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PALAIS DES CONGRÈS DE MONTRÉAL

Refurbishment Project of Expressway Tunnels in South Korea

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Tunnel Safety Specialist, Safety Coordinator

PIARC TC D5 (Road Tunnel Operation) member (2008 ~)

◦ Working Experience

- Korea Expressway Corporation (Oct. 1995 ~)
  (Team Leader, Construction Office)

◦ Educational Background

- B.S. on Building Equipment
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Seung-Wan Ryu

Tunnel Safety Specialist

PIARC TC D5 (Road Tunnel Operation) member (2012 ~)

◦ Working Experience

- Korea Expressway Corporation (Aug. 2006 ~)
  - VE(Value Engineering)
  - Construction site supervisior(Mechanical Eng)
  - Planning and Design of tunnel

◦ Educational Background

- B.S. on Aerospace Engineering
- M.S. on Control system of Aerospace Engineering

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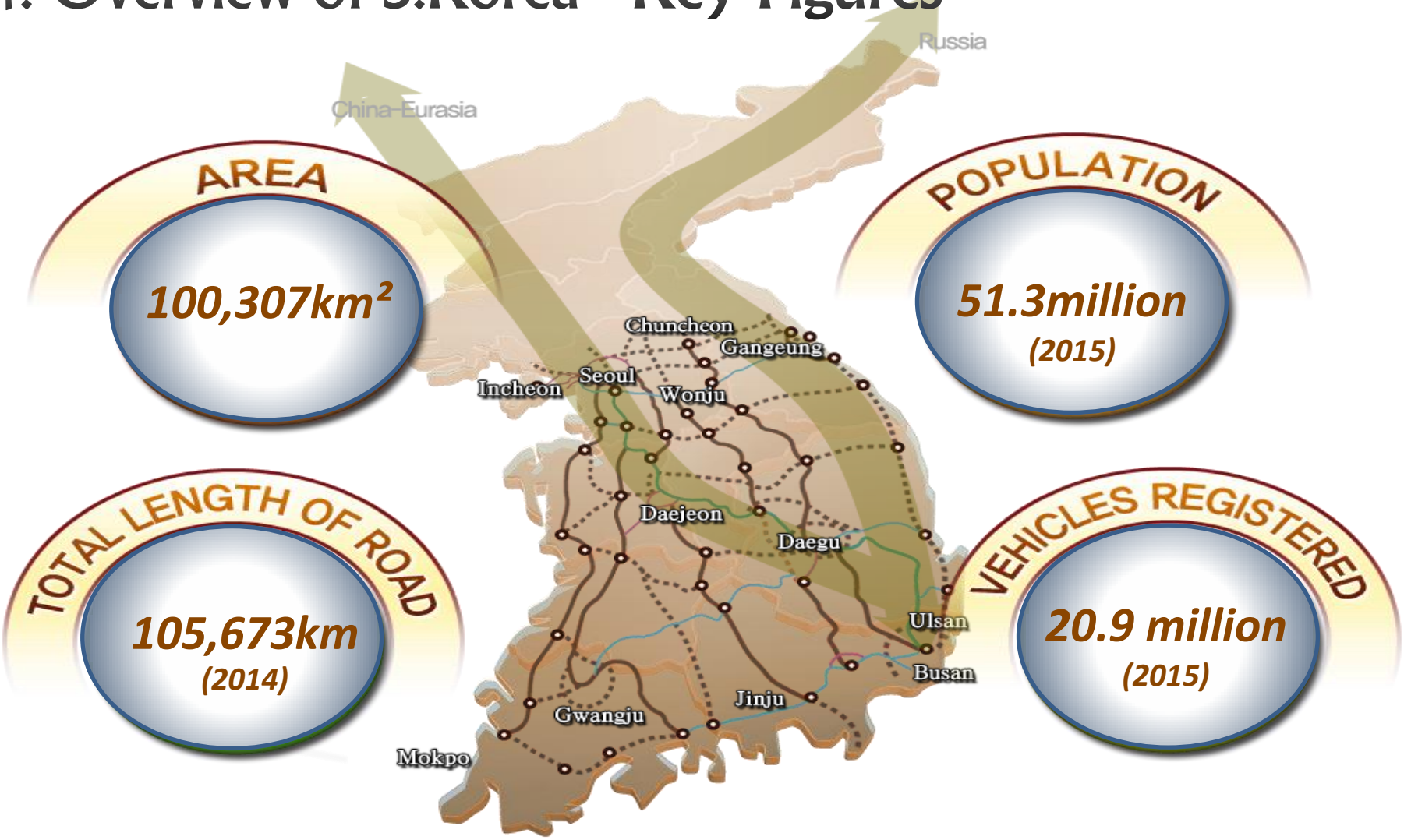
I. Introduction of KEC

