Household Water Demand Prediction Model with Changing Economic Effects by Using Input-Output Table Model

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Abstract

In this paper, 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. There are three scenarios in birth calculation; high, medium, and low. Cases of with and without effects from AIDS were applied to death calculation. Migration was calculated from impacts of changing economic structure from Input-Output (IO) table model and society effects. Water use unit analysis is calculated by two scenario; (1) Constant water use unit calculated by questionnaire, interview and field survey, (2) Water use unit varying with impacts from changing economic structure by declared Thai governmental strategy. The result 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.

Keyword: Household water demand, Cohort-component methods, Input-output table

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 sector of industrial water demand model (SUTTINON, P., 2008), not only industrial activities changed from declared government strategy, but at the same time household water demand got impacts from this policy also, such as, changed daily life style with higher income from higher GDP per capita, migration from the other provinces to have better job opportunity, and etc. Waterworks authority generally calculates household water demand without economic impacts from other sectors, such as, industrial side. This proposed model can forecast household water demand by using population model with varied water use unit per capita in the future.

The objectives of this paper are shown as follow;

1. To develop population model in details of sex, year, and provinces with scenarios of birth and death by using Cohort-component method and migration model with impacts from changing economic structure from Input-output table model.
2. To develop water use unit model in base case or constant rate in the future and varying unit rate from changing daily lifestyle from higher GDP.

Methodology

The model mechanism of household water demand management model 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. (SUTTINON, P., 2006, 2007).

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.

However, only step one was concentrated in this paper.

