Sharing Pipeline Inspection Data and GIS System Data:

Future Picture of Pipeline Management by Mutual Interchange of Big Data

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Abstract: Currently, the Tokyo Metropolitan Government makes efforts to promote measures against deterioration of the water pipelines and reinforcing projects of the earthquake-resistance.

Regarding routine maintenance and management, we have been conducting facility inspection of the pipelines and drawing management by using a GIS system. We believe that the weak points of the pipelines and attached facilities can be more precisely identified by sharing and multiplying data obtained by facility inspection, data in the GIS system, and big data of both systems one another, which can contribute greatly to planning of renewal as well as setting measures for preventive maintenance.

This paper aims to sort out issues related to such sharing and integration of systems to a certain extent and discuss its effects and a future image of maintenance and management methods.

Keywords: Maintenance and management of pipeline system; pipeline diagnosis work; GIS (mapping) system; big data

Introduction

It is imperative for the Bureau of Waterworks of the Tokyo Metropolitan Government to replace aged pipelines or make them earthquake-resistant in order to reduce leakage rates and be prepared for future earthquakes.

Therefore, we diagnose pipeline systems and ancillary facilities on a daily basis. We also maintain and manage pipelines by using a GIS system for managing drawing data, and by improving tangible and intangible features. To continue the optimum rehabilitation of pipeline systems with our limited financial and human resources, we must develop an effective, optimum management methodology using our existing insights and various accumulated "big data." This paper proposes how pipeline management should be performed in the future by reconstructing and innovating existing systems in Tokyo, including the incorporation of big data into the present GIS system.

1. Issues Related to the Maintenance and Management of Pipelines in Tokyo

(1) Maintenance and Management of Pipelines in Tokyo

Water first flowed through the modern waterworks of Tokyo in 1898. For the 120 years since then, the network of water pipes has been supporting city life in the Japanese capital and the daily life of its inhabitants. The water supply system is one of the largest in the world, with a total pipeline length of approximately 27,000 km, almost two thirds of the earth’s circumference.

Water pipelines are not just connected pipes, but include various ancillary facilities and equipment such as valves having different functions, fire hydrants and aqueduct bridges. The entire set of these pipelines controls the flow rate, direction and pressure of all service areas in Tokyo. (Figure 1) (Table 1)

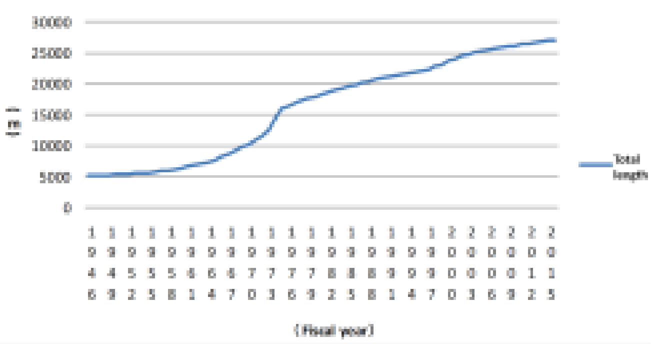

Figure 1: Total extension of managed pipelines in Tokyo by fiscal year

Type	Tokyo’s 23 wards	Tama area	Total
Gate valve	248,605	137,227	385,832
Air valve	9,435	6,475	15,910
Drain valve	7,595	3,291	10,886
Fire hydrant	90,379	42,237	132,616
Vertical shaft	241	75	316
Telemeter	260	55	315
Aqueduct bridge	24	69	93
Total length of aqueduct bridges(m)	535	1,269	1,804

Table 1: Numerical data of pipeline system

1. Pipeline Diagnosis

The Metropolitan Government conducts pipeline diagnosis work in a cycle of seven to ten years all over Tokyo. Corrosion of pipelines attached under roads and bridges and the functioning of valves, fire hydrants and other ancillary facilities are checked during diagnosis by visual inspection and on-site operation testing.