1. Overview of S.Korea - Key Figures



I. Introduction of KEC

1. Overview of S.Korea – Total Road Network

(as of Dec. 2014)

** Expw (as of 2016)*

Name of Route	Authority	Length (km)
Total Length of Road Network		**105,673**
Expressway	***KEC(on behalf of MOLIT)***	***4,453***
National Highway	**MOLIT**	**13,950**
Special , Metropolitan City Road	**Special Metropolitan City Government**	**4,758**
Provincial Road	**Provincial Government**	**18,058**
City, County Road	**City / County Government**	**64,768**

※ **MOLIT : Ministry of Land, Infrastructure & Transport**

I. Introduction of KEC

2. Expressway Network : 7V x 9H + 6 Ring

1969

⋮

2009 — **3,496km**

2016 — **4,453km**

2020 — **5,131km**

Under Construction

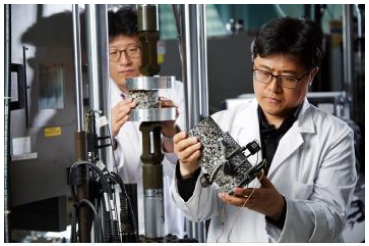
- **New lines : 803km**
- **Expansion : 85km**

I. Introduction of KEC

3. Roles of KEC

- ***Construction***
- ***Operation & Maintenance of Facilities***
- ***Traffic management***
- ***Research & Development***
- ***International Cooperation & Overseas Project***

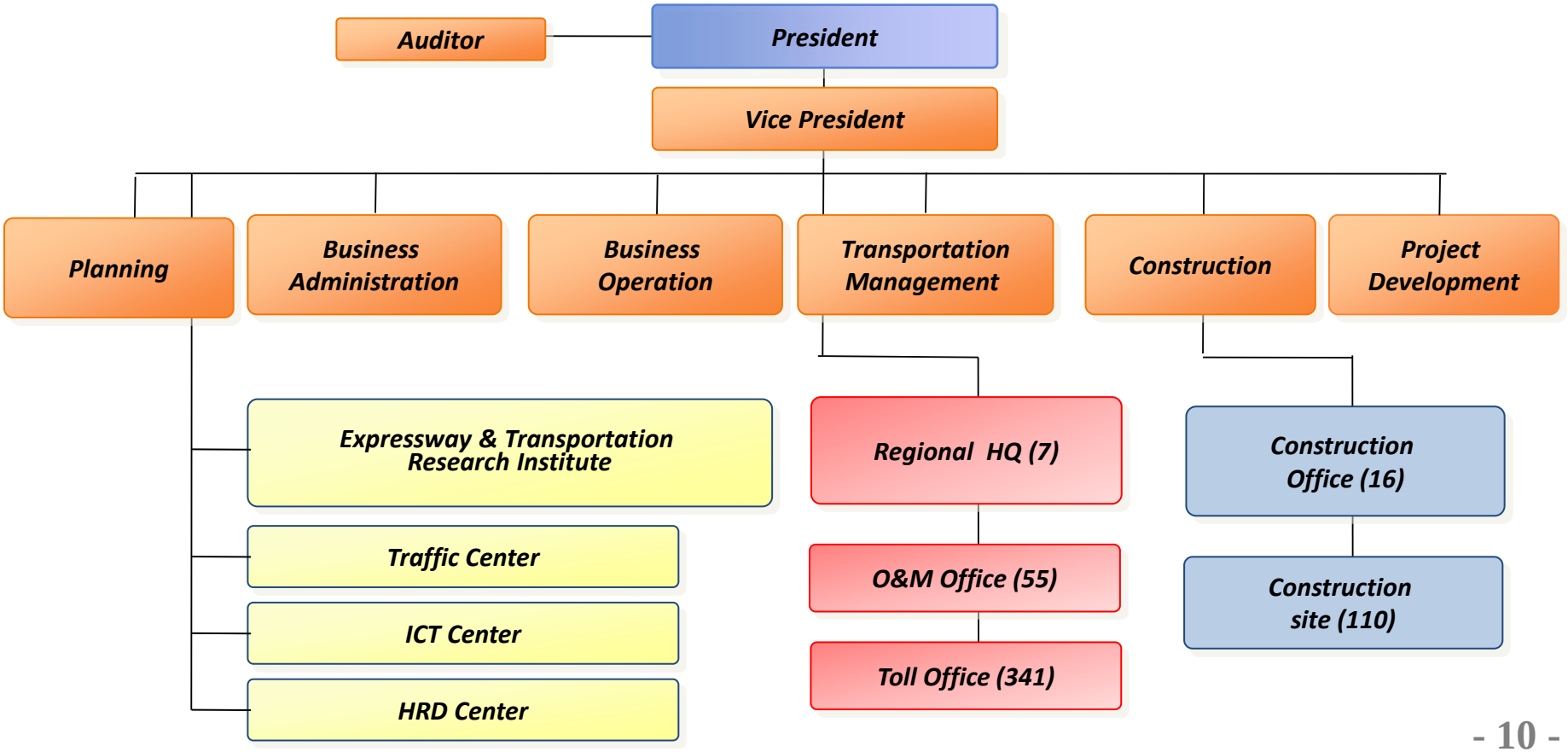
❖ *KEC performs these missions on behalf of the Korean government*



