Role of Research in Infrastructure Rehabilitation/Renewal Decision Process and Financing Options – Seismic Design
水道施設の更新に関する意志決定及び資金代替案に関する研究の役割—耐震計画について

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Role of research in infrastructure rehabilitation/Renewal decision process and financing options – seismic design-

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Abstract

The Ministry of Health, Labour and Welfare has published the Vision of Water Services in June 2004 in order to renovate the Japanese water services system for the sustainable development in the 21st century. This vision is composed many aspects as an attached document, however this paper deals the standpoint relating with disaster management in the Vision, and the lesson learn from Great Hansin earthquake in 1995 and the cost/ benefit analysis of renovation of water distribution system of a model city.

The background of the water vision describes the current situation and future prospect of Japanese water supply sector. The disaster management in the vision describes the needs and action program so as to enforce anti earthquake potential of water services.

The lesson learned from Great Hansin earthquake describes of the importance of water quality management. The cost benefit analysis concludes that the cost to renovate water distribution system brings large enough benefits to water services.

1. Water Vision

1.1 Objectives

On water services in Japan, about 110 years have passed since the modern water system started in Yokohama, and half a century has almost passed since the current Water Works Law was established. During this period, the water services expanded in service area as well as water quantity on the high economic growth period from 1960s to 1980s. And now, it spreads and most of the citizen can use it. In the stability of water quality, water quantity and business management, Japan is one of the countries where world-leading water services are realized.

On the other hand, in the early part of the 21st century, many water facilities in Japan which were developed in the 20th century become too old, and the renovation is the most concern. The 21st will be the century when we will, for the first time, experience the large-scale reconstruction of the water facilities which will be conducted repeatedly in the future. Furthermore, the ever-increasing trend of the population will end and we are about to go into the decreasing population era. In addition, the environment surrounding the water services in Japan is changing significantly: Review of allocation of roles between the public sector and the private sector, and between the citizen and the local government, globalization, move regarding the framework of local autonomy such as merging of municipalities, reduction of young engineers in water entity.

In this way, on the field of water services, it is time for us to deal with those issues and sustainable development with improving water supply service to citizne further based on the previous development.

The problems which the water services and the water administration face and the direction of argument are shown in Living Environment Council Report, "Measures

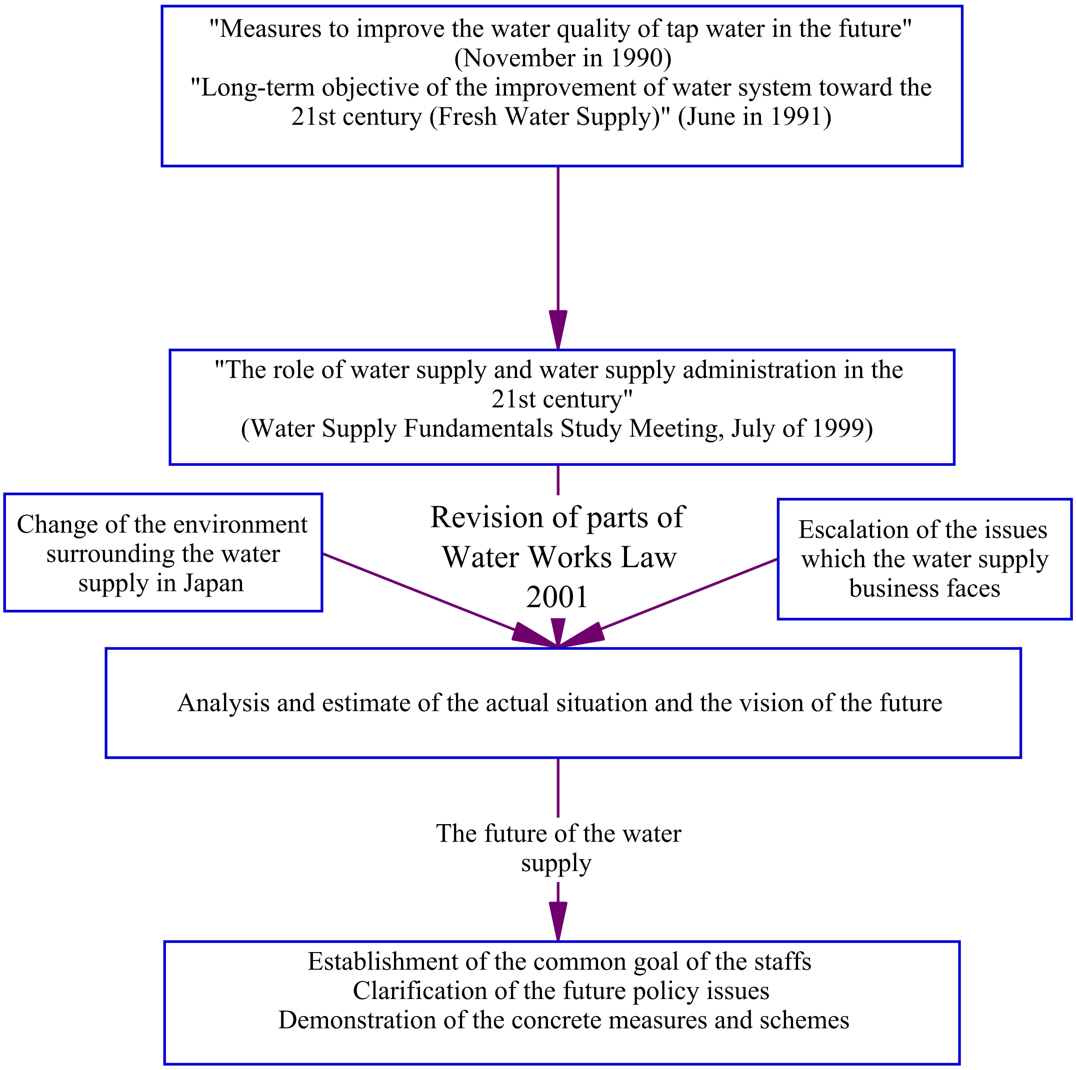

Figure 1 Objectives of the vision of water services

to improve the quality of water services in the future" (November in 1990) and "Long-term objective of the improvement of water system toward the 21st century (New Benchmark for Better Water services)" (June in 1991) in Heisei era. The details of them are concretely shown in "The role of water services and water administration in the 21st century" which was compiled by Water Fundamental Problem Study Meeting in July of 1999. And institutional response is conducted to some of them according to the revision of Water Works Law in 2001. However, the environment surrounding the water services in Japan is changing fast. The problems about the water services including new problems, such as water quality in private wells and the role of water business in the merger of municipalities are increasing.

