【招待論文】

Railway Accident Investigation Status and Issues in Taiwan

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SUMMARY

In addition to damage to facilities, interruption of routes, and inconvenience to passengers, railway accidents are likely to cause serious injuries and threaten life and property. We should make every effort to prevent these unpleasant events. More importantly, lessons should be learnt from every accident to identify the mistakes and make improvements to prevent the same tragedy from happening again. This study reviews the history of railway accident investigation in Taiwan and the current status of accident investigation mechanisms for different railway/metro systems, such as conventional railway, high-speed rail, and metro systems. We compare and discuss representative accidents at different stages to demonstrate the variances in investigation body, independence, resources, quality, and countermeasures. The investigation quality and resources for railway accidents have remarkably improved over time, but further enhancements are needed to resolve issues in the current mechanism. Existing issues are presented at the end of the article to provide further improvements in the railway accident investigations in Taiwan.

Key words

accident investigation, railway system, Taiwan railway

1. INTRODUCTION

Railway assumes substantial responsibility for transportation due to its much stronger transportation capabilities than other types of road transportation. Moreover, its safety issues are at stake for the lives of civilians. Therefore, safety should be the top priority for the authority and operators. Although the "Railway Act (鐵路法)" and "The Mass Rapid Transit Act (大眾捷運法)" in Taiwan have a number of regulations and requirements on the safe organization, personnel, equipment, and operating procedures of railway and metro operators, the causes that lead to accidents are often unpredictable. Thus, totally preventing accidents or unusual events is unlikely, and accident investigation is particularly important.

How to analyze the entire accident process systematically, clarify factors at different aspects, integrate relevant information to deduce the causes of the accident, and finally compile it into recommendations to provide improvement directions for operation and supervision are all efforts that must be taken to prevent the same or similar tragedies from happening again. According to the accident statistics of Taiwan Railway (TR), conventional railway in Taiwan (see Figure 1)[1], although the average accident rate in the past 30 years has generally shown a downward trend, dropping from 34.74 in 1990 to 15.29 in 2021 (reaching a minimum of 11.01 in 2017), a slight increase has been observed since 2018. In 2021, the railway accident rate of TR was still 35 times higher than that in Japan (at 0.43)[2]. Apparently, a large room for improvement exists in Taiwan.

The construction of new railway/metro systems is a highly popular option for the government to promote public transportation in Taiwan, so various types of railway/metro systems exist or are proposed over the country. These systems can be divided into two categories in accordance with the applicable laws and regulations, namely, railway systems and metro systems. The former refers to the conventional railway, TR operated by Taiwan Railways Administration (TRA), Taiwan High Speed Rail operated by Taiwan High Speed Rail Company (THSRC), Alishan Forest Railway operated by Forestry Bureau, and Sugar Railways operated by Taiwan Sugar Corporation. The latter includes all metro systems, such as Taipei Metro operated by Taipei Rapid Transit Corporation, Taoyuan Metro operated by Taoyuan Metro Corporation, Taichung Metro operated by Taichung Mass Rapid Transit Corporation, and Kaohsiung Metro operated by Kaohsiung Rapid Transit Corporation. Among these systems, TR is the longest railway system in Taiwan (with rail line circling around the Taiwan island). It has the longest operating route mileage and

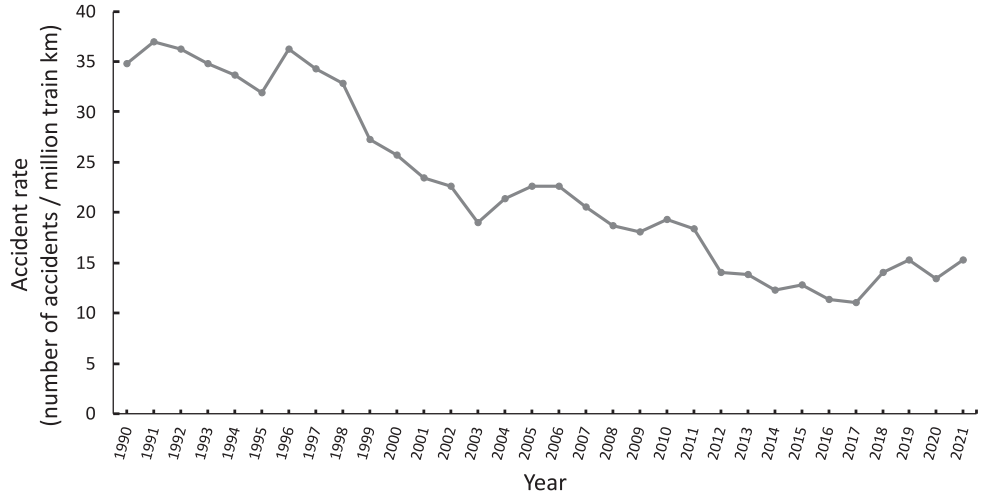

Figure 1　Accident rate of TR

shoulders the responsibility for intercity and commuter transportation at the same time. The average daily ridership before the epidemic was nearly 650,000 people in 2019. However, TR is also the most problematic railway in Taiwan which causes the majority of railway accidents: 96.4% of the total number of railway/metro accidents (702 out of 728) in 2021 were from TR. Two serious fatal railway accidents also happened in the past five years. On October 21, 2018, Puyuma Express train number 6432 derailed and overturned while passing through Xinma Station on the Yilan Line, resulted in 18 deaths and 215 injuries. On April 2, 2021, Taroko Express train number 408 hit an engineering vehicle that intruded into the route, causing train derailment, resulted in 49 deaths and 213 injuries.

Before the overspeed and derailment accident of the Puyuma Express train in 2018, Taiwan did not have an independent railway accident investigation body. Taking TRA as an example, for a long time in the past, accident investigations were conducted by Railway Safety Committee (RSC) within TRA. Whether the investigation results could really identify the problem and whether it was fair were always questionable when such inquiries were conducted by internal departments. Right after the Puyuma Express train accident in 2018, Executive Yuan, the highest administrative organ in Taiwan, set up an independent special investigation for the first time and completed the report within two months. One of the follow-up improvement recommendations for the accident was to establish a Taiwan Transportation Safety Board (TTSB). The formal amendment to the law was completed, and TTSB was established in 2019. The Taroko Express train derailment in 2021 was investigated by TTSB, and a complete accident investigation report was made one year later.

This study aims to compare and consider railway accident investigation mechanisms at different stages over time. Through a unified discussion of accident investigation agency and accident investigation reports, current and past accident investigation situations are summarized to identify existing issues and examine if further improvements can be made.

