Water Practice & Technology Vol 11 No 4
doi: 10.2166/wpt.2016.083

Development of a support tool for sewerage asset management

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Abstract

This paper describes the principal issues for small local governments with limited resources available for introducing sewerage asset management systems and provides some solutions. A ledger management system, as well as support tools for long-life measures and disaster prevention support, and a financial support tool have been developed.

Key words: business continuity, investment plan, PDCA, priority, risk assessment

INTRODUCTION

Many sewerage facilities in Japan were constructed during periods of high economic growth – the 1950s to the 1970s. Recently, as these facilities have deteriorated, road collapses have occurred. The number of facilities requiring renewal has increased rapidly.

On the other hand, social circumstance in Japan are such that financial and human resources are now decreasing, and sewerage revenue will fall because of the declining birth rate, aging population and depopulation. The Japanese government needs to establish an effective management and renovation system to reduce disaster damage, so that service can continue even after large-scale disasters like earthquakes and floods. In such circumstance, asset management is attractive because it is efficient and effective, and can help to ensure business sustainability, and the operation and maintenance of facilities.

By adopting asset management for sewerage, the process and concepts of maintenance and renovation based on a PDCA(Plan-do-check-action) cycle can be indicated, and failure risk and life cycle costs reduced, while sewerage management is also more transparent.

The introduction of sewerage asset management systems in Japan varies depending on regional characteristics and the relative size of local government. Large-scale bodies like that of Tokyo introduced systems some time ago and have worked to improve them using available manpower. Smaller local governments have only just started their efforts to introduce such systems, however.

This paper focuses on small-scale local government, with limited human resources, experience and budget, and describes the principal issues for introducing sewerage asset management systems. Solutions are provided to fit needs and overcome problems. It also presents a system that has been developed (Figure 1) around these solutions.

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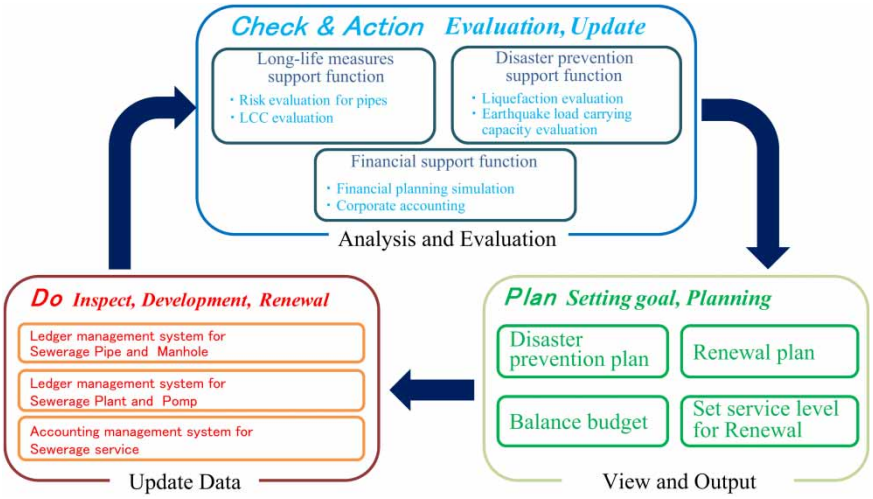

Figure 1 | Sewerage asset management system schematic.

ISSUES AND SOLUTIONS

Database management

Issues

A significant number of local governments manage sewerage, e.g., for operation and maintenance check and repair information, in paper-based documents. This is one of the factors that has caused asset management system introduction to occur slowly. Moreover, local governments have insufficient data on inspection and updating work, since most of these sewerage system have been developed recently and the facilities are still new.

Solutions

To manage maintenance information efficiently, it should be digitized. In recent years, with increasing levels of ICT (information and communication technology), the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has produced an introductory sewerage ledger guideline to encourage digitization. Some methods have also been developed (e.g. Miyamoto 2013) for predicting the deterioration of facilities from limited inspection data. On this basis, the establishment of the sewerage ledger system is efficient in reducing the cost of digitization and enabling advantage to be taken of deterioration prediction methods.

Project priority

Issues

Even in harsh economic conditions, when financial and human resources are limited, local government in Japan needs to maintain very extensive sewerage facilities and provide a certain level of sewerage service. Therefore, prioritization of facility inspection, reconstruction, and renovation is required. Prioritization of sewerage construction, disaster prevention, and environmental protection operation must also be considered.

