The Study of Efficiency of Train Control System Using Communication

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Abstract: Assuming that life of urban transit signaling is about 20 years with the flow of technology development, Seoul urban transit will be required to prepare for improvement soon. The highly developed countries preceding several levels rather than Korea are faced with commercial service, which uses RF, ATC and ATO in Train Control System.

European highly developed countries in the field of railroad have been progressing standardization and technology development of signaling associated with related manufacturers for direct operation between nations. For that, a effective train control system with radio beyond control levels by the existing wayside-onboard communication is in a developed and used stage.

The systems, which advanced countries have been progressing, seem to be applied to domestic within 5 years from now. At present, there are no countries using CBTC for service throughout the world. So, this is investigated to focus on the routes ready to be installed with completed CBTC and trying to introduce the technology.

Especially, considerations for economic aspect are mainly reviewed about controlling ability of headway, flexibility, extension aspect and construction cost on the basis of paper examined in NYCT.

Keywords: CBTC, Train Control System, Headway, Interoperability, Flexibility

1. INTRODUCTION

Train control system using radio communication is used to high reliable trainborne and wayside equipment which is the system to use radio communication for transmitting data between wayside and trainborne, as on-board computer controls optimal speed suitable for train performance and a computer located at wayside central control center transfers position of lead-vehicle and distance of movement limit point to train by periodically calculating position and speed of each train.

This system could be composed various systems with train position detection methods and communication methods between wayside and trainborne, which has a merit to be able to provide not only the high accuracy of train position and resolution and but also some conditions capable of operating as 70 sec. headway within the limit of train performance and track geometry. Especially, this system has a merit to provide parallel operation and also maintain appropriate interoperability in case of renewal of existing line, and wayside equipment is not much required so that contributed to efficiency of maintenance. However, since this system has used radio communication previous questions such as allocation of frequency band are requested to apply it to domestic.

This paper is mainly reviewed to efficiency of train control system using radio communication in the view of construction costs, adjustable capability of headway, flexibility, and extension.

This paper is checked headway of urban transport operating by each domestic local government and target headway of foreign transport where is scheduling to introduce train control system using radio communication.

For extension and flexibility of train control system using radio communication, comparative data such as flexibility, extension, safety and operation performance on the basis of the line from Hoyt Schermergorn to lefferts and Howard Beach/JFK is reviewed to apply train control system using radio communication to NYCT.

For construction costs, it's compared and studied construction costs of domestic urban railroad signaling

Recently finished construction and ones of foreign railroads trying to introduce train control system using radio communication. Whole construction costs used for improving existing urban railroad signaling and for installing new lines are resulted from above.

2. HEADWAY ADJUSTABLE CAPABILITY

2.1 Headway of domestic urban transport

Headway of domestic urban transport shows some differences from when target headway was designed, and has been operating as a minimum headway for the rush hours. Headway for each route is as below table 1.

Table 1 Headway of domestic urban transport [2]

Line	Headway		Line	Headway	
	RH (min)	NH (min)		RH (min)	NH (min)
Seoul line 1	3.0	4.0	Seoul line 7	3.0	5.0
Seoul line 2	2.5	5.5	Seoul line 8	4.5	6.0
Seoul line 3	3.0	6.0	Pusan line 1	4.0	6.0
Seoul line 4	2.5	5.0	Pusan line 2	4.0	6.0
Seoul line 5	2.5	5.0	Daegu line 1	5.0	6.5
Seoul line 6	4.0	6.0	Incheon line 1	4.0	8.0

2.2 Headway of foreign urban transport using CBTC

Nowadays there is no site operating revenue service with CBTC system in foreign, but minimum headway or target headway is checked through some site under constructions or site where have been validated the function, the effects are as below table 2.

