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Comparison of two sewer condition assessment protocols in S. Korea

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ABSTRACT

The operation and management of social infrastructures can create significant headaches for municipal governments. Sewer systems are no exception, and prioritizing plans and strategies for asset management is usually adopted as a cost-effective solution. The condition assessment, which is an important element of asset management, provides current information about the condition of municipal facilities. Condition assessments were first used by Water Research Centre (WRc) in the UK, the country with the longest history of sewer management, and are now widely used in many countries. Korea uses the condition assessment protocol developed by the Ministry of Environment (MOE), but as this protocol does not fully reflect the underground environment in Korea, the assessments and judgments are ambiguous. The sewer condition assessment and rehabilitation decision-making (SCARD) program developed by this study is based on the MOE protocol with the defect items, score, and condition grading system modified in consideration of the type of buried pipelines in Korea. To compare the assessment results produced by these two protocols, a closed-circuit television inspection was performed on 11 km of sewer pipeline in the sampled area in P city. The inspection indicated that SCARD set a higher score of structural defects common to both protocols for items that affect the collapse mechanism (fracture, damage, etc.). The amount of pipeline that received a grade of five for internal condition rating of identified structure defects was 45% with the MOE protocol, which was much higher than the 0.6% given with SCARD. This result showed that there was a big difference between the two protocols in condition grade evaluations of structural defects. In the future, the findings of this study can be used to develop an objective protocol reflecting actual sewer pipeline conditions.

Keywords: Sewer; Asset management; Condition assessment; SCARD; Korea

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1. Introduction

Many municipalities are having financial difficulties managing their sewer networks [1,2]. The important factor of sewer system management is to allocate a budget for various activities including the inspection, repair, and maintenance of sewer pipes [1]. Since the cost of maintaining the sewer network must be balanced with the costs of other operations, prioritization is considered the most effective strategy [3]. Asset management is a formal system for determining the most cost-effective methods of sustaining the appropriate service level in the social infrastructure system [4]. For example, it can be considered that the sewer pipeline has a high service level when the I/I ration is low.

The condition assessment is an important element of asset management, as it can provide the current condition data of the assets managed and help allocate the optimum budget [5]. As it began with the condition grading protocol developed by WRc in the UK, many countries have developed protocols based on this to assess the conditions of their sewer pipelines.

There have been many studies on condition grading protocols for sewer pipelines including protocol comparison [3,6,7]. Canada's National Research Council (NRC) reported its comparisons of various condition grading protocols, including the WRc protocol and the protocol it developed in Edmonton and Winnipeg [8]. Canada has substituted the first edition of the internally developed Canadian infrastructure report card, which updates current sewer pipeline conditions, for the condition report [9,10]. Some cities that used the WRc protocol in the past are now using their own internally developed protocols, and the NRC reported that it was interesting to compare the internally developed protocols with the WRc protocol [3].

MOE recently cited the New Zealand protocol in developing a protocol including the structural and operational defect code and score in order to rate the sewer pipeline according to its internal condition [11]. The scores assigned to the defect items are calculated for a sewer pipeline based on the distance between manholes divided by the length of the pipeline to be calculated for a "Mean score" used to decide the rehabilitation method. The "Peak Score" is the highest score and is used for prioritizing rehabilitation. However, the MOE protocol does not reflect the buried sewer pipeline environment in Korea, and the result of assessment and judgment are ambiguous. For this reason, Korea needs a new protocol based on defects (joint and fracture) to Hume pipes, which are the most widely used type of pipes in Korea [12,13]. Based on this research, a sewer pipeline rehabilitation decision-making protocol system called "Sewer condition assessment and rehabilitation decision-making (SCARD) Program" modifies the way the internal condition of a sewer pipeline is assessed in the MOE protocol [14].

This study compared the results of the condition assessment of the SCARD program with the MOE protocol based on the data obtained with a closed-circuit television (CCTV) inspection of some sewer pipeline routes in zone T of the sample P city. The data comparing the sewer pipeline condition assessment protocol currently used in Korea with the newly developed protocol, modified to reflect the current status, will help in making an objective protocol that properly represents the actual sewer pipe aging condition.

