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HOUSEHOLD WATER DEMAND MANAGEMENT MODEL BY USING INPUT-OUTPUT TABLE WITH IMPACTS FROM PRICING POLICY

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***ABSTRACT*:** Household water demand prediction model was developed by using input-output table to calculate effects from declared policy. The next important step is water demand and supply analysis with governmental scenarios and pricing policy to control higher water demand with limited water supply in Lower Chao Phraya River Basin. Developed household water demand management model is a powerful tool for policy makers to make decision which policy is suitable with each evaluation standard such as; 1) maximum net benefit with higher price; 2) maximum user's satisfaction with higher cost from investment and subsidy; and 3) minimize raw water needed to support water demand. By this model, Policy makers can forecast household water demand with effect from changing economic structure and calculate the impacts from declared governmental policy.

KEYWORDS: household water demand prediction model, Input-output table, pricing policy

1. INTRODUCTION

Lower Chao Phraya River Basin (LCPRB) is one of the important areas of development in economic and industrial sector in Thailand. Half of Thai Gross Domestic Product or GDP was produced in this area because LCPRB is the central of economic, education, and political process. Not only high economic activities grow in this area, but number and density of population in this area increase also. An increase in demand from high density and growth rate of population in this area is likely to cause a rise in need of infrastructure especially water in household water use.

From the limitation of water supply and water protected measure such as groundwater pumpage closing policy, water shortage may be the main problem to obstruct development of economic activities in this area and Thailand also. If the policy makers cannot control the rapidly increasing water demand in this area, conflicts among each user in industrial, service, household, and agricultural sector may be the critical problem.

The result of household water demand (SUTTINON, P., 2008) in year 2025 shows that; (1) For case of medium total fertility rate with AIDS effect, migration, and constant water use unit per capita, household water demand will be 1,112 million cubic meter per year. (2) In case of varied water use unit, water demand will increase to 1,769 million cubic meter because of higher unit of water use from better daily life style in urban area. This water has to be supported by governmental agencies with constraints of water supply in this area.

From the difficulty of water supply scheme in recent year, saving water was been considering more than developing new water sources. Water demand management is an appropriate toolbox for improving efficiency and sustainable use of water with considering economic, social and environment

1.1 Objectives

The objectives of this paper are shown as follow; 1) to analyze water demand-supply curve from secondary data of government agencies and questionnaire survey including constraints of each water source in each province; 2) To develop integrated water management model including government option scenarios; with/without leakage reduction system, and case of with/without subsidy from governmental side to select the optimum scenario for policy maker to make decision with water demand management system by using equilibrium analysis, pricing policy, and cost-benefit analysis.

Study area

The study area is located in Lower Chao Phraya River Basin. There are 7 provinces in this area; Ayutthaya, Bangkok, Nakon Pathom, Nontaburi, Pathum Thani, Samut Prakan, and Samut Sakhon. Bangkok is the capital of Thailand and the main water user in this study area.

2. METHODOLOGY

The model mechanism of household water demand management model developed is shown in figure 1. The model was divided into four parts; water demand, water supply, integrated water management model, and Strategic decision making with uncertainly for infrastructure development..

Firstly, household water demand model was developed in Lower Chao Phraya River Basin, Thailand. There are two main part in this model; (1) Population model, and (2) Water use unit model. Population model by age, sex, and 76 provinces was developed by using Cohort-component method.

Secondly, water demand and supply in each source with price, constraint of quantity, and quality were collected by primary data, and secondary data. These data are important to generate water demand-supply curve in the next step.

Thirdly, integrated water management model in case of governmental options was analyzed by using outputs from water demand and supply models. There are 2 main topics for scenarios as follow; (1) with/without leakage reduction system, (2) with/without subsidy from governmental agencies. The net benefits of each scenario can be calculated by using this water demand management model. Policy makers can choose the suitable strategy by each evaluation standard.