The diagnosis results are used for the daily maintenance and management of pipelines, as we assess aging degradation of pipes according to a certain set of criteria. We immediately repair ancillary facilities having high urgency or priority. (Figure 2) (Photo 1)

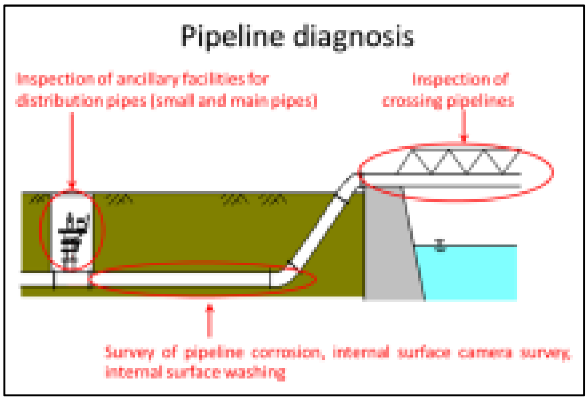

Figure 2: Pipeline diagnosis

Photo 1: Diagnosis of pipeline attached to bridge

2. Replacement of Aged Pipes (replacing with earthquake-resistant joints, planned maintenance and repair)

The year of installation (fiscal year) is a factor that affects the aging degradation of pipelines. Accordingly, we select pipeline routes in chronological order of installation years and replace pipes in a planned manner.

When any replacement of road pavement is planned, we attempt to schedule the pipeline replacement concurrently with the construction work.

The installation rate of earthquake-resistant joints is steadily increasing under the replacement plan, which is based on an indicator of installation year. The plan is systematically implemented to achieve the target values. (Photo 2) (Figure 3)

Photo 2: Replacement of aged pipeline

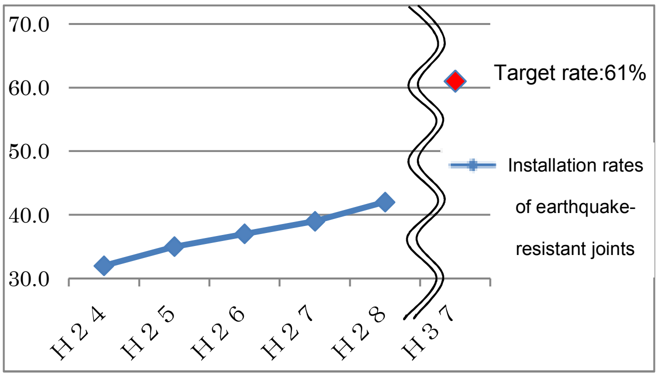

Figure 3: Changes of installation rates of earthquake-resistant joints

3. Accident Response (emergency repair work)

Not only aged pipes but also some installation-related factors (e.g. soil conditions, joint connections, automotive traffic at locations where pipes are laid, changes of pressure in pipes, damage caused by other construction works) may cause water leakages under or on the ground. If this happens, we carry out emergency repair work immediately and then restore the installed pipeline. (Photo 3)

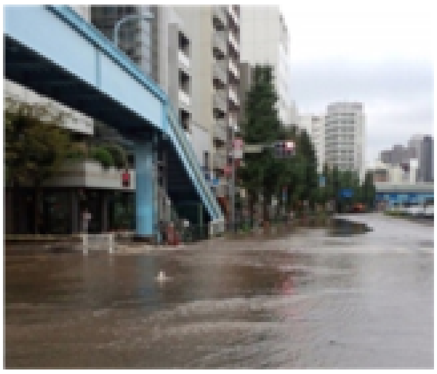

Photo 3: Water leakages caused by large-scale accidents

(2) Management with Drawings (GIS System)

In addition to the on-site management actions outlined above, we introduced the GIS (mapping) system in 1991 to manage drawings. This system enables us to search the installation situations of pipelines and ancillary facilities and display them on a PC monitor overlapped with images of geographical maps and pipeline layout drawings. This visually indicates the huge amount of pipeline information held by the Bureau of Waterworks.

The GIS system also centrally manages relevant information including the installation year, type and diameter of pipelines indicated on maps. It can also output drawings that were made when the pipelines were installed.

