Sewerage infrastructure asset management based on a consumer-centric approach

Hanseul Jo1 · Jaena Ryu2 · Jungwoo Shin3

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Abstract
In most developed countries, such as the USA, the E.U., and East Asia, the importance of public infrastructure asset management has been stressed for a long time. Among the various types of public infrastructure, sewerage systems are one of the most cost-intensive facilities to manage. Sewerage systems are considered highly difficult to manage due to the undetermined level of service needed, different standards of user satisfaction, and the large gap of service understanding between experts and users. To address these issues, this study aims to define the appropriate target level of service improvement by combining consumers’ expected level of service and complaint data. In this study, the case of the inland flood management project in South Korea is investigated because of the global trend of increasing flood damage. The complaint data represent the frequency of flood damage in the area. Using the contingent valuation method, we found that people want to use 25% of their current monthly sewage bill on the management project. In addition, the results of this study demonstrate that people prefer to deal with the problems caused by old service infrastructure when it can be handled at a lower cost during early stages.

Keywords Asset Management · Complaint · Consumer-driven · Flood control · Level of service · Sewerage infrastructure

Introduction
Public infrastructure is essential, as it is part of the history of social development (Uddin et al., 2013). They are essential facilities that represent national competitiveness, the integrity of social systems, and the quality of welfare and even influence the quality of residents’ lives (Schraven et al., 2011; Uddin et al., 2013). Public agencies have invested heavily in maintenance, repairs, renovation, and reconstruction to maintain these public infrastructures at the consumer-needed level of services (LoS) for a long time. However, government agencies experience difficulties managing public services due to the aging infrastructure, limited budget, and low consumer satisfaction (Han et al., 2015; Osman, 2012; Schraven et al., 2011; Uddin et al., 2013). Discussions on public infrastructure asset management are ongoing to deal with these problems. Furthermore, as the COVID-19 pandemic led to a large amount of unexpected expenses (Curristine et al., 2020), the need for the strategic management of public infrastructure has become an important issue.

Public infrastructure asset management is a systematic process of operating physical public assets, including infrastructure facilities and buildings, by maintaining and upgrading them cost-effectively (Moon et al., 2009). The core of asset management is to aid decision-making for the most efficient budget planning. However, the lack of management systems, awareness of poor public service quality, and limited budget has led to the poor management of public infrastructure (Giglio et al., 2018; Uddin et al., 2013). In particular, the biggest obstacle to managing consumer-based asset management is the different understanding of LoS.
between experts and actual users. Although asset management requires quantitative standards to determine the current state of assets and define the goal, it has been difficult to establish appropriate standards reflecting the consumer-centric LoS (Osman, 2012; Schraven et al., 2011).

There are various fields of public infrastructure assets, including transportation, energy production and distribution, buildings, and reaction facilities. Among these, water infrastructure services consist of five categories: water supply, structures such as dams, diversion, levees, and so on, agricultural water distribution, sewers, and stormwater drainage (Uddin et al., 2013). These water infrastructure services are considered as essential services that meet the required quality of services, but each level of consumer-centric services is still unknown (Han et al., 2015; Hensher et al., 2005). Due to the large gap in understanding service evaluation between experts and users, a consistently appropriate service assessment is also not easy to determine (Serag et al., 2020).

To the best of our knowledge, despite the fact that sewerage infrastructures require a large amount of cost burdens to maintain for long-term operations, scant attention has been paid to enhance the utility efficiency by considering the service satisfaction from the perspective of actual stakeholders (Tscheikner-Gratl et al., 2019). Most studies assess the status of the infrastructure and results of renovation projects accurately. However, it should be emphasized that it is more important to define the influential criteria with high satisfaction to design optimal project objectives and operate cost-effective management systems.

One of the representative cases, the inland flooding, which is a critical issue due to ongoing climate changes, shows how difficult it is to define the appropriate standard LoS for all residents (Caradot et al. 2011). There have been lots of efforts to provide various performance indicators supporting the asset management decision-making process, but most of them are to assess performance from the point of view of providers, not so much to understand LoS from the perspective of consumers (Han et al. 2015; Hensher et al. 2005). In addition, it is difficult to establish consistent and reliable indicators that fully reflect users’ satisfaction and acceptable service levels (Osman 2012; Serag et al. 2020). Despite the importance for the cost-effective asset management in sewer systems (Baah et al. 2015), consumer-centric management through an effective decision-making process has not been made properly in flood management systems.