Finally, after assessment of possible demand and supply, strategic decision making model was applied to analyze whether and how the new water infrastructure should be invested to support the water demand with uncertainty of water demand in the future. In this paper, step 2 and 3 were concentrated to calculate the suitable choice with constraints in this study area.

2.1 Water demand model

Water demand in each scenario case was forecasted by household water demand developed by SUTTINON, P as shown in figure 2. (SUTTINON, P., 2008)

2.2 Water supply model

Water supply in each source with price, constraint of quantity, and quality were collected by secondary data (annual report and master plan from government agencies), and primary data (questionnaire survey of Kochi University of Technology). These data are important to generate water demand-supply curve in the next step.

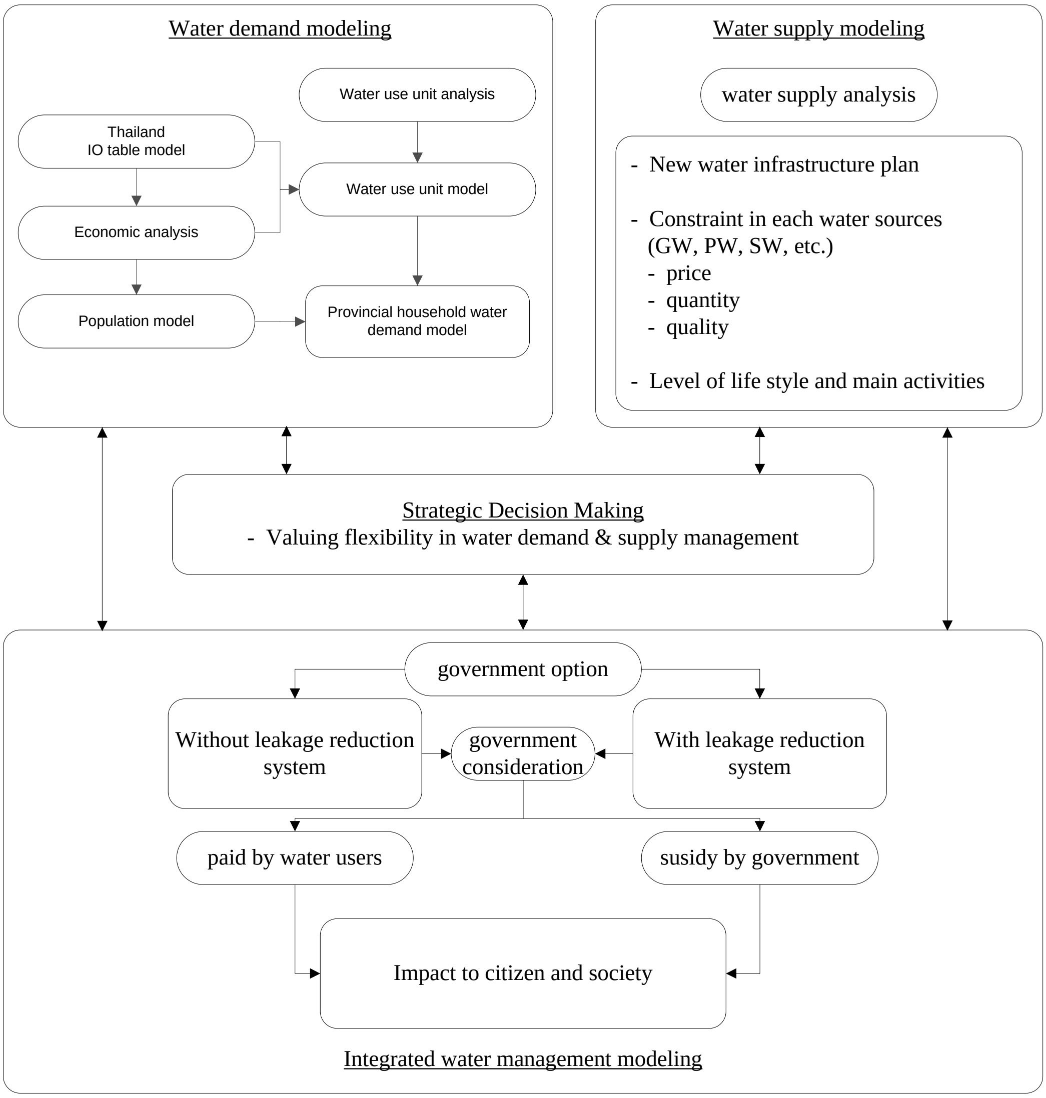
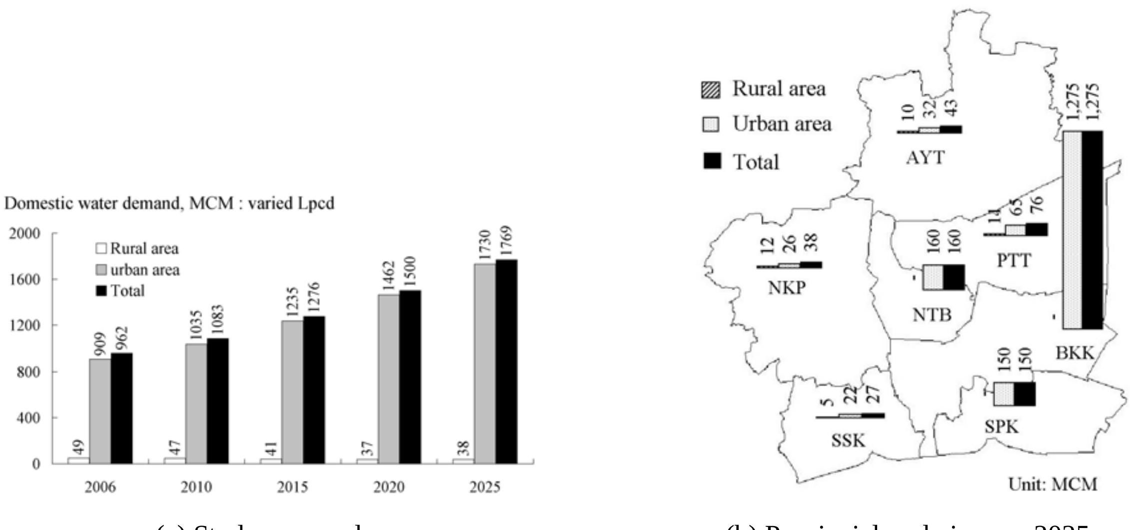