2. RAILWAY/METRO SYSTEMS IN TAIWAN

As mentioned above, quite a few different types of railway/metro systems exist in Taiwan. In 2022, nine different railway/metro operators are in charge of 10 systems (Figure 2). These systems can be divided into two categories in accordance with the applicable supervision laws and regulations – railway systems (regulated by "Railway Act") and metro systems (regulated by "The Mass Rapid Transit Act"). They can also be divided into five different types according to the characteristics of its operation: (1) conventional railway, such as TR; (2) high-speed rail (HSR), such as THSR; (3) industrial railway, such as Forest Railway or Sugar Railway; (4) metro system with exclusive right-of-way, such as Taipei Metro; and (5) metro system with non-exclusive right-of-way, such as Kaohsiung LRT in Figure 2.

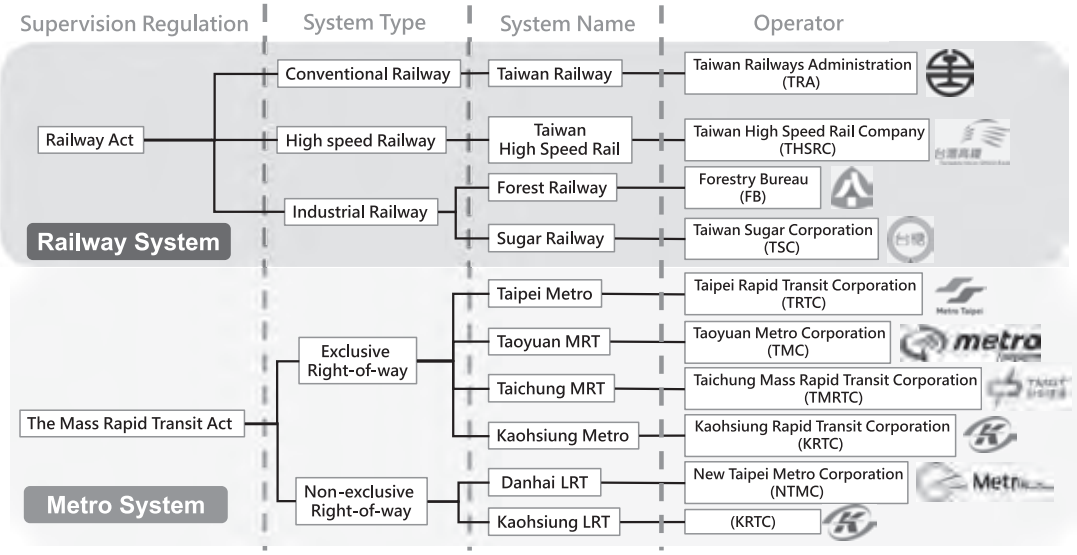

Figure 2　Railway/Metro systems in Taiwan

3. HISTORY OF RAILWAY ACCIDENT INVESTIGATION IN TAIWAN

With the evolution of the government's organizational structure and related laws, the investigation body may be a unit within the railway operators, oversight agencies, or external independent investigation agencies. This section explains the evolution of the relationship between the operating units, supervisory units, and main accident investigation units at the five different stages in Taiwan.

3.1　First Stage (1978–2006)

At the first stage (1978–2006), TR was the only railway in Taiwan. The relationship between oversight agencies, railway operators, and investigation body is illustrated in Figure 3. TR has long been responsible for intercity and commuter trips on the western trunk line as well as connecting the eastern region of Taiwan through the South-Link Line and North-Link Line. As the most important railway system at that time in Taiwan, all accident investigations were carried out by RSC within TRA[3]. The investigators from the RSC were all employees of TRA, and their roles in RSC were only part time. In this way, the operating units conducted their own investigations with limited resources and manpower. Whether it was fair and could really identify the actual causes were questionable[4].

Besides the railway system, accidents of the Taipei Metro, the only metro system in Taiwan at that time, were all investigated by RSC of TRTC, the metro operator.

3.2　Second Stage (2007–2014)

At the second stage (2007–2014), TR still conducted accident investigations by itself (RSC), whereas accidents of THSR were investigated by the High Speed Rail Accident Investigation Team (HSRAIT), which was organized by the Ministry of Transportation

and Communication (MOTC). The relationship between oversight agencies, railway operators, and investigation body is illustrated in Figure 4. Since the start of HSR operations in 2007, the Bureau of High Speed Rail (BOHSR) under MOTC has supervised HSR operations. To promote safety, MOTC formulated the "Establishment and the Operation Directions for HSRAIT（高速鐵路行車事故處理小組設置與作業要點)" and established HSRAIT to investigate serious operational accidents for HSR. The main task of the team was to investigate the causes of HSR accidents and propose suggestions for improvement as well as liability appraisal for accident damage compensation and subsidies. HSRAIT had a chair-