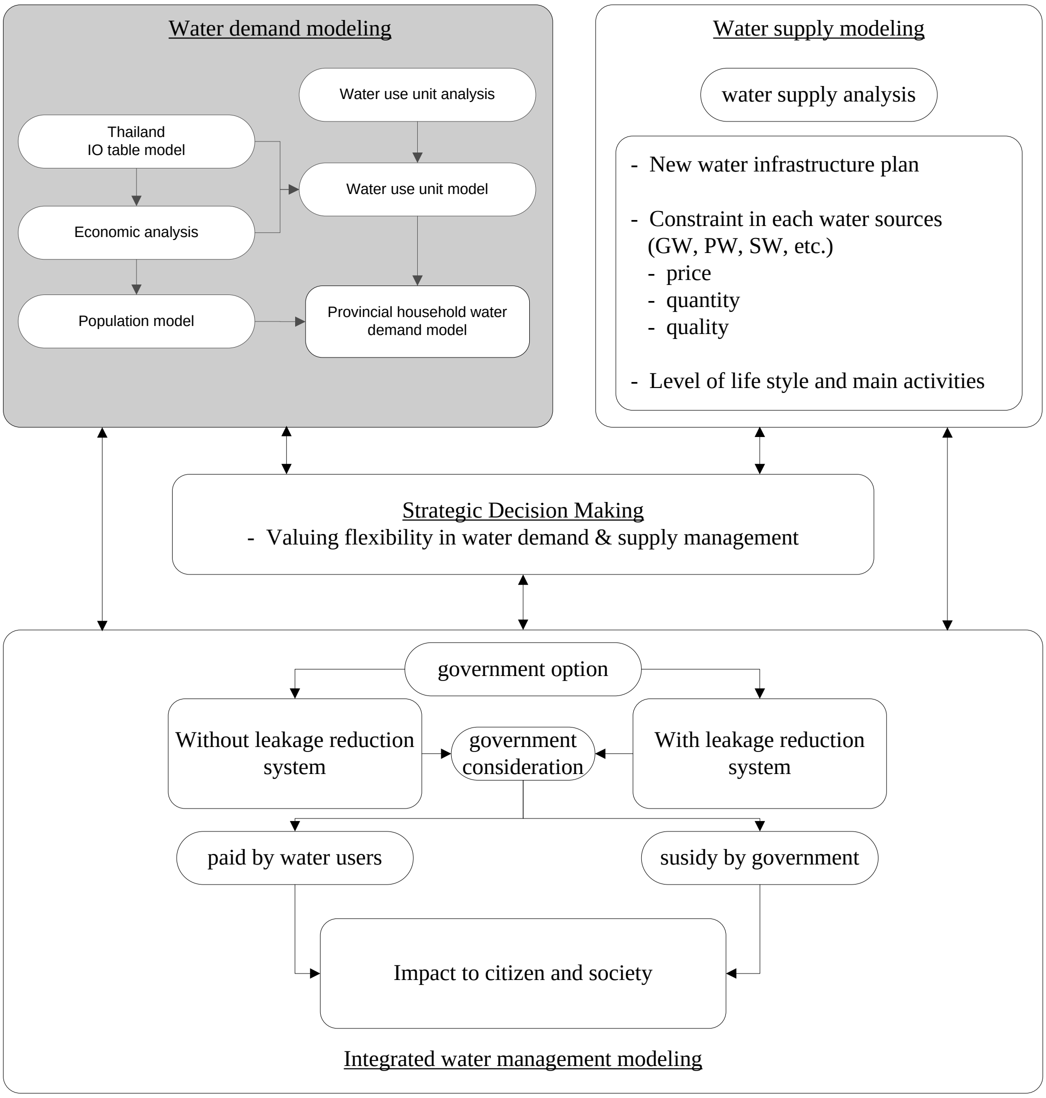


Figure 1. Model mechanism.

Population model

Firstly, Population model was developed by using Cohort-component method. The cohort-component method is based on the traditional demographic accounting system. With a base population in a starting year, new births are added to the updated population, new death are subtracted to generate a new cohort in next year. Not only birth and death are calculated, but migrations in international and domestic scales are also measured.

Each component of changed population is separately analyzed by age, sex, and each province as follows:

$$P_t = P_0 + B - D + M \qquad (1)$$

Where, P_t is population at the end of the calculated period; P_0 is population at the starting of period; B is new births; D is new deaths during period; and M is migration including international and domestic. In this analysis, international migration was assumed to zero because of small ratio comparing with provincial scale.

Base population data was collected in full demographic detail; age (0,1,2,…,100 and over), sex (male-female), net migration (people in and out) and 76 provinces from Department of Provincial Administration of Thailand or DOPA, Cohort-component was measured in provincial scale. New birth rate was calculated by using data of Age-Specific Fertility Rate (ASFR) in Table 1 and Total Fertility Rate (TFR) in Table 2 from government agencies.

Table 1. Age-Specific Fertility Rate (ASFR) in 2005

	ASFR							TFR
	15-19	20-24	25-29	30-34	35-39	40-44	45-49	
2005	0.06429	0.10680	0.09797	0.05903	0.02409	0.00598	0.00108	1.79620

(Source: DOPA.& NESDB.)

The birth scenarios are 3 scenarios; high, medium, and low TFR. Next, deaths are analyzed in scenarios of with and without effect from AIDS in form of life expectancy in each age as shown in Table 3. Finally, net migration was calculated by using regression analysis as following parameter; 1) population growth rate, 2) population density, 3) gross provincial domestic (GPP), 4) GPP per capita, 5) income per capita, and 6) expenditure per capita. Changing economic structure in the future was calculated from IO table model with selected scenarios of declared governmental strategy.

Table 2. Total fertility rate (TFR) in each area

	Total	Bangkok	Vicinity	Central	East	West	North	Northeast	South
1990	2.2800	1.3000	1.5900	1.9730	2.0000	2.0400	1.9800	2.7800	2.8500
2000	1.8223	1.1700	1.2300	1.6400	1.6300	1.6900	1.7600	2.1500	2.2500
2025									
High	2.0500	1.3162	1.3837	1.8449	1.8337	1.9012	1.9799	2.4186	2.5311
Med	1.7000	1.0915	1.1475	1.5299	1.5206	1.5766	1.6419	2.0057	2.0990
Low	1.3000	0.8347	0.8775	1.1700	1.1628	1.2056	1.2556	1.5338	1.6051

(Source: DOPA.& NESDB.)

