THE DEVELOPMENT AND APPLICATION OF URBAN WATER CYCLE HEALTH ASSESSMENT MODEL

By

CHA, Byungsuk

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF PUBLIC MANAGEMENT

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Committee in charge:

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Executive summary

Domestic urban water cycle policies have been concentrated on one side of water quality or water quality. However, a new direction for city water circulation needs to be established in accordance with policies to manage water quality and water quality in an integrated manner. Developed countries have a very comprehensive approach such as city water circulation, natural environment, community of sustainability.

In this study, the definition model of urban water cycle health was proposed and quantitative evaluation of actual water cycle in city was planned. In this study, it is important to list various factors related to urban water cycle and to compare quantified water cycle factor in practical projects. However, for more practical evaluation, development of various evaluation factors and related legal and administrative system improvement will be necessary..

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1. Introduction

1.1.Statement of problem

Water is an essential element in human life and a means of improving the quality of life. The awareness of water has been continuously changed with the improvement of the national income level, and the need for a response system for climate change and water management became more important according to global environmental issues. In the case of Korea, accordingly, the present government is proposing the unification of water management as the first task of the water management policy for the integrated management of water quality and water quality. Previous water management has been managed mainly by the functions of each department, such as water quality management by the Ministry of Land and Transportation, disaster management by the Ministry of Administration and secure, water quality management by the Ministry of Environment, and agricultural water management by the Ministry of Agriculture. There is a lack of connectivity between water management policies, overlapping budgets, and centralization of water management.

Water has been recognized as a means of development and securing in the past, mainly managed to supply water or to protect floods. However, now that water is recognized in connection with management and ecosystem health, it restores the water circulation and emphasizes ecosystem recovery. Therefore, there is a need to integrate and manage the watershed with a focus on local governance (Ministry of Environment, 2018). The government is now beginning to introduce a future-oriented water management system that is prepared for climate change and has sustainability, equality, and adaptability. With the introduction of integrated water management, we expect to be able to provide sustainable urban environment and various water activities through abundant water flow, securing safe water, and water circulation urban environment management system.

What should be noted here is the importance of urban sector in the area of integrated water management. The city is a place where various economic activities and property are concentrated, and the center of various policies. At the same time, it is the most sensitive area for meteorological damage such as various floods and drought due to climate change. The serious economic and social damage of New Orleans in the United States by Hurricane Katrina in 2006 and the ongoing European and regional disasters that have been repeated over the past decades have continuously exposed this risk to all nations around the world (Saleh, 2009). In this regard, developed cities such as Hanover, Berlin in Germany, Hammarby in Sweden, Seattle, and Portland, New York and LA in the USA have already been applying low impacts development technique to cope with climate change in development of city (Yoon, 2000).

The population of cities are steadily increasing. As a result, water degradation, urban heat island effect, drought and floods due to climate change, and destruction of ecosystems are repeatedly appearing. Australia is trying to build livable, sustainable and productive city to cope with these kind of issues (Howe, 2012). Korea has also been conducting various researches on urban water circulation and has made efforts such as legislation, making a guideline related to this. The purpose of this study is to propose evaluation models that can efficiently implement them to overcome the current limitations of domestic laws and systems related to city water circulation system. This study will draw implications for how to apply that model to future land use planning by comparing the derived evaluation models with actual land use plans.

1.2. Domestic Law Status

Table 1 shows the status of laws, systems, and evaluation related domestic water management. Space planning is a system that affects projects that plan or develop a new city or redevelop a city, including urban planning to envision the city's future, and district unit plan to guide the city's detailed plans. In addition, the environmental plan is related to various evaluation systems according to the water quality pollution control system, the water environment conservation law, the environmental impact assessment law, the water reuse promotion and support law, and the natural disaster countermeasures law (Bahn, 2000). According to Bahn, domestic spatial planning is very difficult to collaborate with environmental planning, because environmental planning is established after spatial plan such as the population planning and the development planning considering the development of the city.

Another point to note here is the re-establishment of an environmental plan linked to unification of water management. The separated management policy among water quantity, quality, green spaces in the past was inevitable resulting from different policy management department such as the Ministry of Transportation, Ministry of Public Administration and Security, Ministry of Environment. However, it seems that there is a need to establish new urban water management plan based on integrated water management policy. In the newly enacted Water Management Basic Law, it is written that “the state and local governments are in a position to balance water of all shapes in the process of water circulation, to ensure water quality, conservation, drought and flood. And the impact on the environment, the economy and society should be considered together”. In other words, for a comprehensive consideration of the urban water cycle in the above-mentioned Water Management Basic Law, it is necessary to prevent the redundant investment of the budget through the evaluation system in which the spatial planning and environmental plan are linked and could be enhance the efficiency of each plan.