The characteristic of the vision is to analyze and estimate the actual situation and the prospects of the future as quantitatively as possible based on the results of Water Fundamental Problem Study Meeting, to argue the future of the water services as a result of them, and to aim at establishing the common perceptions about the future of the water services among all persons involved in the water services.

The objective of the vision is to show the process so that the stakeholders can have the common goal, can divide their responsibilities each other and can work together in the early part of the 21st century. Therefore, in this vision, we decide to show the important policy issues concerning the water services in the future, and demonstrate the concrete measures, the schemes, and the process to deal with the issues clearly and comprehensively.

Foreseeing the middle of the 21st century, we decided that the target period of this vision was approximately ten years.

1.2 Disaster management – Need -

In water business, securing of water for life and livelihood is required even in cases of natural disaster such as earthquake, accident of water quality, and emergency such as terrorism. Therefore, it is necessary to secure the safety of principal water facility, and the water supply to main facilities, and the system in which renovation is implemented immediately even when it is damaged.

However, among principal facilities such as purification plants and distribution reservoirs, the facilities which are now reinforced against earthquakes account for 23% around the country, the main pipe lines (conduits, main water pipes and etc.) which are reinforced against earthquakes account for almost 13%, and the water suppliers which create the temporary water supply plan account for approximately 34%. In this way, we cannot say that we are well prepared in both software side and hardware side on a nationwide scale. In addition, facilities become too old, so the vulnerability against earthquakes is increasing.

Now water is indispensable for national life and industrial activity. We will implement systematic and efficient facility renewal so that the facilities can fulfill the functions enough and the fairness of the burden between the current users and the future users can be kept.

We will resolve the problem relating to the people who cannot obtain sufficient water even at normal time as early as possible and will implement stable water supply in the regions which are weak to drought.

In emergency situations such as natural disaster including earthquakes, electricity failure and accident of water quality, the improvement of facilities will be implemented to minimize the damage to facilities, and in case of the damage of facilities caused by the disaster and accidents such as burst of water pipes, the system in which appropriate temporary measures and quick restoration can be implemented will be developed to minimize the influence by water failure and low water on users.

In the implementation of these measures, we will achieve accountability about the effect and cost to users, will gain social consensus, and will advance them based on the characteristics of the region.

1.3 Disaster management – Enhancement measures -

On the anti earthquake measures, the manual of anti earthquake measures for water services which was revised in 1996 on the base of the experience of Great Hanshin Earthquake is available. Also, the enhancement of the cooperation with the bureau in charge of disaster prevention administration, and the steady implementation of the measures against emergency situation such as accidents of water quality are required

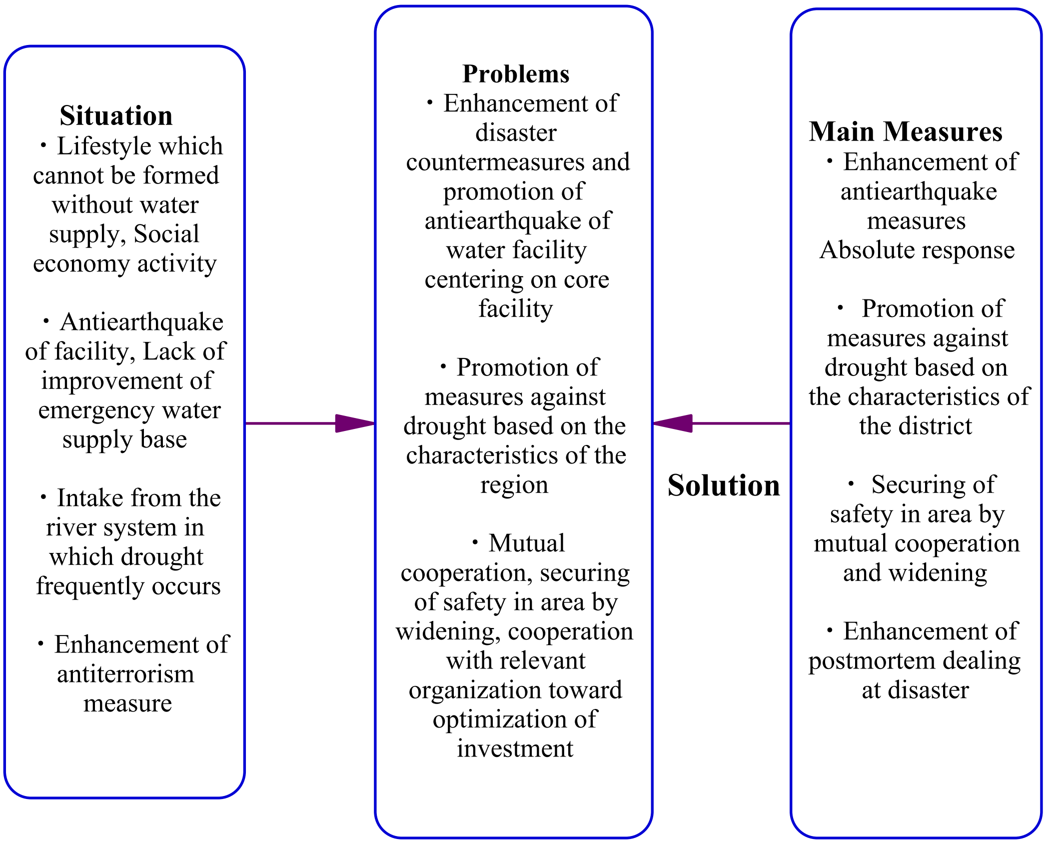

Figure 2 Disaster management of water supply

for water suppliers. Then, we should take it into consideration that we are not only pressed by postmortem dealing but also take measures to prevent them in cooperation with relevant persons. We will promote the measures for securing water to important facilities such as evacuation centers and medical facilities at disaster , and we will absolutely and immediately promote the anti earthquake measures mainly in the districts which are expected to suffer great damage from large-scale earthquakes such as Tokai earthquake and Tonankai・Nankai earthquake.

The water system is the network structure centering on principal facilities such as filtration plants. These operate as an individual system, or multiple systems are established in conjunction with each other according to the situation of cities. To secure the safety of water system against the risk at disaster, from the view of risk dispersion and avoidance of redundant investment, it is effective in risk management and economy to secure the safety in area by mutual cooperation and broad-based measures.