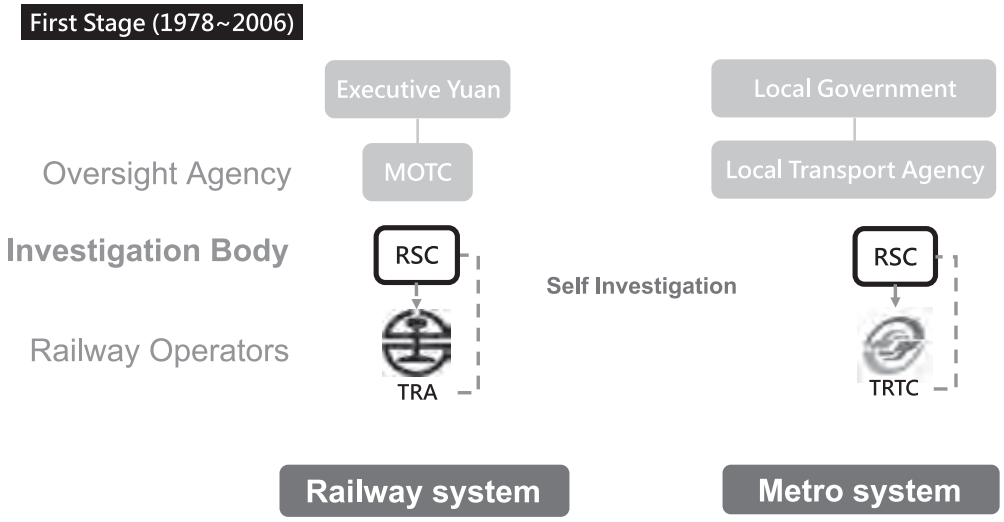

Figure 3　Illustration of the relationship at the first stage

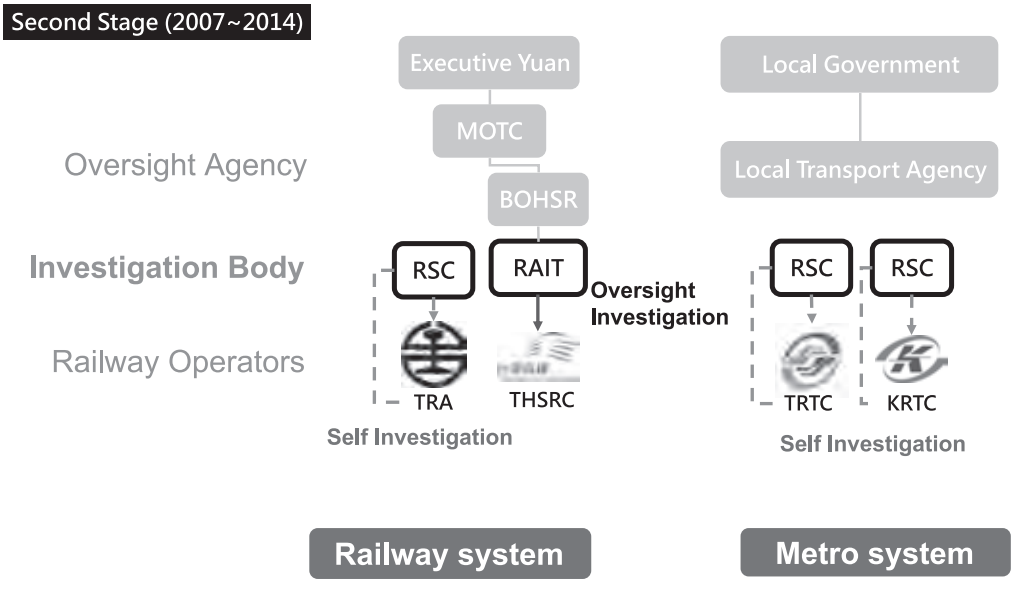

Figure 4　Illustration of the relationship at the second stage

man, who was appointed by the Director of Department of Railways and Highways or the Minister of MOTC, and the other members (10 in total), who were experts from railway operations, civil engineering, mechanical and electrical engineering, and law, were appointed by MOTC. After MOTC received the notification of a major HSR accident, it immediately notified the chairman to assign a committee member to serve as the project investigator to investigate the cause of the accident. After completing the investigation, the project investigator completes a draft report of the accident. The handling team held a meeting for review and adjusted the content of the draft report according to the review comments. Finally, when the accident report was completed, the handling team reported it to MOTC for approval. The MOTC may, when necessary, send the report to the relevant agencies for reference in the judgment of liability for the accident.

Regarding the metro systems, the investigation mechanism had no change from the first stage to the second stage.

3.3　Third Stage (2015–2018)

At the third stage (2015–2018), HSRAIT was modified in to Railway Accident Investigation Team (RAIT). Accidents of all railway systems, including HSR, TR, Forest Railway, and Sugar Railway were all investigated by RAIT. The relationship between oversight agencies, railway operators, and investigation body is illustrated in Figure 5. Since 2015, in response to the revision of the Railway Law, the MOTC has formulated the "Operation Directions for the MOTC to Investigate Major Railway Accidents (交通部調查鐵路重大事故作業要點)". In addition to HSR, other railway systems have been included in the scope of the investigation. The way to investigate major accidents was mainly to hold a review meeting every two months

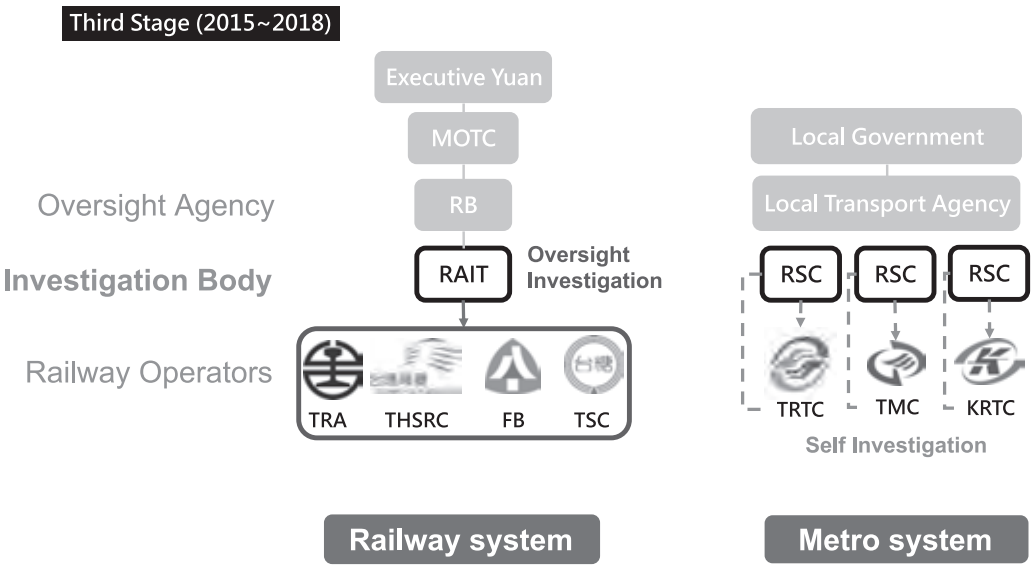

Figure 5　Illustration of the relationship at the third stage

and invite committee members to review the major accident investigation results. The members of railway agencies/operators participated, reported the cause of major accidents, and accepted the inquiries of the committee members. When a major operational accident occurs, depending on the needs of the case, the MOTC may select several committee members to conduct a special investigation with the "Railway Operation Supervision Team（鐵路營運監理小組）" of MOTC and report the results to the review meeting. Experts appointed by MOTC were divided into regular committee members and project committee members. Regular committee members was mainly appointed by MOTC from experts and scholars in railway operations, civil engineering, mechanical engineering, and electrical engineering as well as by relevant specialists from relevant units or subordinate agencies within MOTC.

Project committee members were additional experts that could be appointed due to the needs of individual cases. During the investigation, the railway agency must submit the operational accident report before the deadline and provide relevant data and items such as operation records, facilities, and equipment. The relevant operational personnel must also cooperate in the explanation. After the investigation was completed, a report was made on the findings of the investigation. Moreover, the matters to be improved were proposed, and the railway agency was required to make improvements. Afterward, to improve railway safety, in 2016, the scope of the investigation was expanded, including other operational accidents and abnormal events deemed necessary for investigation by MOTC.

In 2018, to further improve the independence of the special investigation unit for railway accidents, the "Operation Directions for the MOTC to Investigate Major Railway Accidents" was revised and renamed as "Operation Directions of the RAIT of the MOTC（交通部鐵路行車事故調查小組作業要點）", and these professional investigators appointed by MOTC were officially called the RAIT.

Regarding the metro systems, the investigation mechanism still had no change from the second stage to the third stage.