Therefore, this study uses a contingent valuation method (CVM) to confirm the real users’ required LoS for flood control and analyze respondents’ willingness to pay (WTP) depending on the LoS. The expected LoS improvement and the number of residential complaints were used as indicators to identify the quantitative LoS. The expected LoS improvement is a type of stated-preference (SP) data which represent how much the respondents actually feel the urgency and require the service improvement. It is helpful to identify personal requirements. The number of residential complaints is a form of revealed-preference (RP) data that helps to indirectly determine the frequency of flood damage to the extent that residents feel uncomfortable in the area they inhabit. Both variables are useful in that they represent respondents’ discomfort intolerance to the service. It is also meaningful to find out the objective standard points by combining SP and RP data. Furthermore, the operating period of sewage retention facilities, one of the flood control facilities, is used to see the gap between the experts’ criteria determining the urgency of the flood control and the respondents’ service satisfaction.

The purpose of this research is to support the asset management enhancing people’s satisfaction by presenting the consumer-based level of the flood control infrastructure services in Korea, called “Designation, etc. of Areas for Priority Control of Sewerage Maintenance.” It contributes to presenting additional consumer-based standards, where public service and public needs, including the physical urgency of facilities, are matched in the process of designating the priority areas. By presenting various variables, this study identifies the differences between public satisfaction and discomfort intolerance and proposes new standards of the strategic level of sewage services to improve residents’ service satisfaction.

This study consists of four parts as follows. “Literature reviews” describes the flood control situations in Korea and examines the problems of current flood control service management process. In “Methodology,” the CVM that is used to analyze consumers’ LoS and WTP are explained. “Empirical analysis” shows the results of the empirical analysis and defines the consumer-centric LoS to the “Designation, etc. of Areas for Priority Control of Sewerage Maintenance” project. In this section, the amount of WTP and the actual sewerage expenses are considered to discuss the application of this study’s results. Finally, “Conclusions and remarks” presents the implications of this study. Figure 1 is a flowchart describing the structure of this study.

Literature reviews

Previous studies to measure LoS

Asset management for public water resource infrastructures is generally conducted through the following, as shown in Fig. 2 (EPA, 2017). The asset management procedure consists of 10 steps, classified into three stages: understanding the current state of assets, determining the purpose of management, and establishing strategies. In the first step, understanding the current state of assets, the structures and properties of the asset are defined and then evaluated and
scored. Based on this assessment, the remaining operation period is derived, and the estimated maintenance costs are calculated. Second, the targeted level of public infrastructure services is determined to establish operational strategies. Moreover, a feasibility study and cost estimation are conducted concerning the predicted risks and alternatives.
Finally, based on the preceding analysis process, operational strategies for efficient asset management in terms of costs and benefits are developed, followed by a series of decision-making steps. Providing consumer-centric services is further emphasized in this asset management process because it positively affects satisfaction and performance improvements (Chavez et al., 2016).

In the fifth step, “setting target LoS,” the CVM is considered a method to identify consumer-based levels of services and handle difficulties in the process. The CVM is a typical method for estimating the economic value of non-market goods, such as environmental or public goods (Alberini et al., 1997). It is appropriate to determine the LoS and WTP using the CVM, as the flood control service in this work also aims to provide the appropriate level of public infrastructure-based services. It is useful to understand respondents’ preferences for a particular level of public services, as it directly shows the amount of WTP.

Thunberg and Shabman (1991) conducted the early CVM study of the flood control project, which is known to develop the theory of the WTP model for flood risk control policy (Zhai et al., 2006). Thunberg and Shabman (1991) surveyed landowners in Lower Knock, Virginia, in the USA, by obtaining the WTP for the project to reduce the financial and psychological damage caused by flooding. The reduction in the probability of flooding more than once in a decade was set to the level of hypotetical service. They distinguished the modes of payment into two types: paying at once and paying annually. For a classic recent example, Clark et al. (2002) conducted a survey related to a flood control project for respondents in Milwaukee in the USA. The implementation of the hypothetical level maintains the same probability of flooding as before. The preference difference between flood control projects with different added values was analyzed. Both studies found that people who live or have properties in the flood risk area are willing to pay more for flood asset management services.