Table 3. Life expectancy in each age.

Age	2006				2025			
	With AIDS		Without AIDS		With AIDS		Without AIDS	
	Male	Female	Male	Female	Male	Female	Male	Female
0	0.9675	0.9772	0.9705	0.9862	0.9917	0.9904	0.9922	0.9932
10	0.9959	0.9983	0.9964	0.9986	0.9976	0.9984	0.9978	0.9989
20	0.9924	0.9931	0.9930	0.9973	0.9942	0.9971	0.9948	0.9980
30	0.9829	0.9866	0.9912	0.9952	0.9918	0.9936	0.9939	0.9967
40	0.9662	0.9854	0.9812	0.9888	0.9838	0.9871	0.9863	0.9923
50	0.9455	0.9699	0.9509	0.9733	0.9620	0.9778	0.9641	0.9817
60	0.8783	0.9240	0.8801	0.9321	0.9120	0.9475	0.9127	0.9551
70	0.7150	0.7800	0.7158	0.8002	0.7752	0.8409	0.7755	0.8609
80+	0.3576	0.4030	0.3580	0.4227	0.4194	0.4637	0.4196	0.4837

(Source: DOPA.& NESDB.)

In this paper, household water demand was divided into 2 parts; urban area and rural area. The definition of each area in this research is shown as follow;

(1) Urban area is the area inside responsibility area of municipality,

(2) Rural area is the area outside responsibility area.

By the Act of Municipal shown in box 1, municipality or urban area in this area have to provide safe water or pipe water to support the citizen in service area. From this reason, it is recommend that people in urban area has enough water from governmental supply system.

Box 1. The Act of Municipal.

By the Act of Municipal 1953 and 1999 (No. 10), municipal area was divided into 3 types as follow;

(1) Section 9: District municipality ("Tedsaban Tumbon" in Thai language) is the area declared by Ministry of Interior.
(2) Section 10: Town municipality ("Tedsaban Muang" in Thai language) is the area with population more than 10,000 persons and basic needed infrastructures declared by the Act.
(3) Section 11: City municipality ("Tedsaban Nakhon" in Thai language) is the area with population more than 50,000 persons.

Section 51 of the Act of Municipal declared that municipality has to provide safe water or pipe water to support the citizen in the municipal area.

Water use unit analysis

Water use unit analysis is the main activities in the first step of water demand management model. For household sector, water use per capita per day was analyzed from each activity in daily life of citizen in this study area.

Firstly, number of questionnaire sample was designed by statistical analysis with 95 percentage significant level. 400 samples of household questionnaire were needed to analyze. However, sending questionnaires were 2,000 samples because of 20 percentages of response rates. The number of sample in each province was weighted again with number and density of population in 7 provinces. Figure 2 shows the map of study area and scatter of questionnaire survey in household survey. Bangkok is the main target of this survey because high density of population.

Household questionnaire survey used in this research was developed to analyze water use in urban area. For water use unit in rural area, the constant rate of water use is 50 liter per capita per day defined by Rural Development Information Center of Community Development Department (CDD, 2007).

Household questionnaire survey

There are 3 main topics in this household survey. The questions are as same topic as industrial sector but details are different. The first topic is water use and source. Monthly water use in average and maximum rate, water price, initial cost for investment, problem, and solution are collected in this topic. Water sources consist of tap water, groundwater, and surface water (pond, river, irrigation canal or natural canal).