3.4 Fourth Stage (2018 Puyuma Accident)

The fourth stage was right after the overspeed derailment accident of the Puyuma Express trains on October 21, 2018. Executive Yuan formed a special investigation team for this particular accident. The idea was that this investigation team was independent from the MOTC, which was the first time for railway accident investigations conducted outside the MOTC. The relationship between oversight agencies, railway operators, and investigation body is illustrated in Figure 6. At 4 : 50 p.m. on October 21, 2018, Puyuma Express train number 6432 derailed at Xinma Station, Su'ao Town, TR Yilan Line. The next day (October 22), Executive Yuan immediately instructed the establishment of a 15-member team to investigate the cause of the accident as soon as possible. Members mainly included experts and scholars with backgrounds in civil engineering, mechanical engineering, electrical

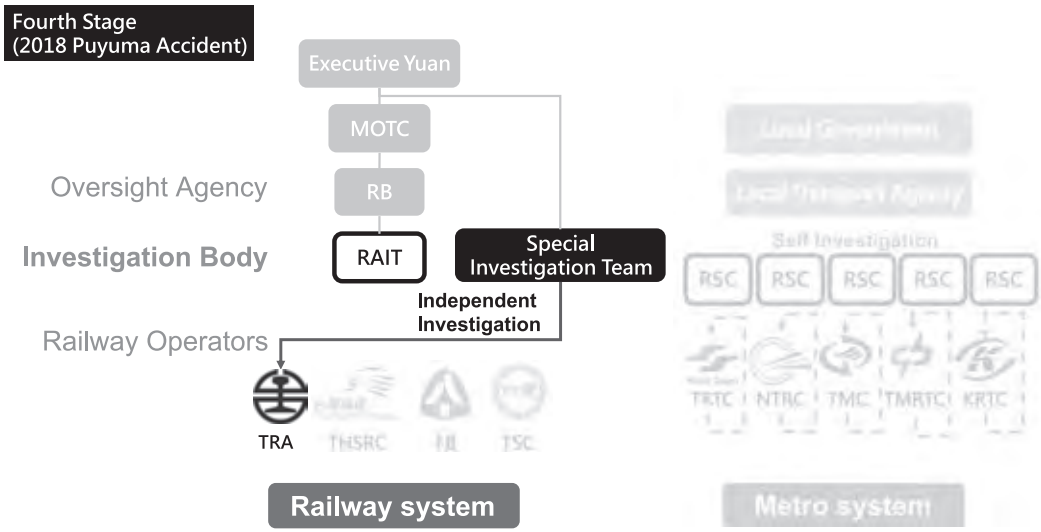

Figure 6　Illustration of the relationship at the fourth stage

engineering, and railway safety. The investigation team held a press conference on November 26 to announce the preliminary investigation results and then continued in-depth discussions. After a number of on-site investigations, working meetings, interviews with TR personnel, interviews with Puyuma Express train manufacturers, and related tests and rolling stock simulations, the "Accident Investigation Facts, Causes and Problems and Improvement Proposal Report" was published two months later on December 21.

Regarding the metro systems, the investigation mechanism still had no change.

3.5　Fifth Stage (2019-Now)

At the fifth stage (2019-present), TTSB is responsible for the safety investigation of all major transportation accidents in Taiwan, including road transport, railway and metro systems. The relationship between oversight agencies, railway operators, and investigation body is illustrated in Figure 7. TTSB is an independent agency of the Executive Yuan, formerly named as the Aviation Safety Council (ASC). It is responsible for the independent investigation of aviation accidents to promote aviation safety. In the past, relevant discussions were made about reorganizing the ASC to a national transport accident investigation unit, including other transport systems, similar to the National Transportation Safety Board (NTSB) of the USA and the Japan Transport Safety Board (JTSB) of Japan. Owing to the derailment accident of the Puyuma Express train in 2018, the public formed a consensus and accelerated the promotion of amendment. At the beginning of 2019, Legislative Yuan passed the amendment of "The Organization Act of the Taiwan Transportation Safety Board (國家運輸安全調查委員會組織法)" and "Transportation Occurrences Investigation Act (運輸事故調查法)." ASC was officially restructured into TTSB, with members appointed by the Premier for a four-year term and who can be re-elected when the term expires. The

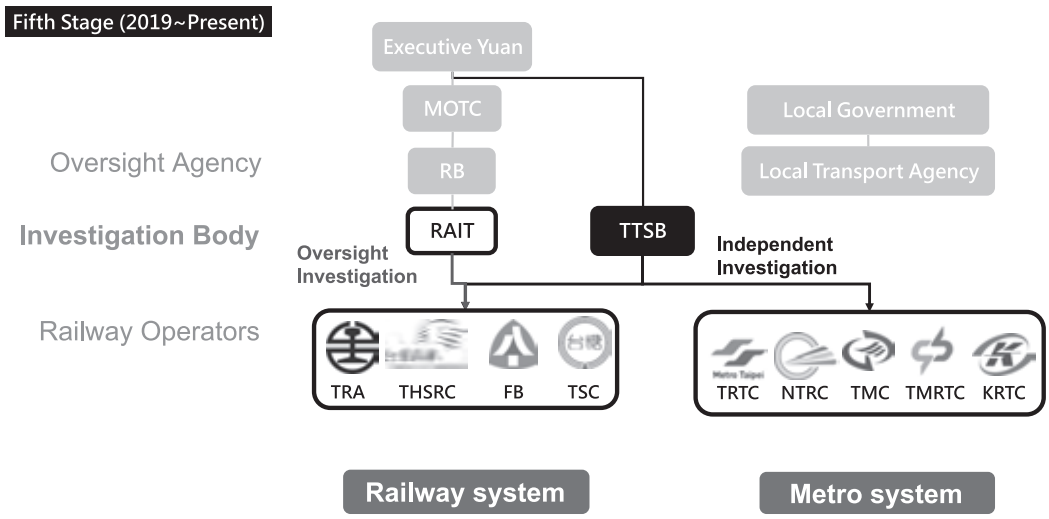

Figure 7　Illustration of the relationship in the fifth stage

purpose of TTSB is to investigate major transport accidents independently and impartially for air, rail, water, and road to promote transport safety. According to the Transportation Occurrences Investigation Act, the main task of TTSB is to designate a member as the chief investigator, who will convene an investigation team to be fully responsible for directing the investigation, when a major transportation accident occurs in the country, and invite representatives of relevant agencies and experts to participate. During the investigation, TTSB may prioritize the preservation and processing of other materials related to the accident as it is necessary for the investigation of the accident. The investigation team may also interview relevant personnel. The interviewee shall not refuse without justifiable reasons and shall state the facts truthfully. After the completion of the investigation, the investigation team of TTSB shall write a draft report on the investigation of the accidents, and send it to the domestic and foreign agencies involved in the investigation and the agencies under investigation. The investigation report shall be released after deliberation, revision, and approval by the committee meeting of TTSB.

4. REPRESENTATIVE ACCIDENTS AND THEIR INVESTIGATIONS FOR EACH STAGE

To demonstrate the variances of accident investigation at different stages, one representative accident is selected for each stage. In addition to explaining the situation and course of the accident briefly, analysis is performed in the aspect of investigation body, independence, resources, quality, and recommendation.