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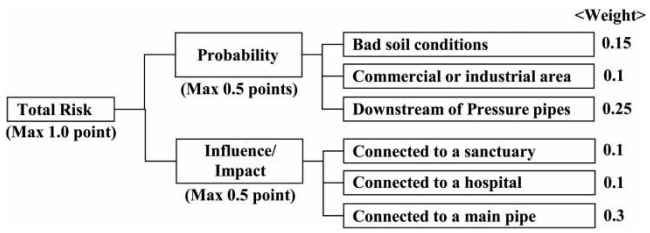

Figure 2 | Example of risk evaluation – e.g., poor soil conditions under a pipe correspond to 0.15 point and the risk value is calculated by evaluating each item.

Solutions

A useful method of prioritization is risk assessment (e.g. Tanimoto *et al.* 2011). This is used to calculate risk value by combining damage possibility and potential impact. Each item of the risk assessment needs to be weighted, as shown in Figure 2. There are several methods for doing this, one that is used commonly, because it rational, is the analytical hierarchy process (AHP).

Financial evaluation

Issues

Future operation and maintenance budgets will be reduced as sewerage revenue decreases due to population decline. Strategic business planning is essential to take into account not only inspection and repair costs, but also revenue decline and depreciation. Local government needs to disclose its budget planning openly, as well as long-term revenue and expenditure planning.

Solutions

Long-term financial simulation is required. A few financial simulation models (e.g. Nada *et al.* 2010) have been developed to date and MLIT has compiled a financial database for local government across the country, to help them monitor their current financial condition and evaluate their business sustainability, in the face of changing sewerage charges and business plans.

SUPPORT TOOL

To solve the adaptation issues discussed above, a ledger management system and support tools have been developed.

Management flow

Figure 3 shows an asset management examination flow chart and the corresponding relationships in the ledger management system, long-life measures, and disaster prevention and financial support tools to the flow. The asset management system can be used to evaluate whether the local government can achieve the target service level. When it is shown that this cannot be done, the budget is redrawn. Depending on the flow, the system, based on the PDCAcycle shown in Figure 1, can be implemented.

Ledger management system

Data concerning the design, construction and inspection of sewerage facilities (pipes, treatment plants and pumping stations) can all be digitized. The ledger management system, which shares these data

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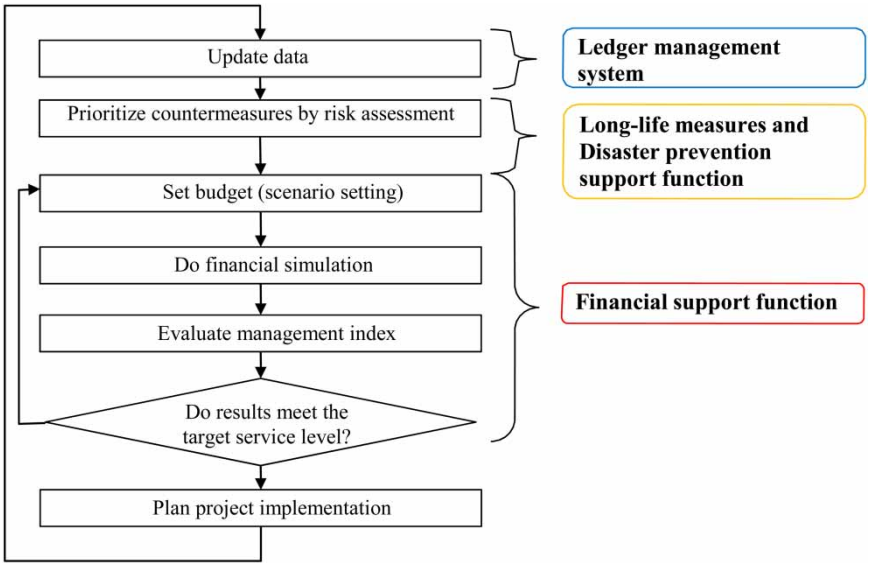

Figure 3 | Asset management flowchart based on a PDCA cycle.

with other support tools, is developed using them. GIS is used for conveyance facilities – pipelines – and a general purpose database for treatment plants. Text is used to enhance general versatility.