In addition to functions for predicting the extent of impact caused by water suspension and turbid water when an accident or water service work takes place and for aggregating installation years of pipelines, pipe types and the number of gate valves according to certain conditions, the system can show the positional relations with other underground facilities. This allows us to maintain and manage pipelines with a broad perspective, even from the office. (Photo 4) (Figure 4) (Figure 5) (Figure 6)

The use of tablet computers having the same search function as the GIS system enables us to respond on-site immediately in case of a sudden leakage and its subsequent water supply suspension and/or turbid water in extensive areas. (Photo 5)

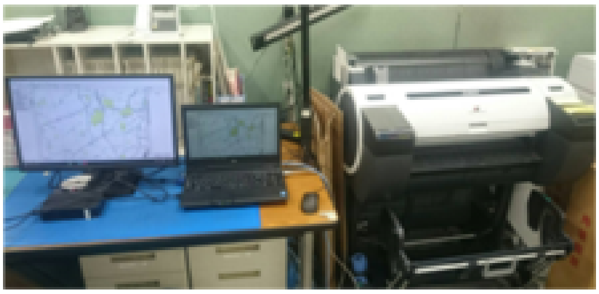

Photo 4: GIS system

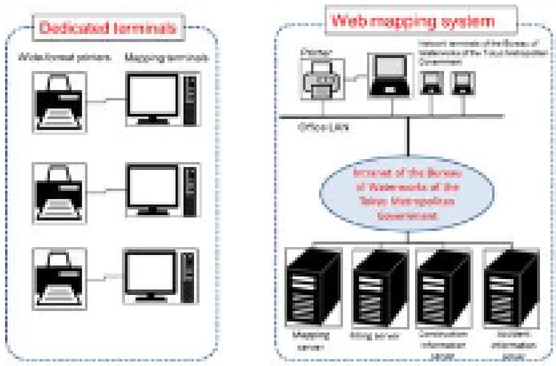

Figure 4: GIS system architecture

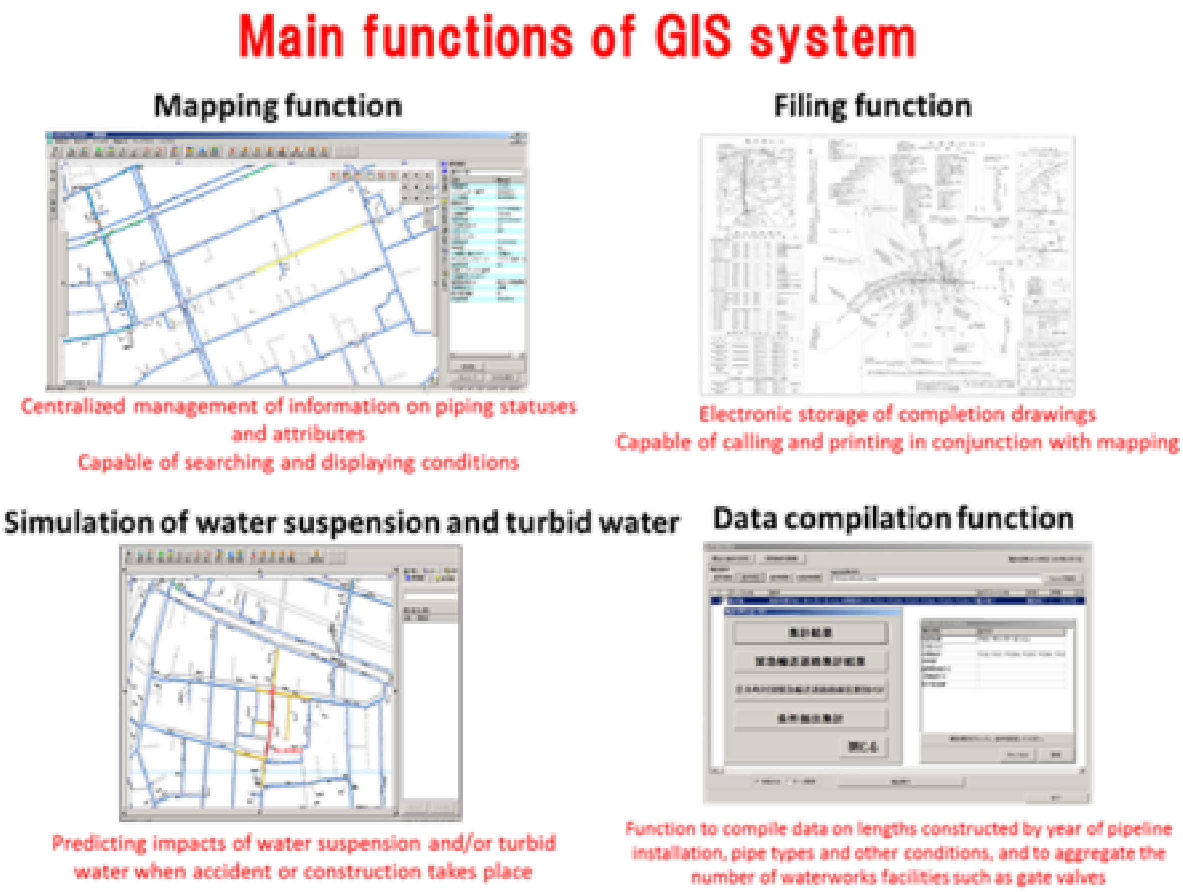

Figure 5: Main functions of GIS system

Figure 6: Display of GIS system

Photo 5: Field survey with portable terminal

2. Issues Related to the Maintenance and Management of Pipelines

The Tokyo Metropolitan Government has pipeline rehabilitation projects including for replacing aged pipes and installing earthquake-resistant joints. They have set goals of making 5,000 km of pipelines earthquake-resistant in 10 years from fiscal 2016, and achieving an installation rate of earthquake-resistant joints of 61% after 10 years (in fiscal 2025), and are actively proceeding with these projects. Under the replacement plan based on a limited indicator i.e. the installation year, however, the investigation results for the soundness of pipelines and the leakage repair outcomes are not reflected in the planned rehabilitation projects. Therefore, some factors such as the difficulty of the site environment, the degree of aging of ancillary facilities and past accident rates may not be fully grasped, and so it is necessary to precisely identify the site conditions and utilize various information. Under such circumstances, the current GIS system does not effectively use the large amount of diagnosis (evaluation) data acquired through pipeline diagnosis work because pipeline diagnosis data and pipeline drawings are separately managed as different data sets.

This incurs the risk that data will not be effectively used and office work will not be efficient, not only when on-site works are carried out but also when an overall plan of rehabilitation projects is made. (Figure 7)