I. Introduction of KEC

4. Organization

- *5HQ with 18 division*
- *7 Regional HQ, 7 R&D office, 16 Construction Office*
- *Total Staff : 5,939*

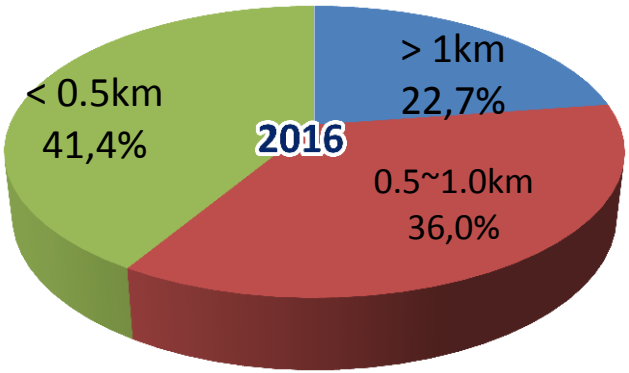


I. Introduction of KEC

5. Tunnels & Bridges of Expressway

- ***Tunnels : 481 (340km)***

  - No. of over 1km : 109 / 1.0-0.5km : 173 / under 0.5km : 199



- ***Bridges : 8,895***

  - No. of over 1km : 62 / under 1km : 8,833

6. Financial Status

(1USD=1,100KRW)

Capital

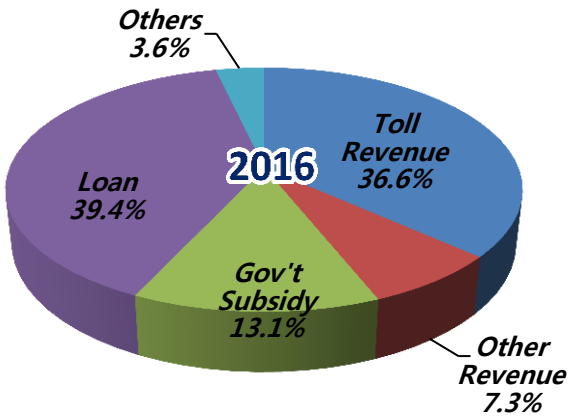
- *Authorized Capital : $31.8bil*
- *Paid-in Capital : $26.8bil*

Shareholders

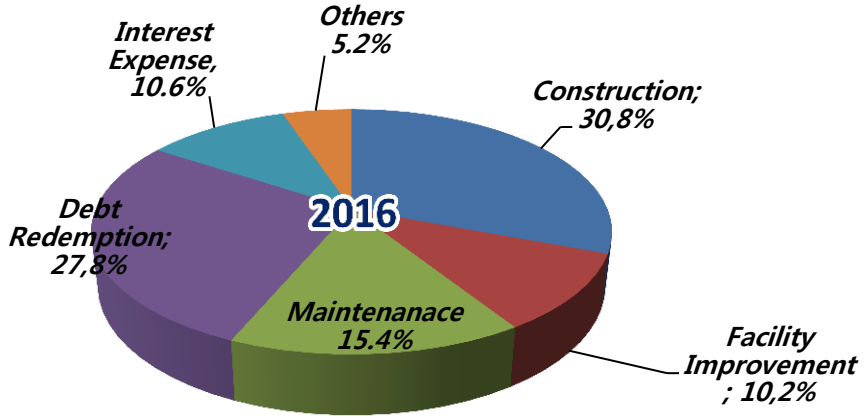
- *Government : 84.46%*
- *Export-Import Bank of Korea : 11.12%*
- *Korea Development Bank : 3.13%*
- *Industrial Bank of Korea : 0.76%*
- *Korea Housing Finance Corp. : 0.51%*
- *Kookmin Bank : 0.02%*

