



PARIS
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INTERNATIONAL
RAILWAY SAFETY COUNCIL

Project on Safety Performance Indicators and Risk Level Assessment of Railway Infrastructure

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General information on railways in Korea

4.5 billion railway passengers in Korea (in 2014)

- ▶ 218 million train-kms, 71 billion passenger-kms
- ▶ A single company (Korea Railroad Corporation (KORAIL) operates all HST and conventional rail by 2015, Single IM From 2016, new company will start HST service
- ▶ 14 RUs for subway : mainly owned by regional governments
- ▶ Passenger increase trend of about 1~2%
- ▶ About 60,000 staff members work on railway operation and 600 on safety-related work

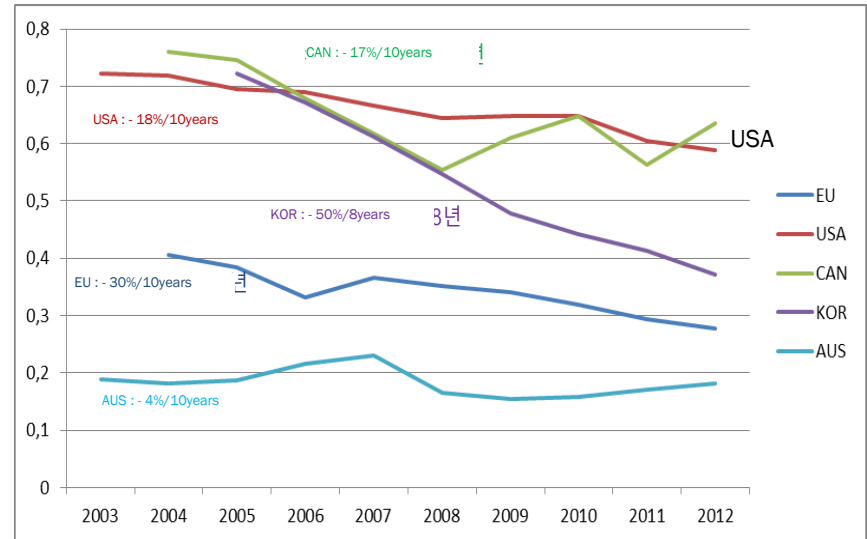
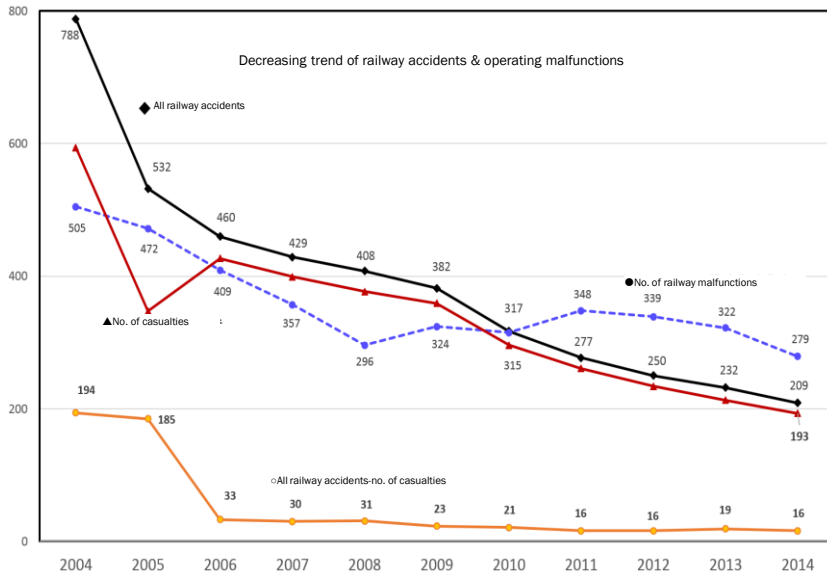
General information on railways in Korea

- Total of 4,520 km lines for passenger service
 - High-speed track 556km (41% of the track is in tunnels, 31% on bridges)
 - Conventional track 3,270km
 - Urban (subway) track 535km (88% of the track is in tunnels, 8% on bridges)
 - New lines are under construction, new high-speed line will be open in 2016

- Railway Safety Act legislated in 2004, amended in 2014

Background of Project

- ❖ Achieved the most rapid decrease in accident rate
- ❖ There's only been one railway fatality in the past 11 years



