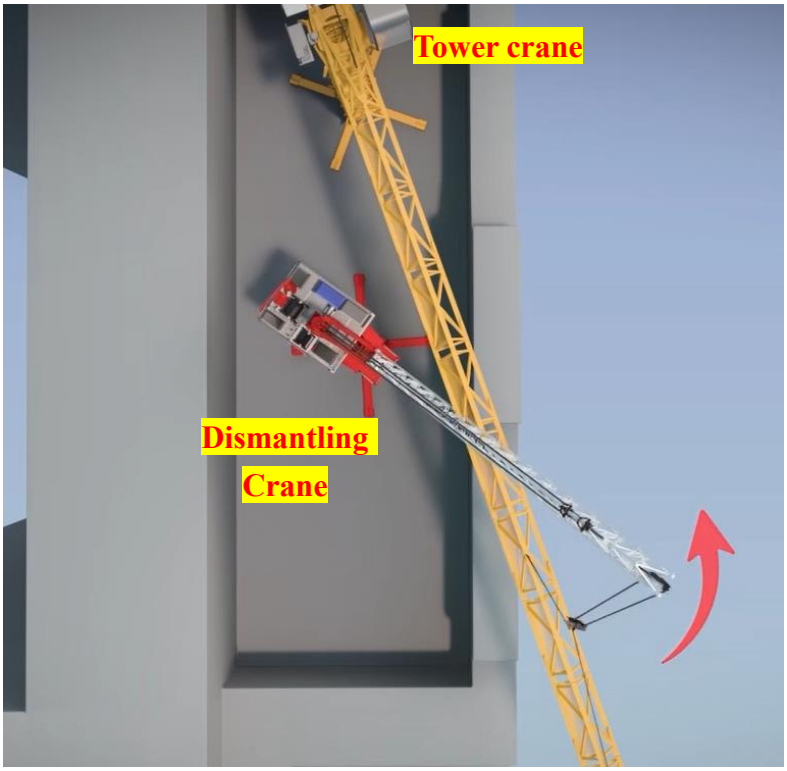

Figure 3 The dismantling crane lifts the tower crane truss diagonally (schematic diagram)

At 1227:03, while the train was making a stop at platform 2 (southbound track), the tower crane truss invaded the track. At 1227:10, train doors opened, and the train attendant walked out from door 10 of car 04 onto the platform, facing the north end (the rear of the train) while confirming passenger boarding and alighting. Upon hearing the impact, the station security guard turned around to look south at 1227:06 and moved to the south end of the platform. After discovering smoke and dust in the track area, he notified the station master via walkie-talkie at 1227:13 and continued moving toward the south end of the platform. The station master heard the impact and the call from the station security guard on the walkie-talkie, and proceeded to the south end of platform 1 to learn about the situation.

At 1227:04, 10 power alarms began to appear in the Power Supervisory Control and Data Acquisition (PWR SCADA) system in the

TMRT Operation Control Center (OCC). Subsequent alarms were also received including alarms for facility power substation instantaneous overcurrent and DC circuit breaker feeder tripping (the third rail, 750-volt voltage) for the northbound track between Feng-le Park Station and Daqing Station (towards Beitun Main Station). At 1227:10, the third rail power system of the northbound track between Feng-le Park Station and Daqing Station reclosed automatically, and power was restored at 1227:11. The third rail of the southbound track where the train was located had not been affected by scattered objects and no power outage had been caused.