So, as disaster countermeasures, we will promote the measures systematically so that the safety in area can be secured by the review of the program on facility improvement toward securing the safety not in individual facility but in the whole system, the mutual cooperation or widening in neighboring water supliers or in water supliers in a certain sphere, and establishment of the cooperation system with local residents. Then, we will take important measures so that the water supply route to especially important facilities such as evacuation centers at disaster and hospitals can be secured.

On securing the safety in area, we should respond to not only hardware side, improvement of facilities, but also software side, the emergency water supply and the rapid emergency repair which contribute to shortening of influential period after the disaster. On emergency water supply, and improvement of emergency repair, individual water supplier develops the plans on those issues. And in addition, we will improve the system so that small-scale water suppliers can be supported by the neighboring water suppliers. Because the organization of smaller-scale water suppliers is more vulnerable in general.

Toward the expression of comprehensive measures effect with the measures relating to securing of drinking water at the disaster which will be conducted by the bureau in charge of disaster prevention administration, and the improvement of efficiency, under the close cooperation with local residents and appropriate allocation of roles, we will conduct the adjustment at the plan level in the local disaster prevention planning and the systematic budget securing.

To respond to the problems, we will promote the following measures.

・Enhancement of Anti earthquake Measures, Absolute Response

・Securing of The Safety in Area by Mutual Cooperation and Widening

・Enhancement of Postmortem Dealing at Disaster

1.4 Disaster management – Action program-

To enhance the stability of water supply at disaster, in hardware, we will intensively tackle securing of the lifeline under the concept in which the principal facilities of water services, and the important bases in securing of water supply at disaster such as bases of temporary water supply and medical facilities are unified. We will improve the system in which required water is supplied at disaster, and which includes the improvement of the connecting lines that enable broad-based mutual transfer across the sphere as well as in the neighboring water supplier. We will improve and enhance the system to implement prompt restoration in case of suffering of a facility.

Also, in software, we will promote the development of the local disaster prevention program and the conclusion of the mutual support agreement in cooperation with the bureau in charge of disaster prevention administration.

Further, we will establish an audit system which is composed of several water suppliers, investigate and coordinate the general measures in both software side and hardware side in the broad-based disaster countermeasures, secure the safety in area, and mainly develop a scheme to minimize the damage caused by water failure and low water. In addition, we will enhance and strengthen the support measures in technology and finance to support the measures which water suppliers implement.

From the experiences that the last earthquake disaster gave, many problems have found to remain to be solved by our Bureau against natural disasters, such as earthquakes, floods or water shortage, and against incidents, such as contamination of toxicants or pathogenic microorganisms to the source of water supply, any of which may occur in the future.

To prevent or reduce the influence of water failure and low water on the national life and socioeconomic activity at disaster such as earthquake and drought, and in the situation of terrorism and others, by estimation of the water facility function in which the improvement can be instructed, improvement of the stability of water supply

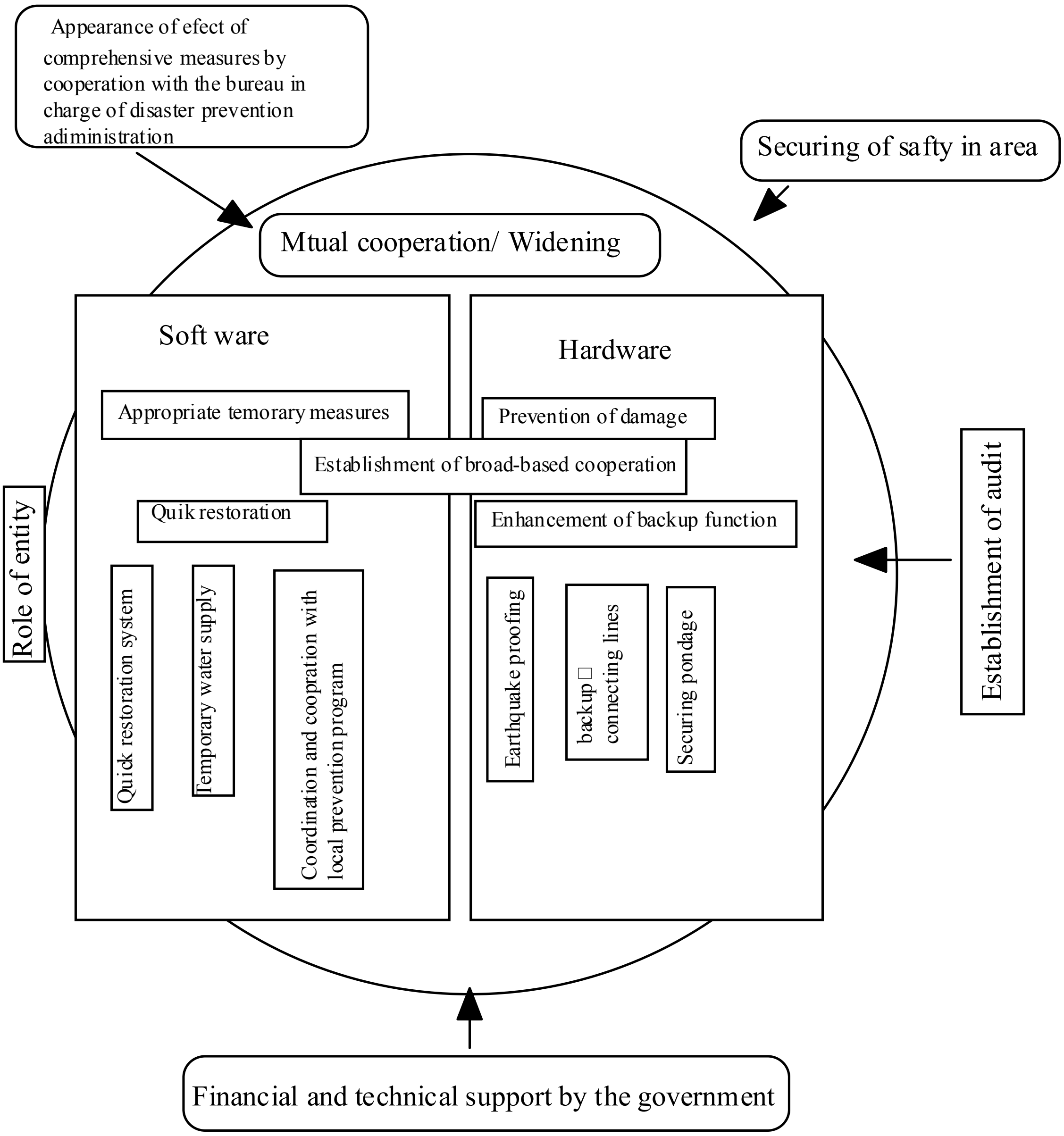

Figure 3Action program of disaster management

against the drought, intensive and strategic improvement of facilities in cooperation with the bureau in charge of disaster prevention administration, we will improve the safety and stability of the whole water system, and further promote the enhancement of temporary water supply system and quick restoration system at disaster.

