日本大学生産工学部 鉄道工学リサーチ・センタ 特別シンポジウム
「国際協調による鉄道安全性向上の取り組み」

Railway Accident Investigation and Safety Improvement in Taiwan
台湾における鉄道事故調査と安全性の向上

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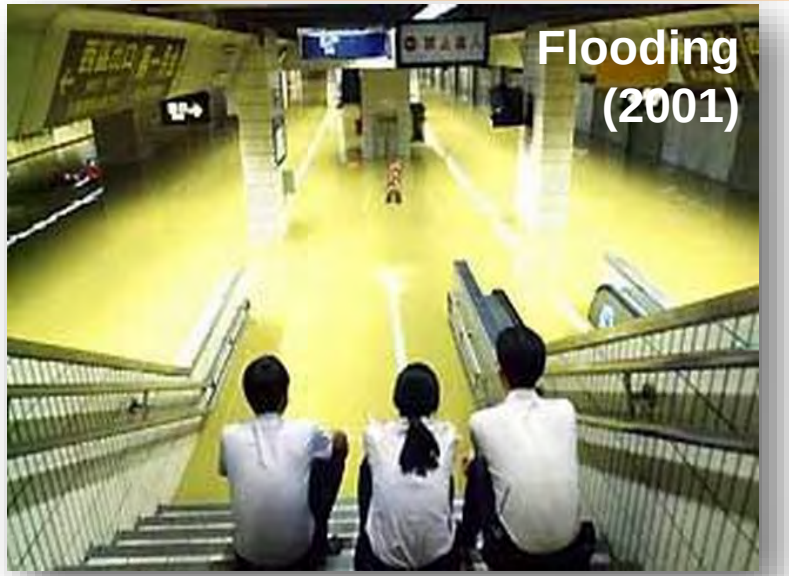
Railway Technology Research Center
National Taiwan University

Learning from accidents is one of the most important ways to improve railway safety!



Relationship among railway related organizations in Taiwan

Highest administrative body

行政院 (Executive Yuan)

交通部 (MOTC)

ASC Aviation Safety Council 飛航安全調查委員會

Oversight Agency

鐵道局 Railway Bureau

RAIT 鐵路行車事故調查小組

Railway Operators

1948.3 TRA

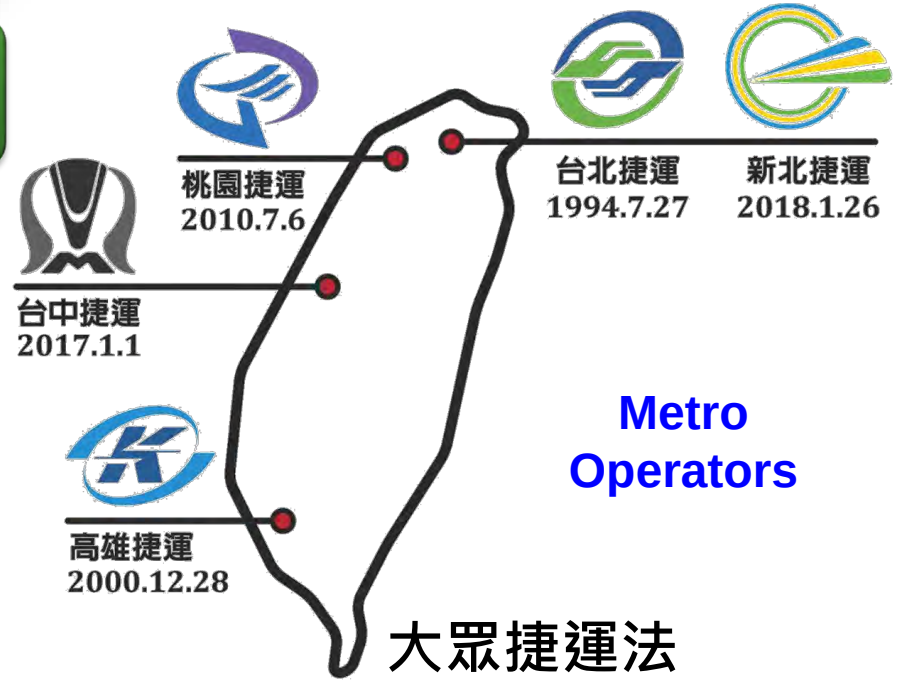
1998.5 台灣高鐵 TAIWAN HIGH SPEED RAIL

鐵路法
Railway Law

交通部 (MOTC)

地方交通局 (Local Transport Agency)

Oversight Agency



Metro Operators

大眾捷運法
Mass Rapid Transit Act

However…

Oct 21st, 2018


Fatality: 18
Injury: 267

The usual way and usual process?

交通部 (MOTC)

鐵道局 Railway Bureau

RAIT
鐵路行車事故調查小組

台灣鐵路

Accident

Investigation by Operational Safety Committee (行保會) within the Operators

Drafting a Investigation Report

Discussion by the RAIT
鐵路行車事故調查小組

Adoption by the RAIT

Action I: Reform ASC to the Transportation Safety Board (TSB)

【檢討普悠瑪】政院5裁示 成立「運安會」獨立調查海陸空大事故

陳彥宇　2018/10/25

© Image1 author　行政院發言人Kolas Yotaka（左1）在政院會後記者會轉述賴清德裁示，政府應痛下決心，全面檢討，避免遺憾再發生。（攝影：李智為）

飛安會轉型運安會 楊宏智：草案已報行政院

陳葦庭　2018/11/7

© 中央社　飛安會轉型運安會 楊宏智：草案已報行政院

Action II: Form a Special Accident Investigation Team (1021鐵路事故行政調查小組) directly under Executive Yuan (行政院)

1021 Accident

Fact-Finding Investigation

Test and Analyses

Discussion on the causes by the Team

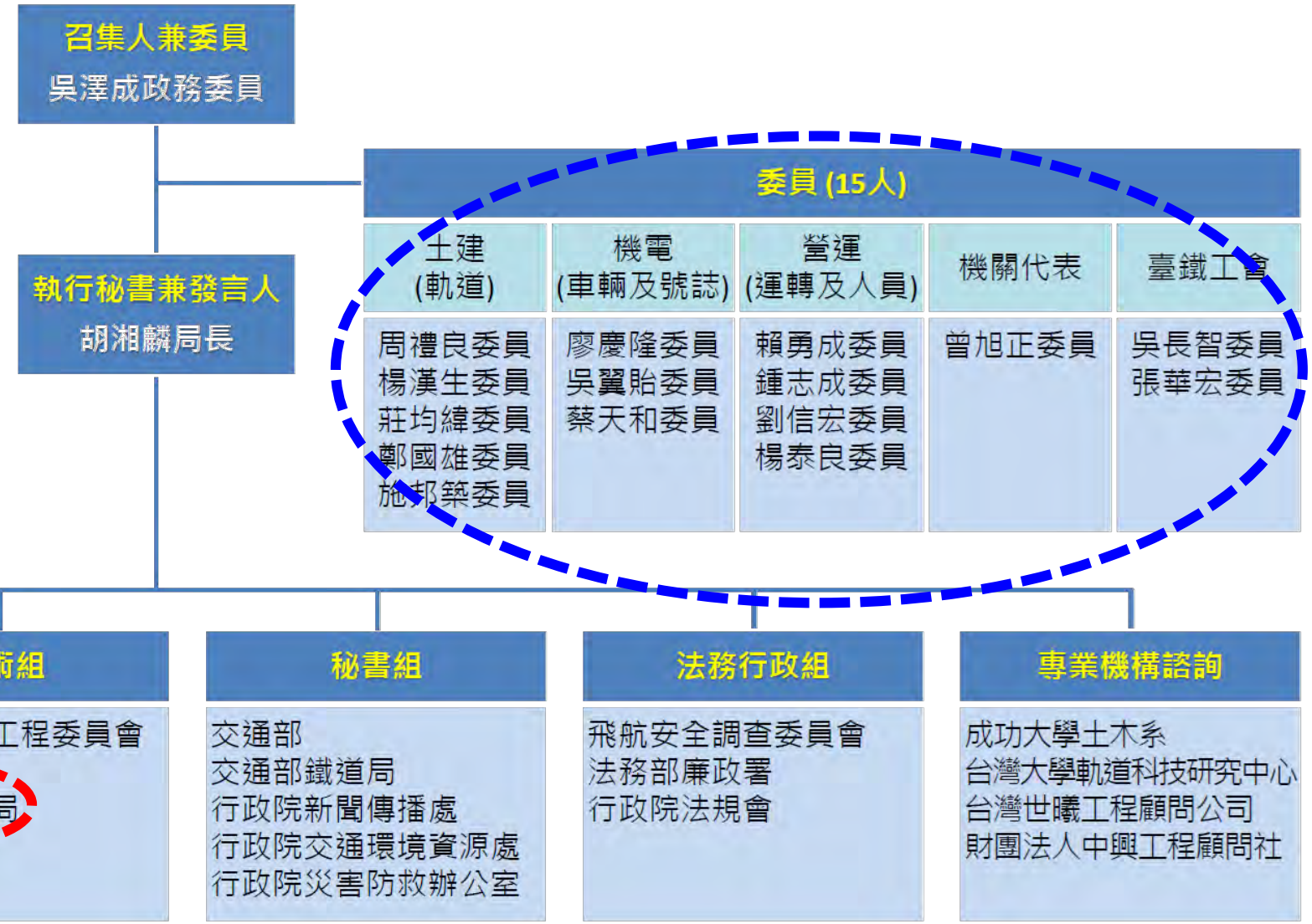
Nov 26th Media Conference for Preliminary Results on Causes

