

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

Chan-Woo, Park / Duck-Ho, Shin / Sang-Log, Kwak

Korea Railroad Research Institute

# 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

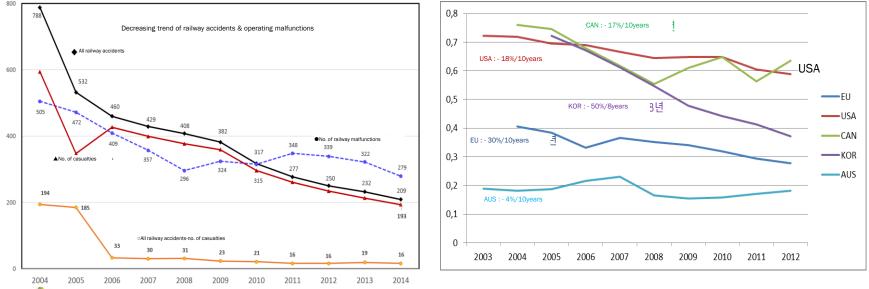
#### • Total of 4,520 km lines for passenger service

- 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



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





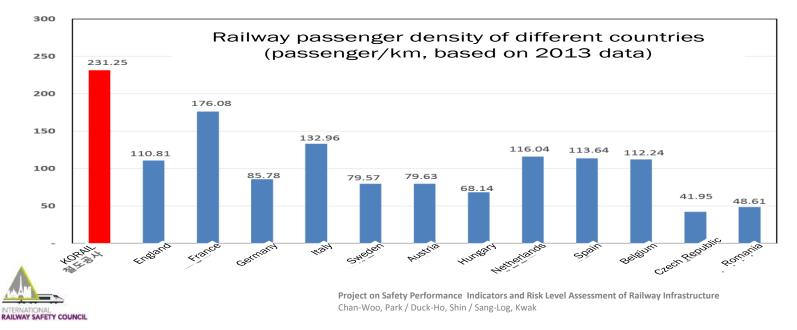
The railway is considered the safest transportation in Korea

- 25 times safer than road transportation
- 50% of total fatalities come from suicide
- 40% of total fatalities come from trespassing

	Trasnportation Share %	Accident Fatalities (5yrs)	<b>Fatalities/Share</b>	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	-	-



- 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)



- **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%



- 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

 $\boldsymbol{\diamondsuit}$  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%

	В	efore adjustme	ent (Until '15.0	7)	After adjustment (After '15.08)			
Track block and tramline power cut time	Track block		Tramline power cut		Track block		Tramline power cut	
power out time	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

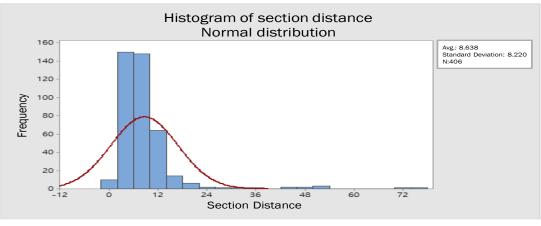
#### Analysis of management incident logs

- 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
  - = (Section "A"'s avg. frequency per year) x

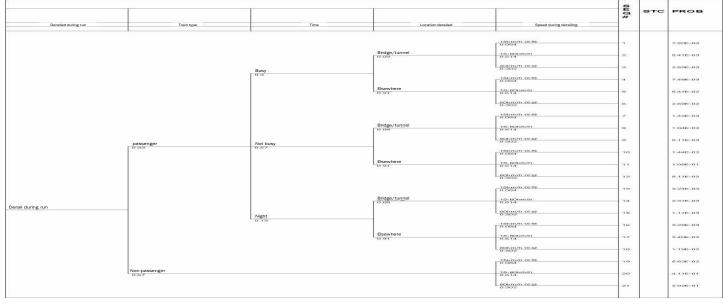
KORAIL's total distance of operation

operation distance of each section



# **Event severity indicators**

- Solution 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





### 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

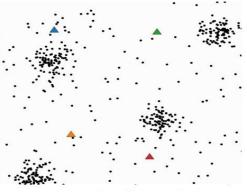
Severity Frequency	Insignificant	Marginal	Critical	Catastrophic
Frequent	Undesirable	Intolerable	Intolerable	Intolerable
Probable	Tolerable	Undesirable	Intolerable	Intolerable
Occasional	Tolerable	Undesirable	Undesirable	Intolerable
Remote	Negligible	Tolerable	Undesirable	Undesirable
Improbable	Negligible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