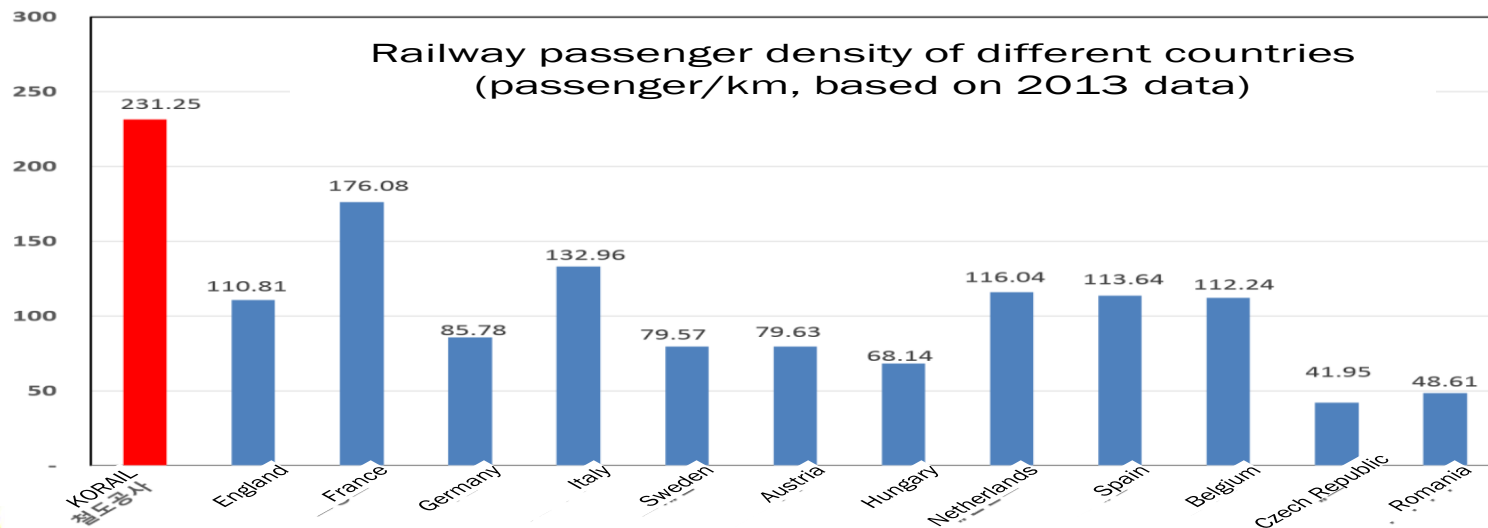
Background of Project

- ❖ The railway is considered the safest transportation in Korea
 - 25 times safer than road transportation
 - 50% of total fatalities come from suicide
 - 40% of total fatalities come from trespassing

| | Trasportation Share % | Accident Fatalities (5yrs) | Fatalities/Share | Comparision to railway |
|---------------------|------------------------------|-----------------------------------|-------------------------|-------------------------------|
| Railway | 24.90 | 391 | 15.7 | 1 |
| Airplane | 0.14 | 23 | 164.3 | 10.4 |
| Road Vehicle | 74.85 | 29,706 | 396.9 | 25.3 |
| Maritime | 0.11 | 666 | 6,054.5 | 385.6 |
| Total | 100 | 30,786 | - | - |

Background of Project

- Due to the high density of passengers, in the event of an accident, there will be a huge social impact and passenger rescues and provision of alternate means of transport will be difficult
 - In the event of an accident, a much more number of people may be harmed
 - Securing alternate means of transport such as buses are difficult (due to lack of maintenance time)



Background of Project

- ❖ **Concerns for the safety of railway facilities increase due to a high proportion of worn out facilities**
 - 42% of the bridges and 44% of the tunnels are at least 30 years old
 - 35% of equipment including Substation Equipment, Signaling Equipment, and Communications Equipment has long exceeded the lifespan

| Category | 2011 | 2012 | 2013 | 2014 | 2015 July |
|--------------------------------------|--------------|--------------|--------------|--------------|--------------|
| Total average | 29.1% | 31.0% | 31.8% | 31.7% | 35.3% |
| Subway Electricity | 9.5% | 8.8% | 8.8% | 9.4% | 9.8% |
| Information and Communication | 42.2% | 55.0% | 58.7% | 48.7% | 30.9% |
| Signal Control | 33.6% | 30.7% | 30.6% | 34.1% | 41.4% |