Budget

- *Total Capital Revenue : $9.7bil*

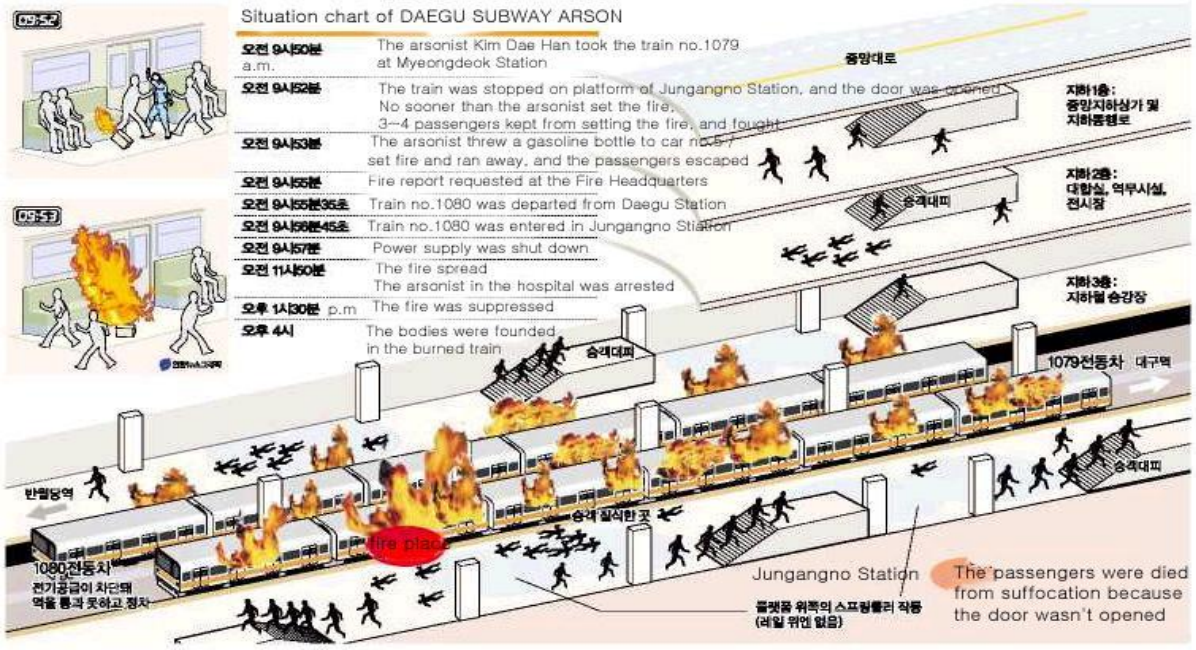


- *Total Capital Expenditure : $9.7bil*



II. Background of Refurbishment

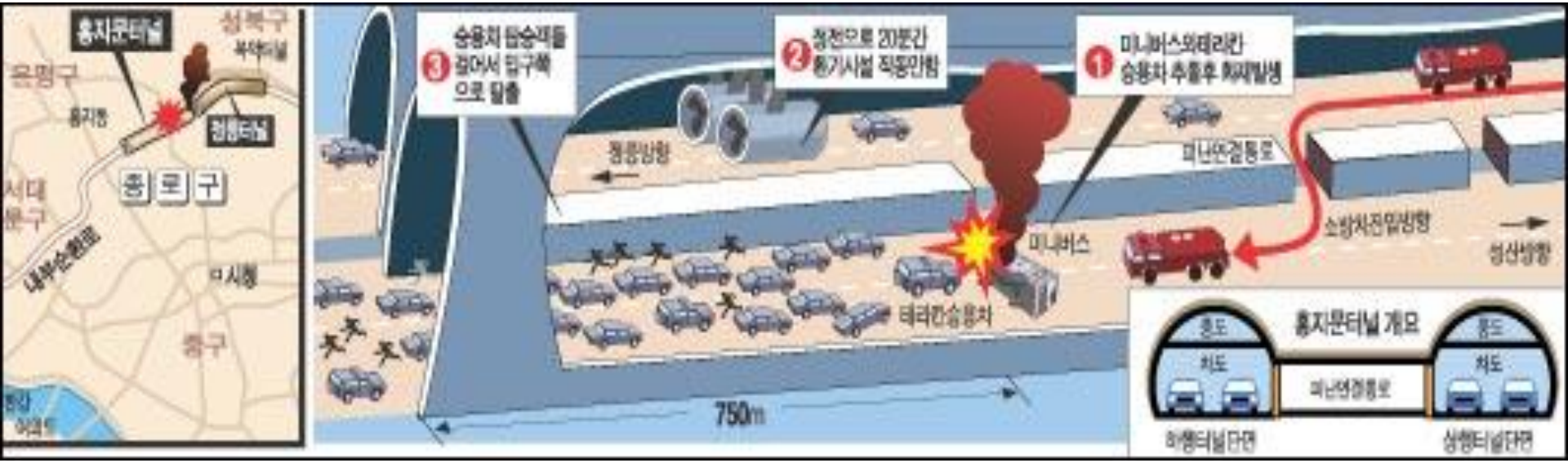
Subway fire in 18.Feb. 2003, Dae-gu city



- Cause of Fire — Arson (attempted suicide)
- Loss / Damage — 192 fatalities, 151 wounded, 11mil. USD
- Issue / Problem — Equipment / Procedure / Education / Drill