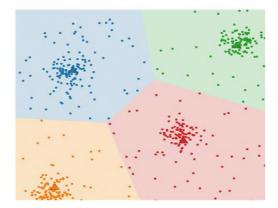


# Accident rate assessment matrix in accordance with the amount of work on and secured work time for railway track

- ✤ 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,

#### Severity **C2** C1 C3 **C4** C5 C6 Service Service Service Service Service Service unavailable for unavailable unavailable for unavailable for unavailable for unavailable for +8 h~-23 h +10~-19 min or +20min~-1 h 59 +2 h~-7 h 59min for+24 h or Frequency less than 10 min 59min or +1 minor injury min or +10 deaths (with converted) or or +2 deaths total operation no casualty +1 serious +1 death injury distance of 3.950km F6 В А Α А Α Annual average А +700 cases F5 Annual average В В A А А A +300~-699 cases F4 В В B А А Annual average A +170~-299 cases F3 С В В В А А Annual average +90~-169 cases F2 С С В В В А Annual average +30~-89 cases F1С С С В Annual average В В +0~-29 cases

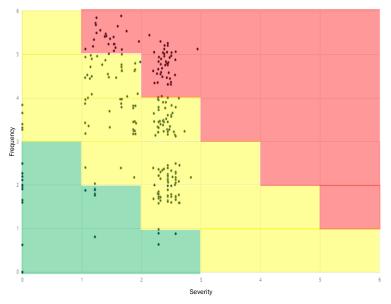
#### the Risk Matrix can be developed



## 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 caus	e⊷	Section A	Section B ·	Section C .
Total·root·cause·	No. of sections	41⊷	194 <i>₀</i>	<b>171</b> ₽
C00¢	Percentage	10%⊷	41.0     194.0       0%.0     48%.0       20.0     153.0       5%.0     38%.0       2β.0     182.0       5%.0     45%.0       26.0     195.0	<b>42%</b> ~
Technical cause	sections.	153 <i>₀</i>	233.	
C01₽	Percentage	5%⊷	38%⊷	57%⊷
Technical cause C01 + Natural	No. of sections	2 <b>β</b> ₽	<b>182</b> ₽	<b>201</b> ₽
disaster C02	Percentage	6%⊷	45%⊷	<b>50%</b> ~
Technical cause C01 + Natural	No. of sections	26.	195 <sub>*</sub> ,	<b>185</b> ₽
disaster·C02·+· Error·while· maintenance·C03 <sub>*</sub>	Percentage	6%⊷	48‰	46‰∘



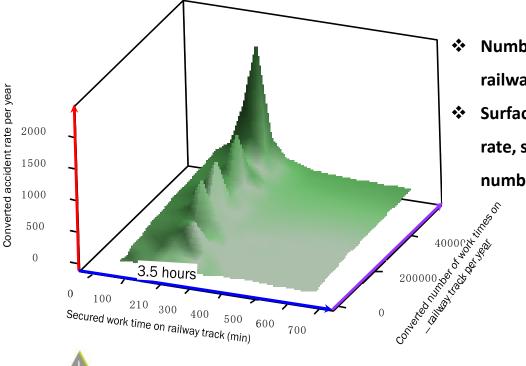
### Detailed risk profile of sections with risk level A (41 sections)