2. Methodology

To compare the SCARD protocol with the MOE protocol as different methods for calculating the risk of sewer pipe failure, the structural and operational (hydraulic) condition grades of the inside of sewer pipes were analyzed. The data for assessing the condition grade were collected by a CCTV inspection company, and the defects observed in the pipeline between manholes were scored according to the protocols. Both protocols used the same information and CCTV inspection data.

2.1. Study area

The area of zone T in the small to medium sized city P is approximately 1,999 ha, and the south subzone of T is around 950 ha. Total sewer pipeline length is 201 km, and 167 km (83%) of it is circular pipe (Fig. 1). This study elected to survey and study 11 km of circular pipeline with a diameter of 250–1,000 mm through the sewage collection criteria from the circular pipes buried in the south subzone. The years in which the selected pipeline was installed varied widely, from prior to 1990, the year in which the installation data were first available in the GIS database of P city, to 2001. Municipal GIS was not properly updated from the time of pipe installation until 1990. The materials of the pipes included HP (Hume pipe, 88.9%), PC (prestressed concrete pipe, 3.7%), PE (polyethylene pipe, 7.0%) and PFP (polyethylene powder lining pipe, 0.4%).

2.2. Assessment criteria of the Ministry of environment

In 2011, the MOE established a standard manual to solve the problem of reduced reliability due to the

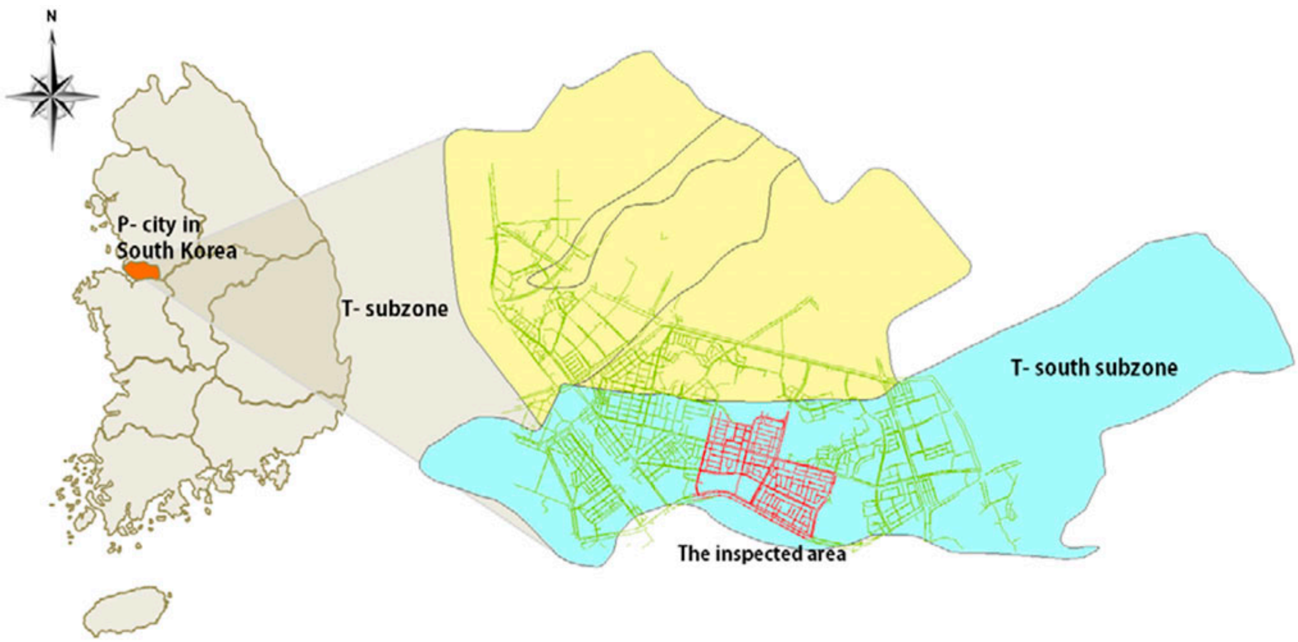

Fig. 1. Study area.

lack of objectivity of the defect judgment criteria in CCTV inspection for the rehabilitation of sewer pipelines. The MOE protocol is based on the protocol developed by the Water Research Centre (WRc) (2001; 2004) in the UK and the New Zealand Water and Wastes Association Inc. (NZWWA) (2006) [15–17]. It uses the scoring method to rate the condition of the span between manholes in 5 grades.