Table 2 Headway of foreign CBTC site [2]

System	Site	Authority	Company	Headway
AATC	SanFrancisco	BART	GE-Harris	150s→80s
Seltrak	Newyork Canarsie line	NYCT	Simens	Target 90s
Seltrak	Paris line 13	RATP	Alcatel	Target 90s
SACEM	Hong Kong	MTRC	Alstom	120s→95s
IAGO	Singapore NEL		Alstom	Target 90s

2.3 Review and effect

With reviewing foreign case of CBTC system, it will be finally expected almost 95~80second headway. Domestic urban transport can be expected to shorten headway from 2.5 minute to 30~45second in the rush hours if headway of foreign case are compared with one of domestic urban transport [2].

Table 3 Domestic urban transport operation numbers [2]

Division	Time		Seoul line 3	Seoul line 4
Train operation number by operation time	RH	7 – 9	73 units	87 units
		18 - 20	59 units	76 units
	NH		295 units	347 units

Train operation is divided into R · H and N · H in domestic urban transport, N · H not much requests for high density of train operation but R · H requests for it so that the operation number has been running as 180second for the rush hours in 3 line and 73 unit has been running for almost 10,800second from 7 to 9 hour in the rush hours. In case of renewal into CBTC system 113 units for 3 hours will be expected as the effect of train operation.

3. FLEXIBILITY AND EXTENSITY

3.1 System requirement satisfaction

In figure 1 and table 4, it is evaluated by levels of each system to satisfy conditions required for renewal of existing urban transport investigated by NYCT.

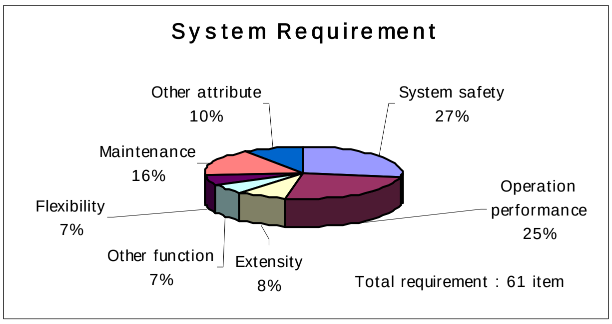

Fig. 1 Evaluation of technology grade [1]

Table 4 System grade level [1]

System category	System grade point	Grade level(%)
Communication Based ATC	1649	95.9
Overly type ATC	1538	89.4
AF Cab signaling	1383	80.4
Wayside Fixed Block/Wheel Detectors	1148	67.9

3.2 Review and effect

We checked 7 characteristics from each system as studied above. Compared with current systems used in domestic, these systems are similar to AF onboard system, thus, CBTC system is appeared excellent with 90% of performance in the safety of system if compared CBTC with AF onboard system. For operational performance, almost 20% of big difference between 90% of CBTC system and 70% of AF onboard system represents CBTC's superiority, for extension, CBTC is close to almost 100% but AF onboard system is under 80%. Also, it shows in flexibility that CBTC approximates almost 100% but AF onboard system is under 80%, so there is difference over 20% in maintenance and cost aspect. It appears superiority of CBTC system. As explained above, it seems similar in safety and other performance of each system and shows almost 20% difference in operational performance, extension, flexibility, maintenance and cost. It is regarded as CBTC system is superior over 20% to existing AF onboard system on the basis of 100%.

4. CONSTRUCTION COSTS

4.1 Construction costs of domestic urban transits signaling

Construction costs is as followings when Seoul subway 5 line and 7 line constructed recently was in design step.

Table 5 Construction costs of urban transits signaling(unit : billion korean won) [2]

Category	Seoul line 5	Seoul line 7(1'st)
Length	52.4km	17.7km
Work costs	110.8	36.8
Import	373.1	192.6
Domestic	68.6	35.7
Total construction costs	604.9	265.1
Construction costs/km	11.5	14.9

4.2 Construction costs of CBTC system

Currently, nowhere is operating commercial service with CBTC system through worldwide but investigation data for model line (line from Hoyt Schermergorn to Howard Beach/JFK : about 14km 483m) considering CBTC introduction is checked as basic data. It divides into Wayside

ABS, AF Cab Signalling, Communication-Based, Overlay Communication-Based for evaluation.