In addition, most flood control policy studies using CVM have been conducted in several countries, referencing various types of national flood control situations. For example, the half probability of flood risk is set to the hypothetical LoS in the case of Japan (Zhai et al., 2006), and the different flood probability scenarios depending on the flood control systems and insurance programs are suggested as the form of hypothetical LoS in the case of the Netherlands (Botzen and van den Bergh, 2012). There are some studies not mentioning the decrease of risk probability but focusing on the amount of residents’ WTP living in the floodplain with different levels of flood risk (Ghanarpour et al., 2014; Maghsood et al., 2019; Netusil et al., 2021). Most of these studies used the frequency reduction or variety level of flooding probability as the hypothetical LoS. Next, the effect of the flood control project, geographical features of the residential area, and the type of properties were used as additional variables. However, even though several efforts have been made to define LoS in certain theoretical frames, there is a lack of consideration for the appropriate LoS from the residents’ point of view. The variables that reflect respondents’ subjective perceptions of services are limited to geographical characteristics, and survey data are also limited in terms of universal application in public policy. Moreover, few studies have attempted to analyze LoS quantitatively.

For these reasons, this study aims to provide objective indicators to reflect personal needs by applying additional variables representing consumer-based service levels to the CVM. Using the expected LoS improvement by respondents and the number of complaints, which is a combination of SP and RP data representing the level of residents’ anxiety of flood, this research may contribute to establishing sustainable sewage infrastructure management strategies in the future.

Flood control projects in South Korea

Rainfall intensity has been increasing due to rapid climate change, and flooding has become a common issue (Gunnell et al., 2019; Huong and Pathirana, 2013; Kim et al., 2018; Miller and Hutchins, 2017; Peng et al., 2015; Schreider et al., 2000). In China, rapid urbanization and poor underground stormwater infrastructure led to economic losses of 214 billion yuan in 2017 (Wang et al., 2020). The total cost of damage from inland flooding in the USA was estimated to be 20 billion USD in 2019 (Smith, 2020). The economic losses caused by extreme weather and climate changes in the EU were estimated to be about 446 billion euros between 1980 and 2019, equivalent to 11.1 billion euros per year (EEA, 2020).

According to the Ministry of Inferior and Safety (2020), the damage from typhoons and heavy rains in 2019 amounted to 214.4 billion Korean won (KRW), which is 189 million USD. Moreover, the inland flooding issue in Korea is not significantly different from this global trend. The eight metropolitan cities, Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan, and Sejong, have experienced at least 20 extreme rainfall events beyond the 1-h probable precipitation in the past 10 years (WAMIS, 2021). In particular, Ulsan exceeded the 1-h probable precipitation 30 times, and the maximum precipitation was 193.5 mm, which was 121 mm above the standard level. In addition, 33% of the 566 sewage retention facilities operated beyond the planned operation period (ME, 2020a). Accordingly, flooding damage caused by intensive rainfall and aging facilities has been pointed out as a critical issue to be solved.

As a result, the Korean government is trying to deal with the problems in flood-prone areas by conducting
the “Designation, etc. of Areas for Priority Control of Sewerage Maintenance” project in 88 districts in 2013 (ME, 2020b). This project aims to identify districts where flooding has occurred frequently and support solutions such as improving storm drains and installing and expanding sewage retention facilities. The government plans to allocate 1.14 trillion KRW (984 million USD) for expanding sewerage systems by 2020. The final 16 selected cities will be provided 399 billion KRW (299 million dollars) to solve the fundamental causes for flooding by 2025.

However, despite the government’s efforts, residents’ inconveniences have increased. As shown in Fig. 3, after a steady increase over the past decade, the total number of complaints related to sewerage services reached 138,626 in 2019 compared to 59,308 in 2011 (ME, 2020a). The number of complaints related to sewage culverts in 2019 was 28,920 (20.86% of the total), which is 41.84% higher than the previous number of complaints. The number of complaints related to drainage systems increased by 23.95% year-on-year to 21,315, which is 15.38% of the total complaints.

Furthermore, Fig. 4a describes the number of complaints related to drainage systems by region in 2019. The three regions with the largest complaints were Changwon, Gyeongsangnam-do; Gimpo, Gyeonggi-do; and Dongdaemun-gu, Seoul. Considering that Wanju-gun in Jeollabuk-do and Changnyeong-gun in Gyeongsangnam-do have the most designated flood risk areas (Ministry of the Interior and Safety [MOIS] of Korea, 2021), there is a large difference between the two priority areas defined by the government and the areas where residents encounter frequent inconveniences. Regarding the fact that Pohangsi in Gyeongsangbuk-do and Hampyeong-gun in Jeollanam-do were allocated the largest budget for flood control in 2019, as shown in Fig. 4b, we find that there is also a large gap between the designation and budget.