Long-life measures and disaster prevention support function

Risk evaluation for pipe damage

This tool is designed to enable evaluation of inspection, repair and reconstruction priorities for sewer pipes on the basis of risk of road collapse (Figure 4, left). By registering the information indicated in

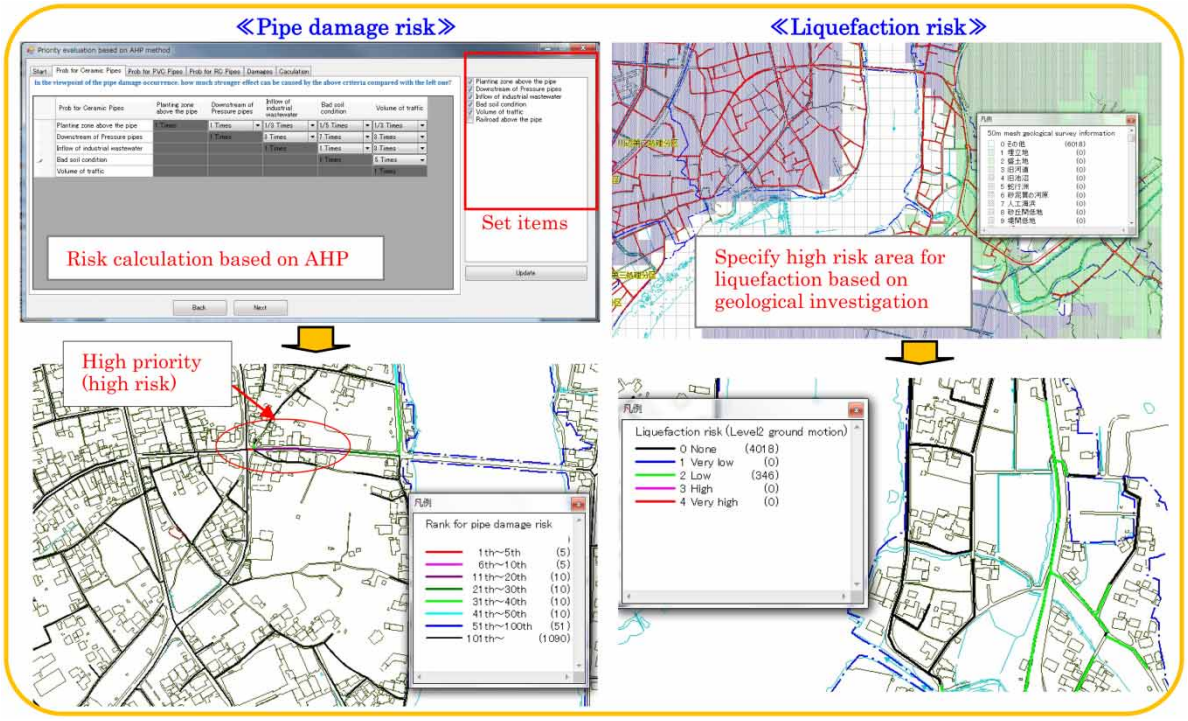

Figure 4 | Output image of risk ranking.

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Table 1 in the ledger management system, AHP can be conducted on the tool to calculate the risk values for sewer facilities and prioritize countermeasures. It is noted that:

Table 1 | Input and output data – pipe damage risk assessment tool

Input	**1)** Pipe age, **2)** Number of laterals, **3)** Pipe diameter, **4)** Pipe type, **5)** Whether or not the pipe was under planting zones, **6)** Downstream of pressure pipes[a], **7)** Influent industrial wastewater, **8)** Soil conditions, **9)** Whether or not the pipe was transferred from the developer, **10)** Volume of traffic using road, **11)** Commercial or industrial area, **12)** Disaster prevention base near pipe, **13)** Railway above pipe, **14)** River above pipe
Output	**1)** Possibility of malfunction, **2)** Effect of malfunction, **3)** Risk value, **4)** Ranking. of risk value

[a]'Pressure pipes' have a relatively higher potential for generating hydrogen sulfide, which attacks reinforced concrete aggressively.

- Evaluation results can be displayed on a map so that it links to the GIS ledger management system.
- Each user can select the items arbitrarily as the importance of evaluation items and data volumes depend on the characteristics of the local government concerned.
- The evaluation unit is set as the length of pipes between manholes to enable prioritization based on things like treatment area.

Priority evaluation based on liquefaction risk

This tool is used to evaluate liquefaction risk at the sewer pipe location, on the basis of geological survey information (Figure 4, right). It translates evaluation results to mesh data and superimposes those on GIS sewer pipe location data, to enable evaluation of liquefaction risk on each span of sewer pipes.