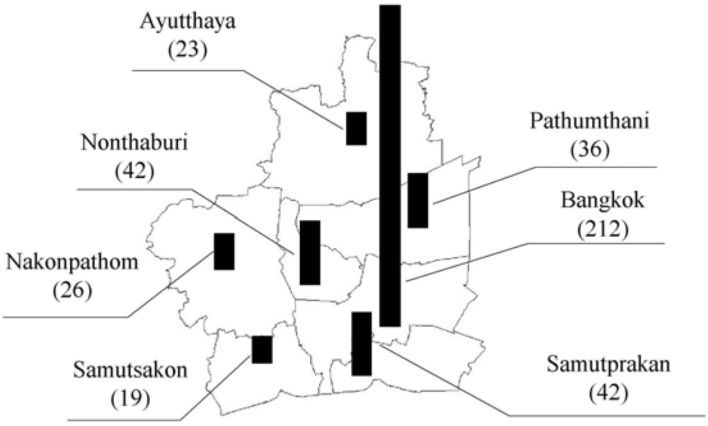


Figure 2. Scatter of household questionnaire samples.

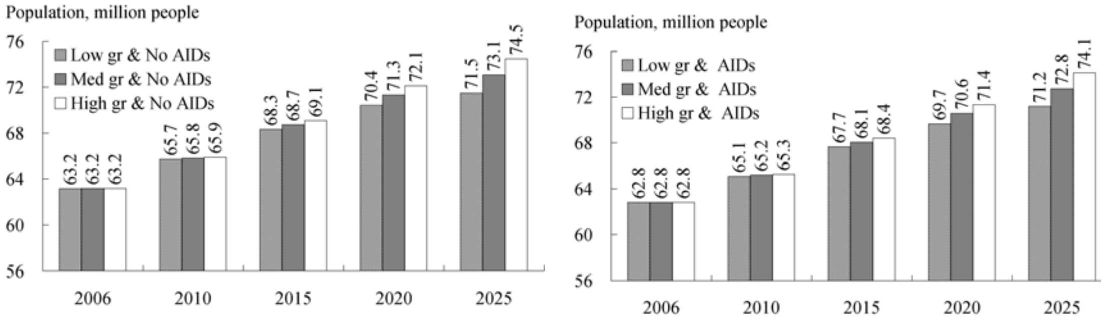
In the second part, water use in each activity is collected, for example, the water use, duration, and facility in bathroom, toilet, laundry, cleaning, garden, and kitchen. The third part is concentrated in changing water source from the past, water use situation, reason to choose pipe water, changing water use with suitable price, and water saving policy.

Results

Population model

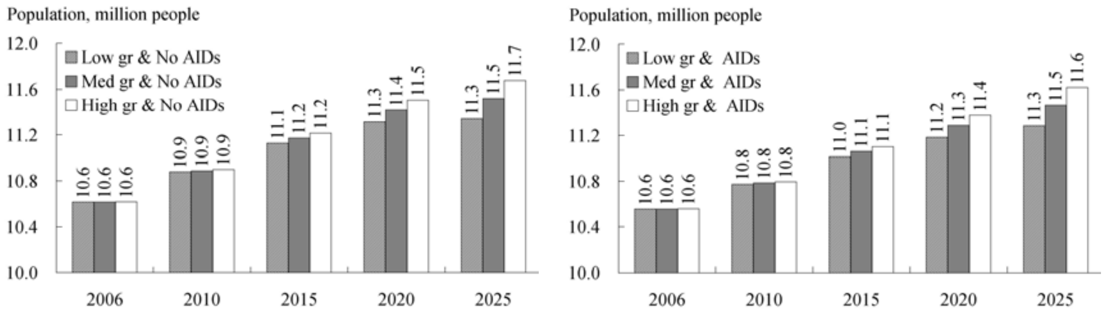
Figure 3 shows results from population model in case of Thailand scale. Three scenarios of birth, two scenarios of death, and migration are applied in this model. In case of medium total fertility rate (FTR) and life expectancy with effect from AIDS, there are 72.8 million people in 2025 or 0.78% of population growth rate per year. In case of with and without effect from AIDS with medium FTR, the difference is approximately 330,000 people.

The results in study area as shown in figure 4 are as same trend as Thailand scale but the average population growth rate without effect of migration is lower than that case. This low average rate is resulted from the low FTR in Bangkok and Vicinities. In 2025, FTR of Bangkok and vicinities are only 1.0915 and 1.1475 but the average rate of Thailand is 1.7000.