In summary, despite a large amount of investment, the seriousness of flood damage and residents’ inconveniences has increased steadily. Due to the gap between the physical urgency defined by experts and the residents’ distress tolerance of inland flooding, the public performance review has not significantly increased positively. Although the government dispenses a large budget for public infrastructure improvement to deal with frequently flooded areas, it is necessary to discuss whether budgeting is based on reasonable criteria to increase public consumer satisfaction. A consumer-centric approach to strategic asset management is necessary to ensure efficient public infrastructure management projects to improve flood control services.

**Methodology**

The CVM for analyzing LoS is used to identify differences in respondents’ preferences according to the level of public services. In the CVM, researchers usually find respondents’ public preferences by asking the WTP for hypothetical goods (Ahn et al., 2020; Huh et al., 2020; Ryan, 2004). It is appropriate to use CVM in this study because it is a well-known method to estimate the non-market value of environmental or public goods, as mentioned above. A CVM can be classified as an open-ended or closed-ended question based on the form of the question (Hanley et al., 1998; Ryan, 2004). The CVM commonly presents a dichotomous choice where the respondents answer only “yes” or “no”; if respondents have WTP above the presented bill, they answer “yes”; otherwise, they respond “no.”
There are three forms of questions in the CVM: single-bounded dichotomous choice (SBDC), double-bounded dichotomous choice (DBDC), and one-and-one-half bounded dichotomous choice (OOHBDC). The SBDC has the disadvantage of having a lower statistical efficiency than DBDC (Hanemann et al., 1991). In the DBDC, which asks an additional question about the payment, the inconsistency of responses is indicated because the second question is influenced by the first question (Cooper et al., 2002). Therefore, the OOHBDC, which only asks an additional question in certain answers, is used in this study in order to deal with those problems.

The theoretical background of the OOHBDC CVM is the utility difference model that maximizes consumer utility ($u$) in their choice. In Eq. (1), $j$ indicates whether the consumer would like to pay (1) for a good or not (0), and $S$ shows the consumer’s characteristics. The variable $y$ represents the consumer’s income. The total utility for the consumer’s choice consists of $v$ that the researcher captures and the part of utility $\varepsilon$ that is not observed by the researcher.

$$u(j, y: S) = v(j, y; S) + \varepsilon_j (\text{when } j = 0, 1)$$ (1)

This theoretical model always assumes that customers choose a reasonable alternative that maximizes their utility. The consumer answers “yes” only if the utility by paying $A$ dollars for the alternative is larger than the utility when they do not pay for it. By using the utility difference between responding “yes” and “no,” the probability of refusing the payment $P_0$ can be described as a form of the cumulative distribution $F_n$, shown in Eq. (2). As it is a closed-ended question, Eq. (3) shows the actual probability that the consumer is willing to pay over the presented bill (Hanemann, 1984; Hoyos and Mariel, 2010).

*Note. USD $1 = KRW ₩1,132.02 (2021.03.17) (www.bok.or.kr)

**Source: Korean Ministry of Environment (ME), 2020a. 2019 Statistics of Sewerage.

Fig. 4 Comparison between the number of complaints and the amount of budget by region. a The number of complaints. b The amount of budget by region. *Note. USD $1 = KRW ₩1,132.02 (2021.03.17) (www.bok.or.kr) **Source: Korean Ministry of Environment (ME), 2020a. 2019 Statistics of Sewerage.
\[ P_0 = F_q(\Delta v) = G_c(A) \]
where \( \Delta v = v(1, y - A; S) - v(0, y; S) + (e_1 - e_0), \eta = e_1 - e_0 \)
\[ \text{Pr}(WTP \geq A) = 1 - G_c(A) \]
(2)

The respondents were divided into two groups, and each was asked for their WTP a lower amount \((A^L)\) or an upper amount \((A^U)\). Equation (4) shows the respondents’ answers in the OOHBDC CVM.