The various defects that can occur inside a sewer pipe can be mainly categorized into three types: structural internal defects, operational internal defects, and general defects. Only the structural internal defects and operational internal defects are scored. There are 18 types of structural internal defects and 5 operational internal defects that are scored. Each defect item can be further rated into large, medium, and small, and different scores are assigned.

The score assigned to each defect is used to assess the condition of the pipeline between manholes. The mean score is obtained by adding all defect scores in the pipeline between manholes and then dividing the sum by the length of the pipeline. The peak score is the highest score in a randomly selected 1 m section of the defect scores investigated in the pipeline between manholes. The MOE protocol decides whether repair or rehabilitation is needed based on the mean score and peak score of structural defects (Table 1).

A bad ratio is the ratio of the number of defects in pipeline to the length of the pipeline. It was generally used to judge the overall condition of sewer pipelines before MOE enacted the CCTV inspection judgment criteria in 2011. The enacted MOE protocol uses the bad ratio as a reference value to decide rehabilitation/repair. It is calculated as follows:

$$\text{Bad ratio} = \text{number of defects in pipeline} \div \text{length of pipeline}$$

2.3. Assessment criteria of SCARD program

The excel-based SCARD program was developed by this project as a tool for assessing sewer pipelines and prioritizing rehabilitation. The condition assessment of internal defects of sewer pipeline was based on the MOE protocol with the scoring and condition grade modified. For example, operational (hydraulic) defect scores were modified using head loss on various defects inside sewer. The defect scoring method using the relative weight factor for how close the sewer pipe is to failure has been widely used in European countries, Australia, and New Zealand since WRc in the UK first adopted it [15,18,19]. NWZAA 2006 stated that the defect score just represented the risk of collapse but was not mathematically helpful in determining the probability of collapse or rating of a sewer pipeline [15]. In fact, countries have different scoring systems and are applying them differently according to the sewer pipe conditions of their

Table 1
Classification of type of action using structural defect scores (by the MOE)

Evaluation method	Type of action	Description
Mean score of structural defects	Rehabilitation	BR[a] is more than 0.2 and condition rating is “Bad” grade
	Point repair	BR is less than 0.2 or BR is more than 0.2 but condition rating is less than “Bad” grade
Peak score of structural defects	Normal action	Condition rating is outside of “Bad” grade
	Immediate action	Condition rating is “Bad” grade

[a]BR is bad ratio, which is the proportion of the number of defects in a pipeline.

country. The score presented in the SCARD program modified the MOE protocol through trial and error to optimize it for the Korean environment.

With the SCARD program, the choice of rehabilitation/repair is decided only by the mean score of structural or hydraulic defects between manholes, and unlike the MOE protocol, the maintenance follow-up to hydraulic (operational) defects is divided into 5 levels. The SCARD program not only enables decision-making for rehabilitation/repair but can also prioritize rehabilitation/repairs by applying the weight factors according to environmental conditions (depth of buried pipe, type of pipe, diameter of pipe, buried location of pipe, soil condition, infiltration and inflow (I/I), service location, etc.). For comparison with the MOE protocol, this study analyzed only up to the decision-making process of the SCARD program.

Using the peak score and mean score of structural or operational defects, the MOE protocol divides the internal condition grades (ICG) of sewer pipelines into 5 levels, grade 1 being the best condition and grade 5 being the worst condition. However, it does not present the follow-up needed for each condition grade of operational defects. Moreover, it presents only a dichotomous follow-up to structural defects even though the condition grades are in 5 levels, making it insufficient for proper rehabilitation decisions. On the other hand, the SCARD program rates ICG into 5 grades based only on the mean score, which shows the overall condition of the sewer pipeline between manholes, and divides each structural and hydraulic (operational) defect into 5 levels that reflect the repair/reinforcement and maintenance viewpoint to help decision-making (Table 2).