Fact-Finding Investigation

Test and Analyses

Discussion on the Countermeasures by the Team

Dec 21st Publish Final Report



Important Facts for Investigation

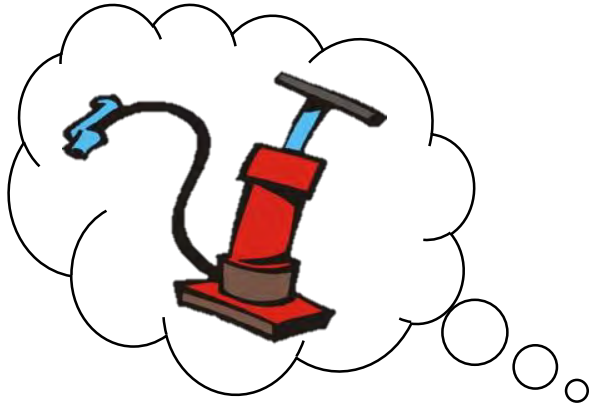
- **CCTV & Cam:**
  - Platform CCTV
  - Dashcam (ダッシュカム)
- **Train Control and Monitor System (TCMS)**
  - Speed
  - Throttle / braking position
  - Main Reservoir (MR) pressure
  - Compressor

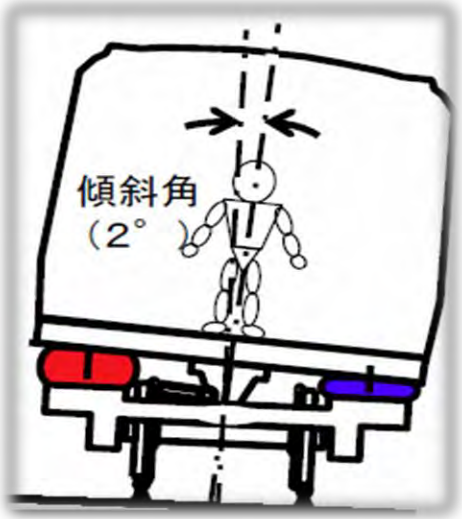
The Black Box

- **Automatic Train Protection (ATP) Record Unit (RU)**
  - ATP on/off
  - Permitted speed

ATP Recorder

- **Communication**
  - Driver – Dispatcher
  - Driver – Maintenance Crew (at the depot)
  - Driver – Conductor
  - Driver – Station Staff
- **Standard Operations Procedure (SOP)**
- **Maintenance Record**
- **Interview with staff related to this accident**
  - Drivers, dispatchers, station staff, maintenance staff, etc.





主風泵
Main Compressor

- Generate **compressed air** for braking, air springs (to support tilting), horn, door operations, etc.
- Puyuma has **4 compressors** per train-set, and the generated compressed air would be storage in the **Main Reservoir (總風缸)**

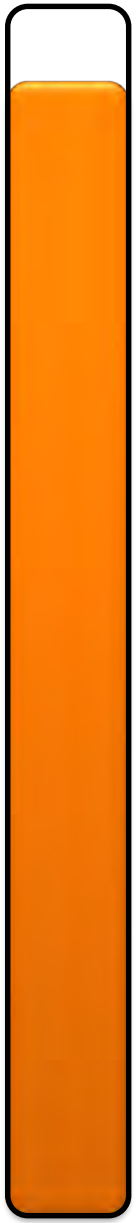
Reference: 1221記者會_1021普悠瑪出軌事故調查結果簡報 https://www.ey.gov.tw/File/56B688191D8706D2?A=C

主風泵失效自趨安全設計
Fail to Safe (MR)

In order to avoid insufficient compressed air for braking, when the MR pressure is less than 5.5 bar, the train will forcibly cut off the power. If the MR pressure is less than 5.0 bar, the train will be forced to stop.

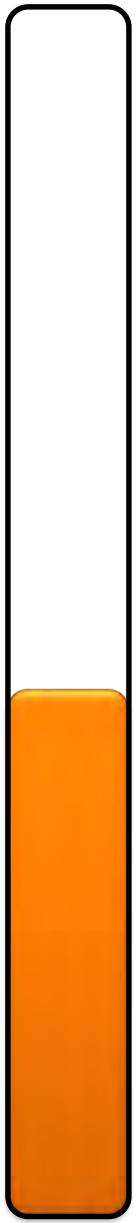
Reference: 1221記者會_1021普悠瑪出軌事故調查結果簡報 https://www.ey.gov.tw/File/56B688191D8706D2?A=C

~ 10 bar
(Normal)