Table 6 Comparission of construction costs [1]

Train control technology	Capital investment expense	Development & Installation expense
Wayside ABS	$202,000,000	$102,000,000
AF Cab signaling	$140,000,000	$72,000,000
Communication -based	$140,000,000	$72,000,000
Overlay CBTC	$249,000,000	$132,000,000

4.3 Estimation of construction costs

4.3.1 Application criterion

Working expense includes equipment cost, engineering service (consultant and design), internal support(incidentals) and reserved fund, equipment cost is almost 30% to 40% except for 60%~70% of other equipment cost

- equipment installation cost : procure and install interlocking, wayside wheel detection system, wayside emergency preliminary signalling etc.
- onboard equipment: the cost for installing onboard equipment on new vehicle and improving existing vehicle. In case of NYCT project installation cost is each $27,000 for existing vehicle and $13,000 for new train.
- electronic equipment : the cost for wayside vital controller, data communication controller, radio equipment, antenna, coaxial cable, track and signal interface equipment, transponder, and installation cost.
- maintenance facilities : the cost for improving maintenance facilities and extending center maintenance facilities.
- master repeater tower location : utility cost and construction of repeater tower.
- spot interlocking control : spot switch board and non-vital logic cost ($29,000/signal).
- trunk communication : the cost for installing cable to link all new technology equipment.
- initial spare parts : apply 5% for onboard equipment, electronic equipment, master repeater tower, spot interlocking, trunk communication.

4.3.2 Construction cost of foreign CBTC sections

It's necessary to analyze a line to calculate construction costs, but we will calculate general cost of construction as an reference to foreign contract amount. Construction costs of CBTC system are per km as followings [1].

- MUNI Project : $7.35million/㎞
- NYCT Project : $7.89million/㎞
- BART Project : $0.94million/㎞
- Kuala Lumpur Project : $2.44million/㎞

The contract amount shows big difference according to project character, because the scope of project is changed by whether CBTC system is installed on existing line or on new line. If CBTC system is installed on existing line, expenses including improvement cost and eliminating cost of existing facilities is much more used up than CBTC system is installed on new line. In addition, existing system and new system shall be used in parallel in case of installing system on existing line, it results in spending much expenses.

4.4 Review and effect

In domestic, working expenses are much more expected for installing CBTC system through existing line than for applying it to new line, but these kinds of matters seem to be solved if system is selected to have the least interaction to existing system. Also, design, consultant, extra expense except construction costs are provided in domestic, which can result in reducing total working expenses. On the assumption that construction costs of domestic CBTC system is the same to one of foreign CBTC cost, it's expected to $2.5million × 0.7 = $1.75million per km, extra expenses including design will be $2.5million × 0.1 = $0.25million if extra expenses including design are expected to about 10% of project amount, so that construction costs can be estimated to $2.0million per km [2].

5. CONCLUSION

It is a obvious tendency for railroad industry to favor CBTC technology as explained above, final headway of foreign CBTC system targets 90 second. Compared with four technologies of Wayside ABS, AF Cab Signaling, Communication-based, Overlay Communication-based Hybrid in an international signalling field, we can figure out CBTC's superiority in satisfaction integrity of system requirements with CBTC system's international tendency. From an economic point of view CBTC system will be also profitable to Life cycle Cost and Cost Elements Summary. CBTC system is relatively profitable as existing subway approximates to onboard signal.

Table 7 CBTC adaptation effect [1], [2]

Category	Existing system	CBTC system	Expectation effect
Headway of adjustable capability	Minimum headway 150 sec.(real RH running time)	Final target headway 90-80 sec.	Expectation of 30-45 sec. reduction
Train operation number for RH(AM 7-9 hour)	73 unit	113 unit(basis on 90 sec.)	Expectation of 40 unit increasing
Flexibility & Extensity	Less than 80%	More than 90%	Expectation of more than 10% increasing
Life cycle & mainteanance costs	100% 100%	97% 98%	3% decrease 2% decrease
Construction costs	Investment & installation costs is equal		

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