(a) Birth scenarios without AIDs (b) Birth scenarios with AIDs

Figure 3. Number of population forecasted from Thailand population model.

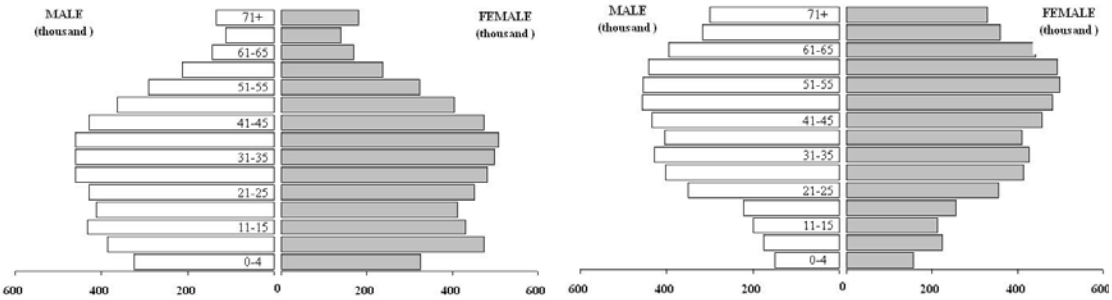


(a) Birth scenarios without AIDs (b) Birth scenarios with AIDs

Figure 4. Number of population forecasted from provincial population model.

The average population growth rate without effect of migration in urban and rural area can be compared in case inside and outside study area. That growth rate of urban area including Bangkok and vicinities is approximately 0.434 % that is half of case of outside study area. The reason is different daily life style of urban and rural area. The population per family in big city is gradually decreasing from the past. People need less children, only 1 or 2 persons is suitable in urban daily life style.

Population structure by age and sex in study area was shown in Figure 5. It shows that high percentage of number of population in age of 26-50 years will move to the upper part or these people will get older but the new generation was born in the lower rate because people will have small family or 1-2 children per household. The Total Fertility Rate or TFR in big city such as Bangkok is only 0.83. This rate in Bangkok is less than the average TFR of Thailand with 1.30. The other reason is that life expectancy of old people is higher because of taking care of life and better medical care.



(a.) 2006 (b.) 2025

Figure 5. Population structure by age and sex in study area.

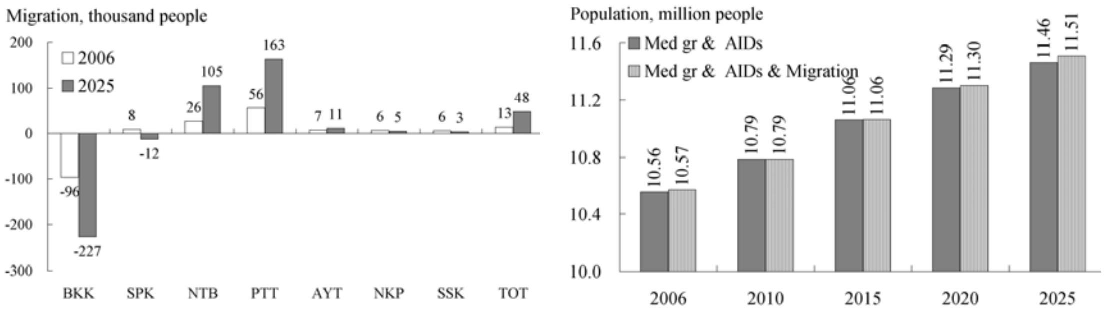
Migration model

Migration model was developed in provincial scale with dimension of time series or matrix of 76 X 20 (provinces X years) in forecasting step. Input data was colleted in period of 2000 to 2004 because of incomplete data in some parameter. The migration model was developed by using techniques of time series and cross section pooling. The method is pooled least square in case of fixed effect with no weighting by White Heteroskedasticity-Consistent Standard Errors & Covariance. The equation of migration model was shown in equation 2.

