Web-Based Decision Making Support System for Integrated Urban Water Management

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1. INTRODUCTION

In this research we suggested a conceptual system for integrated urban water management, named Decision Making Meeting for Integrated Urban Water Management (DMM-IUWM). In this conceptual framework, we applied web-conferencing technology to improve participation of stakeholders in decision-making of urban water policy, which include decision maker and public. A web-conferencing software named “TeamViewer” and Decision-Making support software developed upon “NetLogo” are integrated to achieve a visibility and easy communication meeting environment.

Water is one of the key resources to restrict urban development. Water demand in many cities already exceeds the amount of water resource, which can supply sustainably. Because of the rapid urbanization and economic growth, this problem is especially serious in developing countries (Vairavamoorthy, et al, 2008). Based on Zhang, et al (2010)’s research on the human carrying capacity of Beijing city, the population of Beijing is 2 times what the water resources can supply sustainably. And for cities that lack in water resources, the development of city is greatly restricted by water resources (Gober, et al, 2011). The unsustainable utilization of water resources also leads serious ecological problems, such as ground subsidence, salinity intrusion, and ecosystem deterioration (Jiang, 2009). The integrated urban water management is becoming more and more important for achieving sustainable development, especially for developing countries.

There are two aspects in integrated urban water management: water resource management and water demand management. Existing research on water resource management showed attempt of scholars and government to achieve sustainable water resource management. Zhang, et al (2010) and Stoeglehner, et al (2011) applied ecological carrying capacity of water resource on Beijing city and South-East Queensland region in Australia to assess the water supply sustainability of study area. Government of China (2005; 2010) applied a national project named “South-North Water Transfer Line” to adjust the spatial unbalance of water resource. Stoeglehner, et al (2011) also suggested divide the water supply quality for different water quality require for each water consumption units. There is also attempt through method of laws and regulations on water resource management, such as Chinese government (2005; 2010) cleared water rights allocation already trough 2 times of Five-Year plan; and Gober, et al (2011) developed “WaterSim” model to clarify the impact of policy choice. With the increasing difficulties for developing new sources or expanding existing one, water demand management became research focus to achieve sustainable water management. Kolokytha, et al (2002) summarized that “economic incentives, water pricing policies, public participation and awareness, as well as education and information strategies is powerful Water Demand Management tools”. Xia, et al (2011) argued that the essential of water demand management is changing the public conceptual of water resource from “Public good” to “Financial product”.

These research and projects showed the possible approach to achieve sustainable utilization on water resource. Meanwhile, we can found decision-making on these approaches also connected with more than one of the departments with different knowledge background and geographical position. Gober (2013) also argued that decision making on water resource require participation from a very wide range of water stakeholders-from farmers, industries, and municipal water providers and customers to environmental groups and linked land and energy sectors. Meanwhile, in “South-North Water Transfer Line” the water supply side and consumption side has more than 1000km of distance. The conferencing technology is a possible solution to break such geographical distance.

The rest of this paper is organized as follows. First, we proposed the conceptual decision making process in Section 2. Then we explained the whole framework of DMM-IUWM in Section 3, and with the following separated explanation of the platform include in the system. We also designed a student experiment to testify the system and analyzed the result in Section 4. Finally, we conclude with a summary and future research in Section 5.

2. DECISION-MAKING PROCESS

Decision-making process for DMM-IUWM is simulating typical decision-making process of integrated water resource management, which shown at Fig.1

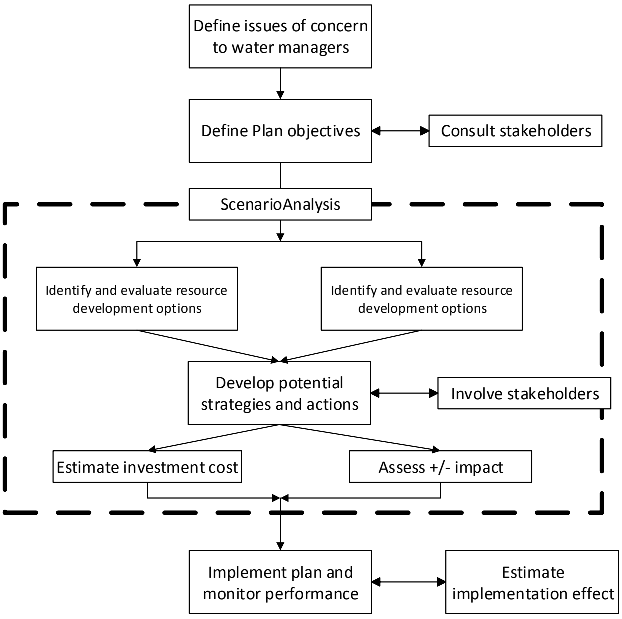


Figure 1. Decision making process

The basic structure of the decision making process is introduced by water resource demand management assistance project (WRDMAP), which aimed to support stronger water policy development and governance through the introduction of integrated water resources management (IWRM) approaches. In WRDMAP, stakeholders' participation is highly appraised for integrated water resource management, and introduced a principle for achieve the participatory decision making process in IWRM. The decision process showed in Fig.1 is the optimized process from the concept introduced by WRDMAP.