The typical objectives of measures to achieve are as follows.

・To increase the percentage of earthquake proofing of core facilities such as water treatment plants and distribution reservoirs to 100%, and achieve it as quickly as possible especially in the strengthening areas of measures against Tokai earthquake (hereinafter referred to as Tokai area), and the promoting areas of measures against Tonankai・Nankai earthquake (hereinafter referred to as Tonankai・Nankai area).

・To advance the earthquake proofing in pipe networks mainly in principal lines. To increase the percentage of earthquake proofing principal lines to 100%, and achieve it as quickly as possible especially in Tokai area and Tonankai・Nankai area.

・To develop the temporary water supply program in the whole business and secure the target volumes of temporary water supply which is set in the program. To achieve it as quickly as possible especially in Tokai area and Tonankai・Nankai area.

・To improve the quick restoration system such as the support agreement at disaster with other supliers in the whole companies. To achieve it as quickly as possible especially in Tokai area and Tonankai・Nankai area.

2. Lesson learned from Great Hansin Earthquake

2.1 Damage of water supply

The Great Hanshin Earthquake occurred at 5:46 am. January 17, 1995 in the southern part of Hyogo Prefecture. The earthquake caused a lot of terrible damage to the citizens in southern Hyogo Prefecture area. The number of fatalities in the earthquake was more than 6300 and the number of destroyed houses, completely or partially, was more than 237 000. The earthquake had significant impact on lifelines, as well as damage of residential and commercial buildings, railroad, and highway. The water supply was cut off in ten cities and seven towns. The countermeasures of water supply in that occasion are an appropriate reference, as shown in followings, for emergency situation.

The outline of the damage of the water supply by the earthquake is shown in Table-1. Because the so many water supply pipes were damaged simultaneously, water in the pipes ran out rapidly and the water pressure flattened. The water leakage at too many damaged points made it difficult to detect the exact location. The damage rates of the water supply pipes were 2.22 location km-1 in Ashiya, 1.00 location km-1 in Nishinomiya, 0.44 location km-1 in Kobe. The extraction of mechanical joint was the main cause of the damage. Supply pipes were damaged at 180 000 households, which were equivalent to 13 percents of total households. But in Ashiya and in Akashi, where polyethylene pipes were used under the road, little damage was reported for those portions. Besides the damage of water distribution pipe systems, water treatment facilities and water supply reservoirs were also damaged. The Niteko dam in Nishinomiya collapsed severely, and the surface of the Kitayama dam also partly collapsed. In the Hanshin Water Supply Authority, the first period aqueduct from the Yodo River was damaged, and the restoration took for about one month. At the sedimentation tank of the Inagawa water filtering plant in the Hanshin Water Supply Authority, the expansion joints extended and water leaked out. Since the damaged joints were restored successively, the plant resumed its operation in someway.

The damage was comparatively small except the Egeyama distribution tank in Kobe. Immediately after the earthquake occurs, the water supply were cut off at 1 265 730 households in ten cities and seven towns in Hyogo Prefecture which was equivalent to 90 percents of total households of these area where water was supplied to 3 495 000 residents. Since the damage of water supply of a city and two towns in southern part of

Awaji Island was comparatively small and restored within short period. The water supply in nine cities and five towns was cut off for longer time. Especially in Kobe, Nishinomiya, Ashiya, Amagasaki, Itami, Tsuna, Awaji, Hokutan Higashiura, the water supply was cut off entirely. The damages of the water utilities in the Hyogo Prefecture amounted more than 55 800 million yen.

2.2 Water quality management in the disaster

In the last case, the target of enhanced disinfection was set at 1.5 ppm of residual chlorine at the outlet of the water purification plant. As no infectious disease outbreak was reported, the system is assumed to work properly. However, it is considered that further enhancement would be necessary as a countermeasure against pathogenic microorganisms in summer.

On the other hand, on a disaster, the sodium hypochlorite which will have intense demand may not available because of extremely bad traffic jam; therefore, emergency logistics including the rearrangement of the system, i.e. the method of delivery, water storage tanks, etc. should be well considered. In addition, the emergency manuals must be prepared for the stock, and water utility agencies and related departments should provide disinfectant by themselves, and whenever needed, pour it by themselves into water truck tanks and water storage tanks.

Just after the last earthquake, considering the water safety for drinking, the emergency operation center discussed to issue the 'boil water' notice as public information through mass media, as well as the enhanced disinfection. The discussion was focused on the USA's case of the Great Northridge Earthquake in 1994. However, the discussion reached to the conclusion that it was very difficult to publish the 'boil water' notice under the circumstances which heat sources such as the electricity or gas were completely cut off throughout the city, and fire had broken out everywhere and spreading owing to shortage of water for fire fighting. If the earthquake disaster occurred in summer, it could have been assumed that 'boil water' notice would have been published whenever or wherever necessary. For future, a nationwide consensus must be established on this problem.

At emergency such as a disaster, it is very important and also useful to execute monitoring on every field spot, with water quality inspection expedited rapidly and simplified, and with handy measuring instruments for water quality. Besides, since the automatic monitoring system for water quality was very effective for monitoring in real time after the last earthquake, new monitoring stations were installed at the outlet of the emergency water tanks, which were newly set up underground at four spots of parks in the Bureau. Thus, the system includes 15 monitoring stations at the terminals of pipe lines now and more stations will be set up successively in future.

As to the mutual assistance system for monitoring and management on water quality on last earthquake, no request for assistance was made for staffs outside of the utility agencies or the like. In future, however, in case of a great earthquake or the like in summer, it will be necessary to make requests for outside staffs' assistance. Therefore, it is required for each of waterworks utilities to set up immediately the system for the acceptance of assistance from the outside and for the dispatch of staffs for assistance. And also, it is desirable that the procedures in such system will be established in a manual-form program standardized on the nationwide scale.