3. Results and discussion

Notwithstanding some modifications, the defect items in the SCARD program are based on the MOE protocol, and the ranking of defect severity was changed from large, medium, and small to 4 levels identified by values 1–4. Both protocols use the mean score of defects observed in the pipeline between manholes to grade condition assessment. The main difference lies in determining the score of each defect item and the range of grade rated with the mean score. The conditions of sewer pipelines finally deduced with the two protocols were compared in the same sample area.

3.1. Comparison of defect scores

Although the defect items in the SCARD program are based on the MOE protocol, they were modified in order to focus on the defects most commonly observed in sewer pipelines in Korea. Moreover, the operational defects in MOE protocol were analyzed hydraulically in terms of impact on water head loss. There were 16 common defect items in the two protocols, and for both, the score range was represented by a range of 0–100.

Fig. 2 shows a graph of the mean value of the severity of defects included in both MOE and SCARD protocols. Except for a few items, the mean value of defects in SCARD was somewhat higher than it was in the MOE protocol. SCARD also assigned higher weight factors to the items related to fracture, dipped pipe and broken pipe which affect structural aging of sewer pipeline, and to items that can cause joints to displace from foundation load, etc. in the sewer pipe alignment. Noting that the proportion of centrifugal concrete pipe is higher in Korea, the SCARD protocol assigned higher scores to destructive patterns that affect the structural condition, such as fracture and sinking [12,13].

The MOE protocol assigned the operational defect score to only 5 items, and SCARD expanded it to 11 items of hydraulic defects. Four of those (joint vertical displaced, dipped pipe, broken pipe, and deformed pipe) overlapped with the structural defects. The hydraulic defects in SCARD reflect the water head loss k presented in WP3 Description and Validation of Hydraulic Performance reported by Care-S [20].

Table 2
ICG for sewer rehabilitation decision-making each protocol

	The MOE protocol				The SCARD protocol			
	Structural defects (Peak)		Structural defects (Mean)		Structural defects (Mean)		Functional defects (Mean)	
ICG	Scores	Type of action	Scores	Type of action	Scores	Type of action	Scores	Type of action
1	0.0–2.0	Normal action	0.0–0.5	Point repair	0.0–2.9	No action	0.0–0.9	No action
2	2.1–15.0		0.51–0.90		3.0–6.4	Point repair	1.0–2.4	1 dredge/10 y[a]
3	15.1–30.0		0.91–1.70		6.5–9.9	Rehabilitation	2.5–6.9	1 dredge/5 y
4	30.1–50.0		1.71–3.00		10.0–24.9	Renewal[b]	7.0–9.9	1 dredge/3 y
5	50.1~	Immediate action	3.01~	Rehabilitation	25.0~	Renewal[c]	10.0~	Immediate dredge

[a]Dredging is implemented once every 10 years.
[b]In the short term, renewal is needed.
[c]Renewal is needed immediately.

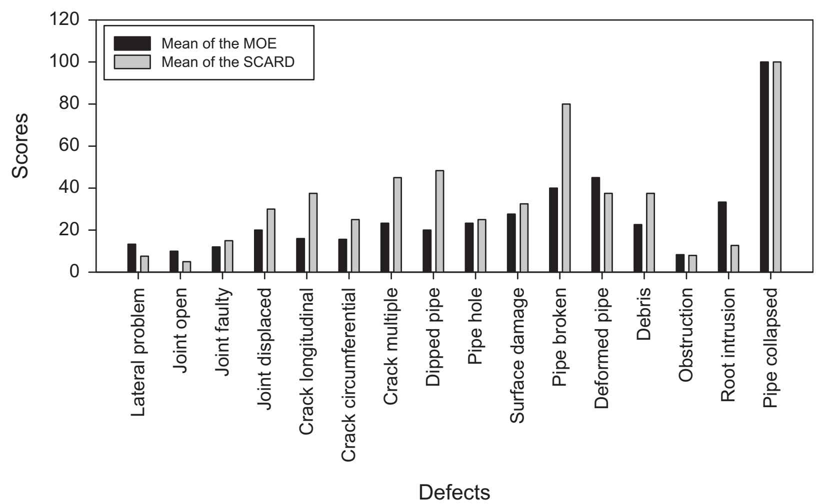

Fig. 2. Comparison of mean value of defects by the MOE and SCARD.