II. Background of Refurbishment

Hong-ji-mun tunnel fire in Jun. 2003, Seoul city



- Cause of Fire — Collision of minibus with RV
- Loss / Damage — 40 wounded (smoke inhalation)
- Issue / Problem — Rush hour / Operational mistake

II. Background of Refurbishment

Regulation Changed in Dec. 2004 : Tunnel Grade

Before	After
• **Classified by length** ≥ 4,000m ≥ 2,000m ≥ 1,000m ≥ 800m ≥ 500m ≥ 200m < 200m	• **Two ways of classification : Length & Risk Assessment** **1) Classified by length** ・ Grade 1 : ≥ 3,000m ・ Grade 2 : ≥ 1,000m ・ Grade 3 : ≥ 500m ・ Grade 4 : < 500m **2) R/A : 6 Categories include 14 factors** ・ Traffic volume X tunnel length (Veh･km/tube･day) ・ Altitude gap and slope ・ Tunnel height and radius of curve ・ Restriction to transportation of dangerous goods ・ Frequency of congestion (Service level) ・ Uni/Bi Directional Traffic / Road shoulder **- Total 51 points maximum, over 29point is Grade 1**

II. Background of Refurbishment

Equipment per tunnel

Tunnel Length (m) / Equipment	Before							After				Note
	Over 4,000	Over 2,000	Over 1,000	Over 800	Over 500	Over 200	Under 200	Grade 1 (Over 3,000)	Grade 2 (Over 1,000)	Grade 3 (Over 500)	Grade 4 (Under 500)	
Automatic Fire Detector	●	●						●	●			
Emergency Broadcasting	●	●	●					●	●	●		
Radio Broadcasting System	●	●	●	●	●	●		●	●	●	●	
Variable Message Sign	●	●	●	●				●	●			
Emergency Lighting	●	●	●	●	●	●		●	●	●	●	
Exit Signaling	●	●	●					●	●	●		
Smoke Ventilation	●	●	●					●	●	△	△	**by risk assessment**
Cross Connection	●	●	●					●	●	●	△	**spacing 750m -> 250m**
UPS	●	●	●	●	●	●		●	●	●	●	

** Extinguisher, Hydrant, Water spray, Fire alarm, Emergency phone, CCTV, VIDS, etc.

**Transition rule : tunnels under design/construction are not mandatory

II. Background of Refurbishment

Social / Political pressure by imbalance of tunnel safety

- Increasing demand from users / the media
- Frequent pressure from National Audit

III. Refurbishment Plan

To satisfy all the equipment to all tunnels…

Equipment	Quantity of tunnels	Budget(Million US$)
Total	**296**	**478 + α**
Cross Connection	**85**	**305 + α**
Tunnel Closure System	18	39
Automatic Fire Detector	14	63
Variable Message Sign	13	48
Emergency Broadcasting	36	8
Exit Sign	139	15

+ α changes depending on the condition of making new cross connection.

III. Refurbishment Plan

Financial / Technical Problem

- Budget

Total cost > $478M, Yearly budget : < $30M

- Environment

Noise, vibration, dust, water pollution

- Traffic congestion

Long closure of 1 or 2 lane for construction

III. Refurbishment Plan

Solutions Used

- Selection by Risk Priority

→ Risk assessment for all old tunnels

- Alternative equipment

→ Jet-Fans instead of cross connection

- Long-term project

→ Cost division, important equipment first

III. Refurbishment Plan

Result of Risk Assessment (1)

Name of Tunnel	length(m)	N of lane	Traffic Volume(AADT)	Opened in	Risk point	Priority
Yong-dam	853	3/3	118,086	1996	26.5	1
Gwang-kyo	502	3/2/2	151,234	1991	26	2
Ban-wall	760	3/2/2	134,951	1991	26	2
Suan-san	684	3/3	118,412	1996	26	2
Gwang-am	752	4/2/2	126,807	1991	24.5	5
Mae-hyun2	970	2/2	38,417	2004	21	6
Dae-jun	812	3/3	78,725	1999	20.5	7
Kwanjiwon	526	2/2	61,349	2001	20.5	7
Cho-goyk	870	2/2	38,417	2004	20.5	7
Ka-kuem	845	2/2	38,417	2002	20.5	7
Gwang-myung	812	3/3	80,087	1995	20	11
Kim-hae	690	4/4	89,220	2001	19.5	12
Jung-won	988	3/3	38,417	2002	19.5	12

III. Refurbishment Plan

Result of Risk Assessment (2)