Background of Project

- ❖ **With the increase of peoples' standard of living, the level of demands for railway services and safety also increases**
- ❖ **It is stipulated in the Railway Track Allocation Guidelines (public announcement by the Ministry of Land, Infrastructure and Transport (MOLIT) that although there must be 3.5 consecutive hours of work time a day on railway tracks for construction, enhancement, and maintenance,**
- ❖ **Railway users (KORAIL) and railway track allocators (Korea Rail Network Authority) may negotiate and adjust work time in accordance with the demand for railway use and required working time**

Project Objectives

● Service Objectives

- Indexing and evaluating the safety of facilities in each railway section pursuant to the International Standards for Railway Safety (IEC 62278, RAMS applied to trains)
- Establishing an efficient strategy to maintain railway facilities based on the risk levels
- Researching the level of securing work time on railway tracks and methods and steps for allocating work time in major developed countries

● **Spatial range: 39 conventional and high-speed railway routes,
406 sections, 680 lines**

● **Duration of Task: 2015.12.01~ 2016.02.28**

Current Status of Sections With Secured Work Time

- ❖ Sections with 3.5 hours of work time secured amount to 67% of 680 sections
 - Supposing the duration of a tramline power cut is the only available work time, the sections with 3.5 hours of work time secured amount to 204 sections (out of 578), decreasing to 35.29%

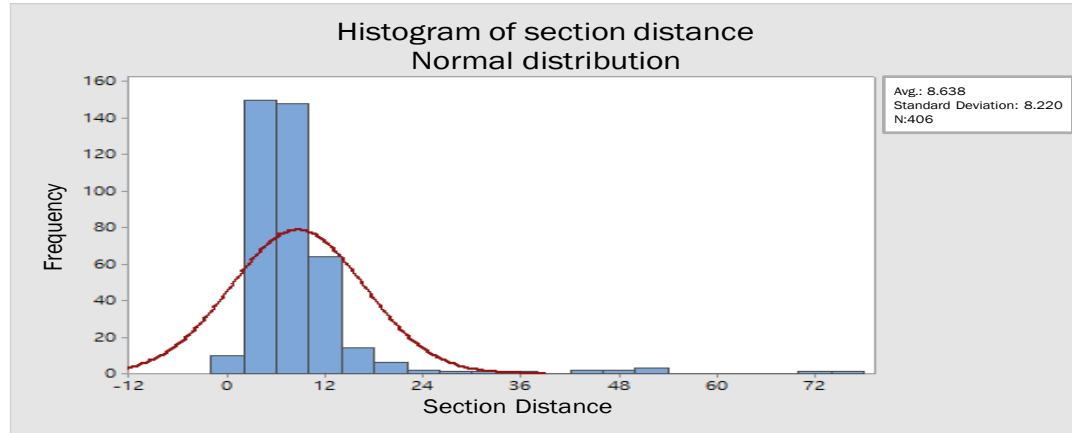
| Track block and tramline power cut time | Before adjustment (Until '15.07) | | | | After adjustment (After '15.08) | | | |
|---|----------------------------------|------------|--------------------|------------|---------------------------------|------------|--------------------|------------|
| | Track block | | Tramline power cut | | Track block | | Tramline power cut | |
| | Tracks | Percentage | Tracks | Percentage | Tracks | Percentage | Tracks | Percentage |
| Less than 1 hr | 1 | 0.15% | 16 | 2.79% | 0 | 0.00% | 2 | 0.35% |
| At least 1hr~ less than 2 hr | 40 | 5.88% | 54 | 9.41% | 18 | 2.65% | 36 | 6.23% |
| At least 2hr~ less than 3hr | 114 | 16.76% | 213 | 37.11% | 97 | 14.26% | 160 | 27.68% |
| At least 3 hr~ less than 3.5hr | 79 | 11.62% | 138 | 24.04% | 111 | 16.32% | 176 | 30.45% |
| 3.5 hr or more | 446 | 65.59% | 153 | 26.66% | 454 | 66.76% | 204 | 35.29% |
| Total | 680 | | 574 | | 680 | | 578 | |