3. Cost benefit analysis of renovation of water distribution net-work

3.1 Risk management

Earthquakes are considered the biggest risk to water supply. So most water utilities undertake measures against the earthquake. The authors consider the financial benefit is the most important factor in the selection of anti-risk measures. It is noted, however, that the priority of risks to be considered by experts or risk managers may not always conform to that of laypersons. (Slovic, 1995) Here discusses a conceptual procedure of selecting priority risks, which comprise a multirisk to water supply.

The risks such as earthquake, flood and draught are now called the primary risks; and the ensuing risk such as damage in water mains and the cost of emergency water service are termed the sub risks.

Anti-risk measures are classified into (1) mitigation, (2) imputation, and (3) retention of the risk. (Kusano, 2000) "Mitigation" means measures to reduce the probability of risk occurrence, or mitigate the risk damage by structural strengthening, moving, etc. In "risk imputation", although the occurrence of a risk is allowed, the caused financial loss is hedged by such measures as insurance schemes, bond issues, etc. A risk with low probability but vary high cost(damage)is often valued higher than a risk with high probability and low cost.(Japan Standards Association, 2000) "Retention of the risk" denotes the option to leave the system in question as it is without doing anything." Mitigation of the risk" is not necessarily superior to "Retention of the risk." If the benefits of the anti-risk measure do not exceed the cost thereof," Retention of the risk." may be opted. The two elements will persist unless 100 percent of the risk is removed.

The cost of a risk is generally defined as the holistic sum of the damage and cost of its sub risks, e.g., in the case of earthquake risk, the restoration cost of damaged facilities, the lost water sales due to the suspension of operation, the cost of emergency water service and so forth. To be also included are: the higher value of water to consumers at the time of severe dearth of tap water than at normal times, or consumer's surplus, the value of industrial, commercial and service production of the community,etc. which are forgone because of interruption of service,orlargely reduced supply.(Tomono and Magara,1996b)

In general there may be more than two measures against a risk. What's more, there will be more than two scenarios about the extant of implementing the measure. One example is an anti-seismic measure against the earthquake risk to water mains. The measure can be (1) the replacement of entire fragile pipes, or (2) the replacement of only a part of it. The condition will be similar in the case of other risks.

2.2 Benefits of Anti-Risk Measures

Benefits of anti-risk measures depend on various factors. As to the earthquake risk, for example, the size of the benefits of anti-seismic measures will depend on the size of real damage, which is related to the assumed intensity of the tremor, the return period of the quake, etc. In case the assumed seismic intensity is high, the potential damage by the risk will be heavy, so the benefits of the anti-risk measure will also be great. Likewise, the benefits will be large if the assumed return period is short; and vice versa.

The benefits of an anti-risk measure are the balance of the cost of the risk less that of the risk after the measure has been undertaken. Now let's assume the cost of risk i to be M_{iO}, the cost after the measure is made to be M_{iR} and B_{iR} as the benefit of the measure against the risk i,

$$B_{iR} = M_{iO} - M_{iR} \quad \cdots\cdots\cdots\cdots (7.1)$$

Denominating *ij* as the sub risk j of the risk *i*, *MiR* (*i*=l to *l* 〔el〕 are expressed as ΣM_{iOj} and ΣM_{iRj} (j= 1 to m), respectively. Therefore, the benefits B_{iR} of Risk *i* is expressed as follows:

$$B_{iR} = \sum_{i,j=1}^{l,m} M_{iOj} - \sum_{i,j=1}^{l,m} M_{iRj} \quad \cdots\cdots\cdots\cdots (7.2)$$

Due to the probabilistic nature of the risk, the values of M_{iO} and M_{iR} are rather nominal. Denoting the probability of the occurrence for each year as *e*, the real value of the benefits BiR is $e(M_{io}\text{-}M_{iR})$. The present worth P_{pT} of an annuity P_a for n years at a discount rate of *r* is expressed as follows: (Grant and Ireson 1970) It is proposed to use the discount rate of 5 percent, which is devised as the of return on working assets of water utilities in general. (American Water Works Association, 1999)

$$P_{pT} = P_a \cdot \frac{(1+r)^n - 1}{r(1+r)^n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7.3)$$

Therefore, the total real risk M_{iOT} and the total real residual risk M_{iRT} for the economic life *n* years of the anti-risk measure are the following:

$$M_{iOT} = e \sum_{i,j=1}^{l,m} M_{iOj} \cdot \frac{(1+r)^n - 1}{r(1+r)^n} \quad \ldots\ldots\ldots\ldots\ldots (7.4)$$

$$M_{iRT} = e \sum_{i,j=1}^{l,m} M_{iRj} \cdot \frac{(1+r)^n - 1}{r(1+r)^n} \quad \ldots\ldots\ldots\ldots (7.5)$$

Therefore, B_{iR} is rewritten as follows:

$$B_{iR} = e \sum_{i,j=1}^{l,m} (M_{iOj} - M_{iRj}) \cdot \frac{(1+r)^n - 1}{r(1+r)^n} \quad \ldots\ldots\ldots\ldots (7.6)$$

Further denominating C_{iR} the cost of the measure against risk i, the following equation examines whether or not the benefits of the anti-risk measure would exceed the cost of the anti-risk measure.

$$B_{iR} \geq C_{iR} \quad \ldots\ldots\ldots (7.7)$$

Since the benefits do not always exceed the cost of the risk, the following benefit cost ratio, should also be considered:

$$E_i = \frac{B_i}{C_i} \quad \ldots\ldots\ldots (7.8)$$

2.3 Case study

The following is a case study on the earthquake for a mode city in Japan. According to a consumer survey conducted by the author et al indicates that these risks, inter alias, are perceived by consumers as the most major risks related to water supply.(Tomono and Shirozu,1996) The model city has the following features:

- Total population: 100,000 persons
- Age group structure of the population: In accordance with the age group structure of Saitama Prefecture as the outcome of the 2000 census
- Water demand: 34,600m3/day
- Total length of water mains in the distribution network:287km, of which pipe material is composed of: ductile iron pipe(DIP)29.7%; cast iron pipe (CIP) 9.5%; steel pipe(SP)3.6%; asbestos cement pipe(ACP)18.2%;polyvinyl chloride pipe (PVCP)32.4%. (Tomono and Magara 1999a)
- Soil condition in the city area: A flood plain of medium consistency

a) The Seismic Risk on Water Mains

Applying the above model city, the earthquake risk against water mains was analyzed, and the benefits of the measures against it were evaluated. (Tomono and Magara, 1999b) The hypothetical earthquake is assumed to have a seismic intensity of Level 2 (Tremor scale: 7).