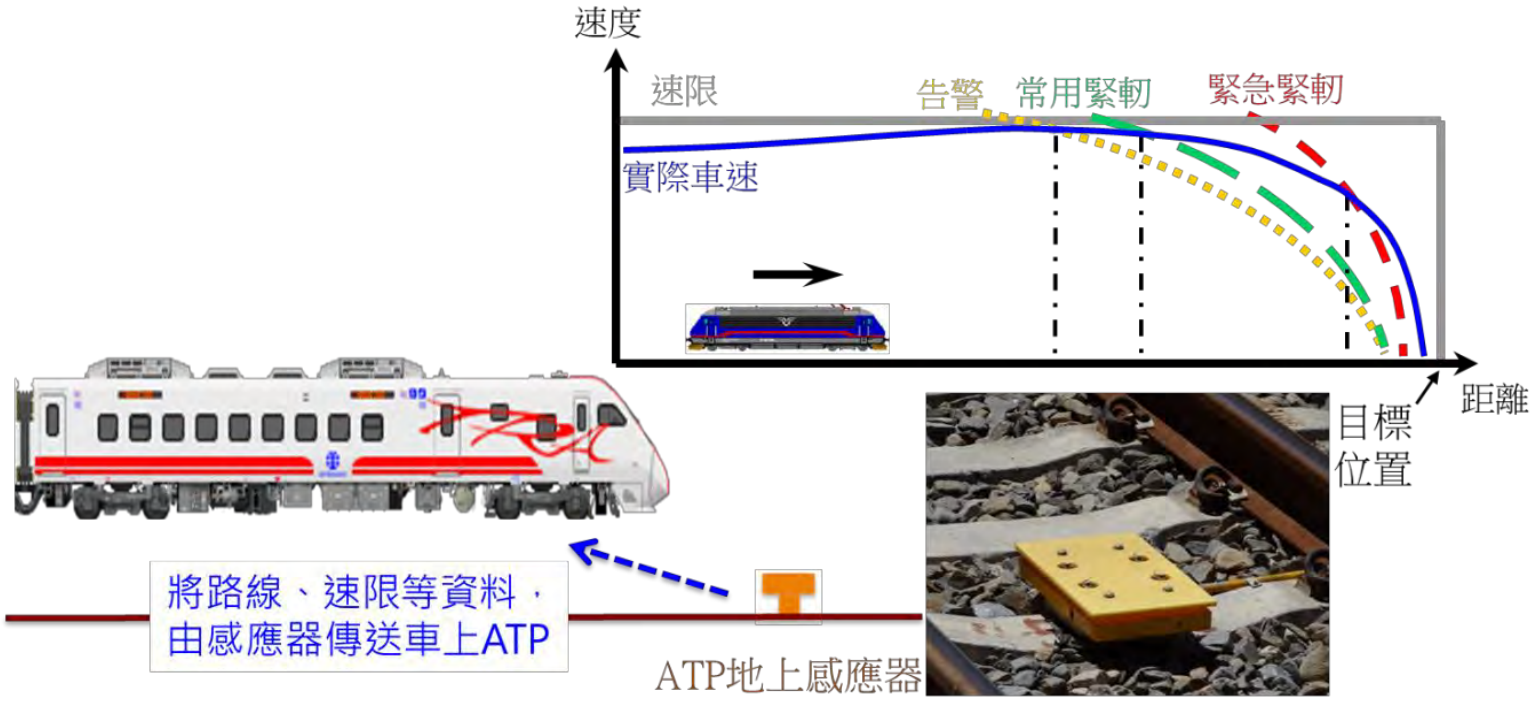
< 5.5 bar
(Automatic Cut
Traction Power)

< 5 bar
(Automatic Stop)

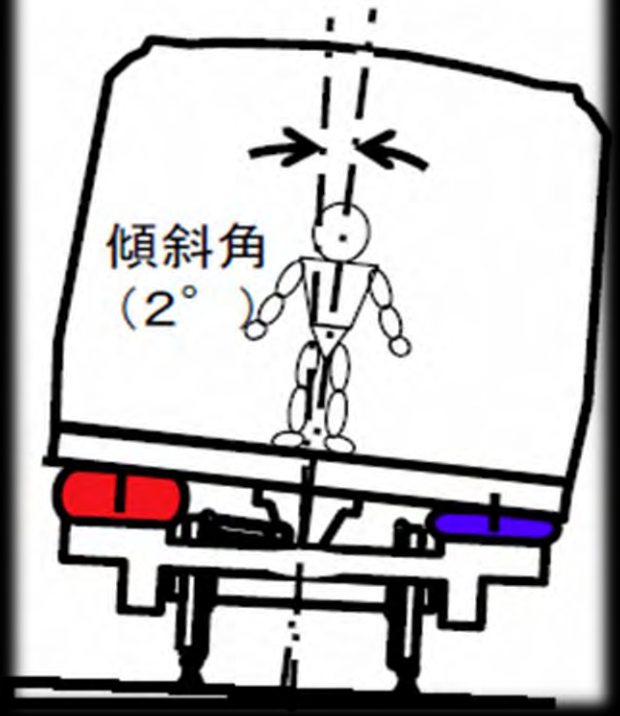


> 6 bar
(Power Resume)

ATP列車自動防護系統
Automatic Train Protection



Reference: 1221記者會_1021普悠瑪出軌事故調查結果簡報 https://www.ey.gov.tw/File/56B688191D8706D2?A=C