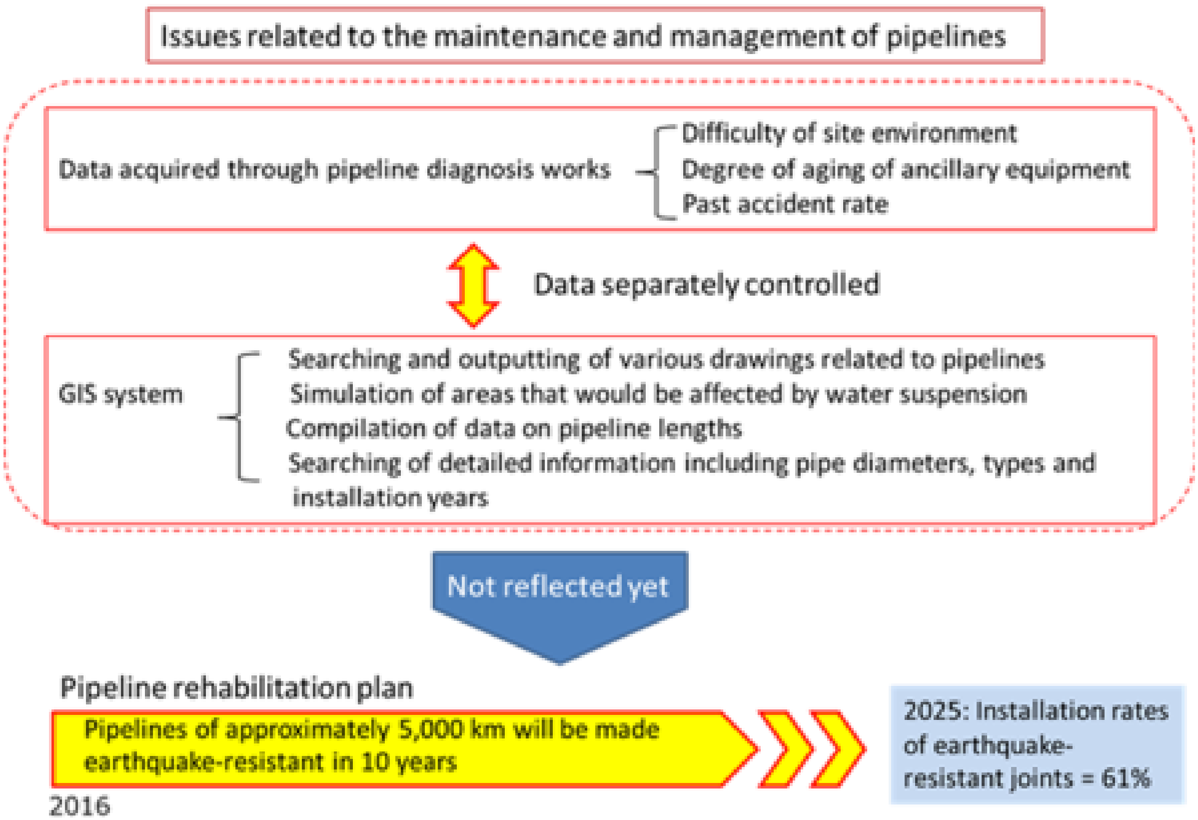

Figure 7: Data and system that are not integrated

Ideal Form of Maintenance and Management (Optimization and Streamlining of Rehabilitation Projects by Integrating Pipeline Diagnosis Data and the GIS System)

The Tokyo Bureau of Waterworks believes that a comprehensive system for maintaining and managing pipelines can be built by integrating evaluation data acquired through pipeline diagnosis work and the GIS system, and effectively using big data for mission-critical tasks such as on-site works and drawing up rehabilitation plans.

In this paper, the term “big data” means the soundness evaluation data of pipes and pipeline ancillary facilities acquired through pipeline diagnosis work performed during the past 30 years and the visual data (drawing information) for 27,000 km of pipelines stored in the GIS system.

The GIS system can search and output various drawings related to pipelines, simulate areas that will be affected by water suspension, aggregate the lengths of pipelines, and search detailed information