\[
\begin{align*}
I^{IY} : & \text{Respondent } i \text{ who is willing to pay over } A^U \text{ in Group 1} \\
I^{IN} : & \text{Respondent } i \text{ who is willing to pay between } A^L \text{ and } A^U \text{ in Group 1} \\
I^I : & \text{Respondent } i \text{ who is willing to pay under } A^L \text{ or not in Group 1} \\
I^{IY} : & \text{Respondent } i \text{ who is willing to pay over } A^U \text{ in Group 2} \\
I^{IN} : & \text{Respondent } i \text{ who is willing to pay between } A^L \text{ and } A^U \text{ in Group 2} \\
I^I : & \text{Respondent } i \text{ who is willing to pay under } A^L \text{ or not in Group 2}
\end{align*}
\]
(4)

*We labeled Group 1, which presented a lower bid \((A^L)\) as an initial value.
We labeled Group 2, which presented an upper bid \((A^U)\) as an initial value.

To identify zero WTP, we used a spike model where researchers asked additional questions if the respondents bid zero or protested when they answered “no” to the researchers. The responses from the open-ended questions in the pilot survey were used as the initial values proposed in the main survey. The initial values were classified into seven sections with upper and lower cut-off points of 15%.

Part B asks questions about sewerage services explicitly. Questions about details, background knowledge, and the importance of sewerage services were asked. Questions about each of the twelve sewerage services were asked separately to determine whether the respondents had prior knowledge, how satisfied they were with the services, and which service urgently needed improvement. To determine LoS in the residential areas where the respondents’ expectations are not met, the expected LoS improvement was additionally asked from the respondents. Personal water resource usage patterns were identified by asking the average water and sewerage bills to the respondents.

Part C describes the “Designation, etc. of Areas for Priority Control of Sewerage Maintenance” project and asks the WTP to obtain it. In order to enhance the respondents’ understanding of inland flooding, its definition, and current issues, the government’s response in dealing with flood damage is also explained. By providing enough descriptions of the project, the survey was conducted with the same background knowledge, regardless of the regional designation issue. The service level was set to withstand 1-h probable precipitation for 30 years. The payment vehicle is the monthly sewerage bill to reflect the real payment for the next 5 years.

Results

The distribution of 1001 WTP responses paying for the “Designation, etc. of Areas for Priority Control of Sewerage Maintenance” project for 5 years is shown in Table 2. The responses from the open-ended questions in the pilot survey were used as the initial values proposed in the main survey. The initial values were classified into seven sections with upper and lower cut-off points of 15%.

Table 3 shows the results of the analysis using the OOH-BDC spike model. Model 1 is a result without covariate; otherwise, Models 2 and 3 are results with variables including the expected LoS improvement, operating period, and so on. All of the RP data that present the residents’ regional

Empirical analysis

Data

In this study, the online survey was conducted by a professional polling firm, Gallup Korea, to identify the respondents’ needed LoS and WTP for the “Designation, etc. of Areas for Priority Control of Sewerage Maintenance” project. The online pilot survey was conducted in September 2020, and the main survey was conducted in October 2020. The residents who lived in the eight metropolitan cities with a large number of aging infrastructure due to early installation participated in the survey. Among the 1155 participants reflecting the diversity of each population where the stratified random sampling was used, 1001 respondents’ data, except for those with unknown addresses, were used for analysis. Table 1 presents the demographic characteristics of the respondents.
**Table 1** Respondents’ demographic characteristics

| Category                             | Respondents | Percentage | Average |
|--------------------------------------|-------------|------------|---------|
| Gender                               |             |            |         |
| Male                                 | 529         | 50.19      |         |
| Female                               | 472         | 44.78      |         |
| Age                                  |             |            |         |
| 20 s                                 | 178         | 16.89      | 43.7073 |
| 30 s                                 | 224         | 21.25      |         |
| 40 s                                 | 239         | 22.68      |         |
| 50 s                                 | 217         | 20.59      |         |
| 60 s                                 | 143         | 13.57      |         |
| Education level                      |             |            |         |
| ~High school education               | 117         | 11.10      | 16.81 year |
| ~Four-year course college education  | 707         | 67.08      |         |
| Graduate School                      | 177         | 16.79      |         |
| Average monthly income per household (10,000 KRW) | | | |
| < 100                                | 25          | 2.37       | 513.927 |
| 100 ~ 149                            | 21          | 1.99       |         |
| 150 ~ 199                            | 40          | 3.80       |         |
| 200 ~ 249                            | 77          | 7.31       |         |
| 250 ~ 299                            | 68          | 6.45       |         |
| 300 ~ 399                            | 144         | 13.66      |         |
| 400 ~ 499                            | 180         | 17.08      |         |
| 500 ~ 699                            | 236         | 22.39      |         |
| 700 ~ 999                            | 149         | 14.14      |         |
| > 1000                               | 61          | 5.79       |         |