Table 1. Evaluation contents, related laws, ministry related to urban water cycle (Bahn, 2000)

division	Space plan	Environment plan	
Item	· Establishment of LID plan · Relation of LID plan · The feasibility of the plan	· Water environment	· Water quality
Contents	· Not mandatory (unevaluated)	·Point pollution source treatment measures · Nonpoint pollution source treatment measures	·Disaster prevention measures against rainfall runoff
Related court plans	· City basic / management plan · District unit plan	· Environmental Impact Assessment	· Disaster impact preview
Related laws	· Act on the Planning and Use of Territory	· Water Environment Conservation Act · Environmental impact assessment Act	· Natural Disaster Countermeasures Act
Related ministry	· Ministry of Land and Transport	· Ministry of Environment	· Ministry of Public Administration and Security

1.3.Domestic Evaluation Status

The current plan for urban water cycle is established through the guidelines of urban management plan and district unit plan related to water cycle. The water quality and quantitative effect are predicted through environmental impact assessment and pre-disaster impact assessment. Among these, the urban management plan and district unit plan of the spatial plan possess some limits that they are not compulsory and do not make a realistic and quantitative evaluation. Only the environmental impact assessment of the environmental plan and the disaster impact assessment preview carried out quantitatively, have practical feasibility.

In the environmental impact assessment system, the evaluation items for the water environment can be related to the urban water cycle. The water environment is divided into water quality, hydrological and marine environment, and water quality part is closely related to urban water cycle. Through water quality change pollution caused by the implementation of urban development project, change of sulfur in the target water area, water use situation, groundwater environment change, they predict amount of point pollution source and nonpoint pollution source in the business area, and reduction plan for pollutant with low impact development technique (Ministry of the Environment, 2015).

The disaster impact preview is a system that minimizes the impact on disasters by reviewing various disaster-causing factors at the early and operating stage of planning of various development projects. There are various disaster impacts related to water. Among them, evaluation contents linked with urban planning are whether to establish land use plan considering reduction of disasters (whether land use plan or facilities are distributed water as much as possible in target area) and measures to reduce rainfall outflows in the region (securing sufficient green areas and ensuring the ability to reduce storm drainage in the target area).

The ultimate goal of these two evaluation systems is to forecast the impacts, and prevent environmental issues and disasters including water-related impacts. The two evaluations themselves are closely related. For example, the installations of a storage facility or an infiltration facility for reducing rainfall in water disaster impact is also related to the nonpoint source reduction facility for environmental impact. The nonpoint sources of environmental impact assessment are estimated based on the urban impervious area, and they can be reduced according to the ecological area rate of the spatial planning related to the impervious water layer. Therefore, it is necessary to contribute to the plan formulation considering the water cycle in the land use planning phase through the urban water cycle evaluation model which can consider the space planning and the environmental plan comprehensively. In the next chapter, the conceptualization of urban water circulation health is used to derive the assessment items, and this study will develop an evaluation model that can be linked to land-use planning, and apply the model to real business projects to derive analysis results.

2. Field research methods for gathering data

2.1 Definition of urban water cycle health

First of all, the current definition of urban water cycle health is focused on a single aspect such as water quantity or quality, so we intend to investigate the literature to establish a new definition linking it. Choi (2009) considered the urban water cycle health as a component of infiltration, direct runoff and evapotranspiration. In other words, urban water cycle is expressed as a rate of change of the natural state and the urbanization state. However, as mentioned above, urban water cycle needs to consider other factors related to water, such as water quality and ecosystem, besides hydrological factors.

According to Article 9 of the Framework Act on Water Management, the definition of water cycle health or soundness is defined as follows. A healthy water circulation means that the function of water for the preservation of life on Earth and for the maintenance of the ecosystem and human activities can be maintained as normal as water plays an important role in nature and human through the rotation process. Wong (2013) uses the term water sensitive city as a concept similar to urban water cycle, suggesting the broad meaning of water supply of various resources, supply of natural environment, and formation of community for sustainability. In particular, the conceptual content of sustainability, livability, and adaptability is the most important consideration and factor in water sensitive city.

In this regard, this study aims to define urban water cycle health considering the specific evaluation of urban development projects. Therefore, urban water cycle health is defined as*: establishment of sustainable urban plan that can adapt to nature and live well by making clean water quality, ecosystem preservation and disaster prevention through various water cycle of the city*.

2.2 Development of analysis model

The evaluation factors should be listed first in connection with the new definition of urban water cycle health, and the analysis model is developed by referring to the existing evaluation model. The selection of the evaluation factors was based on the review of the literature related to the development of urban water cycle indicators. Then the final evaluation factors were selected considering the connection with current water quality and quantity evaluation models.