such as pipe diameters, types and installation years. Thanks to these functions, it will be possible to evaluate in more detail the soundness of pipelines in certain areas and routes and to identify the weaknesses of distribution networks as an area correlated with accidents, by adding pipeline diagnostic information on point-like indicators of pipeline soundness to the system. Feedback will also be provided to assist maintenance and management works. By operating the system in a cycle of planning, on-site use, and data review, it will be possible to carry out maintenance and management most efficiently, thus maximizing the results, with limited human, physical and financial resources.

Once such system is built, it will be possible to draw up pipeline rehabilitation plans from diverse viewpoints and to carry out maintenance and management works efficiently and systematically, thus leading to great improvements. (Figure 8)

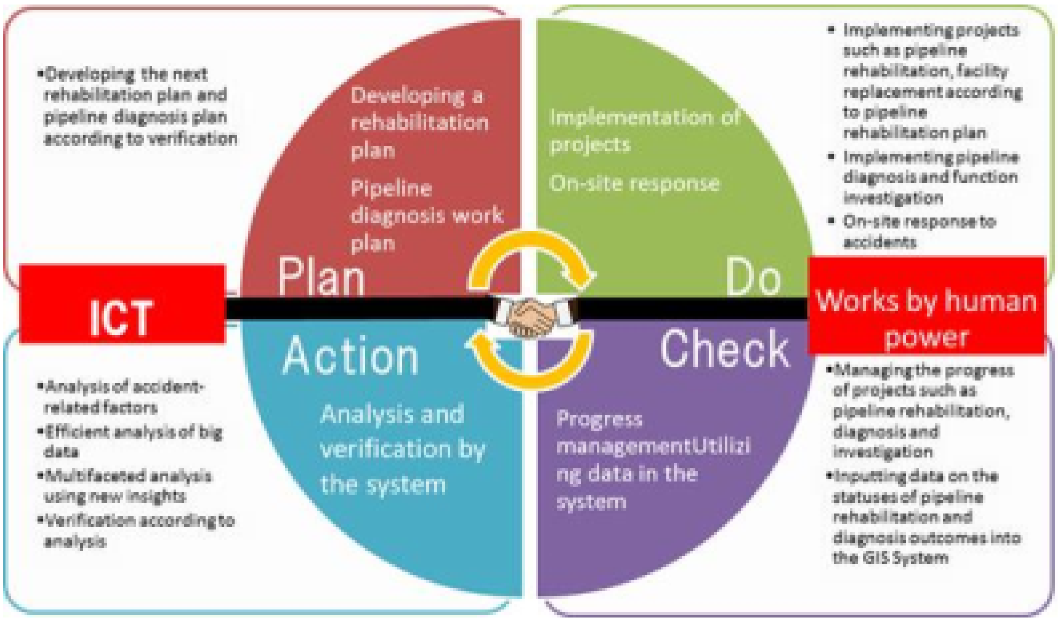

Figure 8: Future Picture of Management through the Integration of Data and System (Plan)