Migra(prov,year) = C1*[Pop_gr(prov,year)]
+ C2*[Pop_density(prov,year)]
+ C3(prov)*[GPP(prov,year)]
+ C4(prov)*[GPP_per_capita(prov,year)]
+ C5(prov)*[Income/Expenditure_per_capita(prov,year)]………(2)

Where, Migra(prov,year) is number of net migration (move in – move out) in each province and year; C1,C3(prov) are constant and constant in each province; Pop_gr is population growth in each province and year, %; Pop_density is population density in each province and year, people per sq.km.; GPP is Gross Provincial Product at market price, million Thai Baht; GPP_per_capita is Gross Provincial Product per capita, Thai Baht per person; Income_per_capita is income per capita, Thai Baht per person; Expenditure_per_capita is Expenditure per capita, Thai Baht per person.

Figure 6 shows migration in study area. Net migration of BKK and SPK is negative in year 2025. It means that move out is more than move in because of high density of population, high expenditure from becoming big city with higher GPP. The direction of migration moves to the upper part of Bangkok (BKK) to Nonthaburi (NTB) and Pathum Thani (PTT) that have good public transportation and not far from BKK. The sensitivity analysis of migration model was analyzed. The main parameters are GPP and GPP per capita with high percentage of change from changed variables.



(a) Migration (b) No of population with migration

Figure 6. Number of net migration forecasted from provincial population model

Population in Urban and Rural area

Final step of population model is to define population in urban and rural area as shown in figure 7. Expansion of urban area was analyzed from the trend in the past from Department of Provincial Administration with the water master plan of Waterworks Authority.

Water use unit analysis

Household water use unit was calculated from questionnaire survey of Kochi University of Technology (SUTTINON, P., 2007). Main domestic water source in this area is pipe water or tap water about 83 % in 2006. This high percentage of pipe water is managed by 2 government agencies; Metropolitan Waterworks Authority (MWA) and Provincial Waterworks Authority (PWA). The service areas of MWA showed in black area of the map in Figure 8 are only 3 provinces; 1 Bangkok (BKK), 2 Samut Prakan (SPK), and 3 Nonthaburi (NTB), however, MWA take responsibility in 81.4 % of water use in study area. Ayutthaya (AYT), Pathum Thani (PTT), Nakhon Pathom (NKP), and Samut Sakhon (SSK) are service areas of PWA as the white areas.

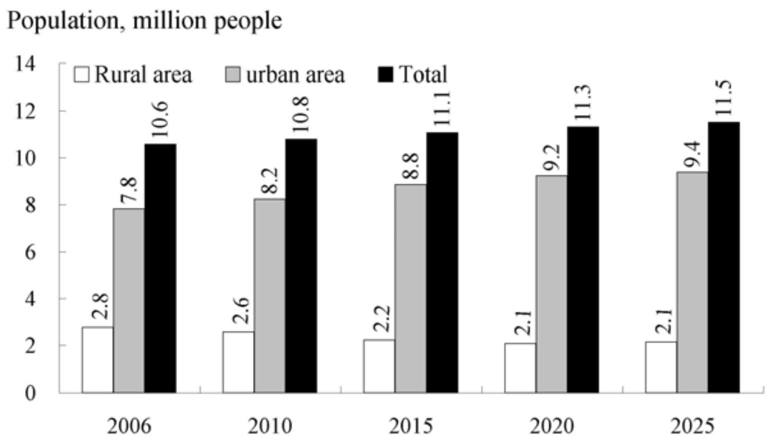


Figure 7. Number of population in rural and urban area

(a) Water source (b) Service area (c) Water use by agency

Figure 8. Household water source and use by process.

Figure 9 shows household water use unit in urban area and GPP per capita in service sector. The water use unit in Bangkok and vicinities located in service area of MWA is higher than other areas because of higher water using activities from higher daily life style.