3. SYSTEM FRAMEWORK

DMM-IUWM combined NetLogo platform and TeamViewer software to achieve visibility and easy communication meeting environment. A virtual city is simulated in NetLogo, and TeamViwer software provide visible, easy communicating decision-making environment for IUWM. The overlooking of system structure is shown at Fig.2.

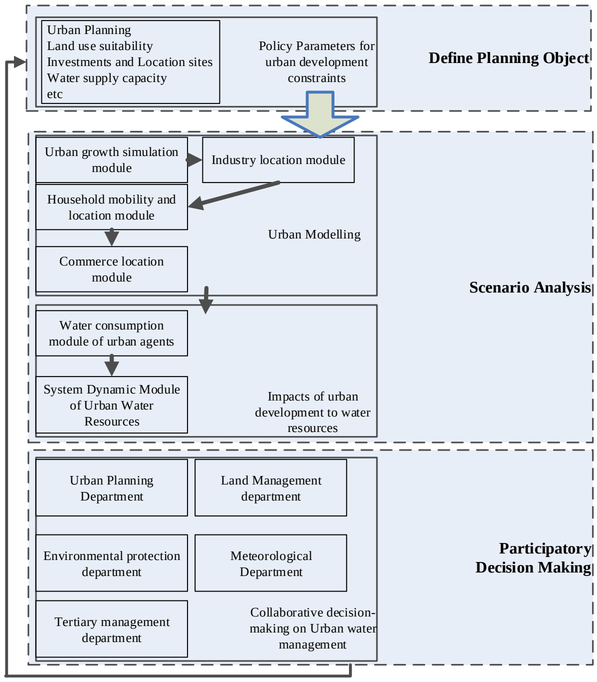


Figure 2. System Framework

3.1 Simulation of Urban Growth

For the decision process introduced in Fig. 1, a simulation of urban area is needed. Because in this paper we discuss about the conceptual of the DMM-IUWM, we only simulated a typical job-oriented Virtual City area to testify the system functions.

In this virtual city, we assume the driving power of urban development is job. The land use development of the virtual city is based on Cellular Automata theory. For initial stage, this city has one downtown area, and with simulation progress, each parcel (represent urban area) will calculate the develop potential by the correlation of river, road, slope, agriculture, plan, distance to downtown, and neighborhood effect, if the develop potential is bigger than threshold, this parcel will decide to be developed. If one parcel has decided to be developed, then it will calculate the potentials to be developed to 4 kinds of land-use type, which is industrial land-use, commercial land-use, and residential land-use. If the biggest one of the potential is higher than the threshold, this parcel will decided to be developed as corresponding land-use type.

After the land-use type is decided, agents will locate to the developed parcel, which based on a defined agent location process. The location process is decided by agents to maximize their utility. After located in the Virtual City, agents will have behaviors and interactions. Water consumption is generated with the agent's behavior. The simulation process of virtual city is shown at Fig.3 and status during simulation process and parameters is shown at Fig.4.