Name of Tunnel	length(m)	N of lane	Traffic Volume(AADT)	Opened in	Risk Point	Priority
Chang-won2	854	2/2	54,119	2001	19	14
Dal-sung2	993	2/2	37,753	1995	18.5	15
Won-duck	982	2/2	32,612	2005	18	16
Jin-nam	992	2/2	32,011	2004	18	16
Hwam-an1	877	2/2	42,810	2001	17.5	18
Jeung-yack	755	3/3	38,279	1999	17	19
Ho-nam	740	2/2	32,612	2008	17	19
Doo-jung	640	2/2	38,417	2004	16.5	21
Suriti	903	2/2	23,882	2007	16.5	21
Young-dong1	618	3/3	34,630	2003	16	23
Oak-chun1	690	3/3	31,286	2003	16	23
Chu-jum	547	2/2	37,653	2004	16	23
Hwam-an2	520	2/2	59,266	2001	16	23

III. Refurbishment Plan

Alternative Equipment

- Function of Cross connection is to separate users from smoke

  - But hard and expensive to make

→ **Use ventilation system(Jet-Fan) to help evacuation**

- Relatively simple & short than build cross connection

III. Refurbishment Plan

Long-term project plan

Year	Target Tunnel	Budget (Million $)	Equipments	Comment
2009	3 tunnels [Gwang-am, etc]	12.7	①, ②, ③	Avg. $ 4.3 M / tunnel
2010	1 tunnel [Suan-san]	5.5	①, ②, ③	
2011	1 tunnel [Yong-dam]	3.4	①, ②, ③	
2012	1 tunnel [Mae-hyun2]	1.1	①, ⑤	Removed ②, ③
2013	2 tunnels [Dae-jun, etc]	2.4	④, ⑤	Slim-type Jet-Fan
2014	3 tunnels [Cho-gok, etc]	2.9	④, ⑤	Less than $ 1 M / tunnel
2015	5 tunnels [Ka-kuem, etc]	4.5	④, ⑤	
2016	6 tunnels [Chang-won2, etc]	5.8	④, ⑤	
2017	5 tunnels [Yung-dong1, etc]	4.6	④, ⑤	
2018	5 tunnels [Bang-gok, etc]	4.6	④, ⑤	
2019	3 tunnels [Gu-wan, etc]	2.8	④, ⑤	
2020~	3 tunnels [Mong-tan3, etc]	2.8	④, ⑤	

※ ① Jet-FAN ② Hydrant ③ Local Control Room ④ Slim-type Jet-FAN ⑤ IRCS(Integrated Remote Control System)

IV. Implementation / Results

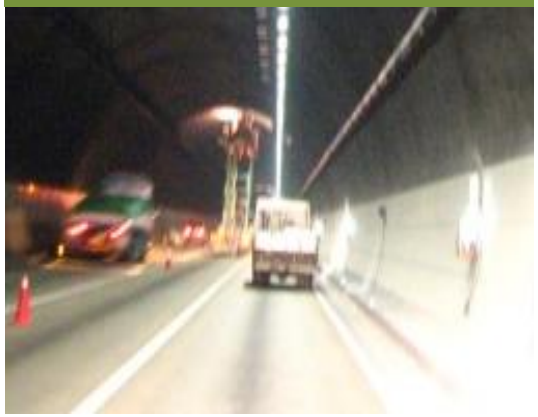
Case : Gwang-am Tunnel (752m, 126,807AADT)

- 3 tube (4/2/2 lane) / 2008.08~2009.09 (8 Month) / Total $5M
- Jet-fans (22ea), Hydrants(63ea), Control system , Power Supply