4. 1　First Stage: 1991 Taiwan Railway Accident in Zaoqiao（1991 Zaoqiao Accident）

At 4：00 pm on November 15, 1991, the southbound Chu-Kuang Express train number 1 was entering the loop of number 134 signal station to prepare to meet the northbound

Tze-Chiang Limited Express train number 1006. When train number 1006 (with failures in ATS/ATW system) entered number 134 signal station, the driver seemed to see the home signal indicating a green light. In addition, the sight was blocked due to the curve in the station. The driver of train number 1006 had no time to slow down when he saw train number 1. It finally resulted in a side collision, and part of these two trains derailed and overturned. Thirty passengers were killed and 112 passengers were injured in this accident[5]. Figure 8 shows the illustration of this accident.

The RSC of TRA launched an investigation, a self-investigation, and completed the investigation report on November 28, 1991 (Figure 3). The investigation lasted about two weeks, and the length of report was only three pages. Interviews with the drivers, conductors, and other related personnel of the two trains were first conducted. To confirm the status displayed by the signal, RSC performed the following actions: (1) collect the driving recorder and operation recorder of the dispatching center; (2) check the maintenance records related to the signal; and (3) on-site test. At the end, the possibility of incorrect signal display was ruled out, and RSC concluded that the cause of the accident was the driver of train number 1006 misjudged the signal aspect of the home signal of signal station number 134. Consequently, train number 1006 failed to stop and collided with the rear of train number 1, which had not fully entered the loop. However, RSC did not propose any recommendation against this accident.

4. 2　Second Stage: 2007 Collision Accident on Mainline for TRA's Train Numbers 3902 and 2719 at Dali Station (2007 Dali Accident)

On June 15, 2007, the driver of train number 3092 bound for Qidu Station from Toucheng Station operated the train by isolating the automatic train protection (ATP) system (i.e., turned off the ATP system). After the train passed through Guishan Station, the driver neglected the first block signal indicating "caution" between Guishan and Dali Station, which means it should slow down to 60 (km/h). He continued to drive at a speed of about 90 (km/h) until he saw the home signal of Dali Station indicating "stop" and started to apply the emergency brake. Although the driver of train number 2719 tried to alarm when he discovered that train number 3902 was approaching at high speed, it was too late

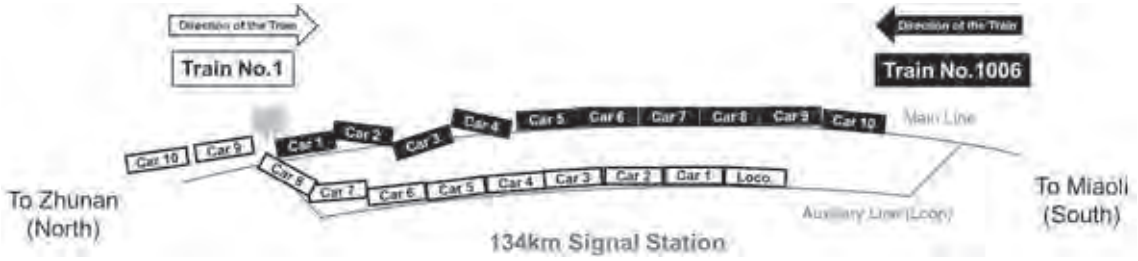

Figure 8　The illustration of 1991 Zaoqiao Accident

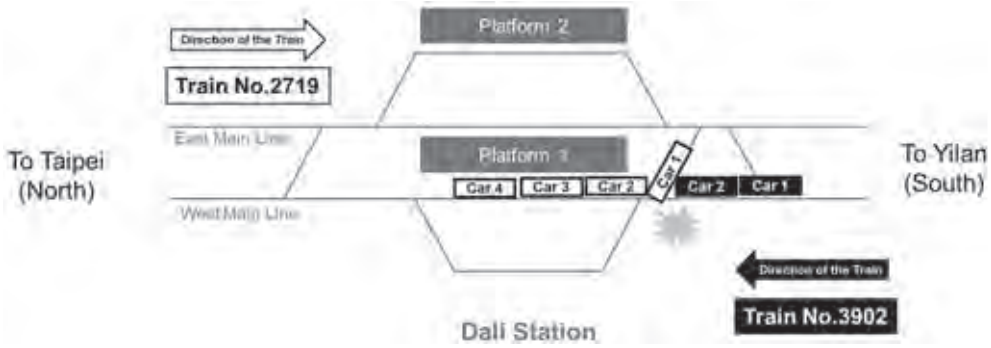

Figure 9　The illustration of 2007 Dali Accident

to avoid the side collision. Five passengers on train number 2719 were killed, and 17 people were injured[6]. Figure 9 shows the illustration of this accident.

The investigation of the accident was again conducted by RSC of TRA because it is not an accident of HSR. The investigation lasted only three days, and the length of report was about four pages, and its content mainly focused on equipment, signal and ATP system, and human operation. The investigation found that the ATP of train number 3902 was turned off soon after departing from Dali Station. All the signals at the accident scene were normal. The driver of number 3902 recklessly turned off the ATP system, did not report to the dispatching center in accordance with the "standard operating procedures for ATP failures," and neglected to pay attention to the home signal of Dali Station. Both the repeating signal and home signal showed the red sign, the driver still entered Dali Station, causing a side collision with train number 2719. The accident report clearly stated that the responsibility for the accident lied with the driver of train number 3902 train, and a decision to punish the relevant dereliction of duty was made. At the end of the report, two preventive measures were proposed by RSC: (1) ATP training operation: Drivers should operate ATP complying with related standard operating procedures. (2) Driver education and training: Drivers are strictly required to abide by the signs and should pay attention to the signal aspect until passing it.

4. 3　Third Stage: 2017 Derailment Accident on Mainline for TRA's Train Number 431 at Sanmin Station (2017 Sanmin Accident)

On October 24, 2017, train number 431 was bound for Hualien from Yuli. It entered Sanmin Station according to the home signal indicating the "slow speed (25 km/hr)". It planned to arrive at the fourth track (loop) and met train numbers 324 (on the main line–second track) and 4637 refuging for train number 431 on the third track (loop). At 16: 25, train number 431 passed the number 18 switch. The driver of train number 431 noticed the abnormally pulling forces. At the same time, the driver of train number 324 was notified of the abnormality of the rear end of the train. As a result, the driver of train number 431 stopped the train immediately.