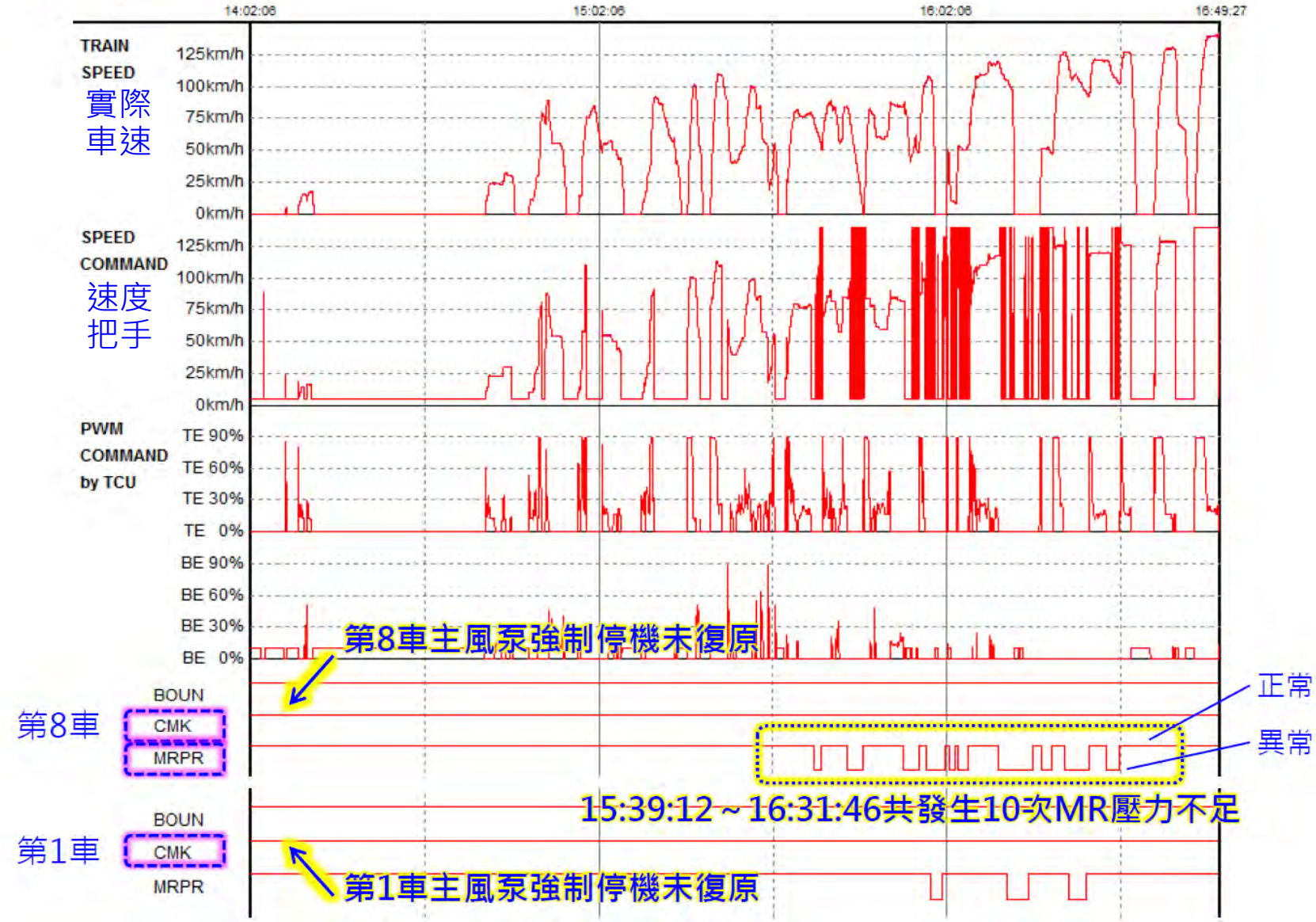


第6432次列車行駛路線

https://www.ey.gov.tw/Page/9277F759E41CCD91/8b719610-9ff9-4c76-bd57-02e20d089a2b

TCMS紀錄 - 第6432次列車主風泵運作狀況

運行方向：樹林→新馬



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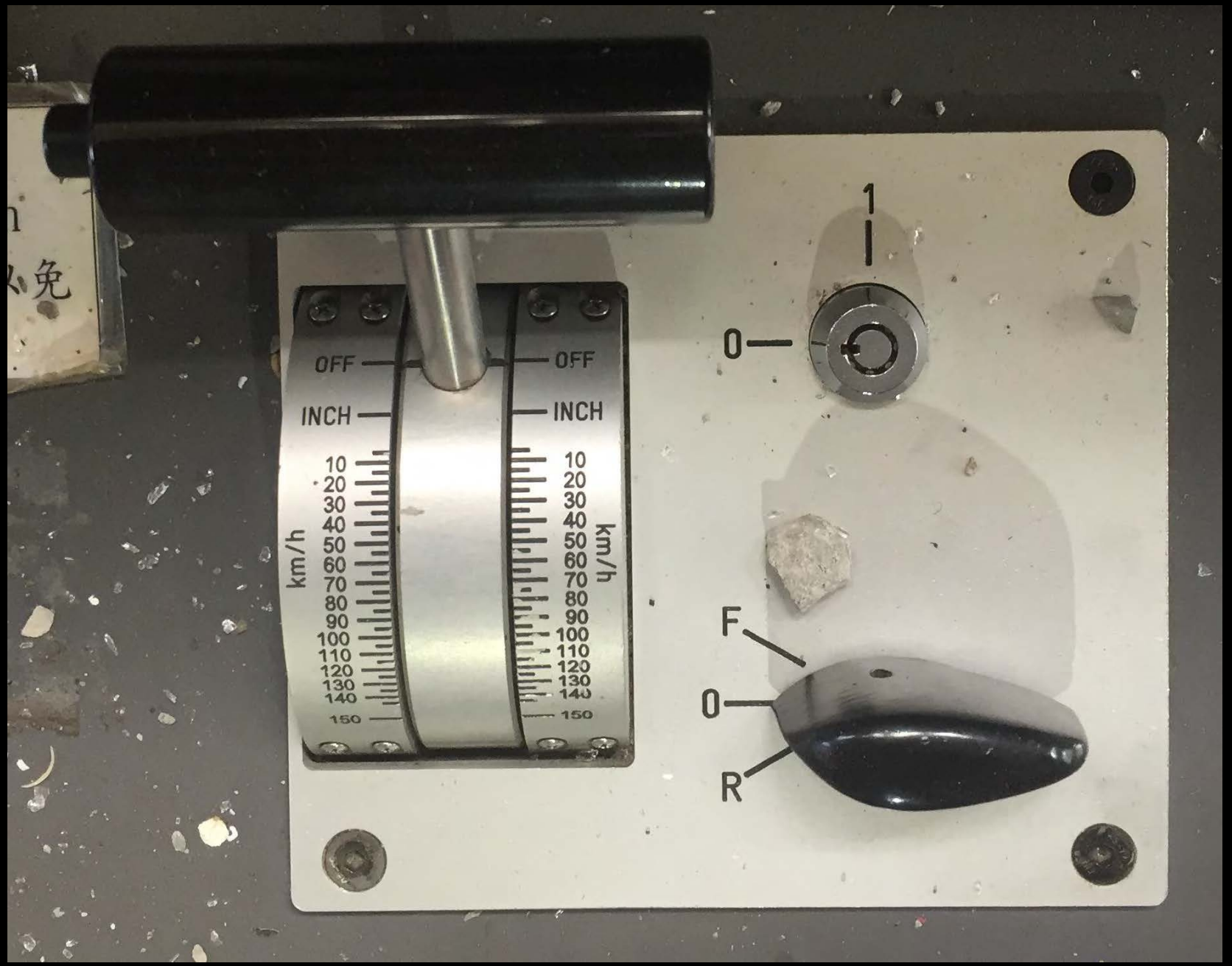
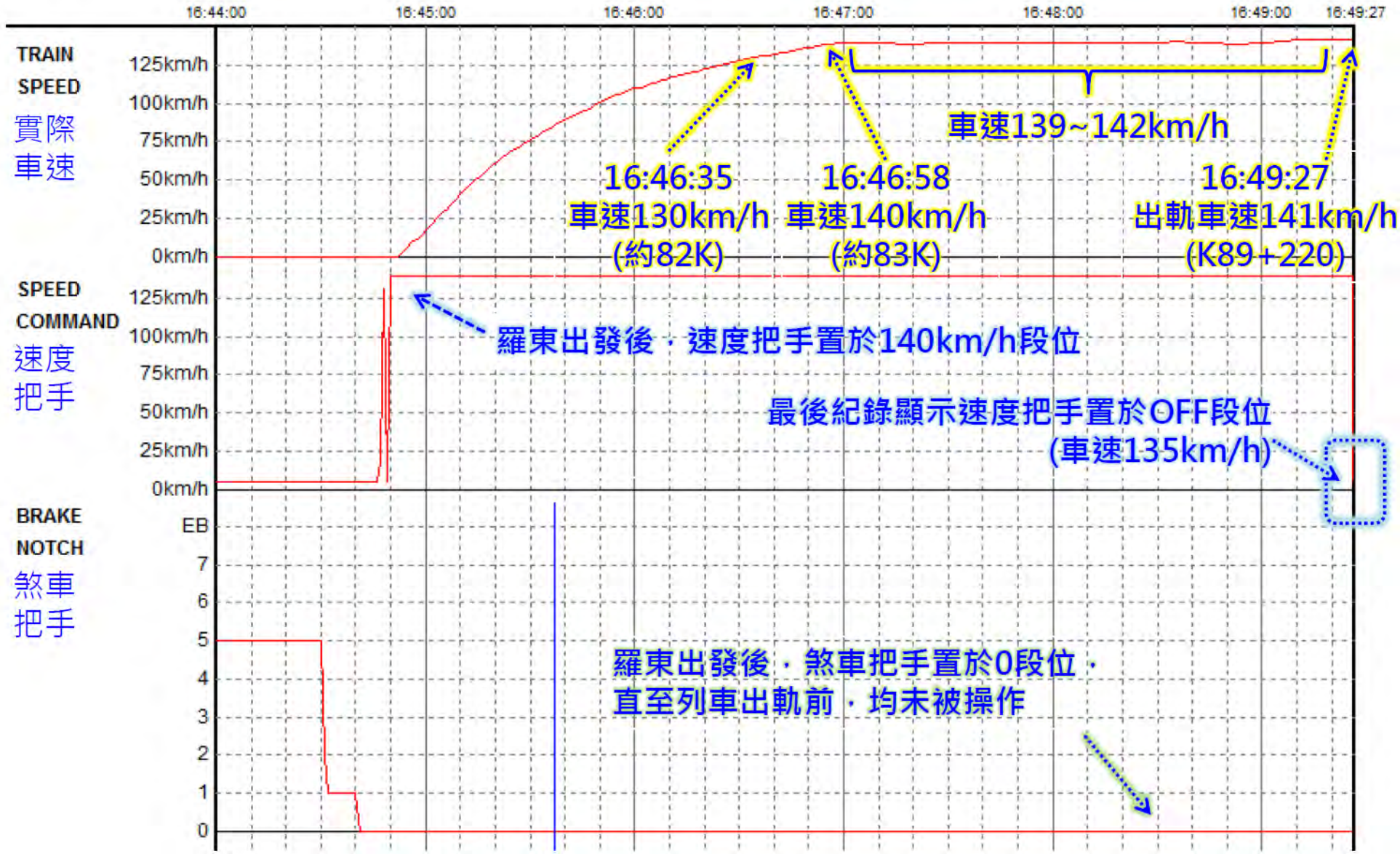