Identifying hazardous factors and root causes

- ❖ **Drew the hazards representing the types of facilities through research and analysis of the list of hazards in railway facilities managed by railway corporations and from risk level assessments carried out by major developed countries such as England, France, the U.S., and Australia**
- ❖ **Analysis of management incident logs**
 - Drew 50 hazards by categorizing facility related hazardous factors into 10 categories and root causes per hazardous factor into five categories

Accident frequency indicators

- ❖ The 406 sections defined in the task sections have different section distances



- ❖ It is difficult to compare the risk levels in sections by simply counting the frequency of accidents in each section. This is because long sections are calculated with high risk levels

Frequency of accidents in each section with converted total operation distance

$$= (\text{Section "A"'s avg. frequency per year}) \times \frac{\text{KORAIL's total distance of operation}}{\text{operation distance of each section}}$$

Event severity indicators

- ❖ Used Event Tree Analysis (ETA) method to calculate the probability of an accident developing in each section
- ❖ Evaluated the severity of an accident through casualties and train operation delay time

| Derailed during run | Train type | Time | Location derailed | Speed during derailling | \$/min | STC | PROB |
|---------------------|-----------------------|--------------------------|--------------------------|--------------------------|----------|----------|------|
| Derailed during run | passenger | Busy 0.33 | Bridge/tunnel 0.33 | 120km/h or less 0.004 | 7 | 7.00E-04 | |
| | | | | 15-60km/h 0.014 | 32 | 5.47E-03 | |
| | | | | 60km/h or less 0.002 | 33 | 2.69E-03 | |
| | | | Elsewhere 0.31 | 120km/h or less 0.004 | 7 | 7.48E-03 | |
| | | | | 15-60km/h 0.014 | 35 | 5.47E-02 | |
| | | | | 60km/h or less 0.002 | 35 | 2.69E-02 | |
| | Not busy | Bridge/tunnel 0.33 | Not busy 0.57 | 120km/h or less 0.004 | 7 | 1.42E-03 | |
| | | | | 15-60km/h 0.014 | 33 | 1.04E-02 | |
| | | | | 60km/h or less 0.002 | 33 | 5.11E-03 | |
| | | Elsewhere 0.31 | 120km/h or less 0.004 | 7 | 1.24E-02 | | |
| | | | 15-60km/h 0.014 | 31 | 1.05E-01 | | |
| | | | 60km/h or less 0.002 | 33 | 5.17E-02 | | |
| Derail during run | Bridge/tunnel 0.33 | Night 0.13 | 120km/h or less 0.004 | 7 | 3.54E-04 | | |
| | | | 15-60km/h 0.014 | 34 | 2.37E-03 | | |
| | | | 60km/h or less 0.002 | 35 | 1.17E-03 | | |
| | Elsewhere 0.31 | 120km/h or less 0.004 | 7 | 2.20E-03 | | | |
| | | 15-60km/h 0.014 | 37 | 2.40E-02 | | | |
| | | 60km/h or less 0.002 | 35 | 1.18E-02 | | | |
| Non-passenger | Night 0.13 | Non-passenger 0.67 | 120km/h or less 0.004 | 7 | 5.03E-02 | | |
| | | | 15-60km/h 0.014 | 30 | 3.11E-01 | | |
| | | | 60km/h or less 0.002 | 31 | 2.03E-01 | | |

Risk Matrix of IEC 62278, the International Standards for Railway Safety

- ❖ Section 4.6.3.4 of IEC 62278, the International Standards for Railway Safety, provides acceptable levels of risk divided into four grades in accordance with the combination of hazard frequency and severity

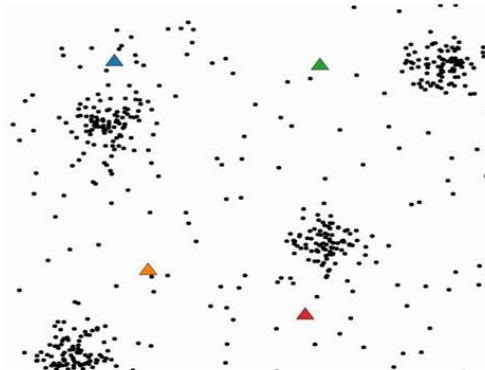
| Severity Frequency | Insignificant | Marginal | Critical | Catastrophic |
|-----------------------|---------------|-------------|-------------|--------------|
| Frequent | Undesirable | Intolerable | Intolerable | Intolerable |
| Probable | Tolerable | Undesirable | Intolerable | Intolerable |
| Occasional | Tolerable | Undesirable | Undesirable | Intolerable |
| Remote | Negligible | Tolerable | Undesirable | Undesirable |
| Improbable | Negligible | Negligible | Tolerable | Tolerable |
| Incredible | Negligible | Negligible | Negligible | Negligible |