The cost of risk:

(Sub risk 1) Damage to water mains (a total for all pipe materials):	¥$1{,}222\times10^6$
(Sub risk 2) Loss in water sales due to the reduction in distributed water:	¥57×10^6
(Sub risk3)Cost of emergency water service (for water wagon, etc.):	¥440×10^6
(Sub risk 4) Loss of consumer's surplus due to the curtailed water service:	¥347×10^6
(Sub risk 5) Loss of general production:	¥$2{,}900\times10^6$
Total	¥$4{,}966\times10^6$

Considering the probabilistic nature of the risk, as its assumed return period is 70 years, the true value of the cost is ¥70.9×10^6. Then applying the uniform series present worth factor of 18.26 at the discount rate of 5% p.a. for the life of the anti-risk measure of 50 years, the total seismic risk is computed as follows:

¥$70.9\times10^6\times18.26=$ ¥$1{,}295\times10^6$

b) Cost of Anti-Risk Measures:

Three alternative measures against the earthquake risk to water distribution mains ware designed as follows:

(1)Alternative A: to replace 20% of DIP,40% of CIP,80% of ACP and 80% of PVCP pipes with DIP fitted with non-slip type joints: Cost:¥$5{,}551 \times 10^6$
(2)Alternative B: to replace, in the same manner, 10%, 20%, 40% and 40% of DIP, CIP, ACP and PVCP: Cost: ¥$5{,}551 \times 10^6$
(3)Alternative C: to replace, in the same manner, 5%, 10%, 20%, and 20% respectively: Cost: ¥$1{,}388 \times 10^6$

c) The implementation of the respective anti-risk measure will realize the true residual risk costs as follows (total for 50 years):

(1)Alternative A:¥157 x 106
(2)Alternative B:¥586 x 106
(3)Alternative C: ¥899×106

d) Benefits of the anti-risk measure

The benefits of the respective anti-risk measures are estimated as the difference between the cost of risk with and without the anti-risk measure as follows:

(1) Alternative A: (¥1,295-¥157)$\times 10^6$=¥1, 138$\times 10^6$
(2) Alternative B: (¥1,295-¥586)$\times 10^6$=¥709$\times 10^6$
(3) Alternative C: (¥1,295-¥899)$\times 10^6$=¥396$\times 10^6$

e) Economic Benefits of the Anti-risk Measure and their Significance

Economic benefits of the anti-risk measures are the following:

(1) Alternative A: (¥1,138-¥5,551)$\times 10^6$=-¥4,413$\times 10^6$
(2) Alternative B: (¥709-¥2,776)$\times 10^6$=-¥2,067$\times 10^6$
(3) Alternative C: (¥396-¥1,388)$\times 10^6$=-¥992$\times 10^6$

This shows that none of the alternatives will bring large enough benefits to recover their costs.

4. Conclusions

It is unavoidable of serious disaster that disturb water supply of potable water. In case of a strong earthquake, physical forces damage water supply. Then public water supply system can not afford necessary water for daily community activities such as not only domestic but also social and business activities, even in a hospital services. In order to reduce the risk of the interruption of continuous water supply it is necessary to renovate the existing water supply system from the both of hardware and software systems. The example of the cost and benefit analysis of the renovation of water distribution system in a model city shows that the cost of it brings large enough benefits to recover it after the disaster.

Therefore, as shown in the water vision, water services supplier should implement further efforts to reduce the risks of damage of their system by the earthquake especially in the areas of high risk large earthquake warned by the government.

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Role of Research in Infrastructure Rehabilitation/Renewal Decision Process and Financing

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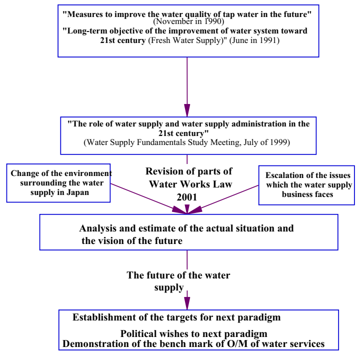
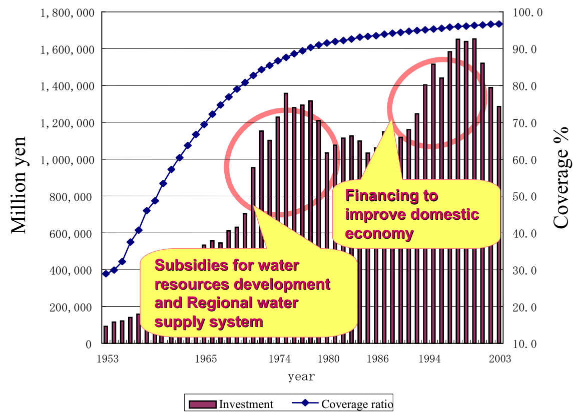
Objectives of the vision of water services