Figure 1. Model mechanism.



(a) Study area scale

(b) Provincial scale in year 2025

Figure 2. Household water demand in case of varied water demand.

Supply curve was analyzed from master plan and report of Waterworks Authority. There are three sources in this area; groundwater (GW), surface water (SW), and pipe water (PW). Groundwater was limited by groundwater law to protect land subsidence. The yield point of GW in this study area is 1.25 Mm^3/d but 0.00 Mm^3/d for raw water produced to household sector. From the problem of quality of water or unsafe water in lower Chao Phraya River, the model was developed under assumption that water source for household in the future is mainly pipe water.

2.3 Integrated water management model

Integrated water management model in case of governmental options was analyzed by using outputs from water demand and supply models. Four scenarios generated in this step were shown in Table 1; (1) 'Inf-NoLeak-NoSub' is case of providing new pipe water (Inf) without leakage reduction system (NoLeak) and without subsidy (NoSub) from governmental agencies, (2) 'NoInf-Leak-NoSub' is case of with leakage reduction system from 30 % to target of 10 % of leakage rate (Leak) and without subsidy, (3) 'NoInf-Leak-Sub' is case of with leakage reduction system and subsidy, and (4) 'NoInf-Leak-Sub*' is as same conditions as case 3 but the objective of case 4 is to find the price of raw water which is bought from Royal Irrigation Department (RID) that leakage reduction system will be effective.