- ❖ The quantitative criteria for frequency and severity for each grade is assigned to each country or project

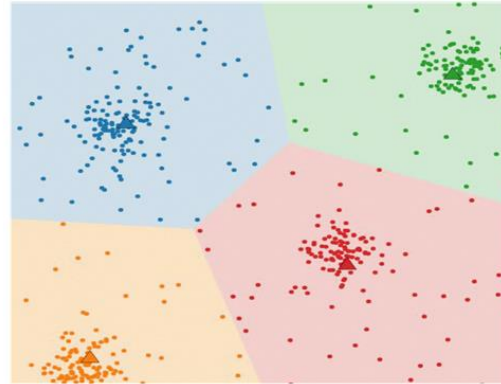
Accident rate assessment matrix in accordance with the amount of work on and secured work time for railway track

❖ K-means algorithm

- The clustering method groups large-scale data into a few clusters in accordance with characteristic values
- The K-means algorithm is the most commonly used clustering method



Before applying K-means Algorithm



After applying K-means Algorithm

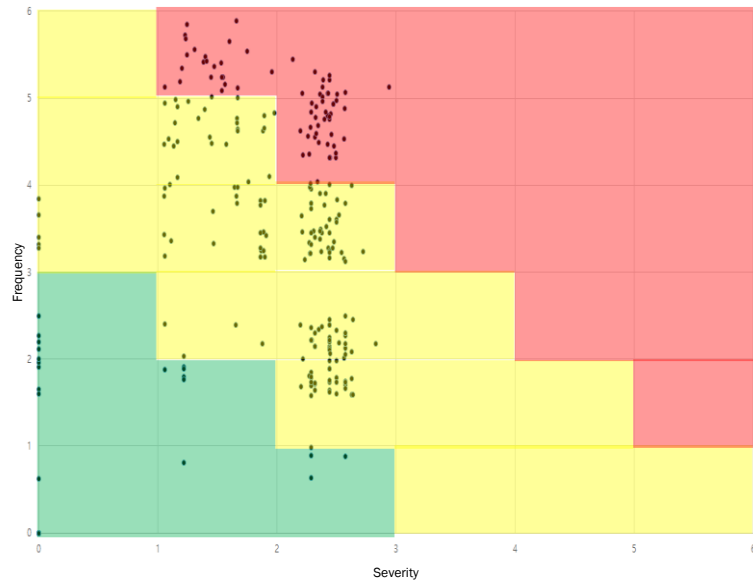
Developing the Risk Matrix

- ❖ Applying 3 K-means Algorithm and using the calculated frequency level, the Risk Matrix can be developed

| Severity Frequency (with converted total operation distance of 3,950km) | C1 Service unavailable for less than 10 min or no casualty | C2 Service unavailable for +10~-19 min or +1 minor injury | C3 Service unavailable for +20min~-1 h 59 min or +1 serious injury | C4 Service unavailable for +2 h~-7 h 59min or +1 death | C5 Service unavailable for +8 h~-23 h 59min or +2 deaths | C6 Service unavailable for +24 h or +10 deaths |
|---|---|---|--|---|---|--|
| F6 Annual average +700 cases | B | A | A | A | A | A |
| F5 Annual average +300~699 cases | B | B | A | A | A | A |
| F4 Annual average +170~299 cases | B | B | B | A | A | A |
| F3 Annual average +90~169 cases | C | B | B | B | A | A |
| F2 Annual average +30~89 cases | C | C | B | B | B | A |
| F1 Annual average +0~29 cases | C | C | C | B | B | B |