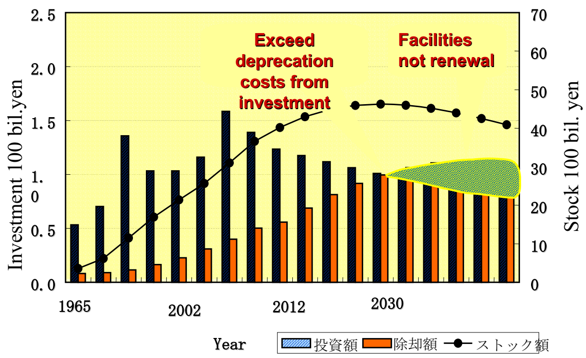
Current situation

- Investment / Stocks
- Personal management
- Facility management

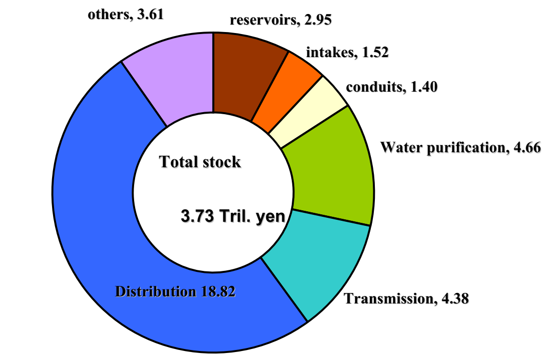
Capital investments and coverage ratio



Stock and Depreciation of water facilities

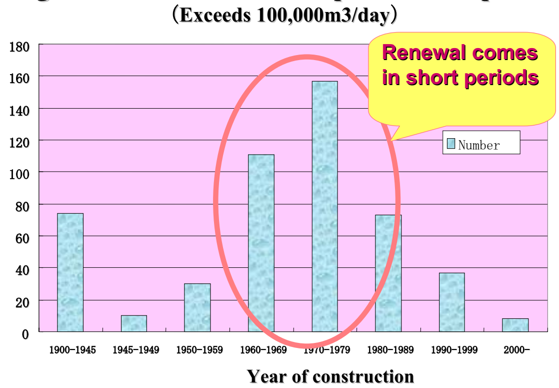


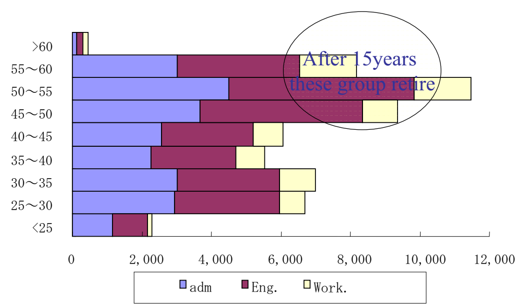
Stock of water services in 2003



Note: reservoir developed by the water resource development agency is not included

Age Distribution of Water purification plants
(Exceeds 100,000m3/day)

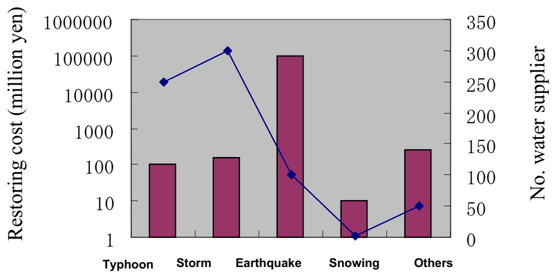




(No. supplier : 1579、Total employ. : 57,609)

Age distribution of employees in water service

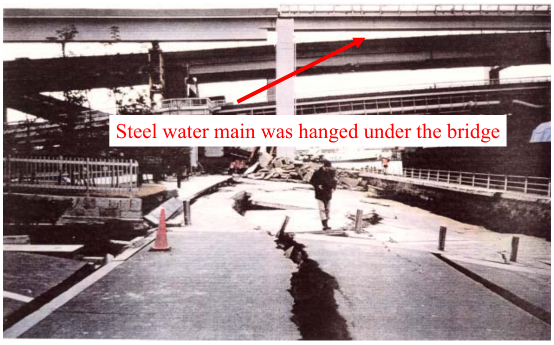
Disaster management (1985~2002)



Great Hansin Earthquake (1995)

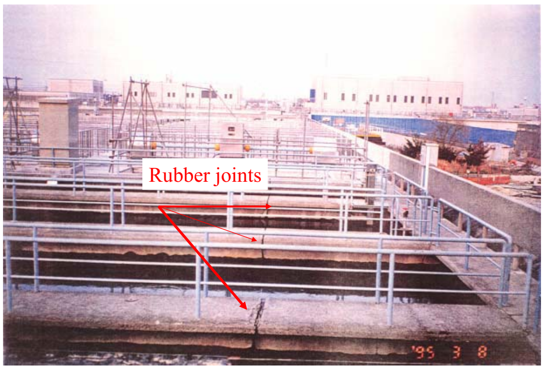
- 5000 death / 2,000,000 habitants
- 891,000 without service of piped water
- 9 weeks to re-supply of piped water to damaged customers
- 60,000 million yen to restore the facilities

Damage of bridges, banks of harbor

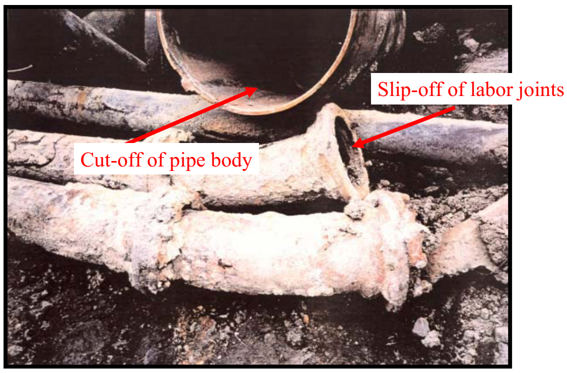


Damage of Bank and Access Road to Raw Water Reservoir

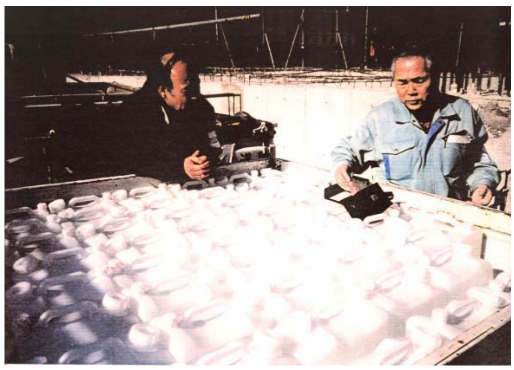
Cut-off of rubber expansion joints of filtration plant



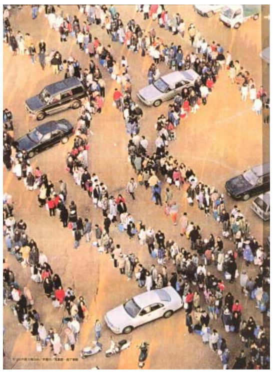
Typical damages of pipes



Check of residual chlorine of water in emergent supply tank



Citizens waiting emergent water supply in school play ground



Several types of water tank

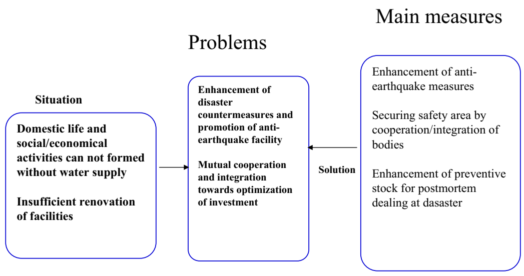
Repairing work of distribution main pipe