Table 1. Scenarios of governmental options' and pricing policy.

Scenario	1	2	3	4
Inf	With	Without	Without	Without
Leak	Without	With	With	With
Sub	Without	Without	With	With

Note: Inf is new water supply system,

Leak is leakage reduction system, sub is subsidy.

From the groundwater ban law, now, the Metropolitan Waterworks Authority (MWA) has two sources of raw water to produce pipe water. The first is free water from Chao Phraya River with pumping capacity of 5.8 Mm^3/d. The second one is new water with average price 0.30 THB/ m^3 from Mae Klong and Tha Chin River located outside service area of MWA with capacity 1.3 Mm^3/d. With limitation of water supply, water leakage reduction system may be one of the interesting options of water demand side management, however, the unit cost of water with this system is very high if compare with cost of raw water. From that reason, policy maker needs to know what price of paid raw water is suitable to construct water reduction system.

Finally, the net benefits of each scenario can be calculated by using this water demand management model. Policy makers can choose the suitable strategy by each evaluation standard.

3. RESULTS

3.1 Water supply model and integrated household water management model

Figure 3 shows how household water demand and supply curve can simulate with four governmental options' scenarios. The water demand for selected economic and population scenario in 2025 by using water demand model is 1,769 MCM/year or 4.85 Mm^3/d as shown in dash line. Demand curve named D in base year was generated by data from government agencies with analyzed data from questionnaire (SUTTINON, P., 2007). Demand curves in the future were transformed to target demand form model as shown in line named D' and D''. The main assumption of this step is water shortage for household sector is unacceptable. It means that household sector was guaranteed by government to have enough water use.