Risk level assessment results by applying the Risk Matrix

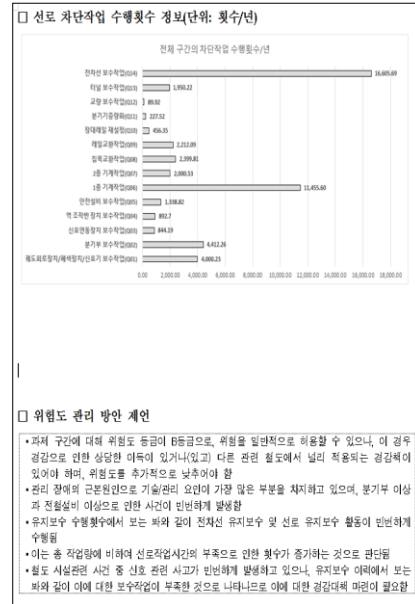
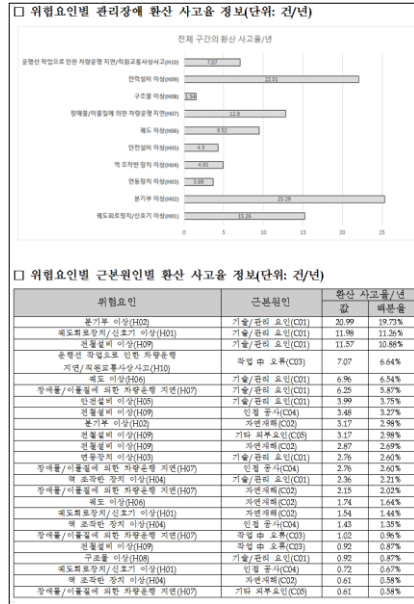
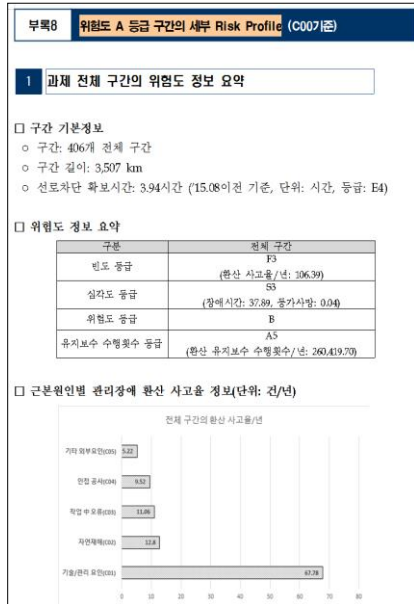
- ❖ When the developed Risk Matrix was applied, it resulted in Section A being approximately 10%, Section B 50%, and Section C 40%



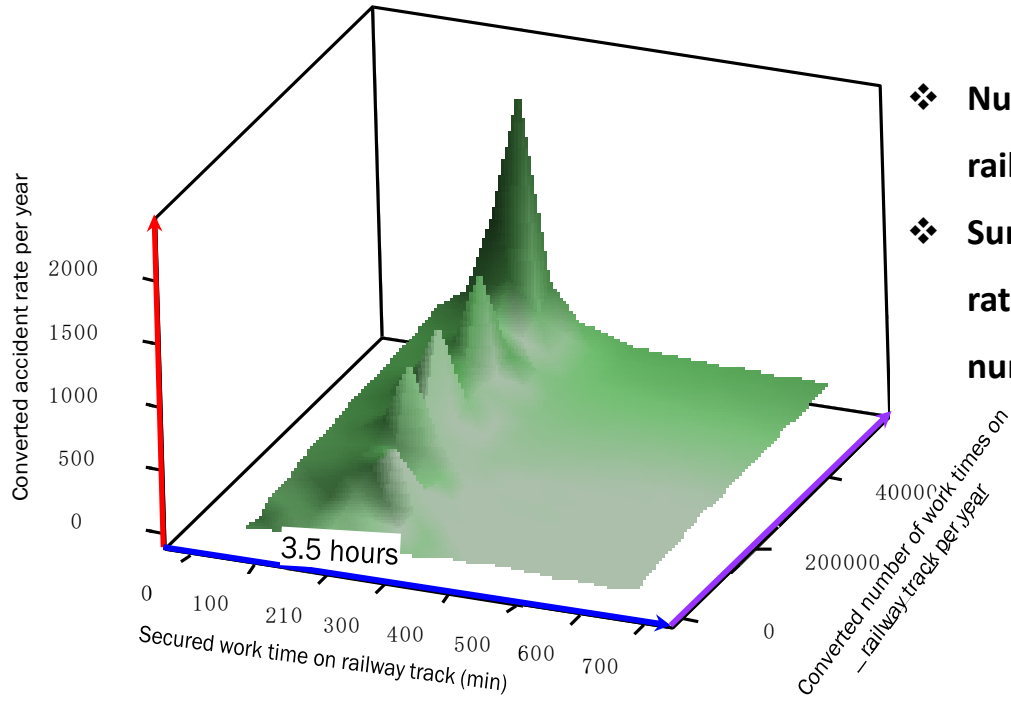
| Root cause | | Section A | Section B | Section C |
|--|-----------------|-----------|-----------|-----------|
| Total root cause C00 | No. of sections | 41 | 194 | 171 |
| | Percentage | 10% | 48% | 42% |
| Technical cause C01 | No. of sections | 20 | 153 | 233 |
| | Percentage | 5% | 38% | 57% |
| Technical cause C01 + Natural disaster C02 | No. of sections | 23 | 182 | 201 |
| | Percentage | 6% | 45% | 50% |
| Technical cause C01 + Natural disaster C02 + Error while maintenance C03 | No. of sections | 26 | 195 | 185 |
| | Percentage | 6% | 48% | 46% |