Varied water use unit model was developed in provincial scale with dimension of time series or matrix of 7 X 20 (provinces X years) in forecasting step. Input data was colleted in period of 2000 to 2004 because of incomplete data in some parameter as same as migration model. The water use unit model was developed by using techniques of time series and cross section pooling. The method is pooled least square in case of fixed effect with no weighting by White Heteroskedasticity-Consistent Standard Errors & Covariance. The equation of model was shown in equation 3.

$$LPCD(prov,year) = C1*[PW\_pr(prov,year)] + C2(prov)*[GPP\_per\_capita(prov,year)] + C3(prov)*[Income\_per\_capita(prov,year)] \quad (3)$$

Where, LPCD(prov,year) is household water use unit in each province and year, liter per capita per day or lpcd; C1,C2(prov) are constant in each province; PW_pr is price of pipe water, Thai Baht per cubic meter; GPP_per_capita is Gross Provincial Product per capita, Thai Baht per person; Income_per_capita is income per capita, Thai Baht per person.

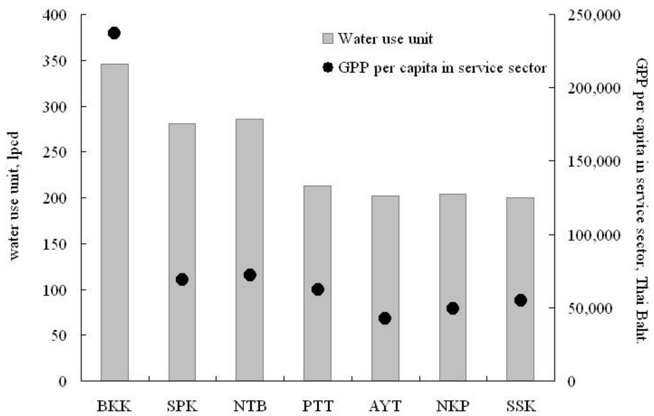


Figure 9. Household water use unit in urban area and GPP per capita in service sector in 2006.

Figure 10 shows water use unit and household water demand by provinces in 2025. In case of varied water use unit, provincial water unit totally increased from the base year. The citizen in Bangkok needs the highest water unit because of luxury daily life style in big city. At the same time, Bangkok is the highest household water consumer because of a lot of population lived in this area and high water use unit. The main parameter analyzed by sensitivity analysis of LPCD model is the price of pipe water with high percentage of change from changed variables.