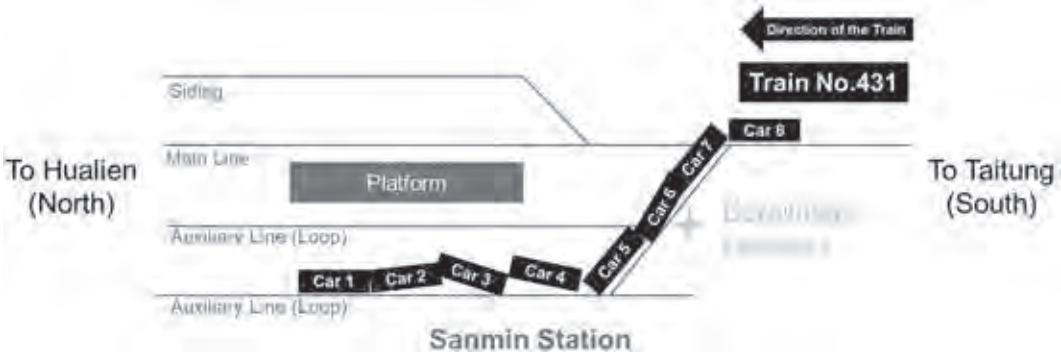

Figure 10　The illustration of 2017 Sanmin Accident

However, the second to sixth cars derailed, and the rear end of the train stopped at the location of the fouling point between the third and fourth tracks, which blocked the route between Sanmin and Yuli Station[7]. Figure 10 shows the illustration of this accident.

According to the Railway Act, the RAIT, which is organized by MOTC, and the railway operation supervision team (11 investigators) conducted the oversight investigation. Then, the investigation results were confirmed, and the investigation report was completed on January 24, 2018. The investigation lasted about three months, and the length of report was about 45 pages. The investigation report contents included environment (temperature, rainfall, and slope), track (configuration and design, alignment of the accident section, and maintenance status), sleepers (deterioration and replacement status), vehicles (wheel status, maintenance records), personnel (background, training records, communication records, and interviews), and train operations (speed and deceleration data). The cause of the derailment involved composite factors such as track alignment, the status of sleepers and spikes, and rail structure, and an external research team was commissioned to conduct mechanical research and analysis. The direct cause of the accident was concluded as follows: The sleepers caused insufficient pulling force of the spikes, which led to the train derailing at normal speed. In addition, the report identified a number of indirect reasons: (1) The criteria for judging the replacement of sleepers are not specified. (2) The track inspection standards are not comprehensive. (3) The standard operating procedures cannot be implemented. (4) The materials are not properly dispatched. (5) The experience of on-site personnel is insufficient. (6) The overall safety awareness needs to be strengthened.

4. 4　Fourth Stage: 2018 Derailment Accident on Mainline for TRA's Train Number 6432 at Xinma Station (2018 Puyuma Accident)

The accident occurred at 4 : 50 pm on Sunday, October 21, 2018. Puyuma Express train number 6432 was bound for Taitung Station from Shulin Station. The accident occurred in Xinma Station (the train was scheduled to pass through this station). The driver of train number 6432 was driving and troubleshooting simultaneously, and recklessly

turned off the ATP system. Moreover, he did not notice that the speed (141 km/h) had exceeded the speed limit (75 km/h) while the train entered the tight curve with radius 306 m at Xinma Station. The train finally derailed and overturned. In this accident, 18 passengers were killed and 215 were injured[8]. Figure 11 shows the illustration of this accident.

Before the derailment, train 6432 subject to failures of air compressors, power loss, and unintentional stop, the measures taken by the relevant personnel (including the driver, dispatcher, and maintenance crew) could not pinpoint the exact problem and corresponding remedy. At the same time, the driver continued to try to solve the abnormal situation while driving, and did not decelerate in accordance with the regulations before entering the curve in Xinma Station. In addition, the ATP system was isolated, and the ATP remote monitoring function of the Puyuma Express train was not properly installed. All relevant protective measures were not implemented so the accident occurred.

Right after the accident, Executive Yuan set up the "1021 Railway Accident Administrative Investigation Team" (hereinafter referred to as special investigation team), which invited experts in the railway society, relevant public sector entities (including the ASC and RB), and representatives of TR Labor Union. This investigation was an independent investigation outside of the MOTC. The report also stated that the task of the special investigation team is to clarify the facts, summarize the reasons, identify problems, and develop suggestions for improvement to prevent similar accidents recurring, rather than for punishment or accountability.

The investigation lasted about two months, and the length of report was about 114 pages. The investigation contents included rolling stock utilization plan (operation process), track (alignment and maintenance), train (wheel, bogie, air compressor, main reservoir, tilting device, traction device, and braking system), personnel (qualification, management, testing, and training), operating regulations, and climate. In addition to holding working meetings, the special investigation team collected videos of the train operations,

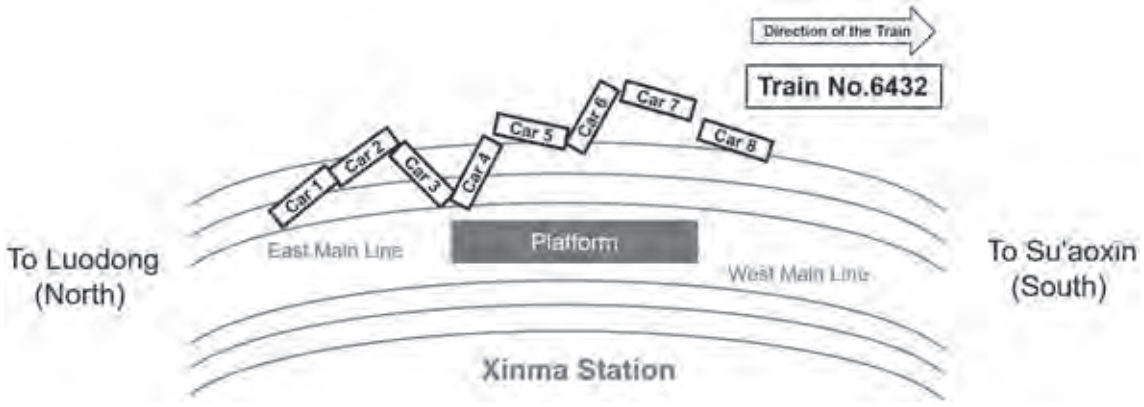

Figure 11　The illustration of 2018 Puyuma Accident

performed track engineering related assessments, calculations, simulations, and driver behavior analysis. Then, they conducted fault tree analysis and Swiss cheese model to carry out causal analysis and countermeasures. Finally, the direct causes were summarized as: (a) the ATP was switched off, (b) the corresponding procedures for switching off the ATP were not effective, and (c) the train did not slowdown in time. The investigation also listed a number of indirect/potential causes, such as poor safety culture, improper driver training, lack of rigorous communication procedures and standardized languages, and lack of rolling stock troubleshooting procedure, etc.

At the end of the report, the special investigation team proposed four immediate improvement suggestions. Overall improvement suggestions were also put forward from five aspects, including organization, equipment, procedures, personnel, and environment, and MOTC and TRA were required to be included them in their follow-up improvement measure.