4. Conclusions

The never-ending mission of water suppliers is to provide a stable supply of water. This requires careful maintenance and management of water pipelines.

To effectively and continuously use such pipeline diagnosis data collected by experienced staff, we must consider how to integrate such data with the current pipeline management system and how to develop the integration.

It is also important to examine the possible use of ICT including portable terminals and AI in the future and to introduce such new technologies when appropriate.

The Bureau of Waterworks of the Tokyo Metropolitan Government will actively carry out innovative trials and develop new technologies in order to improve its entire water supply system including pipelines.

In the earthquake-prone country of Japan, one of our important missions is to supply water steadily within Tokyo, the capital of Japan having key functions. We must enhance these functions and improve the safety for citizens through system innovations.

We would like to make a plan for improvement of facilities, with the big data.

Now, we inspect relation between those big data, and we are going to device a method in near the future.

As a result, we think that we contribute to the making of widespread system that total can manage the maintenance of our pipeline. (Figure:9)

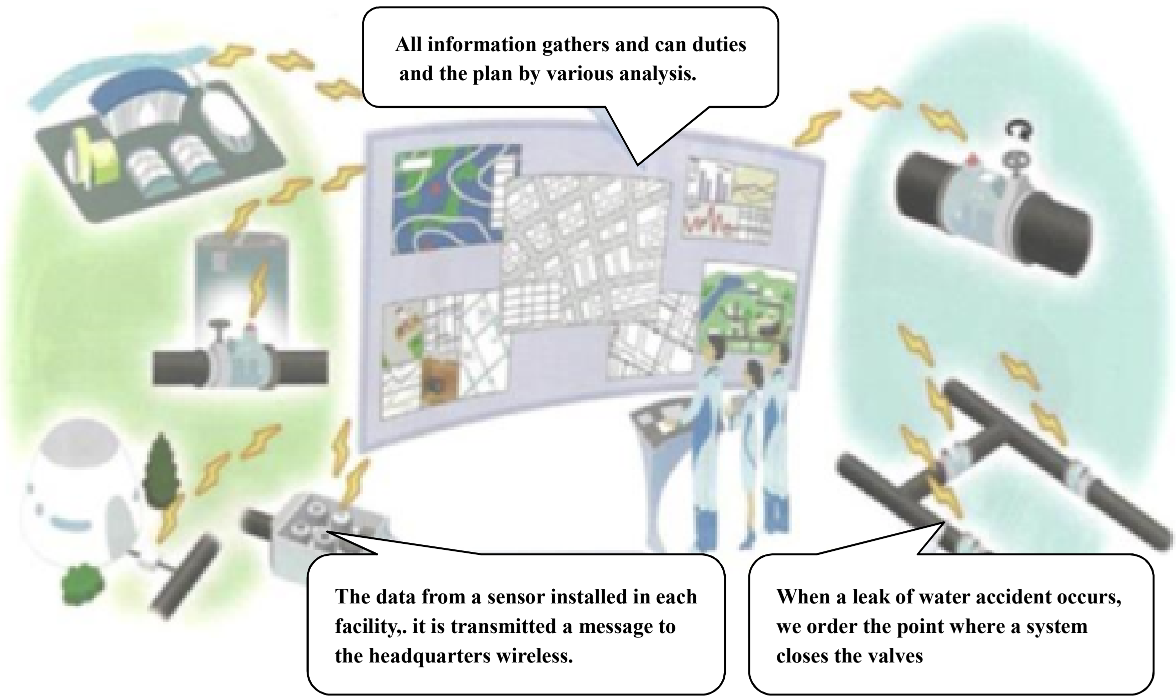

Figure 9: Effect by the total management system

Source of reference : [Pipe Stars Project]

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