At 1227:19, the train attendant heard the departure warning and boarded the train. At 1227:21, the station security guard arrived at the south barrier door of platform 2 to confirm the situation. The station security guard discovered the truss in the track area but was unable to immediately stop the train from leaving the station due to the lack of equipment on the platform for initiating an emergency train stop. At 1227:29, the train departed from Feng-le Park Station. At 1227:31, the station security guard located at the south barrier door and wanted to notify the train attendant to stop the train but his walkie-talkie was unable to communicate with the train attendant's handheld radio. Therefore, the station security guard raised his hands to signal the train attendant to stop the train. However, as TMRT had not established regulations for emergency stop gestures, the train attendant could not understand the meaning of raising hands. The train attendant then proceeded to the front of the train and requested OCC to stop the train immediately at 1227:34 upon discovering the truss in the track area ahead. At the same time, the train attendant was trying to take out the key to open the driving desk cover and press the emergency train stop button but was unable to complete either reporting or opening the

cover. At 1227:46, the train collided with the truss on the track at a speed of 43.7 km/h. At 1227:47, the truss penetrated the car from door 09 on the right side of the operating direction of car no. 04, struck the passenger sitting on the left side of the car facing the direction of travel, and then penetrated through the left window. The passenger was pushed out of the car and fell into the track area below. At 1227:52, the speed of the train dropped to 0 km/h.

In accordance with the Transportation Occurrences Investigation Act, the Taiwan Transportation Safety Board (TTSB) established an investigation team to conduct investigation and invited a total of 11 agencies (institutions) to participate, including the Ministry of Transportation and Communications, the Railway Bureau of the Ministry of Transportation and Communications, the Occupational Safety and Health Administration of the Ministry of Labor, the Transportation Bureau of Taichung City Government, the Urban Development Bureau of Taichung City Government, the Department of Rapid Transit Systems of Taipei City Government, Taichung Mass Rapid Transit Co., Ltd., Highwealth Construction, Chyi Yuh Construction Co., Ltd., United Machinery International Enterprise Co., Ltd., and Chia Yuan Construction Engineering.

The highlights and analysis contents of the final report include (1) The process and reasons for the truss fracturing from the dismantling crane; (2) Tower crane safety inspection and operating procedures; (3) Review of regulations for aerial lifting operations near traffic hubs; (4) Traffic maintenance plan for construction projects; (5) MRT emergency train stop equipment and authorization; (6) Emergency response mechanism to foreign objects invading MRT track area; (7) The foreign object intrusion

detection mechanism of unmanned driving system; (8) Display design of system alarms in the operation control center; and (9) Analysis of survival factors.

Based on the comprehensive factual report and analyses, the final report presents a total of 18 findings including "related to probable causes", "related to risks" and "others" (see Attachment for details).

The "Findings related to probable causes" and "Findings related to risk" are briefly summarized as follows:

1. **Findings Related to Probable Causes:** To smoothly loosen the root of the tower crane's truss from the rotating base, the operator adjusted the position of the tower crane truss by rotating the dismantling crane truss. During the process, the operator may have lifted the tower crane truss diagonally, causing the hoisting steel cable of the dismantling crane and the lifting point of the tower crane truss to form an angle and exceed the critical angle. Multiple rods of the dismantling crane truss were exposed to a pressure sufficient to bend or buckle, resulting in buckling and fracture. Furthermore, initial plastic deformation occurred at the connection between sections 1 and 2, following which other sections of the truss began to bend and deform until fracture due to buckling finally occurred with the rods in section 4. Part of the truss invaded the TMRT track area and hit the acoustical barrier, resulting in scattered objects. The third rail power outage occurred on the northbound track due to contact with scattered objects. However, when the third rail power system automatically performed line tests, no abnormalities were detected because the scattered objects had bounced away; the power supply therefore resumed and was restored successfully. No third rail power outage occurred on the southbound

track where the train had been located as the track had not been affected by scattered objects; as the train departed from Feng-le Park Station, although the security guard discovered that a truss had invaded the track, he was unable to immediately stop the train from leaving the station because the station platform did not feature equipment for personnel to initiate an emergency train stop. The train attendant had noticed an anomaly on the track, although she immediately notified OCC to stop the train, and tried to use the key to open the driving desk cover and press the emergency stop button, before completing the notification and opening the cover, the train had collided with the truss that had invaded on the track at a speed of 43.7 km/h.