- The evaluation results for liquefaction refer to public geological survey information.
- A 50 m mesh was chosen for these evaluations because, if the mesh is too large, the accuracy is reduced as the number of similar evaluation results increases.
- Depending on the evaluation results, if a high risk of liquefaction covers a wide area, more accurate liquefaction data – e.g., from borehole survey logs – needs to be collected.

Financial support function

Budget equation management

This tool can be used to predict (1) countermeasure costs, (2) countermeasure facility sizes, and, (3) the level of facility deterioration and related risk values – see Figure 5. When a lower budget is set in the scenario, the degree of deterioration of facilities and associated risk values tends to be higher, because their renovation has to be postponed year-on-year. In relation to this tool it is noted that:

- In a limited budget scenario, countermeasures are conducted for facilities with high risk values, to minimize total risk. Countermeasures that exceed the facilities' budget must be moved to next year, in ascending order of risk.
- The best scenario is determined to confirm the balance between the facilities' risk value and degree of deterioration.

Financial planning simulation

To transfer public accounting to corporate accounting systems and adjust budgets with local public financial bureaus, financial condition visualization is necessary. This tool simulates income and

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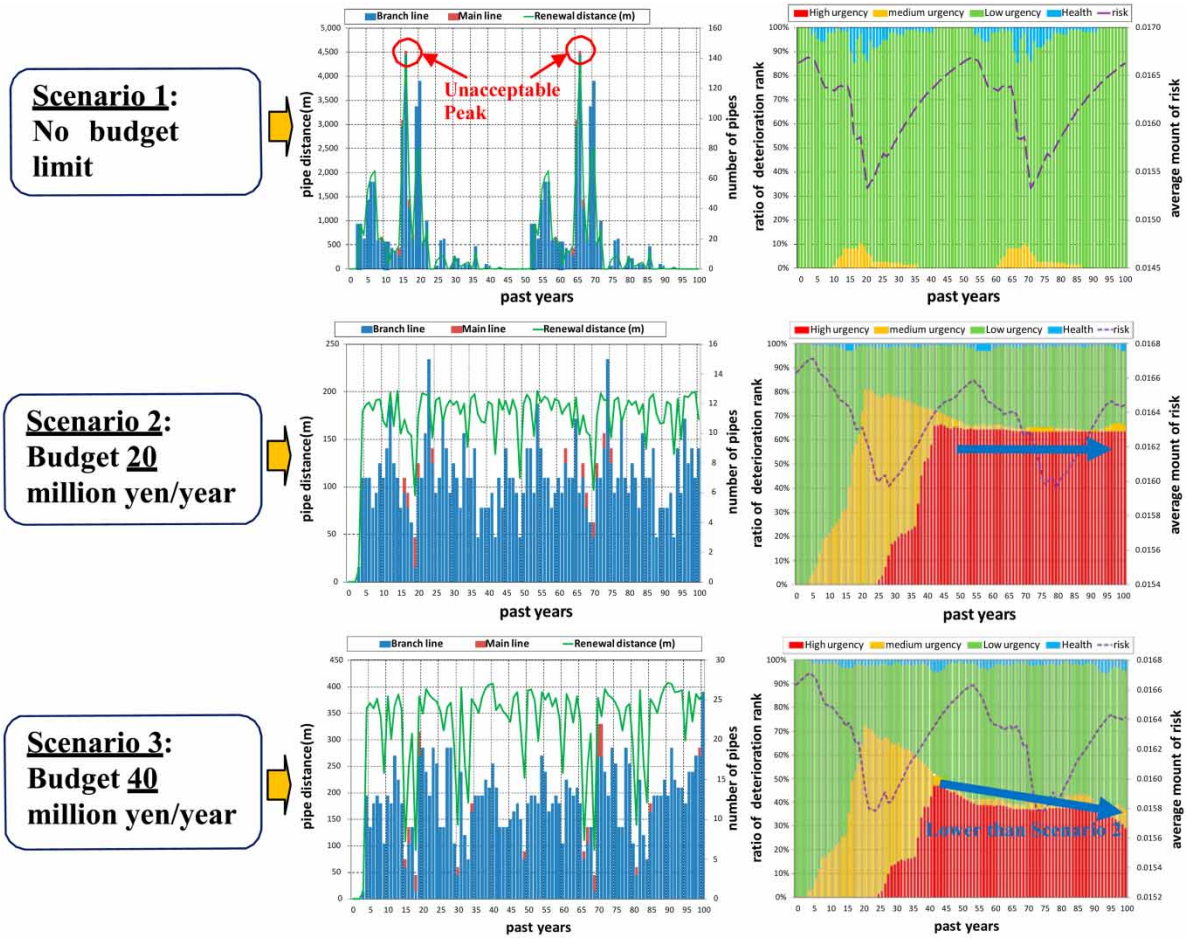

Figure 5 | Balance between risk and budget limit.