Detailed risk profile of sections with risk level A (41 sections)

- Risk profiles and risk level calculations have been made for 406 sections being managed
- A detailed risk profile for sections with risk level A (41 sections) has been made, as well as a management strategy being established



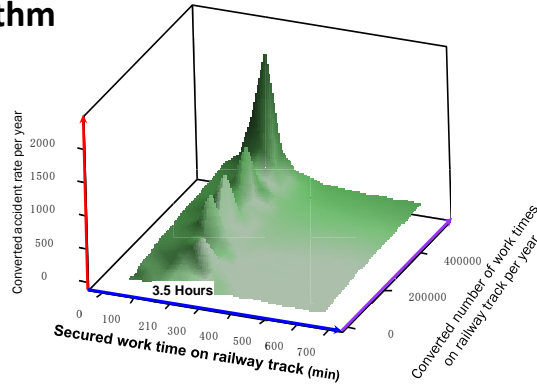
Correlation of accident rate



- ❖ Number of times work is done and secured work time on railway
- ❖ Surface plot graph showing the trend among accident rate, secured time on railway track block work and the number of times work is done on railway track

Accident rate assessment matrix in accordance with the number of times work and secured work time

- ❖ The secured work time and the number of times work is done on railway track are grouped into a few sections
- ❖ The number of times work is done, secured duration of rail work and rate of accidents is grouped using the K-means algorithm



[Defining section of secured work time on railway track]

| Section code for secured work time on railway track | Defining secured work time (min) on railway track |
|---|---|
| E1 | Less than 120 min. |
| E2 | 120 min. or above - less than 180 min. |
| E3 | 180 min. or above - less than 210 min. |
| E4 | 210 min. or above - less than 270 min. |
| E5 | 270 min. or above - less than 360 min. |
| E6 | 360 min. or above - less than 500 min. |
| E7 | 500 min. or above |

[Defining section of converted accident rate considering total operation distance]

| Converted accident rate | Converted accident rate |
|-------------------------|-----------------------------|
| F1 | Less than 30 |
| F2 | 30 or above - 90 or lower |
| F3 | 90 or above - 170 or lower |
| F4 | 170 or above - 300 or lower |
| F5 | 300 or above - 700 or lower |
| F6 | 700 or above |

[Defining section of the converted number of times work is done on railway considering total operation distance]

| Section code for no. of works on railway track | Defining section of no. of works on railway track |
|--|---|
| A1 | Less than 22,690 |
| A2 | 22,690 or above - less than 43,645 |
| A3 | 43,645 or above - less than 68,566 |
| A4 | 68,566 or above - less than 117,402 |
| A5 | 117,402 or above - less than 312,608 |
| A6 | 312,608 or above |