Table 3
Statistical analysis for the number of inspected defects in each pipeline

	Structural defects		Operational and hydraulic defects	
	The MOE	The SCARD	The MOE	The SCARD
Mean	16.9	16.1	3.2	6.5
Median	14.0	14.0	2.0	5.5
Standard deviation	11.8	10.9	3.2	5.2
Total	4,241	4,035	809	1,634
Max	62	55	19	33
Min	0	0	0	0

3.2. The number of inspected defects

The CCTV inspected defects assessed by two protocols were compared (Table 3). The MOE protocols identified 4,241 structural defects, while the SCARD protocol identified 4,035 from sewer pipelines between 250 manholes in the sample area. The MOE protocols also identified 809 operational (hydraulic) defects, while the SCARD protocol identified 1,643. The reason why the MOE protocol found more structural defects was mainly because the SCARD protocol categorized "lateral protruding" as a hydraulic defect and not a structural defect. The number of lateral protruding defects identified in both protocols was 432, or 8.2% of the total (Fig. 3).

The rate of structural defects discovered in all sewer pipelines between manholes was similar in both protocols, but the number of operational (hydraulic) defects was 6.5 in SCARD, around 3.3 more than the MOE average. This difference can be attributed to the fact that SCARD counted broken pipe, dipped pipe, horizontal and vertical joint displacement, and deformed pipe in both structural and operational (hydraulic) defects, so some items were counted twice. Although the total number of defects found by the SCARD protocol and the MOE protocol may be slightly different, both protocols identified the internal defects of sewer pipeline at similar rates. While there was some difference in the severity grade assigned to each defect item, the number of added defect items and the number of structural and operational (hydraulic) defect items, the most commonly observed defect items from the CCTV inspection, were almost the same, and thus, the difference should not significantly affect the condition assessment.

3.3. ICG of sewer

The part used to compare the ICG determined by the two protocols (MOE and SCARD) is the condition grade according to the mean score of the structural defects. Although the score range of defects and score range of mean values of ICG are set differently, the mean scores are calculated in the same way (Table 2). The MOE set the critical value of the worst condition as a mean value of 3 points or more, while the SCARD set it at 25 points or higher.

The pipeline between 250 manholes in the sample area was evaluated using two protocols, and the mean scores according to sewer age were plotted in a graph (Fig. 4). Due to the lack of records in the GIS of the sample area, the actual age of some older sewer pipes could not be checked. Considering that the sewage treatment plant in the sample area was constructed 22 years ago, the old sewer pipes without records were assumed to be 25 years old by estimating that the oldest sewer pipes were installed 3 years prior to the sewage treatment plant. According to the MOE protocol, the percentage of sewer pipelines rated grade 5 (worst condition) in terms of structural defects was 7.2% of 14- to 15-year-old pipes and 60.2% of 25-year-old pipes, while according to the SCARD protocol, it was 0.0% of 14- to 15-year-old pipes and 1.1% of 25-year-old pipes.

The results can be compared to the distribution rates of the structural pipe grade (SPG) reported by NRC in Canada and Office of Water Services (OFWAT) in the UK (Table 4). In its MIIP report, NRC (2006) reported that 4% of all 30-year-old sewer pipes received a grade of 5, while OFWAT reported that 2% of all 42-year-old sewer pipes received a grade of 5