USD $1 = KRW W1132.02 (2021.03.17) (www.bok.or.kr)

**Table 2** Distribution of responses by the bid amount

| Bid amount (KRW) | Lower bid is presented as the first bid | Number of respondents |
|------------------|----------------------------------------|-----------------------|
|                  | A<sub>L</sub> | A<sub>U</sub> | Yes–Yes | Yes–No | No–Yes | No–No |
| 1000             | 3000          | 36           | 15      | 0      | 18     | 69    |
| 2000             | 4000          | 23           | 14      | 4      | 20     | 61    |
| 3000             | 6000          | 26           | 28      | 5      | 23     | 82    |
| 4000             | 8000          | 33           | 16      | 8      | 23     | 80    |
| 6000             | 10,000        | 23           | 16      | 14     | 22     | 75    |
| 8000             | 12,000        | 23           | 10      | 9      | 26     | 68    |
| 10,000           | 15,000        | 24           | 11      | 7      | 24     | 66    |
| Total            |               |              | 188 (18.78%) | 110 (10.99%) | 47 (4.70%) | 156 (15.58%) | 501 (50.05%) |

| Bid amount (KRW) | Upper bid is presented as the first bid | Number of respondents |
|------------------|----------------------------------------|-----------------------|
|                  | A<sub>L</sub> | A<sub>U</sub> | Yes | No–Yes | No–Yes–Yes | No–No–No |
| 1000             | 3000          | 51           | 8   | 0      | 17     | 76    |
| 2000             | 4000          | 51           | 9   | 4      | 18     | 82    |
| 3000             | 6000          | 31           | 8   | 5      | 25     | 69    |
| 4000             | 8000          | 40           | 6   | 4      | 14     | 64    |
| 6000             | 10,000        | 29           | 6   | 7      | 24     | 66    |
| 8000             | 12,000        | 37           | 5   | 9      | 22     | 73    |
| 10,000           | 15,000        | 40           | 5   | 10     | 16     | 71    |
| Total            |               |              | 279 (27.87%) | 47 (4.70%) | 39 (3.90%) | 135 (13.49%) | 500 (49.95%) |

USD $1 = KRW W1132.03 (2021.03.17.) (www.bok.or.kr)
### Table 3  Result of CVM Analysis

| Variables                                           | Model 1       |       | Model 2       |       | Model 3       |       |
|-----------------------------------------------------|---------------|-------|---------------|-------|---------------|-------|
|                                                     | Means S.E     |       | Means S.E     |       | Means S.E     |       |
| Constant                                            | 0.8667*** 0.0693 |       | -3.5510*** 0.5514 |       | -3.5430*** 0.5648 |       |
| Bid                                                 | -0.0001*** 0.00001 |       | -0.0001*** 0.00001 |       | -0.0001*** 0.00001 |       |
| Household income                                     | - 0.0517* 0.0290 |       | 0.0600** 0.0292 |       |               |       |
| Age                                                 | - 0.0053 0.0052 |       | -0.0055 0.0052 |       |               |       |
| Gender                                               | 0.1349 0.1233 |       | 0.1403 0.1239 |       |               |       |
| Background knowledge of sewerage services           | - 0.1234* 0.0644 |       | 0.1345** 0.0648 |       |               |       |
| Importance of sewerage services                     | - 0.7185*** 0.0943 |       | 0.7224*** 0.0938 |       |               |       |
| Satisfaction in flood control service               | - 0.1479** 0.0590 |       | 0.1474** 0.0599 |       |               |       |
| Expected level of service improvement               | <10% - 0.1619** 0.0749 |       |               |       |               |       |
|                                                     | 11~20% - 0.1689 0.1606 |       |               |       |               |       |
|                                                     | 21~40% - 0.1631 0.1781 |       |               |       |               |       |
|                                                     | >41% - 0.0726 0.1907 |       |               |       |               |       |
| Number of complaints                                 | 1~4 - 0.3287 0.4045 |       |               |       |               |       |
|                                                     | 5~9 - 0.2464 0.3649 |       |               |       |               |       |
|                                                     | 10~19 - 0.3874* 0.2233 |       |               |       |               |       |
|                                                     | 20~29 - 0.1995 0.3140 |       |               |       |               |       |
|                                                     | 30~49 - 0.1268 0.2434 |       |               |       |               |       |
|                                                     | 50~99 - 0.2888 0.3478 |       |               |       |               |       |
|                                                     | 100~199 - 0.2699 0.2165 |       |               |       |               |       |
|                                                     | 200~299 - -0.1288 0.2671 |       |               |       |               |       |
|                                                     | 300~499 - -0.2476 0.2192 |       |               |       |               |       |
|                                                     | 500~799 - 0.1446 0.2493 |       |               |       |               |       |
|                                                     | >800 - -0.1985 0.6063 |       |               |       |               |       |
| Operation period                                     | - 0.0076 0.0077 |       | 0.0079 0.0079 |       |               |       |
| Time overrun                                         | - -0.0006 0.1786 |       | -0.0144 0.1940 |       |               |       |
| Spike                                               | 0.2959 |       |               |       |               |       |
| Mean WTP                                            | 10,459 KRW*** 509.94 | (9.24 USD) |               |       |               |       |
| Confidence interval                                  | 9460~11,459 KRW (8.36~10.12 USD) |       |               |       |               |       |
| Observations                                        | 1001 |       |               |       |               |       |
| Log-likelihood                                      | -1250.459 |       | -1203.15 |       | -1200.579 |       |