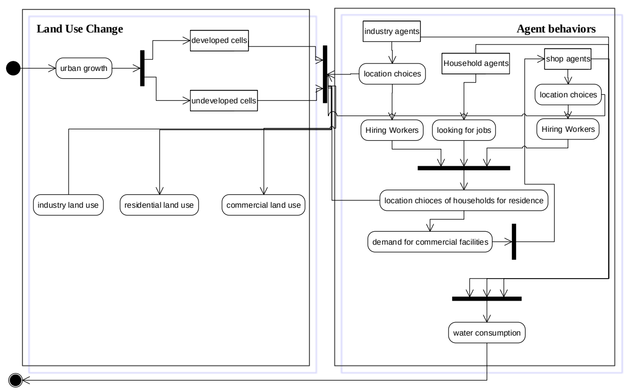
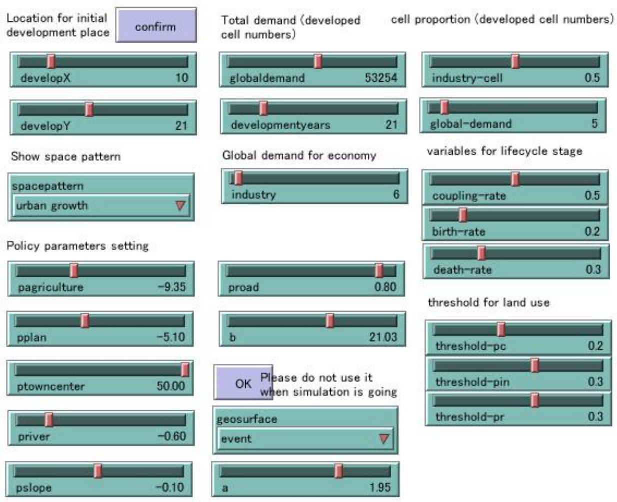
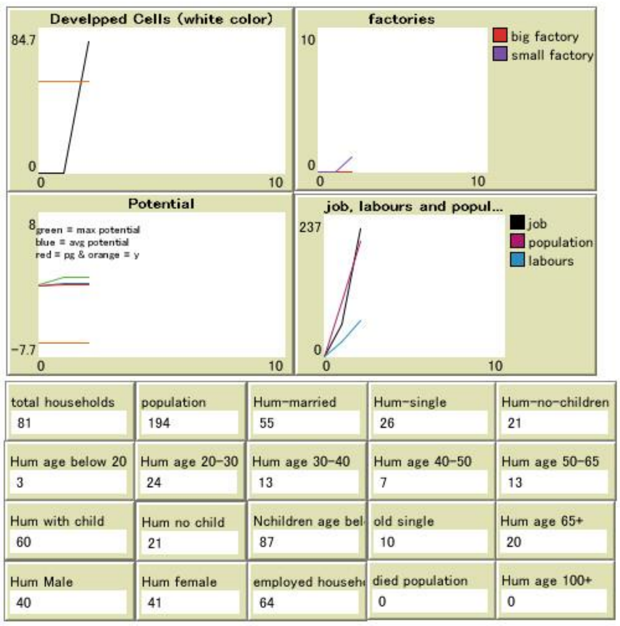


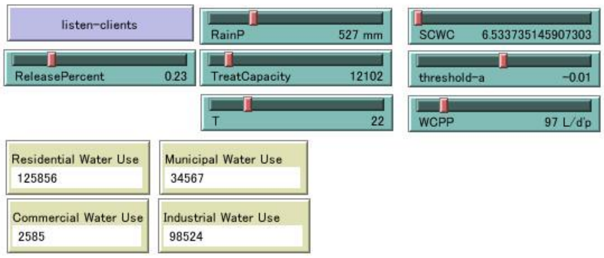
Figure 3. The simulation process of Virtual city



(a) Urban growth control parameters



(b) Status Monitoring during urban growth process



(c) Urban water supply and wastewater treatment system control parameters and monitoring

Figure 4. Virtual city control parameters and monitoring

3.2 Simulation of Urban Water Supply and Waste Water Treatment System

Urban water system can be divided to 3 parts: supply, consumption, and waste water treatment.

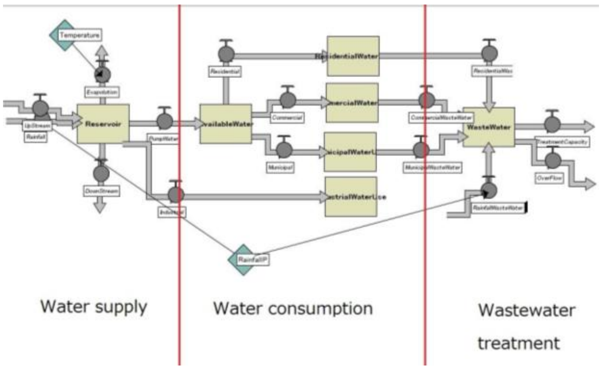


Figure 5. Simulation of Urban Water Supply and Waste Water Treatment System

Fig. 5 showed the simulation of urban water supply and waste water treatment system, which is developed by "System Dynamics Model Builder" function of NetLogo. System Dynamics model is a simulation method for understanding complex system over time. The using of feedback loops and stocks and flows, makes system dynamics model be a good tool to simulate water system.

For water supply part, we assume the water resource for urban water consumption is from reservoir. In the real situation, the water resource can be from surface flow, lake, ground water, etc., but for simplify the simulation, we assumed the water resource is taken from reservoir. The impact factors for the amount of available water for urban use are precipitation, temperature, upstream flow, and downstream flow.