4.5 Fifth Stage: 2021 Derailment Accident on Mainline for TRA's Train Number 408 at Qingshui Tunnel (2021 Taroko Accident)

On April 2, 2021, TRA Taroko Express train number 408 was bound for Taitung Station from Shulin Station. At about 09:28, the train collided with a large truck on the track (K51 +450.1) right after the train leaving the Heren Tunnel (before entering Qingshui Tunnel). The truck slipped down the side slope and stopped on the track. This accident caused all eight cars of the train to derail, and the left side of eighth car (the front of the train) hit the tunnel entrance and was damaged. It finally caused the train to derail and overturn. In this accident, 49 passengers were killed and 213 were injured[9]. Figure 12 shows the illustration of this accident.

According to Transportation Occurrences Investigation Act, TTSB was responsible for the investigation of the major railway occurrence and completed the investigation report in May 2022. This investigation was an independent examination. The investigation lasted about 13 months, and the length of report was about 243 pages. The investigation contents included vehicles (the train and the truck), weather, personnel, operating scheduling, track, signal, communications, recorders, on-site measurements, organizational management, worksite safety, design of railway tunnel, and interviews with relevant personnel. Finally, the

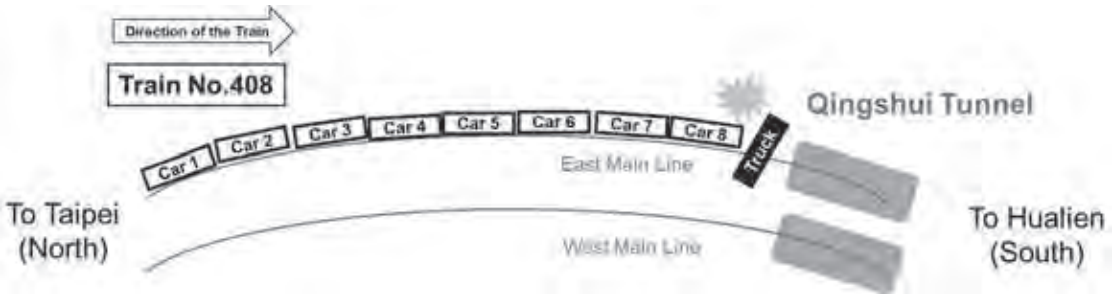

Figure 12　The illustration of 2021 Taroko Accident

direct causes of the accident was summarized as follows: The director of construction site entered the site illegally, and the truck (stopped on the side slope) slipped onto the track due to his operation mistake. He did not carry the radio with him, which prevented reporting in time. After the train driver exited the tunnel, it was unable to prevent the train from colliding with the truck at a speed of 123 km/h.

According to the relevant investigations, three types of investigation findings were proposed:

(1) Investigations related to the possible cause: Important factors related to the accident included unsafe behavior, unsafe conditions, or factors related to the cause of the accident.

(2) Investigation findings related to risks: Potential risk factors affecting railway transportation safety may indirectly lead to the occurrence of this accident.

(3) Other investigation findings: Those findings promote railway safety, resolve disputes, or clarify pending concerns.

A list of safety improvement recommendations were put forward to TRA, MOTC, Construction and Planning Agency, and the Ministry of the Interior and Public Construction Commission.

4.6 Comparison among Accident Reports from Different Stages

Table 1 compares representative accident investigations on investigation body, independence, resources, quality, and countermeasures over five different stages.

Table 1 The comparison of the accident report of the five stages

	1st Stage (1978-2006)	2nd Stage (2007-2014)	3rd Stage (2015-2018)	4th Stage (2018)	5th Stage (2019- Now)
Representative Accident	1911 Zaoqiao Accident	2007 Dali Accident	2017 Sanmin Accident	2018 Puyuma Accident	2021 Taroko Accident
Date	1991.11.15	2007.06.15	2017.10.24	2018.11.21	2021.04.02
Operator	TRA	TRA	TRA	TRA	TRA
Investigation Body	RSC of TRA	RSC of TRA	RAIT	Special Investigation Team of Executive Yuan	TTSB
Independence	Self Investigation	Self Investigation	Oversight Investigation	Independent Investigation	Independent Investigation
Resources-Time	2 weeks	3 days	3 months	2 month	12 months
Resources-Manpower	12-16 (Part-time)	12-16 (Part-time)	8 (Part-time)	15 (Part-time)	9-13 (Full-time)
Resources-Budget	Operator	Operator	Oversight Agency	Executive Yuan	Independent Agency
Quallty-Data Collection	Less	Less	Moderate	Complete	Complete
Quality-Causal Analysis	Direct factors only	Direct factors only	Direct, indirect, and potential factors	Direct, indirect, and potential factors	Direct, indirect, and potential factors
Quallty-Length	3 pages	4 pages	45 pages	114 pages	243 pages
Recommendation (number of Items)	No (0)	Less (5)	Moderate (16)	Complete (26)	Complete, comprehensive, with tracking (22)

(1) Investigation body: The operator of these five representative accidents is TRA, but the investigation body of these reports varies from the internal sector of the operator (RSC for the first and second stages) to the oversight agency (RAIT for the third stage) and the independent investigation body (special investigation team under Executive Yuan for the fourth stage or TTSB for the fifth stage). The trend is to elevate the investigation body from internal investigation to external investigation. Such transition has a substantial effect on the quality and resources of the investigation.

(2) Independence

A railway accident may not always be contributed by the operators; other parties such as an oversight agency may also be involved; hence, keeping parties with conflicting interests out of the accident investigation is important[11]. Self-investigation, from the first and second stages, is performed by railway operators for internal safety management; however, investigators often belong to departments involved in the accidents. Oversight investigation, from the third stage, is performed by an oversight agency based on the responsibilities of safety supervision to propose improvement measures and require the operator to implement them. Although it is outside the operator, some accidents could also be contributed by the policies or negligence set by oversight agencies. Independent investigation, done by the third parties at the fourth and fifth stages, is performed for improving safety, and it sometimes needs oversight agencies to strengthen the supervision action or require other relevant agencies involved in the accident to conduct related improvement. The transition from self-investigation, oversight investigation, to independent investigation is a very important step for the history of railway accident investigation in Taiwan.

(3) Resources

The quality of the investigation is often related to the amount of resources, such as manpower, duration of the investigation, and budget. Except for TTSB at the fifth stage, all manpower for the first four stages are part-time investigators with limited budget (no specific budget for accident investigation) and time (within three months). TTSB has its own dedicated manpower (full-time investigators), specific budget, and sufficient investigation duration guaranteed by the law. This feature is the most distinct difference compared with other mechanisms.