Accident rate assessment matrix in accordance with the number of times work and secured work time

| Time secured for maintenance | Category | No. of works on railway track with converted total operation distance | | | | | |
|--|-------------------------------|---|---|---|--|---|--------------------------------|
| | | Less than 22,690 (A1) | 22,690 or above - less than 43,645 (A2) | 43,645 or above - less than 68,566 (A3) | 68,566 or above - less than 117,402 (A4) | 117,402 or above - less than 312,608 (A5) | 312,608 or above (A6) |
| Less than 120 min. (E1) | No. of sections | 9 | 6 | 8 | 5 | 0 | 0 |
| | Converted accident rate | [0.00, 33.61, 113.40] | [0.00, 35.20, 211.23] | [0.00, 103.86, 314.99] | [0.00, 19.41, 97.05] | [0.00, 0.00, 0.00] | [0.00, 0.00, 0.00] |
| | Converted accident rate level | [F1, F2, F3] | [F1, F2, F4] | [F1, F3, F5] | [F1, F1, F3] | [F1, F1, F1] | [F1, F1, F1] |
| 120 or above - less than 180 min. (E2) | No. of sections | 25 | 10 | 16 | 5 | 1 | 1 |
| | Converted accident rate | [0.00, 46.02, 147.57] | [0.00, 48.86, 239.39] | [0.00, 86.76, 287.27] | [81.61, 154.16, 239.39] | [287.27, 287.27, 287.27] | [579.18, 579.18, 579.18] |
| | Converted accident rate level | [F1, F2, F3] | [F1, F2, F4] | [F1, F2, F4] | [F2, F3, F4] | [F4, F4, F4] | [F5, F5, F5] |
| 180 or above - less than 210 min. (E3) | No. of sections | 11 | 11 | 29 | 11 | 8 | 3 |
| | Converted accident rate | [0.00, 82.76, 422.46] | [47.25, 196.40, 590.29] | [0.00, 124.73, 377.99] | [0.00, 233.75, 614.23] | [242.63, 598.23, 1,445.32] | [1,009.94, 1,554.54, 2,347.90] |
| | Converted accident rate level | [F1, F2, F5] | [F2, F4, F5] | [F1, F3, F5] | [F1, F4, F5] | [F4, F5, F6] | [F6, F6, F6] |
| 210 or above - less than 270 min. (E4) | No. of sections | 44 | 37 | 24 | 11 | 7 | 1 |
| | Converted accident rate | [0.00, 116.26, 503.41] | [0.00, 109.03, 761.71] | [0.00, 143.19, 1,175.21] | [0.00, 403.47, 1,231.17] | [0.00, 291.23, 1,396.46] | [422.46, 422.46, 422.46] |
| | Converted accident rate level | [F1, F3, F5] | [F1, F3, F6] | [F1, F3, F6] | [F1, F5, F6] | [F1, F5, F6] | [F5, F5, F5] |
| 270 or above - less than 360 min. (E5) | No. of sections | 27 | 20 | 12 | 6 | 0 | 0 |
| | Converted accident rate | [0.00, 17.01, 115.84] | [0.00, 57.86, 251.99] | [0.00, 88.65, 189.00] | [0.00, 63.49, 160.79] | [0.00, 0.00, 0.00] | [0.00, 0.00, 0.00] |
| | Converted accident rate level | [F1, F1, F3] | [F1, F2, F4] | [F1, F2, F4] | [F1, F2, F3] | [F1, F1, F1] | [F1, F1, F1] |
| 360 or above - less than 500 min. (E6) | No. of sections | 15 | 14 | 4 | 2 | 1 | 0 |
| | Converted accident rate | [0.00, 39.20, 158.42] | [0.00, 54.73, 280.54] | [0.00, 64.40, 141.75] | [0.00, 44.83, 89.77] | [0.00, 0.00, 0.00] | [0.00, 0.00, 0.00] |
| | Converted accident rate level | [F1, F2, F3] | [F1, F2, F4] | [F1, F2, F3] | [F1, F2, F2] | [F1, F1, F1] | [F1, F1, F1] |
| 500 min. or above (E7) | No. of sections | 15 | 6 | 0 | 0 | 0 | 0 |
| | Converted accident rate | [0.00, 24.01, 211.23] | [0.00, 0.00, 0.00] | [0.00, 0.00, 0.00] | [0.00, 0.00, 0.00] | [0.00, 0.00, 0.00] | [0.00, 0.00, 0.00] |
| | Converted accident rate level | [F1, F1, F4] | [F1, F1, F1] | [F1, F1, F1] | [F1, F1, F1] | [F1, F1, F1] | [F1, F1, F1] |

Conclusion and future plans

- ❖ **Based on the risk level assessment, the MLIT will:**
 - **secure appropriate work time on railway track per each section, as well as manage the risk level of sections with high risk levels**
 - **continuously assess the risk level of railway facilities in each section**
 - **collect data needed for thorough assessment of the risk level of railway facilities**



Thank you.