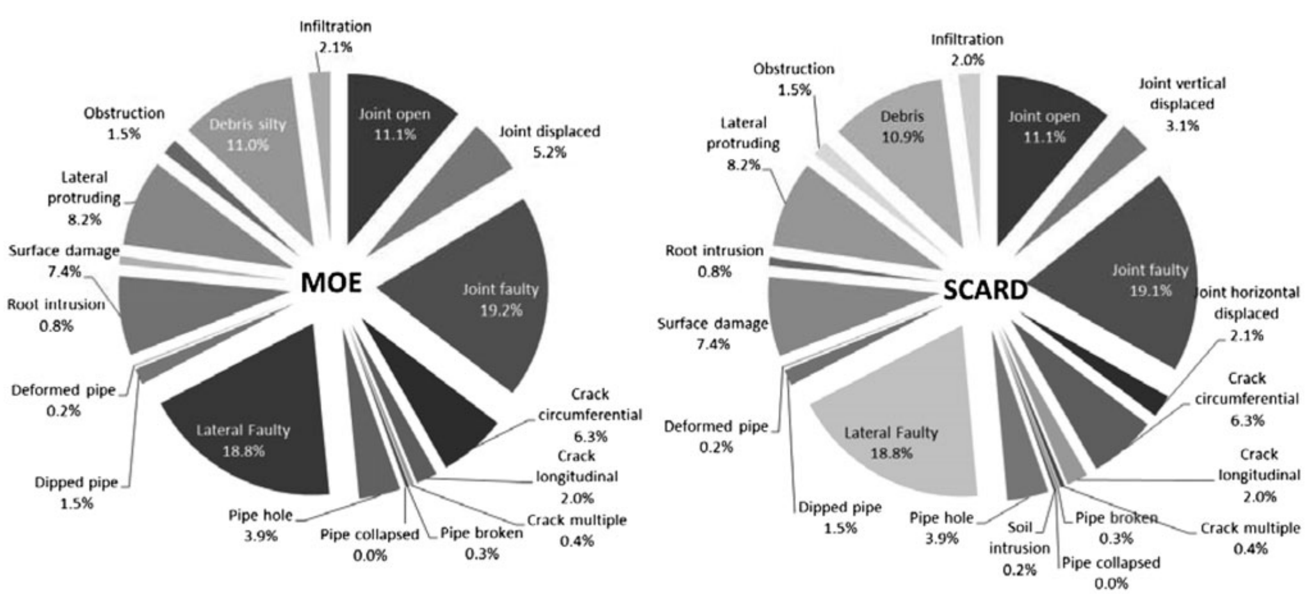

Fig. 3. Proportion of inspected defects in study area (MOE vs. SCARD).

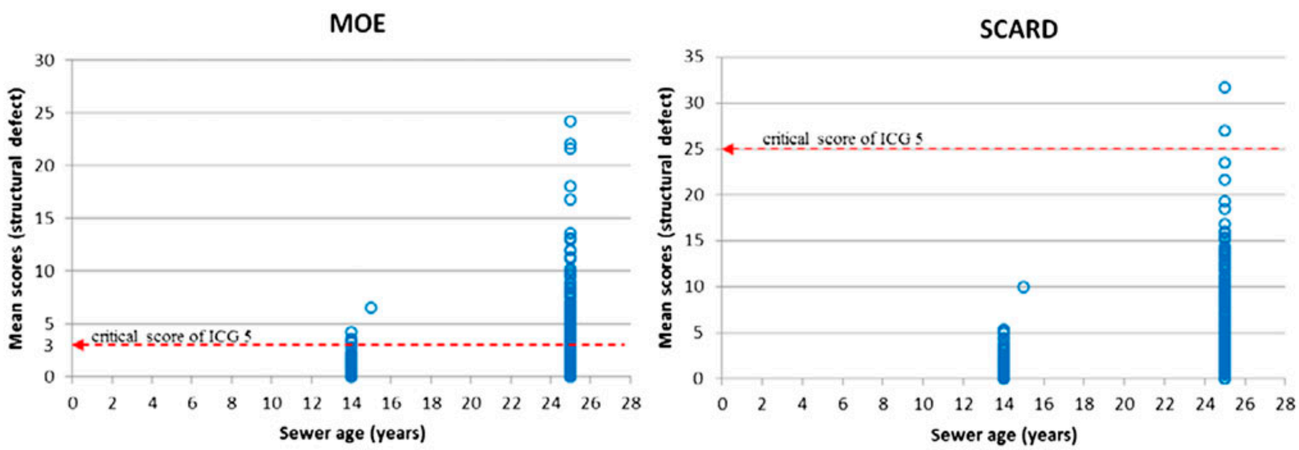

Fig. 4. Mean scores comparison on sewer age by both protocols.