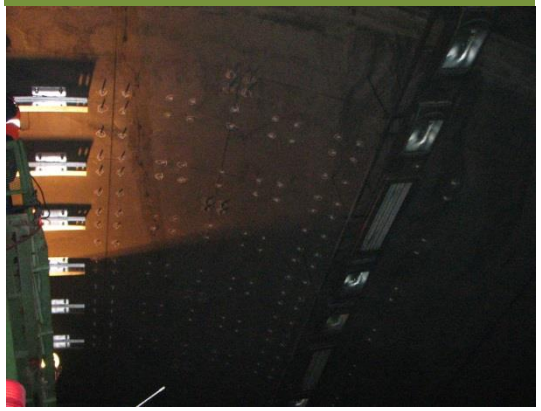
IV. Implementation / Results

Process of Jet-Fan installation

1) Survey

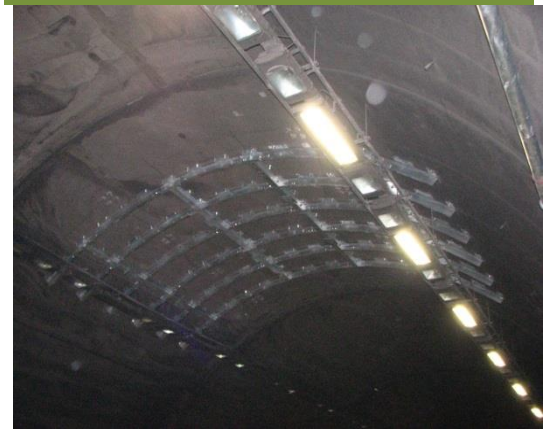


2) Drilling

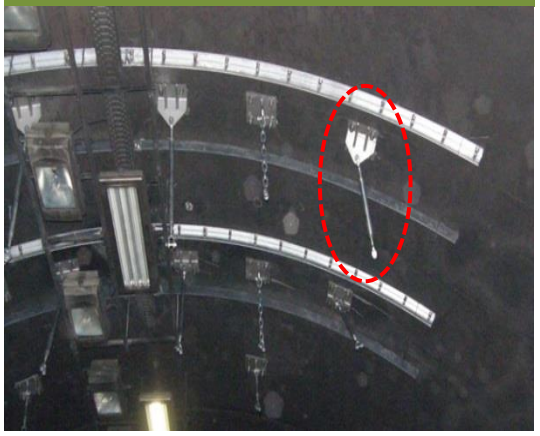


3) Beam base

4) Assemble beam



5) Fix Bracket



6) Install Jet-Fan

IV. Implementation / Results

Hydrant Installation

1) Marking

2) Chipping & Cutting

3) Trimming

4) Fix Hydrant box

5) Hose & Extinguisher

6) FD connection

IV. Implementation / Results

Hydrant Pipe (Utility box)

1) Hydrant

2) Main Pipe

3) Valve & ℃ Sensor

4) Obstacles

5) Pipe route

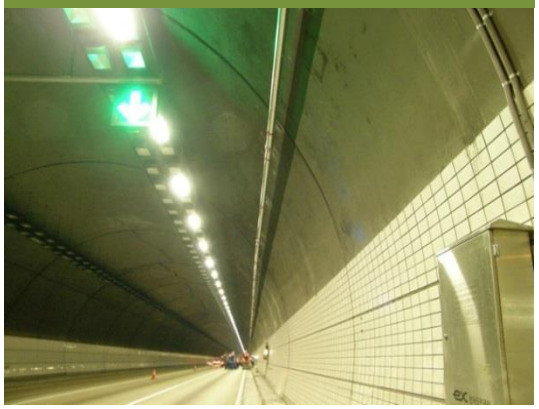
6) Control center

IV. Implementation / Results

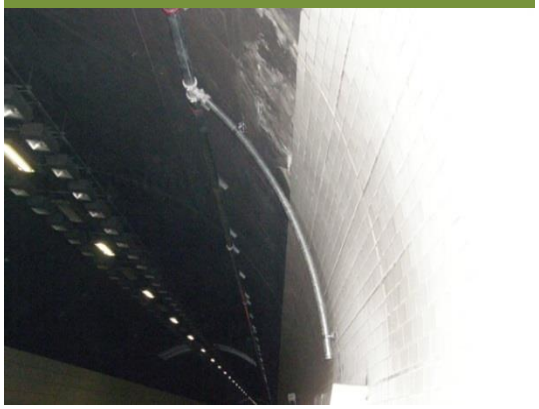
Hydrant Pipe (wall)

1) Install Bracket

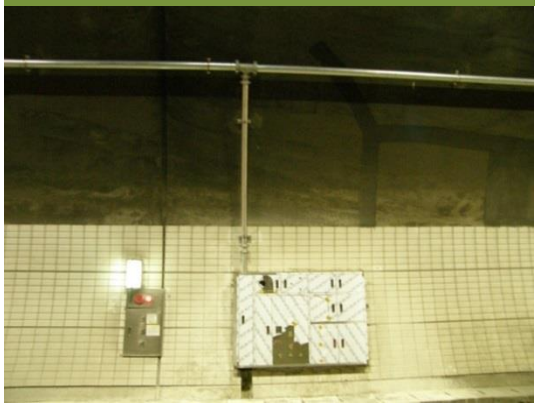
2) Install Main Pipe



3) Branch pipe



4) Connect to Hydrant



5) Heating Cable

6) Insulation / Cover

IV. Implementation / Results

Other Equipment

Wind speed sensor

Local Control room

Hydrant pump & Tank

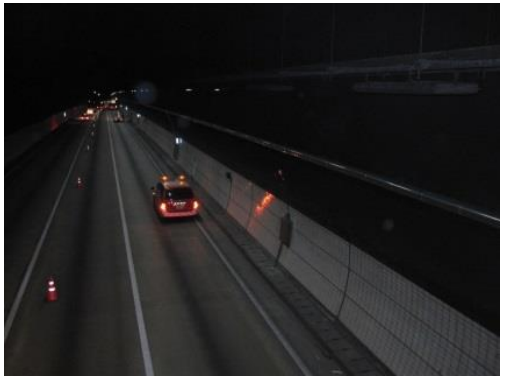
CCTV

RTU

Local panel / sensors

IV. Implementation / Results

Traffic Management



IV. Implementation / Results

Results

Equipment	N of tunnels	'09~'16	'17	'18	'19	'20	'21~
Cross Connection (Jet-Fan)	85	22	5	5	3	3	47
Tunnel closure system	18	16	2	-	-	-	-
Automatic Fire Detector	14	8	4	2	-	-	-
VMS, LCS	13	10	2	1	-	-	-
Emergency Broadcasting	36	10	-	12	14	-	-
Exit Signaling	139	52	-	9	16	11	51