Water consumption part is divided to 4 parts; industrial water consumption, commercial water consumption, residential water consumption, and municipal water consumption. The amount of water consumption of each part is calculated with the agents behavior explained at 3.1.

Industrial water consumption think to have their own water supply and wastewater treatment facilities, and other parts of water consumption is thinking to support by municipal water supply and wastewater treatment facilities.

The amount of wastewater from commercial, residential, and municipal water consumption think to be treat by municipal waste water treatment facilities. And the treated water release to surface flow.

3.3 Support of Participatory Decision Making

Participatory decision making is very important part for decision making in urban water policies, because it is related with many stakeholders. The success of involving stakeholders is the one of the key point for achieve sustainable IUWM.

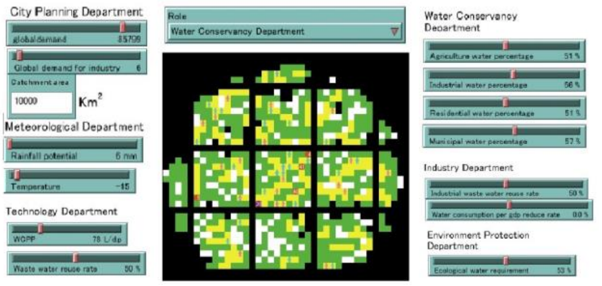
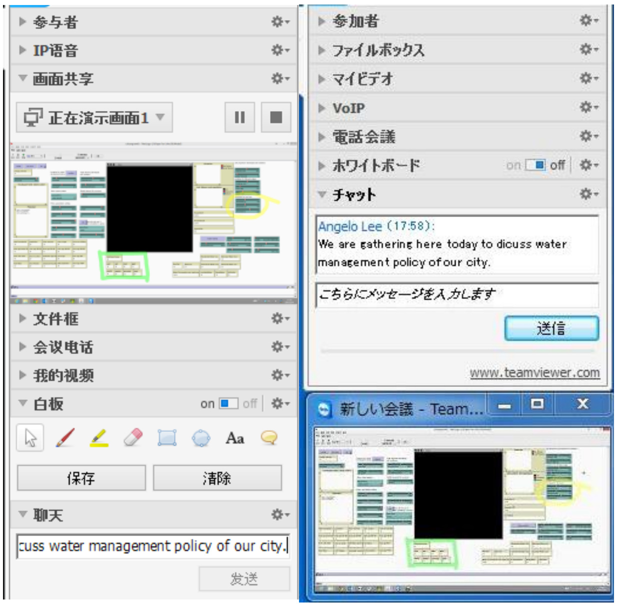


Figure 6. Example of server- client parameter setting

The object which defined in process of decision process in IUWM, is normally charged by different planner. Like the impact factors of water supply for urban water consumption is normally charged by Meteorological Department and Water Conservation Department, and these apartment's working place is different. DMM-IUWM provide a Server-Client decision supporting environment to let these planner to set the related parameters to model by their professional knowledge background. Fig.6 showed one of the example of the related departments involved in decision making process. With the selection of the identity only adjust of parameters related will be reflect to server, and the all of the legal adjust from clients will broadcast to all clients.

DMM-IUWM also provide web-meeting environment, which include the function of Screen Sharing, Remote control, Video chatting, Voice chatting, Type chatting, File transfer, White board. Through these functions, stakeholders can easily propose their argument, communicate with others. The simulation result can be observed by all participants of decision meeting. The example of functions for web-meeting is shown at fig. 7.



(a) (b)

Figure 7. Functions of Web-meeting environment
(a. Toolbox of server; b. Toolbox of clients)

4. STUDENT EXPERIMENT

4.1 Experiment Design

The purpose of student experiment is testify DMM-IUWM to estimate the effectiveness of functions. This experiment is also focused to test effectiveness of DMM-IUWM for improve public participants and understanding of decision-making on urban water management.

The assumed planning issue is a virtual city named "X city", has a predictable low precipitation in the near future, local government must use limited budget to balance amount of water resource and consumption.

A meeting holder, "Mayor" controls the meeting progress and stakeholders of decision making on urban water policy attend meeting to set the parameters and make their proposals. The participants and their responsibility of experiment showed in Table 1; the experiment process and the method are showed at Table 2.