Table 4
Comparison of distribution of sewer assets by structural pipe grade (SPG)

Source	Average pipe age (years)	Percent of sanitary sewer pipes at structural pipe grade (SPG) (%)				
		1	2	3	4	5
MIIP study, Canada (2006)	30	71	16	4	5	4
OFWAT, UK (2000)	42	60	17	13	8	2

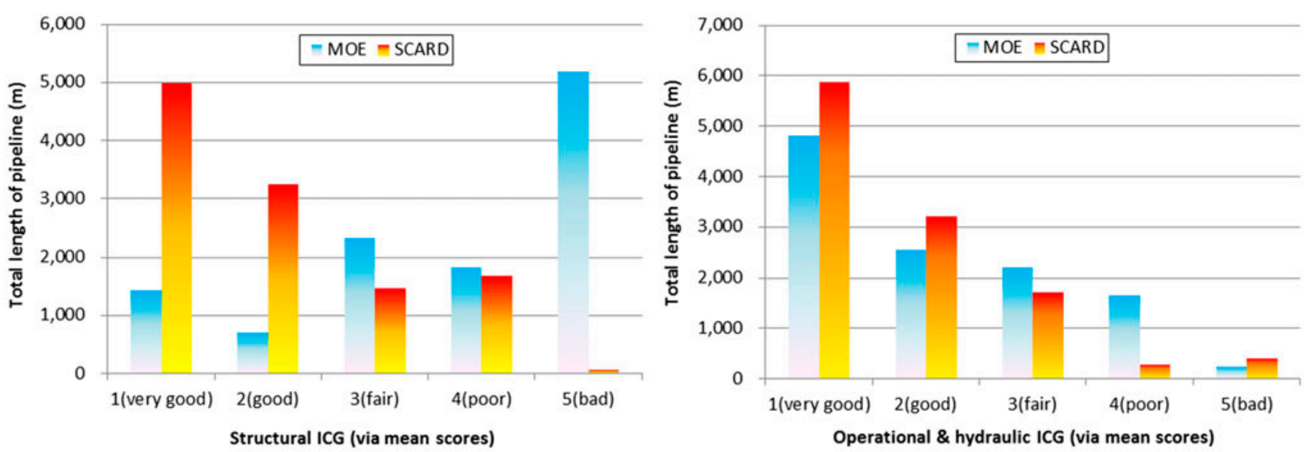

Fig. 5. Total length of pipeline according to structural and operational (hydraulic) ICG.

[8,19]. Therefore, it can be concluded that the rate of sewer pipes receiving grade 5 under the MOE protocol is excessive. The mean value range setting for the structural condition based on the SCARD protocol is considered to be closer to that of other countries (case studies of NRC and OFWAT). Such comparisons should not be considered as absolutely accurate, since the internal condition differs according to the surrounding environment of the sewer pipeline, so one can assume that the condition grade in SCARD was set to produce a result similar to that of other countries (case studies of NRC and OFWAT).

Fig. 5 shows the total length of pipeline according to structural and operational (hydraulic) ICG via mean scores. With the MOE protocol, the grade 5 (worst condition) ICG was the highest. On the other hand,