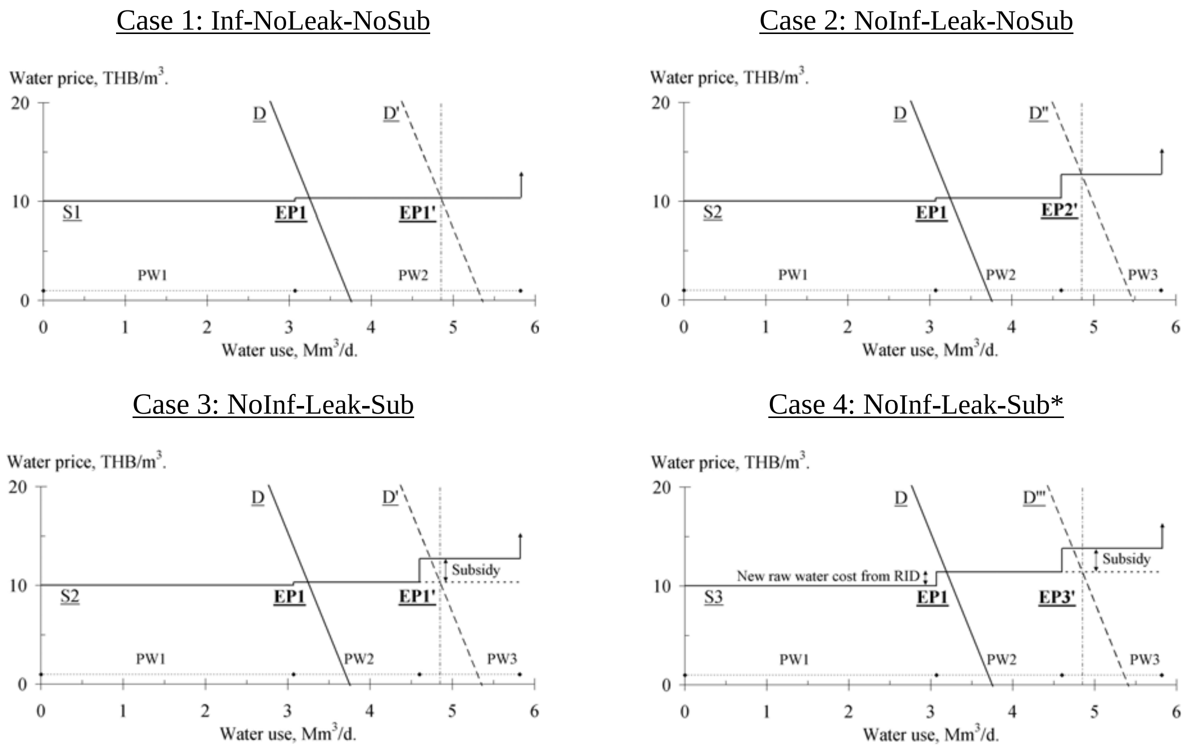


Figure 3. Household water demand and supply curve in each scenario.

Water supply curve in case 1 was generated from constraints of groundwater and pipe water. The upper limit of GW is 0 Mm^3/d for household sector from the groundwater ban law. The second step is PW1 or the pipe water that was produce from Chao Phraya River. The third period is PW2 with higher price from paid raw water to RID for other rivers. The equilibrium points in case 1 is EP1'; demand at 4.85 Mm^3/d with price of 10.33 THB/m^3.

In case 2 or case of with leakage reduction system, supply curve was shifted higher with additional unit construction, operation, and maintenance cost approximately 2.47 THB/m^3 in period PW3. The equilibrium points name EP1 was shifted to EP2' at price of 12.7 THB/m^3 with 4.85 Mm^3/d of demand. It means that users have to pay higher cost for the same amount of water in case 1. The satisfaction of users in this case is lower than case 1 because they pay higher price for the same quantity of water.

In case 3, users actually pay for water at 12.7 THB/m^3 with only 4.73 Mm^3/d of water demand that is lower than needed water in case of without subsidy. It means that users have to reduce water use and comfortable life because of higher price; however, if government side subsidizes higher unit cost from leakage reduction system for user, users can get the same satisfaction as case 1 but can save raw water from leakage reduction system.

Case 4 have same mechanism as case 3 but the price of raw water bought from RID is different. The case 4 was generated to calculate what price of bought raw water that water leakage system should be invested.

Table 2 shows the results of household water demand management model in case of governmental options' scenarios by benefit-cost analysis. The benefit was calculated from four topics; (1) water sale, (2) consumer surplus, (3) producer surplus, and (4) free water of leakage reduction from 30 % to 10 % of leakage rate. Total costs were analyzed from two topics. The first is subsidy cost and the second is unit cost of construction, operation and maintenance.

3.2 Evaluation standard

As same as industrial sector, there is a question for policy makers how to select the suitable governmental options to declare and use. There are many ways to choose the suitable option with constraints in this area. Evaluation standards are the tools for government to make a decision. However, the most important assumption in this household evaluation is that there is no shortage for this sector because water for people is the first priority. It means that basic water infrastructures have to construct to support higher water demand. In this topic, there are 3 evaluation standards used in this study as follow;

1. To maximize net benefit:

This standard is concentrated to choose the governmental option that produce maximum net benefit or maximum of (benefit – cost). Table 5.9 shows that maximum net benefit is case 1 and 4 with total benefit of 290.90*10^6 THB/d. In case 1, it means that policy maker should construct only the water supply system without leakage reduction system and subsidy. The reason is that unit water price of leakage system is more highly expensive than unit price bought from RID. The advantage of this case is the citizen can use more water as they need with the cheap price; however, the disadvantage is the difficulty of finding new raw water sources.

2. To maximize user's satisfaction:

From the previous standard, it is possible that the maximum benefit's choice in case 4 will have a problem of user's dissatisfaction.

Table 2 Cost-benefits analysis, impacts from governmental options' scenarios and pricing policy.