- 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

부록	위험도 쇼 특근 구기	의 세부 Risk Profile (C007년)	□ 위협요인별 관리장애 환산 사고율	· 정보(단위: 건/년)			□ 선로 차단작업 수행횟수 정보(단위: 횟수/년)
			전체 구간의	의 환산 사고율/년			전체 구간의 차단작업 수행횟수/년
			응행선 작업으로 인한 자랑응행 지연/직원교통사상사고(H30) 7,0	1			인세 구간의 사단막료 구영횟수/인
			전력설비 이상(889)				전차선 보수작업(014) 16.605.69
1 1	바제 전체 구간의 위험	도 정보 요약		22.05			터널 보수작법(033) 1.950.22
			구조물 이상(HOR) <u>134</u>				교량 보수작업(012) ] 88-92
			장애물/이물질에 의한 자랑운행 지연(H07)	12.8			※77月夏保期10111 日 227.52
미 구강	기본정보		궤도 이상(****	9.52			전대려일 제설정(020) 🔲 456.35
	t: 406개 전체 구간		아전설비 여십04051 4.3				레일교환작업(009) 2.212.09
0.000				-			집목교환학(()) 2,399.81
0 구;	산 길이: 3,507 km		역 조작반 장치 이상(H04) 433				2.57/745(5)(07)
0 41	르카다 하버지가, 204시	간 ('15.08이전 기준, 단위: 시간, 등급: E4)	연동장치 이상(H03) <u>3.68</u>				18-7/45(2005) 18-7/452(2005) 11455.60
0 22	파이번 헤프이션: 0.94이	신 (10.00~1)신 기관, 전계: 시신, 중점: D4)	분기부 이상(H02)	23			15 기거식 (108) 안전설비 보수작업(205) 1.388.82
			궤도회로장지/신호기 이상(H0T)				
□ 위험	도 정보 요약		레프레드레시(인프리 이상(H01)	0.0			역 조작한 장치 보수작업(004) 982.7 신뢰만등장치 보수작업(003) 944.19
			•	5 10 15	20	25	
1	구분	전체 구간 F3					분기부 보수작업(002) 4412.26
	빈도 등급						해도회르장지/해석장지/신요기 보수작업(081) 4.000.23
		(환산 사고율/년: 106.39)	위험요인별 근본원인별 환산 사고	.율 정보(단위: 건/년	)		0.00 2,000.00 4,000.00 6,000.00 8,000.00 12,000.00 14,000.00 16,000.00 18,000.00
	심각도 등급	53			화산 /	···고율/년	
		(장애시간: 37.89, 풍가사망: 0.04)	위험요민	근본원인	22	백분율	
	위험도 등급	в	분기부 이상(H02)	기술/관리 요인(C01)	20.99	19.73%	
	The second s	A5	궤도회로장치/신호기 이상(H01)	기술/관리 요인(C01)	11.98	11.26%	
	유지보수 수행횟수 등급	(환산 유지보수 수행횟수/년: 260.419.70)	전월설비 이상(H09)	기술/관리 요인(C01)	11.57	10.88%	
	L1	(a a notice in the intervention of	운행선 작업으로 인한 차량운행	작업中 오류(C03)	7.07	6.64%	
			지연/적원교통사상사고(H10) 궤도 이상(H06)	기술/관리 요인(C01)	6.96	6.54%	
미 근본	원인범 관리장애 화산	사고율 정보(단위: 건/년)	· · · · · · · · · · · · · · · · · · ·	기술/관리 요인(C01)	6.25	5.87%	
			안전설비 이상(H05)	기술/관리 요인(C01)	3.99	3.75%	
	28	체 구간의 화산 사고율/년	전월설비 이상(H09)	인점 공사(C04)	3.48	3.27%	□ 위험도 관리 방안 제언
	-	에 1 년국 전입 기수를/ 년	분기부 이상(H02) 위원성의 이상(H02)	자연재해(C02) 기타, 이북 col (C05)	3.17	2.98%	
			전철설비 이상(H09) 전철설비 이상(H09)	기타 외부요인(C05) 자연재해(C02)	3.17	2.98%	• 파제 구간에 대해 위험도 동금이 B등금으로, 위험을 일반적으로 허용할 수 있으나, 이 경우
	기타 외부요인(005) 5.22		연몽장치 이상(H03)	기술/관리 요인(C01)	2.76	2.60%	경감으로 인한 상당한 이득이 있거나(있고) 다른 관련 철도에서 널리 적용되는 경감책이
			장애물/이물질에 의한 차량운행 지면(H07)	인점 공사(C04)	2.76	2.60%	있어야 하며, 위험도를 추가적으로 낮추어야 함
	인접 공사(C04) 0.52		역 초작반 장치 이상(H04)	기술/관리 요인(C01)	2.36	2.21%	·관리 장애의 근본원인으로 기술/관리 요안이 가장 많은 부분을 쳐지하고 있으며, 분기부 이상
			장애물/이물질에 의한 차량운행 지연(H07) 궤도 이상(H06)	자연재해(C02) 자연재해(C02)	2.15	2.02%	
	取留中오哥(CD3) 11.06		제도 이상(H00) 제도회로장치/신호기 이상(H01)	자연재해(C02) 자연재해(C02)	1.74	1.44%	과 전철설비 이상으로 인한 사건이 빈번하게 발생함
			액 조작반 장치 이상(H04)	인접 공사(C04)	1.43	1.35%	<ul> <li>유지보수 수행횟수에서 보는 봐와 같이 전차선 유지보수 및 선로 유지보수 활동이 빈번하게</li> </ul>
	자연제해(002) 12.8		장애물/이풀질에 의한 차량운행 지연(H07)	작업中 요류(C03)	1.02	0.96%	수행됨
	-1 L - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1		전철설비 이상(H09)	작업中 오류(C03)	0.92	0.87%	• 이는 총 작업량에 비하여 선로작업시간의 부족으로 인한 회수가 증가하는 것으로 판단됨
1				기술/관리 요인(C01) 인접 공사(C04)	0.92	0.87%	· 철도 시설관련 사건 중 신호 관련 사고가 빈번하게 발생하고 있으나, 유지보수 이력에서 보는
	기울/관리 요안(001)	67.78	에 조작한 장치 이상(H04)	자연재해(C02)	0.61	0.57%	
1	0 10	20 30 40 50 60 70 80	장애물/이플길에 의한 차량운행 지면(H07)	기타 외부요인(C05)	0.61	0.58%	봐와 같이 이에 대한 보수작업이 부족한 것으로 나타나므로 이에 대한 경감대책 마련이 필요함