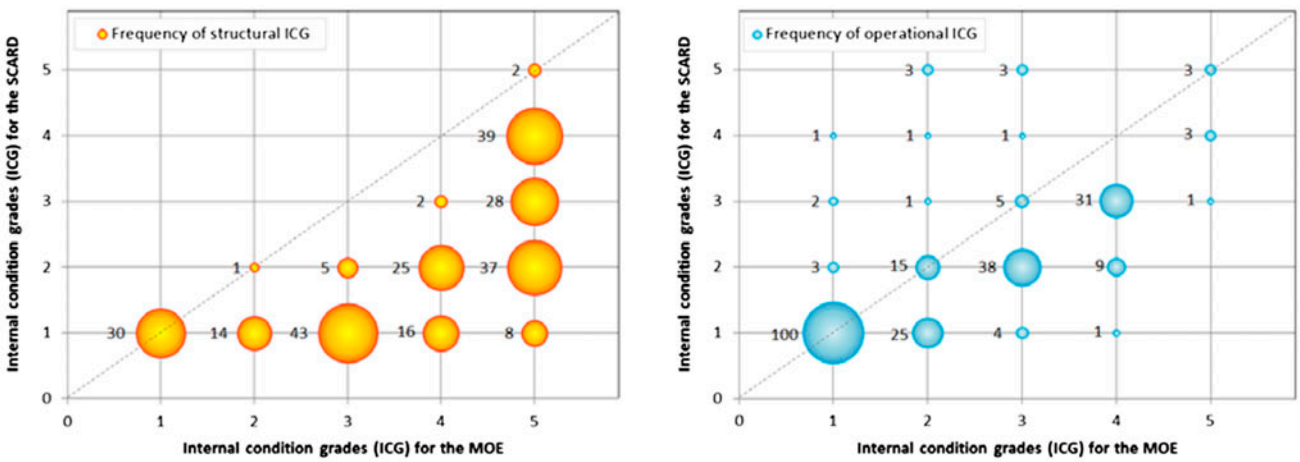

Fig. 6. Frequency of structural and operational (hydraulic) ICG (MOE vs. SCARD).

the grade 1 (best condition) ICG was the highest in the SCARD protocol. The protocols showed a similar pattern for operational (hydraulic) ICG.

The two protocols produced significantly different results in structural ICG for the sewer pipeline in the sample area. The MOE generally seemed to over-assess the aging of structural conditions compared to the SCARD.

Fig. 6 shows the frequency of structural and operational (hydraulic) ICG in 250 pipes. The values on the diagonal dotted line in the figure represent the frequency of sewer pipelines being rated as having the same grade by both protocols, and the values above the dotted line represent the frequency of sewer pipelines being rated higher in the SCARD protocol than the MOE protocol, while the values below the dotted line represent the frequency of sewer pipelines being rated lower in the SCARD protocol than the MOE protocol. In most grades, the MOE protocol rated the structural ICG higher than the SCARD protocol. The number of sewer pipelines that were rated grade 1, 2, 3 or 4 in the SCARD protocol but rated grade 5 in the MOE protocol was 8, 37, 28, and 39, respectively. For the operational (hydraulic) ICG, the MOE protocol had a slightly higher frequency of over-rated sewer pipelines, but some were also over-rated in the SCARD protocol.

4. Conclusion

This study compared the MOE protocol currently used to assess the condition of sewer pipelines in the sample area with the newly developed SCARD protocol. The result showed that the protocols determined a similar rate of defect items. Since the SCARD protocol is based on the MOE protocol, they show a similar rate of defects on all except for some items, and in the severity categorization system. As a result, the difference in the severity rating, some defect items, and number of structural and operational (hydraulic) defect items did not greatly affect the condition grading. The SCARD protocol assigned a higher weight factor to the mean scores of defect items such as joint shear, fracture, damage, or sinking that accelerates structural aging. The average number of structural defects found in the sewer pipeline between 250 manholes was 16.9 with the MOE protocol and 16.1 with the SCARD protocol, a minor difference. However, among 5 ICG grades of sewer pipelines, 45% of the total received a grade 5 under the MOE protocol, which was much higher than the 0.6% under the SCARD protocol. The results of the SCARD assessment was more similar to foreign research cases for the same usage period [10,21]. Although this indicates that the current use of the MOE protocol should be reviewed, one should also realize that differences can be generated by the environment surrounding the sewer pipelines. Future studies need to attain objective assessment results by applying the newly developed condition assessment protocol to more sites and by checking with the experts regarding whether the assessment grades actually reflect the condition of the sewer pipes.

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