	Unit	Case 1. Inf-NoLeak -Nosub	Case 2. NoInf-Leak -Nosub	Case 3. NoInf-Leak -Sub	Case 4. NoInf-Leak -Sub *
Water use	Mm^3/d	4.85	4.85	4.85	4.85
Price at equilibrium point	THB/m^3	10.33	12.70	12.70	14.10
Price paid by user	THB/m^3	10.33	12.70	10.33	10.33
Leakage reduction system		Without	With	With	With
Subsidy		Without	Without	With	With
Benefit					
- Water sale	10^6 THB/d	49.18	49.77	49.18	49.40
- Consumer surplus	10^6 THB/d	240.80	229.44	240.80	238.02
- Producer surplus	10^6 THB/d	0.92	11.82	0.92	4.32
- Free water from leakage	10^6 THB/d	0.00	0.04	0.08	0.35
Total benefit	10^6 THB/d	290.90	291.08	290.98	292.09
Cost					
- Construction cost	10^6 THB/d	0.00	0.32	0.59	0.59
- Subsidy cost	10^6 THB/d	0.00	0.00	0.59	0.59
Total cost	10^6 THB/d	0.00	0.32	1.19	1.19
Net benefit	10^6 THB/d	290.90	290.76	289.79	290.90

Note: 1. * for case 4, the net benefit will equal to case 1 if the price of raw water bought form RID is higher than 1.41 THB/m^3

2. 36.3 Thai Baht (THB) = 1 U.S. Dollar (USD) at Dec 22, 2006.

This standard will concentrate in maximizing user's satisfaction. Case 1 and 3 are the suitable choices for this standard with maximum net benefit. The reason that leakage reduction system is not effective is because the unit cost of raw water is very cheap approximately 0.30 THB/m^3 (average cost of raw water in all rivers) compared with unit cost of leakage reduction system at 2.37 THB/cu.m.

3. To minimize raw water needed to support water demand:

By this standard, case 3 and 4 is suitable choice. Needed raw water in case 3 and 4 is only 4.6 Mm^3/d to produce pipe water or can save raw water more than case 1 approximately 0.25 Mm^3/d, however, the maximum spared capacity is 1.22 Mm^3/d.

As can be seem in Table 2, in the viewpoint of central government, if the evaluation standard is maximum net benefit, case 1 and 4 are the suitable because of the highest net benefit. However, the consumer surplus or user's satisfaction in case 4 is lower than case 3's benefit. It means that if user can choose, case 4 is the second choice. It may be affected to society's problem. Policy makers should carefully make a decision with this option under suitable evaluation standard. The net benefit in case 4 is as same as case1 with the raw water price bought from RID at 1.41 THB/m^3 or 4.7 times of price in present. It means that leakage reduction system should be effective with this unit raw water cost.

4. CONCLUSION

Proposed household water demand management model can predict household water demand by using population model from Cohort-component model and water use unit from analyzed data from questionnaire survey of Kochi University of Technology in 2006. Three case of total fertility rate (high. Medium, and low), two cases of deaths (with and without effects from AIDS), and migration from changing economic structure from Input-output table were applied in this model. Water use unit in the future was analyzed from questionnaire survey and impacts from changing economic structure from Input-output table. Water supply was simulated with constraints of new supply systems and constraint of price and quantity in each water source. The governmental option and impacts from declared policy were calculated by using cost-benefit analysis with data of analyzed water demand and supply. The suitable government option is considered with evaluation standard.

5. RECOMMENDATION

The next interesting topic is whether water infrastructure should be invested under uncertainty of household water demand growth rate in the future. Policy makers have to make a decision to construct for the water demand in the next 20 years. If the water demand growth is low in the future, policy maker should stop water supply project and monitor the water trend in the future. In this case, the risk of loss of construction, operation, and maintenance cost was strongly considered. However, if high water demand will occur, the new water infrastructure should be constructed to support higher water demand. In this case, the risk of loss of damage from water shortage will be mainly considered.

The second topic is how to simulate agricultural sector into the model and how these activities change by declared policy. How to manage the water share of each user and activity with the changing economics structure from declared policy?

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