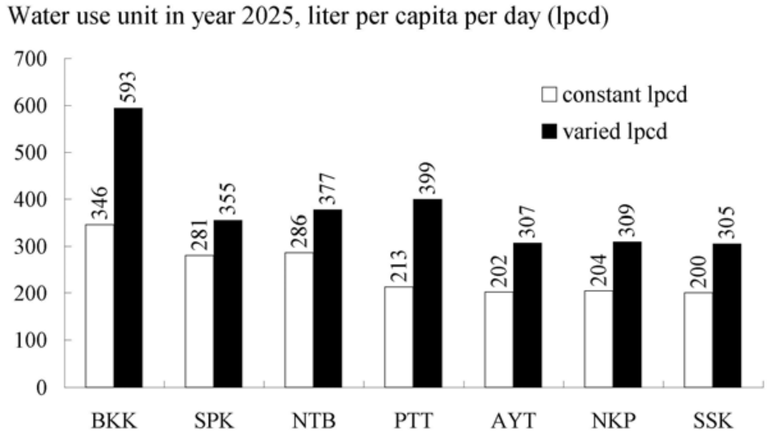


Figure 10. Constant and varied water use unit by provinces in 2025

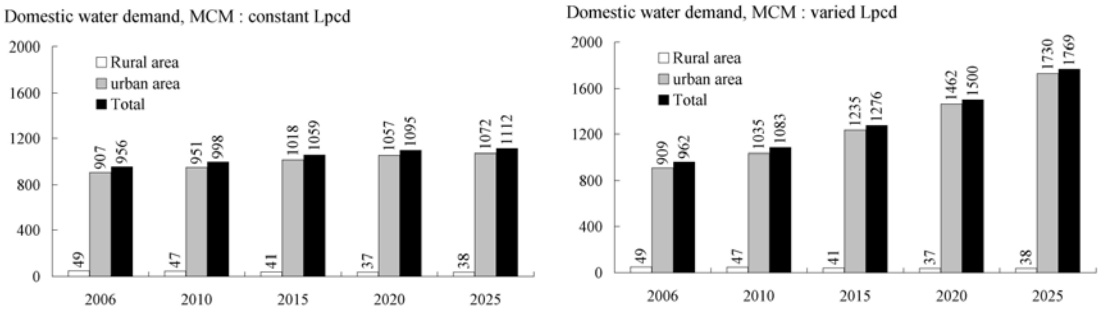
Household water demand

Figure 11 and 12 show household water demand of study area in case of constant and varied water use unit from impacts of changing economic activities from Input-output table model. In case of constant water unit, needed household water demand in 2025 will be 1,112 million cubic meter per year (MCM). The urban area consumes water more than 90% of total use. Case of varied water unit from changing economic activities needs water approximately 1,769 (MCM) that is sharply increased in urban area because higher water use unit per capita per day or lpcd as shown in case of Bangkok in figure 10.

Conclusion & recommendations

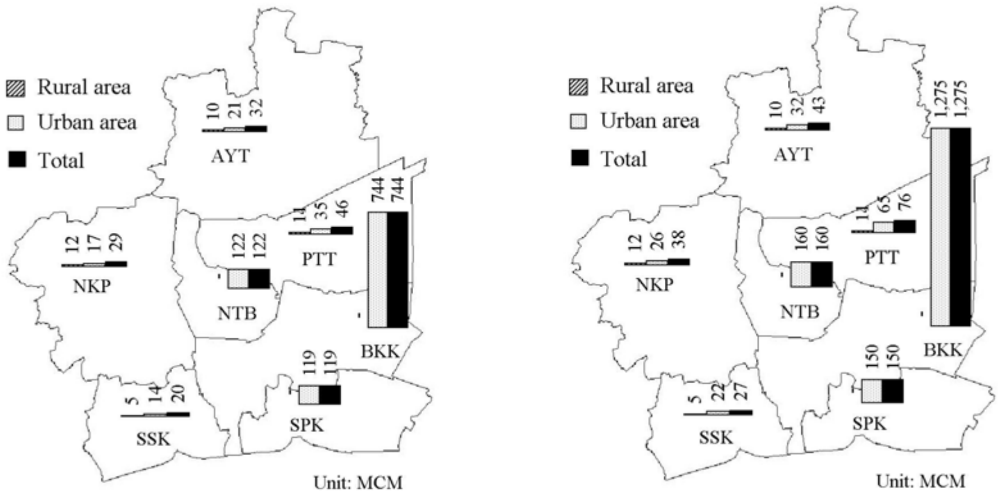
Household water demand model was developed by using population model including birth and death scenarios with migration effected from changing economic activities and water use unit model with scenarios of constant and varied water unit from impacts of changed daily life style. Changing economic activities from declared governmental strategy were analyzed by using Input-output table. Based on the result, it is almost certain that household water demand seems to increase in the future because of higher populations and water use unit. The related government agencies have to manage this huge water demand with limited water supply.

The next interesting topics of research are how water demand and supply are managed together under condition of pricing policy and whether water infrastructure should be invested under uncertainly in the future as follow.



(a) Constant water use unit (b) Varied water use unit

Figure 11. Household water demand in study area.



(a) Constant water use unit (b) Varied water use unit

Figure 12. Household water demand in each province in year 2025.

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.
3. To develop strategic decision making system for uncertainly (high, medium, and low water demand growth) of infrastructure investment (to construct all infrastructure in the starting point, step by step, or do nothing) in the future.

4. To develop integrated water demand management model with industrial and agricultural including water and benefit sharing under conditions of more water demand with limited water supply.

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