***, **, and * refer to statistically significant levels of 0.01, 0.05, and 0.1, respectively

USD $1 = KRW 1132.03 (2021.03.17.) (www.bok.or.kr)
conditions and SP data that show individual characteristics matched the residents’ postal code. household income, age, operation period, and time overrun were continuous variables. The background knowledge and importance of sewerage services and satisfaction in flood control services are defined as factors on a five-point scale. Gender, expected LoS improvement, and number of complaints are dummy variables with only two possible values that refer to whether a respondent is in a certain condition (1) or not (0). In particular, combining the expected LoS improvement, which represents the subjective service assessment by real users, and the number of residents’ complaints, helps determine the quantitative standard points where consumers are responsive.

In Model 1, the estimated coefficient of the bid is negative, and the coefficient of alpha is positive, both of which are statistically significant. Since fewer people answered “yes” to the large bid, as shown in Table 2, the results are reasonably estimated. Zero bidders are 29.59% of the total, which is similar to the result of the spike variable. The average WTP without a protest is calculated at 10,459 KRW, approximately 9.24 USD. The 95% confidence interval is 9460 KRW (8.36 USD) to 11,459 KRW (10.12 USD).

Furthermore, covariates for household income, satisfaction with flood control service, background knowledge, and the importance of sewerage services have significant results in Models 2 and 3. People who are well-aware of sewerage services and consider the services important tend to express higher WTP for the infrastructure management project. Respondents with higher satisfaction with flood control services are also willing to pay more to maintain LoS.

Concerning the two main variables, the expected level of flood control service improvement and complaints about the drainage systems, there is a certain interval where people expressed a higher WTP. As shown in Model 2, which focuses on the expected LoS improvement, people who require less than 10% improvement are willing to pay more for the project. Data for the number of complaints in 2019 are additionally analyzed in Model 3 to define the quantitative LoS demanding less than 10% improvement. As a result, residents living in areas with 10–19 complaints in 2019 tend to pay higher WTP for the service. When caught early, people tend to be highly sensitive and react actively to service improvement to a problem. In other words, by referencing a previous study (Campbell et al., 2014), the results also imply that when people encounter too much flooding in their residential area, they become desensitized to the issue and less willing to solve the problem even if they suffer greater damage, which is why the initial reaction is more important to evaluate before exposing the repeated annoyance. Furthermore, according to the result that the operation period of sewage retention facilities is not significant in these two models, it is found that there is a large gap between the physical urgency criteria usually considered in the asset management decision-making process and residents’ satisfaction when they urgently feel a need for renovation.

In this study, by reflecting the percentage of protesters, the average monthly payment for the “Designation, etc. of Areas for Priority Control of Sewerage Maintenance” project is estimated at 7364 KRW per household which is 6.50 USD. Using the social discount rate of 4.5% (PIMAC, 2008), the total household payment for 5 years is calculated to be 387,925 KRW (342.68 USD). Assuming that the bill is paid for a lifetime, people who agree to the project are willing to pay 1392 KRW (1.23 USD) for additional sewerage expenses. When comparing the fact that the average monthly household sewerage bill was 5488.8 KRW (4.85 USD) in 2019 in Korea (ME, 2020a), the additional amount of 1392 KRW (1.23 USD) is 25.36% of the actual bill; it can be interpreted as people attributing much importance to the flood control service.