2. **Findings related to risks:** The regulations of Clearance Requirement for Operational Safety of Mass Rapid Transit Systems focus on ensuring only the stability of the MRT system's piers and tracks by construction companies during the foundation excavation process, but not the risk assessment of aerial lifting operations in building construction and fall prevention measures; Construction plans proposed by contractors for architecture or maintenance projects adjacent to important transportation hubs are reviewed individually by central and local agencies, and there is no overall joint review mechanism; Contractors has no detailed operating guidelines for the dismantling of tower cranes to follow; TMRT has not clearly specified an authorization mechanism for emergency train stop, nor has it stipulated brief emergency train stop terminology and post-train inspection procedures.

Based on the findings, TTSB has proposed a total of 6 safety recommendations for improvement (see Attachment for details). United

Machinery and Chia Yuan are recommended to require operators to abide by the Regulations for Safety of Cranes and Hoist Equipment when operating tower cranes for engaging in lifting operations; The Occupational Safety and Health Administration is recommended to establish operating guidelines for tower crane dismantling and provide contractors with standard operating procedures to follow; The Ministry of Transportation and Communications is recommended to revise the regulations of Clearance Requirement for Operational Safety of Mass Rapid Transit Systems and the relevant regulations on construction bans and restrictions near railways, and require contractors engaged in aerial lifting operations near MRT and railways to propose risk assessments and preventive measures for high-risk construction projects; The Taichung City Government is recommended to jointly review construction projects near traffic hubs with relevant administrative units. In response to the intrusion of foreign objects into the driverless driving system, TMRT is recommended to evaluate the establishment of emergency train stop equipment at stations, improve emergency communication terminology and authorization for emergency stopping decisions, so that staff can immediately perform emergency train stop actions in the event of an emergency. Post-occurrence inspection procedures should also be established to confirm whether an individual is trapped or foreign objects have fallen under the train.

The draft for this investigation report underwent preliminary and secondary reviews at board meetings on May 3 and May 20, 2024. The final investigation report was reviewed and approved in the 64th board meeting on June 14.

Attachment

I. Findings

Findings Related to Probable Causes

1. During the disassembling of the tower crane truss, after the operators removed the latch on one side between the root of the truss and the lug plate of the rotating disk, a ratchet wrench was placed in the latch hole to temporarily hold it in place. The operators then removed the latch on the other side from the latch hole, because the handle size of the ratchet wrench was smaller than the diameter of the latch hole, so the root of the truss rose slightly, thus failing to remain parallel to the lug plate and resulting in failure from being successfully loosened. Therefore, the operators adjusted the position of the tower crane truss by rotating the dismantling crane.

2. During the process of rotating the dismantling crane, the operator may have lifted the tower crane truss diagonally, causing the hoisting steel cable of the dismantling crane and the lifting point of the tower crane truss to form an angle and exceed the critical angle. Multiple rods of the dismantling crane truss were exposed to pressure sufficient to bend or buckle, resulting in buckling and fracture. Furthermore, initial plastic deformation occurred at the connection between sections 1 and 2, following which other sections of the truss began to bend and deform until fracture due to buckling finally occurred with the rods in section 4.

3. The tower crane truss fell onto Wenxin South Road after losing the hanging force of the dismantling crane. Part of the truss invaded the TMRT track area and hit the acoustical barrier, resulting in scattered objects. The third rail power outage occurred on the northbound track

due to contact with scattered objects, and multiple power alarms appeared in the PWR SCADA system in the OCC. When the third rail power system automatically performed line tests, no abnormalities were detected because the scattered objects had bounced away; the power supply therefore resumed and was restored successfully. No third rail power outage occurred on the southbound track where the train had been located as the track had not been affected by scattered objects.

4. Although the station security guard at Feng-le Park Station discovered that the truss had invaded the track area, he was unable to immediately stop the train from leaving the station and moving towards the truss intrusion because the station platform did not feature equipment like other railway operators have established for personnel to initiate an emergency train stop.