V. Improvements

1. Slim type Jet-fan (booster fan)

- Use larger size Jet-fan with same power (reduce Q'ty of JF)
- Enable low construction/operation cost (efficiency improvement)

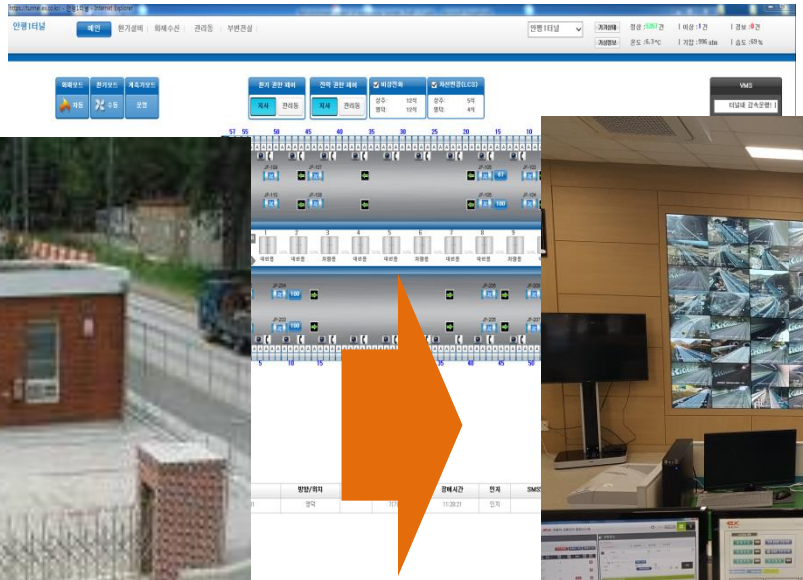
	Normal Type	Slim Type
Diameter	1,250mm	
Length	4.9m	3.6m
Weight	2.2ton	1.6ton
Power	37kW	30kW
Efficiency	70~75%	80~85%
F/B ratio	100%	60%

V. Improvements

2. Removal of local control building

- Due to reduced electricity capacity, no need for E. personnel
- Monitoring & Control system to the nearest branch office
- Save 0.85 million dollar/Each

Local Control



Remote Control

VI. Other Refurbishment Projects

Refurbishment plan of tunnel lightings with LED

Year	Total	~'14	'15	'16	'17	'18	'19	'20	'21~
N. of Tunnels	44	5	2	4	5	3	2	5	18
Cost(Mil. USD)	62.4	6.5	3.9	6.3	10.4	10.7	12.3	12.3	-

VI. Other Refurbishment Projects

Name of Tunnel	length(m)	N of lane	Budget (Million $)	Opened in	Year of Refurbishment	Priority
Sun-san	684	3/3	2.7	1996	2012	1
Sun-cheon2	861	3/3	3.6	1996	2013~2014	2
Gwang-myung	888	3/3	3.5	1995	2014~2015	3
Chung-kye	450	4/4	2.6	1995	2015	4
Da-bu	1,075	2/2	6.3	1995	2016~2017	5
Jung-bu1	300	2/2	2.4	2002	2016~2017	5
Jung-bu2	236	2/2	1.8	2002	2017	7
Jung-bu3	378	2/2	2.1	2002	2017	7
Yong-dam	766	3/3	2.6	1996	2017~2018	7
Ahn-yang	330	2/2	1.4	1996	2018	10
Su-ri	1,886	4/4	14.7	1999	2018~2019	10
Su-am	1,254	4/4	9.9	1999	2019~2020	12

VI. Other Refurbishment Projects

KEC established LED lamp standard for roads in 2013

33V
700mA
25W

Efficiency of luminance(lm/W)	Year
Over 100	2017
Over 110	2018

Factor	Performance criteria
Initial luminous flux	Over 95% of normal luminous flux
LLMF(Lamp Lumen Maintenance Factor)	Over 90% of Initial luminous flux (2,000hr)
CRI(Color rendering index)	Over 75

Standard color temperature(K)	Range of Color temperature(K)
5,700	5,665 ± 355
5,000	5,028 ± 283
4,500	4,503 ± 243

Q & A

Thank you for your attention
Merci pour votre attention