https://www.ey.gov.tw/Page/9277F759E41CCD91/8b719610-9ff9-4c76-bd57-02e20d089a2b

TCMS紀錄 - 出軌前車速及速度/煞車把手位置



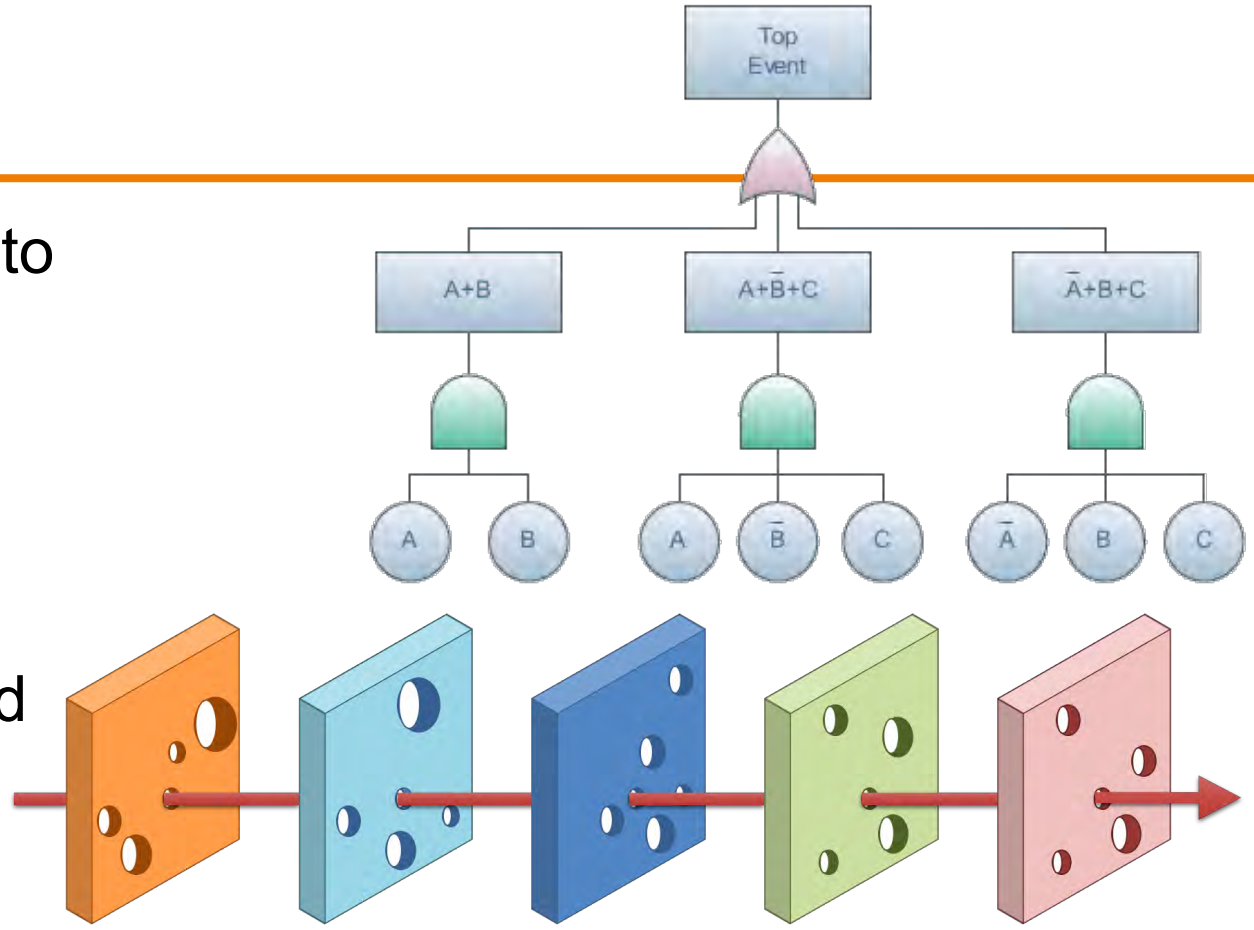
https://www.ey.gov.tw/Page/9277F759E41CCD91/8b719610-9ff9-4c76-bd57-02e20d089a2b

Video from dashboard recorder

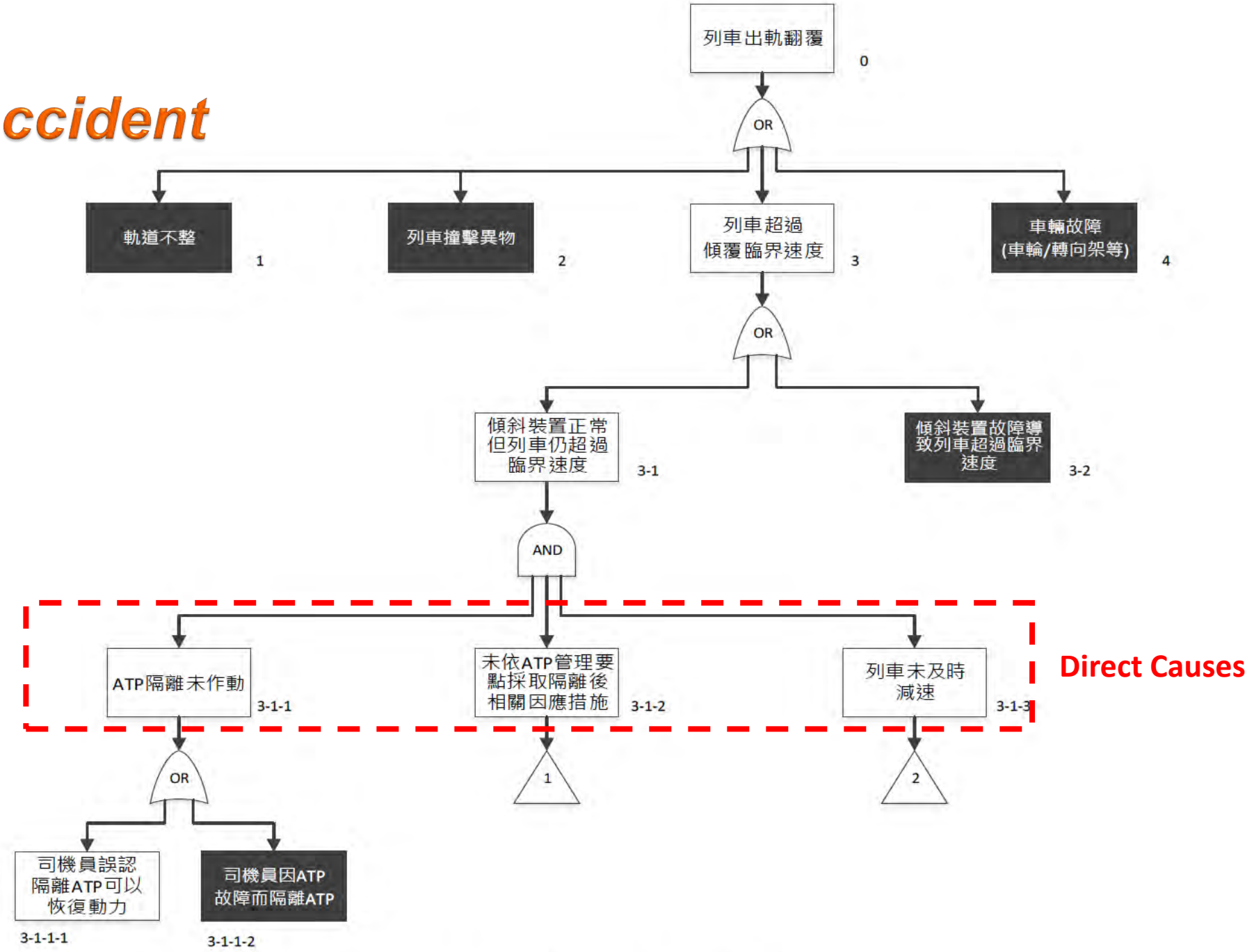
https://www.youtube.com/watch?v=CM-tAATOZo4
https://www.ey.gov.tw/Page/9277F759E41CCD91/8b719610-9ff9-4c76-bd57-02e20d089a2b