In this experiment, 8 people with knowledge of Infrastructure engineering joined decision making process, and act one role shown at table 1. The participators of experiment are researchers in graduate school of natural science and technology in Kanazawa University. The experiment is processed with the Personal Computer which running Windows OS connected in local network of Kanazawa University. Before experiment, a paper which has written the responsibility of the participators in decision process will show to each participator. During decision process, participators explain and set parameters through

DMM-IUWM with following of the experiment process shown at table 2. The experiment was taken 1 hour for the process shown at table 2.

After experiment, all participants asked with a questionnaire, to testify DMM-IUWM. The questions in the questionnaire are shown as below.

1) Can you use DMM-IUWM easily?
2) Can you explain your task very well?
3) Can you understand the proposals from other participators?

Each of questions has scores from 1 to 5; participators give a score with each question after finish the experiment.

Table 1. Students experiment participants and responsibility

Participants	Responsible parameters and action
City Planning Department	• Global demand • Catchment area
Meteorological Department	• Rainfall potential • Temperature
Water Conservancy Department	• Water resources allocation
Technology Department	• Water consumption per person per day
Industry Department	• Industrial waste water reuse rate • Water consumption per GDP reduce rate
Environment Protection Department	• Ecological water requirement
"Mayor"	• Host the meeting and manage schedule
Spectator	

Table 2. Experiment process and method

Experiment Process	Method
"Mayor" describe of planning issue	Through TeamViewer(TV) type chatting
Introduction of participants departments	Choosing "Role" in HubNet(HN) and introduce their responsibility
Set background parameters by related department	Set parameters in HN and explain through TV
Explain the parameters for water conservation and require fund	Set parameters in HN and explain through TV
"Mayor" explain the draft decision for the fund to each water conservation department	Explain the fund decision through TV and set each parameters to Main Model
Compare some draft decision and make the suitable final decision	Run the model with same parameter for several time and compare the final result
Feedback	Answer questionnaire prepared on Website

4.2 Result of Student Experiment and Discussion

During the experiment process, DMM-IUWM simulation process works smoothly, and did not find huge error for simulation process running. It means DMM-IUWM can be works and the functions explained above can be supplied.

With the questionnaire survey, the average score for each question is shown as table.3

Table 3. Result of questionnaire survey.

No.	Average Score
Question1	3.375
Question2	3.75
Question3	3.125

The score shows in this stage DMM-IUWM did not improve the communication significantly, but the function of web-conference and parameter setting is working smoothly.

There are also comments from participators by a random interview. For positive side, because of breaking limitation of geographic location, increase of participation rate can be predicted. Meanwhile, participators feel more positive because of the individual operation and monitoring.

5. CONCLUSION

In this research we introduced a conceptual decision support system for integrated urban water management, named DMM-IWUM. By integrate agent-based simulation system and web-based conferencing function a visibility and easy communication meeting environment was achieved. By the student experiment testify, the function of DMM-IWUM is working well, and it is helpful to improve public understanding and awareness of decision process.

For the future work, a validation of DMM-IWUM by importing real data is needed. And also it is need to applying DMM-IWUM to real decision making process to assess the effectiveness to improve stakeholders participate in decision making process.

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統合的都市水資源管理の WEB ベース意思決定支援システムに関する研究

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キーワード：意思決定支援システム、統合的都市水資源管理、ウェブカンファレンス

水資源は最も重要な資源の一つである。しかし人口増加や経済発展のため多くの国では水資源の不足問題が起きている。気候不確実性背景で経済急成長の発展途上国では水資源不足問題が特に厳しい。都市は人口が集まっている場所で、人と環境の相互作用が最も激しい地域である。都市計画で制限的な水資源を有効に管理するのは持続可能な社会を求めるのに重要な部分である。水資源の管理は多数の利害関係者と関係があるため、水関連の政策を制定する際、利害関係者との交流が順調に出来るのかどうかが最適な水関連政策のキーポイントの一つである。

本研究では MAS モデリングプラットフォーム「NetLogo」とウェブ会議ソフトウエア「TeamViwer」を統合して統合的都市水資源管理の意思決定支援システムを紹介した。NetLogo で発展中の都市水資源システムをシミュレーションした。更に NetLogo の「HubNet」と言う交流機能と「TeamViwer」のウェブ会議機能で水資源計画に関する複数の計画者が自分の専門知識で都市システムのパラメータを設定し、利害関係者が計画プロセスに参加出来る。

研究室規模で模擬会議を行った結果、参加した各計画者が自分の要求や意見が簡単に表現出来た。更に利害関係者が計画プロセスへの参加と新たな省水型技術や政策実行の結果の表示で決定した政策に対する理解度を高めた。

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