(4) Quality

The quality of an investigation can be seen via the completeness of data collection, causal analysis, and length of the report. Limitation on resources would often constrain the quality of the investigation due to insufficient manpower, time, and budget. The self-investigation from the first and second stages have some-

what simple data collection, brief causal analysis (only discuss direct causes), and very short report (less than four pages). Improvement in investigation quality can be seen from the third stage where the oversight agency starts to perform the investigation. Oversight investigations and independent investigation discuss personal, infrastructure, rolling stock, and environment, eliminate factors unrelated to accidents gradually, and then focus on direct and indirect factors. In particular, for the 2018 Puyuma Express train Accident, manpower and budget were generally sufficient due to the severity of the accident and strong public concerns. The only limitation was time because the investigation team was often pressured by the commitment set by the politicians. Independent investigations were quite complete in the collection and compilation of factual information. The content occupied more than half of the entire investigation report. A comprehensive analysis of the accident from all angles can be conducted only with complete information. With sufficient resources, the data collection, causal analysis, and length of report were all considerably improved from the third to the fifth stages. In addition to direct causes, the identification of indirect and potential causes can further derive corresponding countermeasures.

(5) Recommendation

The results of self-investigation often lack clear improvement recommendations (sometimes even none) and may only attribute the responsibility for the accident; the oversight investigation has "measures to be taken" (directly related to the accident, and should be reviewed and corrected immediately) and "recommended items" (recommended items for review that are not directly related to the accident but help improve safety). Independent investigation (by Executive Yuan) includes "immediate improvement suggestions" (directly related to the accident, should be reviewed and corrected immediately) and "overall improvement suggestions" (proposed potential problems from five levels of organization, equipment, procedures, personnel, and environment, and asks the operator (TRA) and oversight agency (Railway Bureau, RB) to implement those recommended improvements). Independent investigation (by TTSB) proposes "safety improvement suggestions," which are aimed at the institutions involved in the accident, the corresponding oversight agencies, and local competent authority and MOTC, which is the most complete scope of recommendations among all stages.

5. Existing ISSUES

With the understanding of the transitions of railway accident investigation mechanisms over time, this research identifies the following issues requiring further improvements.

(1) Possible Inconsistency from multiple inves-

tigations for an accident by different agencies

For major railway accidents, multiple investigations could be conducted by different agencies simultaneously. In this case, the power and responsibilities of on-site investigation sometimes are confusing, and the ownership of the evidence is unclear. Although the Transportation Occurrences Investigation Act prioritizes TTSB in the investigation, the staff of the operators or oversight agencies usually arrive in the accident scene earlier than TTSB.

In addition, the duration of investigations are different. As mentioned before, TTSB usually takes one year for an investigation, whereas the oversight agency often has to conduct oversight investigations in a few months because they are often pressured by politicians and the government to implement immediate actions and administrative punishments. The results and analysis of the oversight investigation may differ from the investigation results of TTSB due to the dissimilarities in investigation duration. This situation could potentially cause disputes and conflicts later on. Hence, relevant parties should work together to come up with a reasonable process ensuring the consistency of the investigation results, and accident investigations must be kept out of the criminal charges or administrative punishments.

(2) RB's conflicting roles in both railway construction and supervision

RB was formed in 2018 by the merger of the former Railway Reconstruction Bureau (RRB) and the BOHSR. RB inherited the planning, design, and construction tasks of RRB for railway reconstruction projects in the past as well as BOHSR's business of planning, implementing, and supervising the construction of HSR and metro systems. As a result, RB is the construction agency and an oversight agency for TRA simultaneously. When the railway project handled by RB is completed, according to the Railway Act, a joint inspection by construction and operation agencies is required before it can enter the final investigation. At this time, TRA changes its role from an operator to an inspector, resulting in a great contradiction between the power and responsibilities between the two agencies because the long-term cooperation between RRB and TRA in engineering is similar to the relationship in general contracts. Considering the smooth progress of the project, RB is unable to perform the supervision against TRA impartially. (RB also has a cooperative relationship with THSRC, but RB has the power to supervise in the contract originally, so the role of supervision can be continued). Although the Railway Act stipulated that MOTC should investigate the accident caused by the construction of RB, the employees of TRA still think that having a fair investigation is difficult. The Taiwan Railway Labor Union has also

expressed dissatisfaction many times and even boycotted the supervision. Regarding this issue, it is better that the function of railway construction can be removed from RB, so RB can be a dedicated oversight agency for all railway systems, similar to Railway Bureau in Japan.

(3) Lack of oversight investigation for metro systems

Currently, the main oversight agencies of the metro systems in Taiwan are the local transport agencies, and internal RSCs established by each of the metro operators are responsible for the accident investigation. Although the establishment of TTSB has filled the gap in the investigation conducted by independent agencies, it only looks into serious accidents (only very few cases in a year). In addition, metro systems still have no oversight investigation because the local transport agency simply has no resources and expertise to conduct accident inquiries. Although metro systems generally perform well in Taiwan, this gap needs to be filled. One possibility is to extend the oversight structure of RB to cover or support the oversight investigations of metro systems.

(4) Missing RSC's role inside TRA

After the 2018 Puyuma Express train Accident, TRA established a specific department dedicated to safety, the Department of Operational Safety; however, RSC was abolished at the same time. However, the investigation body within the operator can still be independent from the safety department due to conflicts of interests, especially for accidents not investigated by TTSB or the oversight agency, RB. As an operator, it is better to keep a relatively self-governing unit with mechanisms dedicated to independent investigations to prevent the recurrence of accidents in a more comprehensive manner.

(5) Drawback of using the investigation report of TTSB to the verdict

International independent transportation safety investigation agencies (such as NTSB) have relevant regulations stating that their investigation reports shall not be used for judicial judgment. The main reason is that the purpose of safety investigation is to identify possible causes and prevent the recurrence of the same accident, which is different from the purpose of judicial and administrative investigation. However, the current provisions of the Transportation Occurrences Investigation Act in Taiwan enables prosecutors to refer to the investigation report as long as it is not the only source, which may cause the parties concerned to respond with conservative words for fear of being involved in punishment or compensation, resulting in the inability to analyze the true cause of the accident effectively. The integrity of the accident investigation can be further improved by expressly stating in the act that it should

not be used as a judicial decision[4].

(6) Lack of thorough analysis on human factors

Generally, in-depth discussion on "human factors" as well as the safety-related issues such as safety culture and organizational culture, is lacking for the accident investigation in Taiwan. For example, the 2018 Puyuma Express train Accident was investigated twice by the special investigation team of Executive Yuan in 2018[8] and another time by TTSB in 2020[10]. Even with the investigation by TTSB, the analysis of the driver's driving behavior, such as details of the historical behaviors of the driver, general behaviors of other drivers in general, and drivers' behaviors with different trains (hardware/software), was lacking. These elements were covered in the Fukuchiyama Accident Investigation Report from JTSB[11]. Understanding these behaviors can further clarify the indirect and potential causes to propose additional recommendations to improve railway safety through human factors.

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