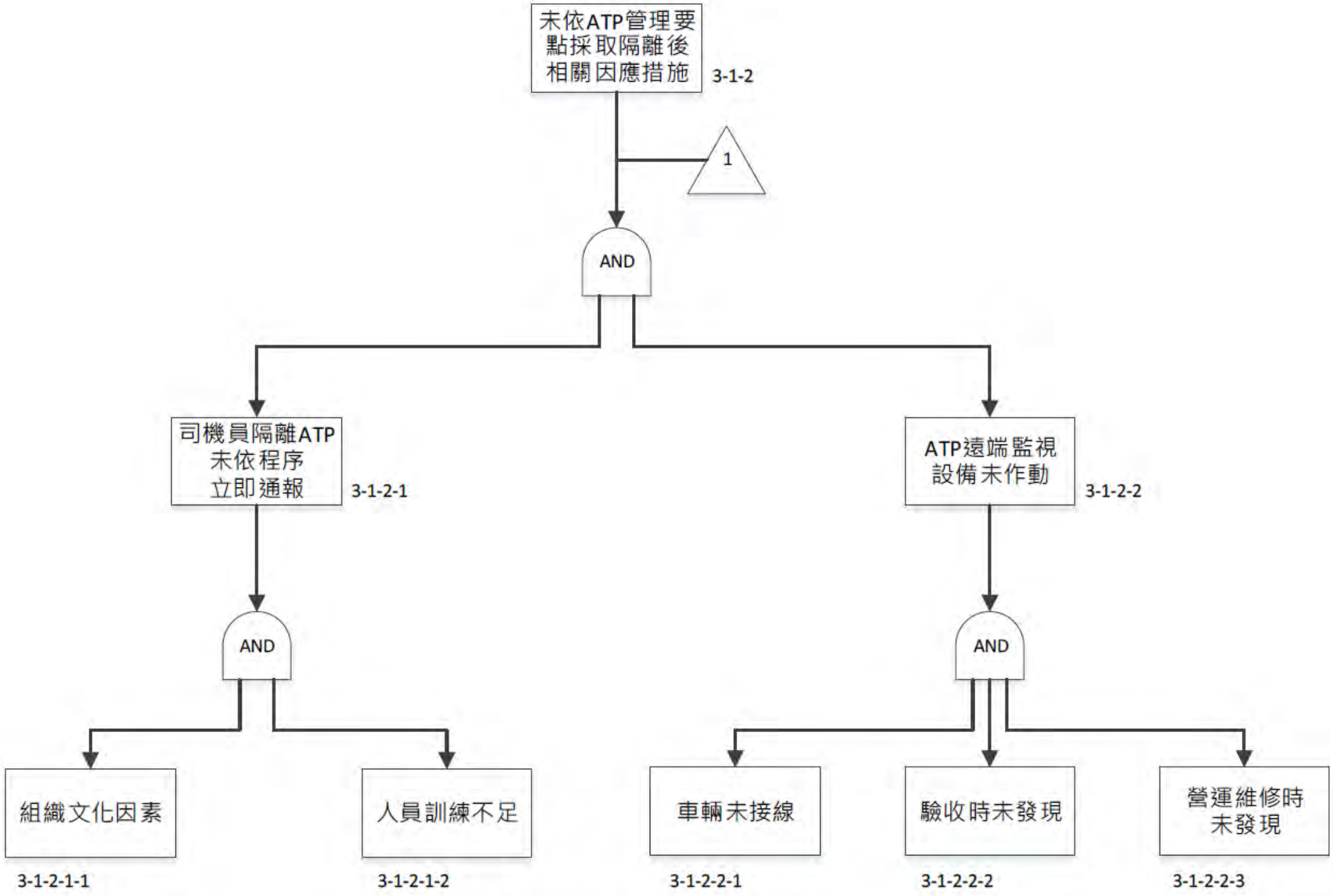
Causal Analysis

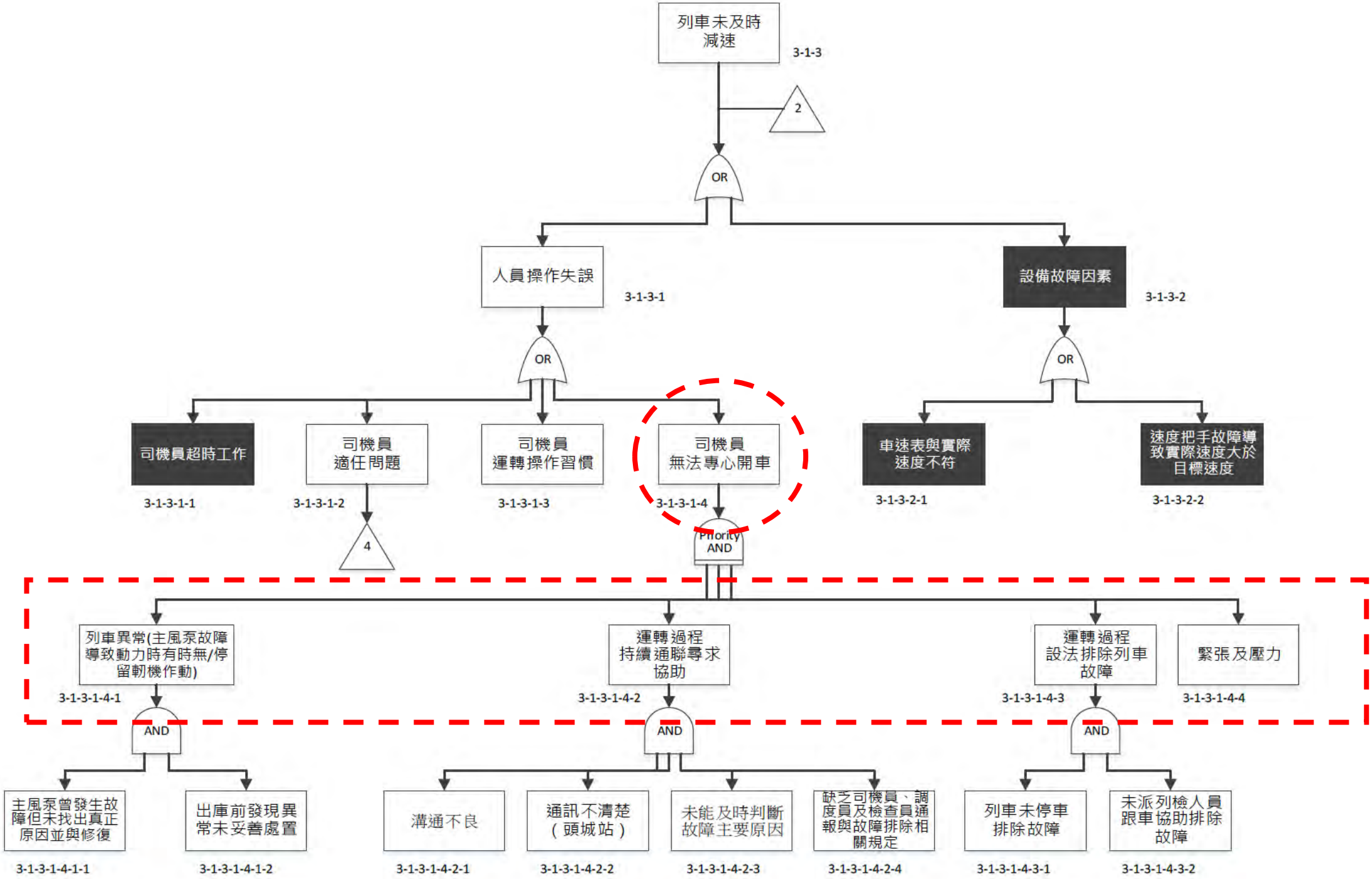
- **Fault tree analysis (FTA)** were used to identify the direct and indirect causes
- **Swiss cheese model** were also used to categorize and present the causes
- A graphical output of **time-sequence Swiss cheese figure** is also proposed and used to present the accident investigation results