5. After the train left Feng-le Park Station, the train attendant noticed an anomaly on the track and immediately notified OCC to stop the train and tried to use the key to open the driving desk cover and press the emergencytrainstop button, but before completing the notification and opening the driving desk cover, the train collided with the truss that had invaded the track area at a speed of 43.7 km/h.

Findings Related to Risks

1. The regulations of Clearance Requirement for Operational Safety of Mass Rapid Transit Systems focus on ensuring only the stability of the MRT system's piers and tracks during the foundation excavation process performed by construction companies, but not the risk assessment of aerial lifting operations in building construction and fall prevention measures. Therefore, it is not conducive to fully identifying the risks that may harm the operation of the mass rapid transit system during the

construction process.

2. Construction plans proposed by contractors for architecture or maintenance projects adjacent to important transportation hubs are reviewed individually by central and local agencies such as construction management, occupational safety, and traffic management. There is no overall joint review mechanism, which is not conducive to comprehensively evaluating the risks that construction operations may cause to the operation of the MRT system or road traffic.
3. The detailed procedures of tower crane dismantling operations, such as the temporary holding method for the truss after the latches are removed and the method of adjusting the truss's position, are not explained in the manufacturer's operating manual. There are no relevant domestic specifications or guidelines to follow, which may easily cause contractors to operate based on experience and ultimately lead to unwanted occurrences.
4. TMRT does not clearly specify that train attendants, station masters, and OCC engineers may execute an emergency train stop immediately without authorization in the event of emergencies. As a result, staff tend to be conservative in their decisions on whether to initiate an emergency train stop without fully understanding the on-site situation. This is not conducive to the immediate execution of an emergency train stop.
5. TMRT has not established emergency train stop communication terminology that is short and succinct and can immediately catch the recipient's attention. As a result, when an emergency occurs, the train attendant still uses general communication terminology to report, which is not conducive to the immediate expression of the need to execute an emergency train stop.
6. TMRT does not explicitly stipulate that post-occurrence train inspection

procedures should include confirming if there is any individual trapped under the train. As a result, the passenger who fell into the track area under car No. 4 was not immediately discovered.

Other Findings

1. According to the results of the material test analysis, the material of the dismantling crane truss complies with specifications, and its chemical composition, mechanical properties, and metallographic structure exhibit no obvious abnormalities. Therefore, the material factors can be excluded from the probable causes for buckling and fracture of the truss.
2. When the station master discovered smoke in the track area, he immediately notified OCC. However, the radio channel may have already been occupied by the train attendant communicating with OCC, and the station master may not have used the emergency call function, thus failing to obtain top communication priority for notifying OCC.
3. Although many power system alarms appeared in the PWR SCADA system in the OCC, most were overcurrent on the third rail of the northbound track and abnormality of station equipment. The power system for the third rail of the northbound track automatically performed line tests and restored the power supply after no abnormality was detected. As the power supply for the third rail of both the northbound and southbound tracks had been normal, and the relevant power alarms had been mostly related to station equipment's abnormality, OCC had no way of knowing that a foreign object had invaded the track area merely through power alarm contents.
4. The driving desk is not designed to be used when the train is driven automatically by the system and is therefore usually locked. Although the train was driven automatically by the system at the time of the occurrence, the train attendant still tried to use the key to open the

driving desk cover and press the emergency stop button when she noticed something unusual on the track. However, according to a practical test performed by the investigation team, it generally takes about 15 to 16 seconds for train attendants who have completed the training to complete the entire process of opening the cover and pressing the emergency trainstop button. On the day of the occurrence, only 12 seconds between the time the train attendant discovered the truss on the track and the time the train collided with the truss, which was not enough for the train attendant to open the cover and press the emergency stop button.

5. When the tower crane truss invaded the TMRT track area, as the train obstacle detection device had not yet collided with the truss, the ATS SCADA in the OCC did not issue any obstacle detection alarm. Without receiving a system alarm and a report from on-site staff, the OCC depot controller was unable to know whether there was a foreign object in the track area and immediately initiated an emergency train stop.