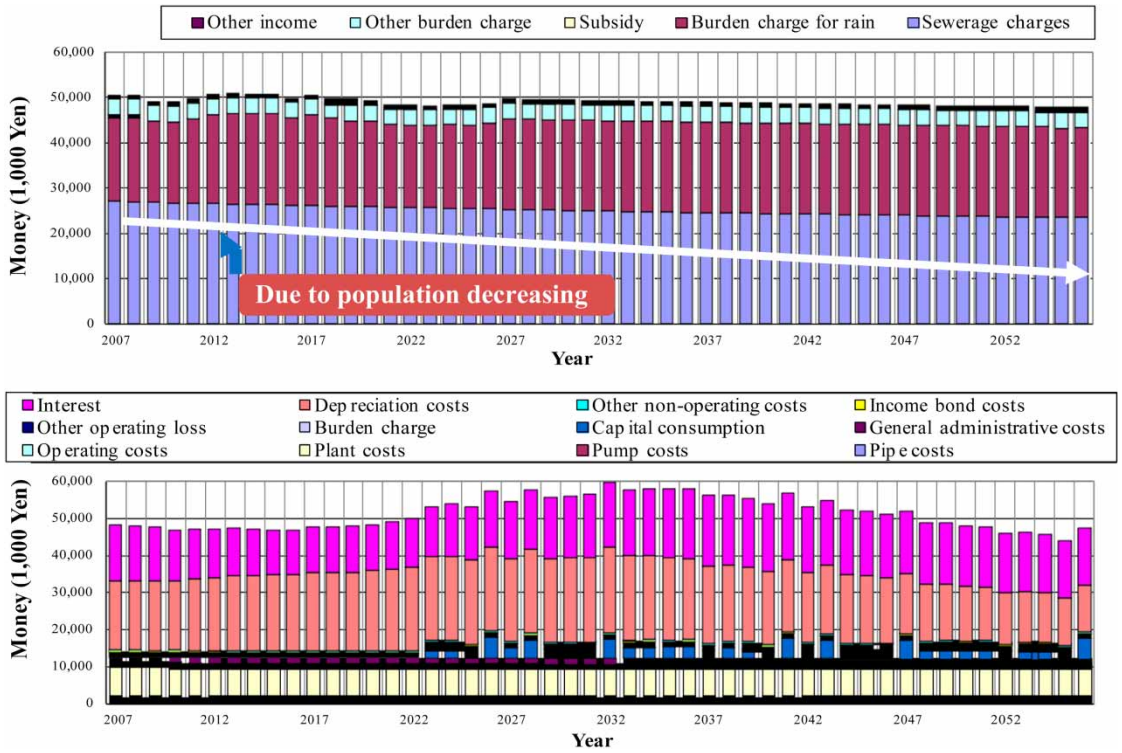

Figure 6 | Financial simulation (above 'income', below 'expenditure').

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expenditure in the long-term. As shown in Figure 6 and Table 2, realistic financial plans can be developed considering future sewerage charges, subsidies, etc.

The points noted about this tool are:

- The evaluation period is 50 years (medium- to long- term) because such facilities can be used for a long time. The long-term trend from the starting year for construction is illustrated graphically.
- The tool can respond to changes in sewerage charges, by preparing several sewerage charge scenarios.
- The results are shown in general spread sheet software – e.g. Excel – so that it is easy to work and create documents with.

Table 2 | Input and output data for the financial simulation tool

	Item	Parameter
Input	Basic information	User population, usage rate (toilet flushing), chargeable sewage rate, average daily
	Future investment	Facility construction cost, facility renovation and improvement cost
	Financial resource for the investment	National grant and bond flotation (interest rate, redemption period)
	Operation and maintenance	Operation and maintenance cost of facilities (treatment facilities, pipes, pumps, etc)
	Usage charge	Sewerage charge, user fee
Output	Financial index	Balance sheet (B/S), income statement (P/L), (C/S)

FUTURE DEVELOPMENTS

Future development plans are:

(1) A public business accounting system is being promoted to the sewerage service business in Japan. A new support tool for public business accounting will, therefore, be added.
(2) A new asset management system will be established to integrate water supply and sewerage businesses.
(3) The system will be developed further through interviews with local government, to meet their needs.

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