# **Correlation of accident rate**



RAILWAY SAFETY COUNCIL

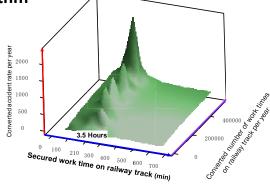
- Number of times work is done and secured work time on railway
- Surface plot graph showing the trend among accident rate, secured time on railway track block work and the number of times work is done on railway track



18

# 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 Kmeans algorithm
  (Defining section of converted accident rate considering



[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.
Eô	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

				No. of works on railway track with	converted total operation distance		
Time secured for maintenance	Category	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)
	No. of sections	9	6	8	5	0	0
Less than 120 min.	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]
(E1)	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 -	No. of sections	25	10	16	5	1	1
less than 180 min.	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]
(E2)	Converted accident rate level	[F1, F2, F3]	[F1, F2, F4]	[F1, F2, F4]	[F2, F3, F4]	[F4, F4, F4]	
180 or above -	No. of sections	11	11	29	11 📣	8	3
less than 210 min.	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, 1,445.12]	[1,009.94, 1,554.54, 2,347.90]
(E3)	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 -	No. of sections	44	37	24	11	7	
less than 270 min.	Converted accident rate	[0.00, 116.26, 506.41]	[0.00, 109.08, 761.71]	[0.00, 148.19, 1,175.21]	[0.00, 409.47, 1,231.17]	[0.00, 32123, 1,396.46]	[422.46, 422.46, 422.46]
(E4)	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 -	No. of sections	27	20	12	6	0	0
less than 360 min.	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]
(E5)	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 -	No. of sections	15	14	4	2	1	0
less than 500 min.	Converted accident rate	[0.00, 39.20, 158.42]	[0.00, 54.73, 280.54]	[0.00, 64.40, 141.75]	[0.00, 44.89, 89.77]	[0.00, 0.00, 0.00]	[0.00, 0.00, 0.00]
(E6)	Converted accident rate level	[F1, F2, F3]	[F1, F2, F4]	[F1, F2, F3]	[F1, F2, F2]	[F1, F1, F1]	[F1, F1, F1]
500 min on	No. of sections	15	6	0	0	0	0
500 min. or above	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]
(E7)	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.