6. Although TMRT is equipped with relevant equipment that can stop trains from operation, given the circumstances of the occurrence, there is no other way to stop the train from departing the station other than taking advantage of the safety design feature that trains are not able to operate if the platform door is not closed. Furthermore, stopping the train from operation using the safety design feature is not a method included in daily operations. TMRT also did not provide the station security guard the training on the platform door system knowledge and had not yet established relevant standard operating procedures before the occurrence, making it difficult to require the station security guard to stop the train from leaving the station on the day of the occurrence by using this method.

7. Regarding the text size and text/background color contrast of the alarm display panel and alarm content presentation of the ATS SCADA, as well as the alarm classification for various levels of the alarm displays of the PWR SCADA system in OCC, design principles and recommendations for well-designed display interfaces should be duly considered. This will enhance OCC engineers' awareness of alarm information and reduce their cognitive load and response time when taking emergency action.

II. Safety Recommendations

Interim Operation Safety Bulletin

On May 30, 2023, TTSB issued the following interim operation safety bulletin made during the investigation period to the Ministry of Transportation and Communications, the Railway Bureau of the Ministry of Transportation and Communications, the Transportation Bureau of Taipei City Government, the Transportation Bureau of New Taipei City Government, the Transportation Bureau of Taoyuan City Government, the Transportation Bureau of Taichung City Government, the Transportation Bureau of Kaohsiung City Government, Taipei Rapid Transit Corporation, New Taipei Metro Corporation, Taoyuan Metro Corporation, Taichung Mass Rapid Transit Corporation, and Kaohsiung Rapid Transit Corporation.

1. It is recommended that the central and local competent authorities establish more rigorous management regulations for construction operations that may affect mass rapid transit operations' safety, supervise contractors to conduct independent inspections and implement supervisory actions.

2. It is recommended that operators of driverless rapid transit systems formulate early warning and response measures for foreign objects invading the track area to assist frontline staff in immediate response. Moreover, the supervisory authority requires operators to evaluate the feasibility of installing an active foreign object intrusion detection system to avoid dangerous occurrences caused by trains colliding with foreign objects.

To United Machinery International Enterprise Co., Ltd.

1. Require operators to abide by the "Regulations for Safety of Cranes and Hoist Equipment" when operating tower cranes, prohibit engaging in lifting operations in improper ways such as shaking or pulling objects, or lifting objects at an angle, which may cause truss to buckle and break due to improper stress.

To Chia Yuan Construction Engineering

1. Require the onsite conductor of lifting operations to remind dismantling machine operators not to engage in lifting operations in improper ways such as shaking or dragging objects.

To the Occupational Safety and Health Administration, Ministry of Labor

1. Establish guidelines for tower crane dismantling operations, thus enabling contractors to establish standard operating procedures in accordance with the guidelines and avoid risks such as using improper auxiliary tools or applying improper operations based on experience.

To the Ministry of Transportation and Communications

1. Review or revise the regulations of “Clearance Requirement for Operational Safety of Mass Rapid Transit Systems” and the relevant regulations on construction bans and restrictions near railways; regulate contractors engaged in aerial lifting operations near mass rapid transit systems and railways; and propose risk assessments and preventive measures for high-risk construction projects to maintain railway operation safety.

To Taichung City Government

1. Establish a joint review mechanism for construction operations near traffic hubs, with construction management, occupational safety, traffic management, and operating agencies jointly participating in the review to facilitate the identification of hazard risks that may affect traffic safety.

To Taichung Mass Rapid Transit Corporation

1. Review relevant emergency train stop equipment and specifications as well as standard operation regulations, including:(1) Evaluate the establishment of emergency train stop equipment at stations (2) Establish brief emergency train stop communication terminology (3) Clearly standardize the authorization of emergency train stop decisions enabling staff immediately to perform emergency train stop in an emergency (4) Clearly define post-occurrence train inspection procedures to confirm whether individual is trapped or foreign objects have fallen under the train.

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