Fault tree for 1021 Accident




未依ATP管理要點採取隔離後相關因應措施
3-1-2
1
AND
司機員隔離ATP未依程序立即通報
3-1-2-1
ATP遠端監視設備未作動
3-1-2-2
AND
AND
組織文化因素
人員訓練不足
車輛未接線
驗收時未發現
營運維修時未發現
3-1-2-1-1
3-1-2-1-2
3-1-2-2-1
3-1-2-2-2
3-1-2-2-3


列車未及時減速
3-1-3
2
OR
人員操作失誤
3-1-3-1
設備故障因素
3-1-3-2
OR
OR
司機員超時工作
3-1-3-1-1
司機員適任問題
3-1-3-1-2
司機員運轉操作習慣
3-1-3-1-3
司機員無法專心開車
3-1-3-1-4
車速表與實際速度不符
3-1-3-2-1
速度把手故障導致實際速度大於目標速度
3-1-3-2-2
4
Priority AND
列車異常(主風泵故障導致動力時有時無/停留軔機作動)
3-1-3-1-4-1
運轉過程持續通聯尋求協助
3-1-3-1-4-2
運轉過程設法排除列車故障
3-1-3-1-4-3
緊張及壓力
3-1-3-1-4-4
AND
AND
AND
主風泵曾發生故障但未找出真正原因並與修復
3-1-3-1-4-1-1
出庫前發現異常未妥善處置
3-1-3-1-4-1-2
溝通不良
3-1-3-1-4-2-1
通訊不清楚（頭城站）
3-1-3-1-4-2-2
未能及時判斷故障主要原因
3-1-3-1-4-2-3
缺乏司機員、調度員及檢查員通報與故障排除相關規定
3-1-3-1-4-2-4
列車未停車排除故障
3-1-3-1-4-3-1
未派列檢人員跟車協助排除故障
3-1-3-1-4-3-2

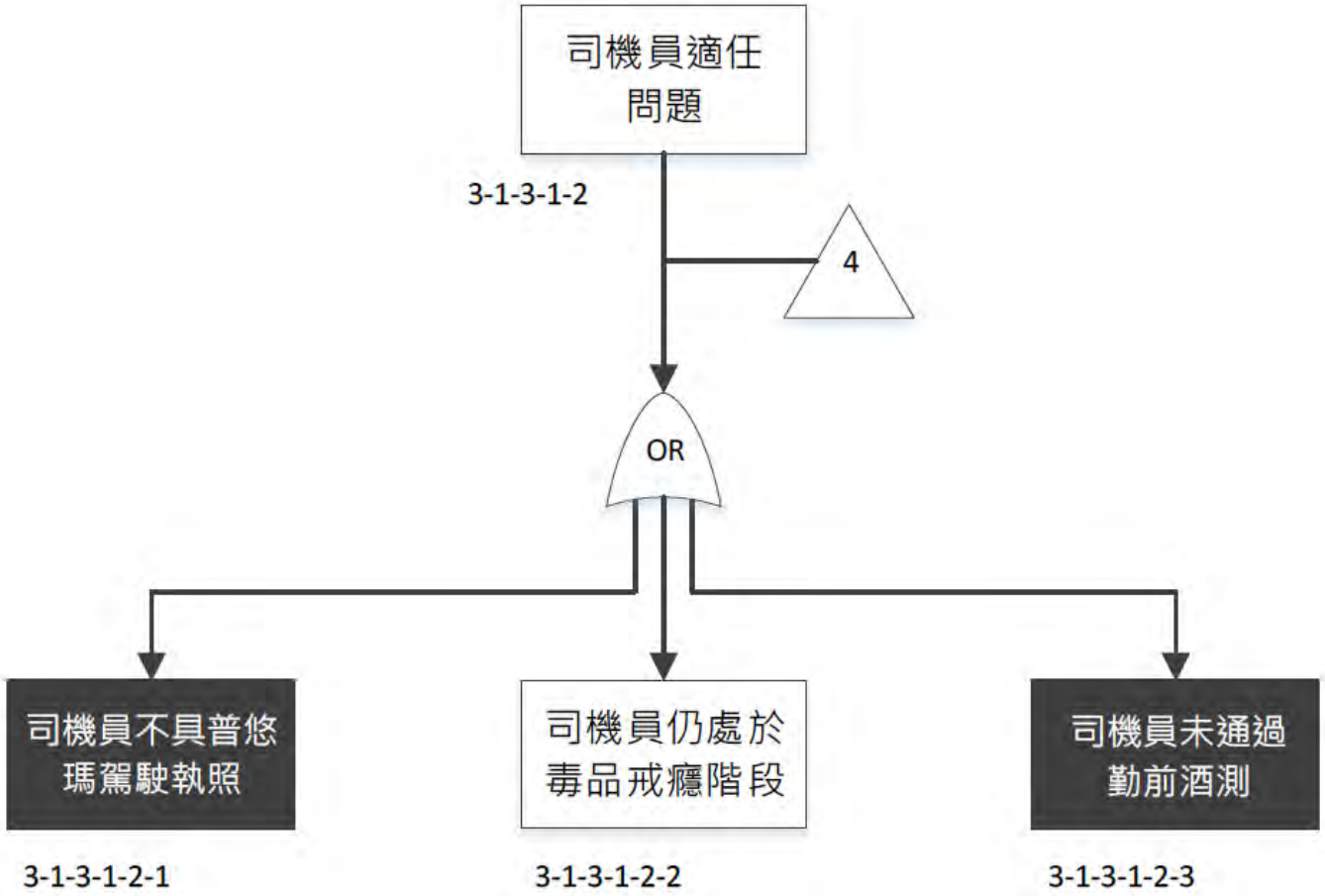
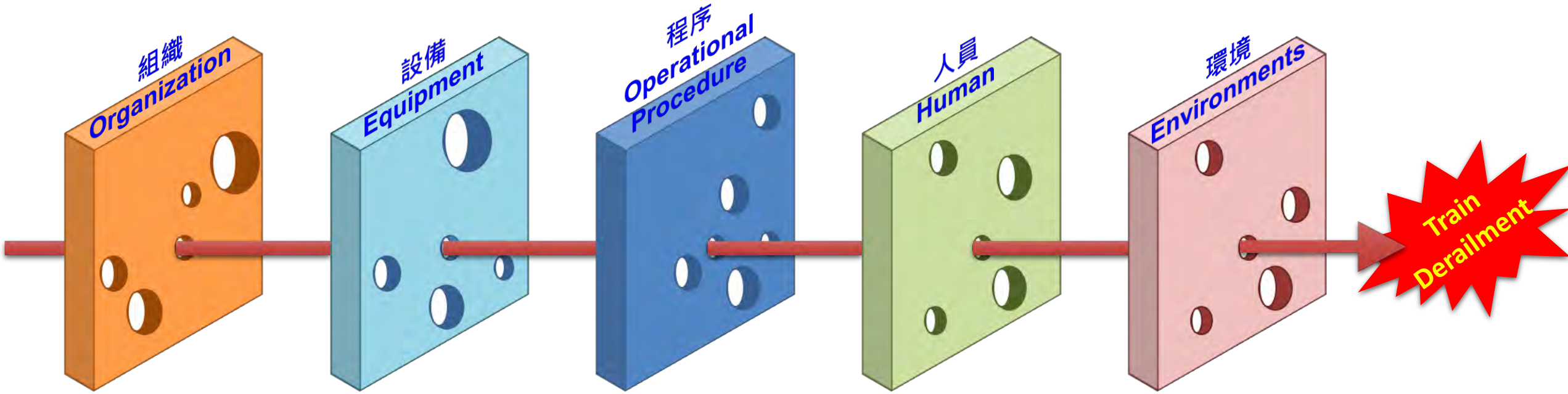