Repairing of service pipe

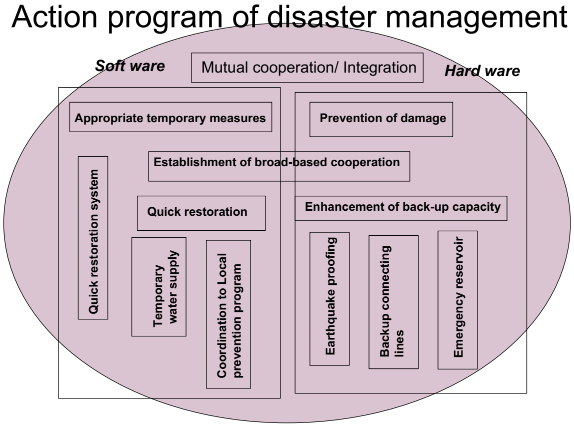
The manual of anti-earthquake measures for water services (1996)

- Design standard of water supply facilities
  - Bench mark for physical strength of each unit facilities
- Guidelines for developing the anti-earthquake plan
- Guidelines for anti-earthquake construction practice

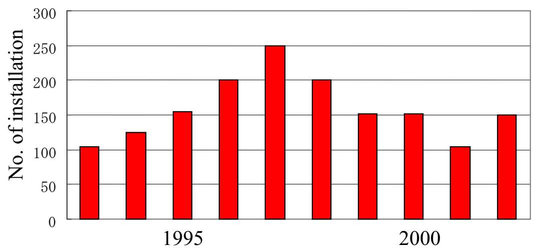
Anti-earthquake management



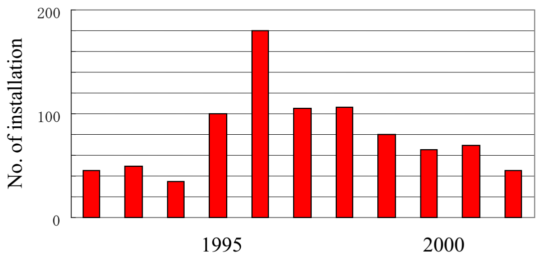
Action program of disaster management



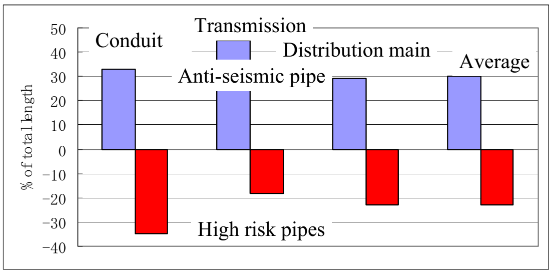
No of Emergency Automatic shut valve Installation



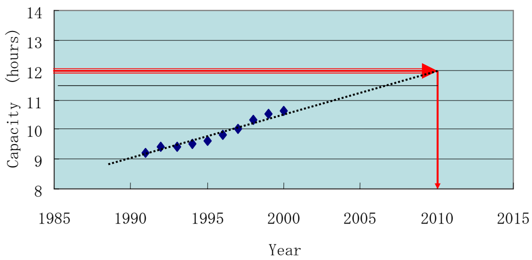
No. of distribution reservoir for emergency purpose



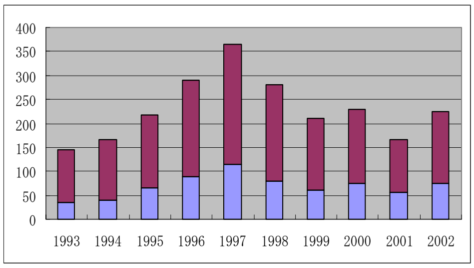
Antiseismic Pipe



Increasing Capacity of distribution reservoir



Installation of emergency automatic shut valve



Case study

- 100,000 habitants
- Water demand 34,600m
- Total length of water mains :287 Km
  - DIP 29.7%, CIP 9.5%, ACP 18.2%,PVCP 32.4%
- A flood plain (common soil condition)
- Seismic intensity :Level 2

Total Seismic Risk

- **Damage of water mains \1222 million**
- **Loss of water sales \57**
- **Cost of emergency water services \440**
- **Loss of consumer's surplus \347**
- **Loss of general production \2900**

- **Total \4966**
- **Return period 70 years**
- **Present worth factor of 18.26 at the discount rate of 5% for the life of the anti-risk measures of 50yeats**

- **The total seismic risk**
- **4966/70 x18.26 = 1295 million yen**

Cost of Anti-risk measures

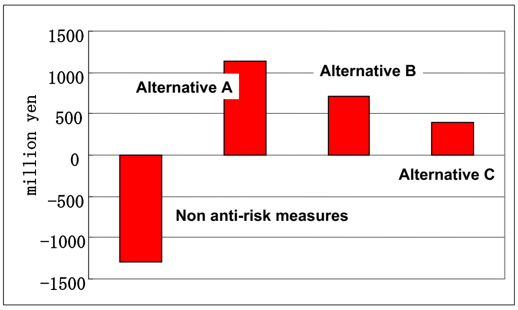
- Alternative A 5551million yen
  - **Replace 20% of DIP , 40% of CIP : 80% of ACP, 80% of PVCP with DIP fitted with non-slip type joints**
- **Alternative B 2776 million yen**
  - **Replace 10% of DIP : 20% of CIP ,40% of ACP, 40% of PVCP with DIP fitted with non-slip type joints**
- **Alternative C 1388 million yen**
  - **Replace 5% of DIP : 10% of CIP ,20% of ACP, 20% of PVCP with DIP fitted with non-slip type joints**

Residual seismic cost

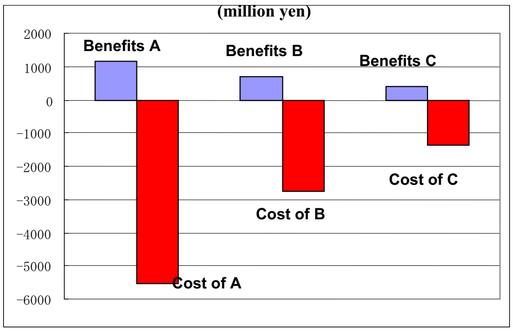
- Residual cost of seismic cost can be calculated by the estimated damage of renovated distribution net –work

- Alternative A 157million yen
- Alternative B 586million yen
- Alternative C 899 million yen

Benefits of the anti-risk measure



Economic benefits of the measures



None of the alternatives will bring large enough benefits to recover their costs

Water quality management in the seismic disaster

- Boil water notice ~ Availability of heat source
  - Summer or winter : Risk of infectious disease transmission
- Residual chlorine monitoring
  - Automatic monitor :Emergency distribution tank
  - Manual field test kits : Emergency water distribution spot

Thank you very much for your kindly attention !