Conclusions and remarks

This study focuses on the recently heightened need for consumer-centric public infrastructure asset management in light of limited budgets, aging infrastructure, and increased financial burdens. In particular, even though water resource infrastructure provides various types of public services, consumer-based asset management has been poorly operated for three reasons: First, each LoS consumer needed is not well known; second, the definition of satisfactory service level differs from person to person, and finally, there is a large gap between the assessment criteria by experts and real users. This study aims to discover consumer-based LoS focusing on the flood control infrastructure management project among the various water resource infrastructure services, which has recently become a critical issue due to climate change. To define the respondents’ subjective value as the quantitative standard LoS that can be universally used in the decision-making process, CVM is used. Key variables for this analysis included the expected LoS improvement and the number of complaints.

According to the results of the CVM analysis performed using the OOHDBC spike model, the monthly household WTP for the “Designation, etc. of Areas for Priority Control
of Sewerage Maintenance” project is estimated to be 10,459 KRW (9.24 USD) on average. Reflecting the proportion of protest-bidders, respondents are willing to pay 387,925 KRW for 5 years, which is 342.68 USD. Assuming that the additional bill is paid for a lifetime, we find that it is equivalent to 25.36% (1392 KRW or 1.23 USD) of the current average monthly sewage bill in Korea. Additionally, the results of analyzing consumer-based LoS with covariates show that people who require less than 10% of flood control service improvement, specifically, people who live in the area with 10–19 complaints to the drainage systems, tend to pay more to deal with flood damage. In summary, from the users’ point of view, the initial response is more critical, and the satisfaction level for improving the flood control service decreases when the service level is beyond a certain level of discomfort intolerance.

With the current trend emphasizing the efficient management of public infrastructure assets and consumer-based services, this study makes two main contributions. First, considering the results of this research, the consumer-based standard LoS, which is universally applicable in a flood control policy, is presented. According to the results, respondents are willing to actively improve flood control services, especially in specific initial intervals. In other words, people prefer to deal with the problem when it can be solved early at a lower cost. Higher consumer satisfaction can be achieved under expenditure limits, considering this fact in the future decision-making process. Second, new RP data that have not been used before are proposed. Within the Sewerage Act in Korea, an area “where flood damage occurs, or is likely to occur, due to sewage inundation or an area which is likely to worsen the quality of public waters” may be designated as the priority control area (ME, 2018). However, this criterion is a provider-based standard of service that only considers physical urgency, not the users’ subjective satisfaction. This study presents the usability of complaint data that has not been utilized before and converts the subjective needed service level into a form of universal quantitative RP data. Consequently, the results of this study can contribute to the establishment of consumer-based sewerage asset management, which is realistic and sustainable.

Meanwhile, a growing number of government agencies consider complaint data on their management process to deal with public discomfort in advance. For example, Goyang-si in Korea has implemented “complaints and discomfort forecasting system,” which is a system that analyzes the regional complaint data to prevent residents’ inconveniences, such as an inland flood, in advance (Goyang-si News Website, 2019). In the USA, data analysis of the government’s 311 on-demand services, an integrated complaint management system, enhances the consumers’ experience, improves the agencies’ performance, and even saves operational costs (Chatfield and Reddick, 2018). Even the UK, the Netherlands, and France, among others, have considered complaint data in their public administration for a long time (Hassan, 2010; European Commission, 2018). Regarding these examples, the result of this study, which is especially limited to the case of sewerage infrastructure asset management, but is widely applicable, supports the empirical evidence that providing consumer-centric services with complaint data can provide efficient management systems in terms of cost-effectiveness and improvement in the quality of life.

This study has a few limitations. First, the difference between aging facilities and the number of complaints in residential areas may be caused by various reasons such as the population and flood damage in the living space. The fact that the analysis was conducted based on the zip codes and not the exact residential address also needs to be considered when it is used in the future decision-making process.

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Data Availability Data available on request.

Declarations

Ethics approval All authors demonstrate ethical participation in the design and performance of manuscript.

Consent to participate and for publication All authors declare their consent to participate in all phases of the manuscript and to publish in the form presented.

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