司機員適任
問題
3-1-3-1-2
4
OR
司機員不具普悠
瑪駕駛執照
3-1-3-1-2-1
司機員仍處於
毒品戒癮階段
3-1-3-1-2-2
司機員未通過
勤前酒測
3-1-3-1-2-3

圖 4.2.1-4　故障樹(4/4)



- Inappropriate safety management & safety culture
- Insufficient training on troubleshooting
- Failure in the acceptance process for ATP remote monitoring system

- Overheating problems in the compressors
- Problems in the ATP remote monitoring system

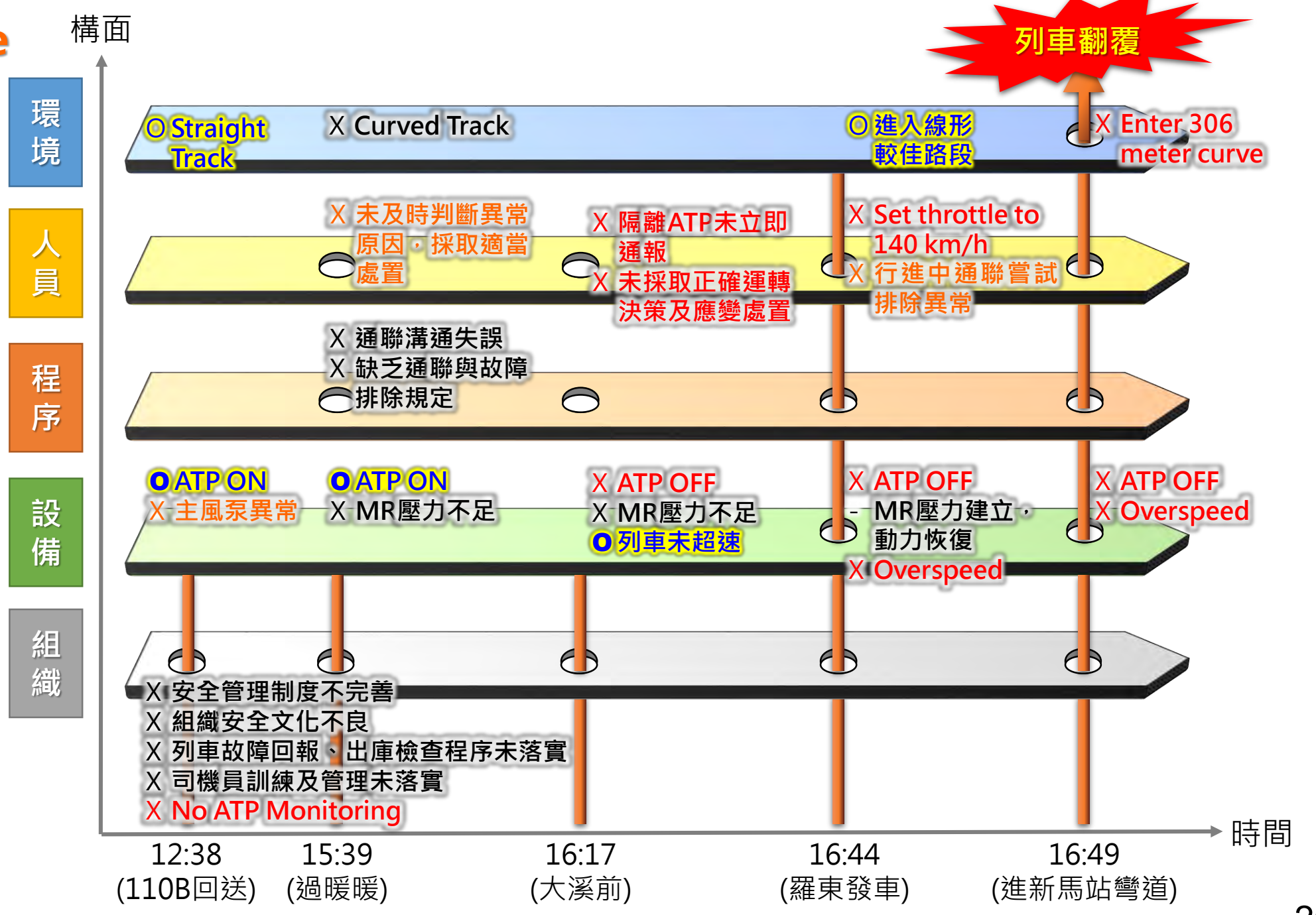
- Communication procedure and languages were not standardized
- Lack of standard troubleshooting procedure
- SOP for switching off ATP is questionable

- Fail to recognize actual cause of problem
- Fail to follow the SOP for switching off ATP
- Overspeed

- Driving under anxiety
- Curved route

Swiss Cheese for 1021 Accident

Time-Sequence Swiss Cheese



Causes

事故列車以 超過速限(75km/h)的速度(141km/h)進入半徑306公尺的新馬站彎道，致列車前進方向第1節車廂右側車輪浮起後出軌並向左側傾覆，隨後第2至8節車廂也相繼出軌。

The accident train entered the 306-meter curve right before Xinma Station at 141 km/h, exceeding the speed limit (75 km/h), causing the train to derail.

事故列車行進中，因 主風泵異常，發生列車動力時有時無、停留軔機間歇作動之異常狀況，相關人員採取之運轉決策及應變處置作為未排除異常狀況；司機員於列車行進中，同時持續通聯嘗試排除列車異常狀況，進入新馬站彎道前未依規定減速。

During the operations, the train were subject to abnormality of the compressors, resulting in power lost and unintentional train stops. None of the driver, dispatchers, and maintenance crew could clearly identify the problem and successfully resolve this abnormality. At the same time, the driver, who were continuously communicating with other railway personnel in order to solve the problem, did not apply brake before entering the curve.

又 ATP系統被隔離，且普悠瑪列車之ATP遠端監視功能未連線，致 相關防護措施均未被執行。

The ATP remote monitoring system were not installed on this train so and the relevant protective measures were not implemented.

Immediate Recommendations (Actions)

1. 檢討 **ATP隔離** 操作、通報及隔離訊號之監視與確認，要求落實執行
   Review SOP for ATP system / Enforce speed limit while switching off ATP

2. 儘速完成普悠瑪列車ATP隔離開關 **遠端監視線路接線** 及測試
   Ensure the ATP remote monitoring system are functioning for all rolling stock

3. 會同日本原廠儘速查明 **主風泵異常根本原因**，徹底改善
   Identify the causes and solutions to the overheating problem of the compressors

4. 執行普悠瑪 **列車特檢**，並加強主風泵保養、清潔或更換必要組件
   Examine all Puyuma train-sets, especially for the compressors.

5. 事故路段搶修後之 軌道平整 改善、擋碴牆 復原並確認 護軌 長度足夠
   Ensure the appropriateness of the track restoration after the accident

Recommendations

- **Organization**
  - Establish safety department and implement safety management system (SMS)
  - Establish a safety first culture in the organization
  - and more…
- **Equipment**
  - Establish Maintenance Management Information System (MMIS)
  - Install a speed-enforcement system for operations without ATP
  - and more…
- **Procedure**
  - All SOP should follow ISO standard
  - Improve the troubleshooting process for rolling stock in operations
  - Establish specific procedure and checklist for outbound inspection (from depot)
  - Standardize the communication languages
  - and more…
- **Human**
  - Ensure drivers correctly understand the function and SOP of the ATP system
  - Strengthen the training of train inspection, troubleshooting
  - Strengthen the assessment of the drivers' ability
  - and more…

Thank You!

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