Lee, J.J. (2005) derived the ecological city planning index through the related literature and expert questionnaire in "Study on Development of Korean Eco City Planning Indicator". Only water indicators are extracted as shown in the table 2 below. Among them, the dark color part indicates the water-related planning index of the core eco-city derived through the final experts meeting, but we decided to consider the remaining items related to the selection of evaluation factors. Water cycle urban planning index can be divided into water use and water landscape, which can be associated with the target of water sensitive city - sustainability, adaptability and livability. In addition, Novotny (as cited Howe, 2012, p177) emphasizes economic, social and environmental bases through the study of “sustainability evaluation of macroscopic scale of future water-centered cities”, while emphasizing water cycle elements such as ecological footprint, carbon footprint, water footprint.

Table 2. Water-related plan indicators in ecological city planning index (Lee, J.J., 2005)

Field	**Detail field**	**Evaluation contents**	**Weight***
Utilizing water resources	Use of sewage water	Reuse second treated water	4.15
		Reuse sewage water	4.18
	Use of rain water	Construct storm water pond	4.08
		Maximize permeability	4.16
	Environmentally friendly sewage	Separate treatment of wastewater and rain water	4.55

	treatment	Construct biological treatment of living sewage (using aquatic plants)	4.20
		Construct natural purification treatment (flock, pond)	4.37
	Construction of a reservoir	Construct reservoirs for flood and dry season	4.11
Water demand restraint	Water saving installation	Install water-saving facility	4.20
Water landscape	Making of water-friendly place	Create natural rivers, wetlands	4.26
		Construct ecological pond	4.14
	Preservation of existing water resources	Utilize existing water resources	4.47
		Utilize water landscape	4.14

*) *The weight is the importance evaluation result of the ecological city planning index*

In addition, Lee, J.M. (2012) compared the above-mentioned indicators with those of other green cities and compared these indicators with those of urban water circulation (water supply and sewage), urban hydrological circulation (natural water), urban artificial circulation (real water, lake, artificial river, etc.). The circulation related to the water and sewage system was quantified in connection with the estimation of greenhouse gas emissions, and the SWMM5-LID model was used to analyze the circulation effect for hydrological and artificial circulation.

In the multivariate impact assessment of KEI, the benefits of rainfall runoff and the reduction of nonpoint pollution sources were assessed as community benefits in connection with ecosystem services - based conservation and vegetation. This can be considered an effective evaluation model for urban water cycle in terms of quantitatively evaluating the effects of low impact development techniques and review of land use plan before setting land use plans. In this model, nonpoint source pollution sources and rainfall runoff reductions are calculated according to land cover type (non-structural technique) and LID facilities (structural technique) in table 3 and 4, where additionally ecosystem value is calculated. Among these, the method of calculating the nonpoint pollution source and rainfall runoff directly related to the water cycle is calculated by taking the land use plan into consideration for each of the following tables' unit amount.

Table 3. Nonpoint pollution and rainfall runoff unit amount of urban area (KEI, 2016)

Land cover type		Non-point pollution source unit amount (per 1 ㎡)			Rainfall runoff source unit amount (per 1 ㎡)	
Main	**Middle class**	**T-N (kg/yr)**	**T-P (kg/yr)**	**BOD (kg/yr)**	**Permeability (mm/yr)**	**Surface runoff (mm/yr)**
Urban area	Residential area	0.0033	0.0002	0.0027	5.00	216.00
	Industrial area	0.0021	0.0002	0.0091	1.00	612.00
	Commercial area	0.0020	0.0002	0.0150	0.50	456.00
	Culture / Sports / Recreation area	0.0028	0.0003	0.0072	25.00	541.00
	Traffic area	0.0015	0.0001	0.0042	0.10	778.00
	Public utility area	0.0018	0.0001	0.0028	0.50	448.00

Table 4. Nonpoint pollution and rainfall runoff unit amount of the structural low impact development technique (KEI, 2016)

LID Facility Name	Applied	Nonpoint source Reduced	Rainfall runoff Reduced

	area (㎡/1식)	amount			amount	
		T-N (kg/yr)	T-P (kg/yr)	BOD (kg/yr)	Permeability (mm/yr)	Surface runoff (mm/yr)
Wooden filter box	1,000.00	2.00	1.00	14.00	56.75	101.66
Permeable packing and permeable block	1,000.00	0.00	1.00	4.00	6.11	18.33
Penetration ditch	1,000.00	8.40	0.00	22.97	694.61	736.00
Penetration trench	1,000.00	0.00	0.00	0.00	694.61	736.00
Penetration box and penetration trough	50.00	0.00	0.00	0.00	34.73	36.80
Raingarden	1,000.00	2.00	1.00	14.00	56.75	401.63
Bio slope	1,000.00	1.04	0.08	2.08	56.75	401.63
Small-scale artificial wetland	1,000.00	1.72	0.52	5.92	0.00	40.53
Vegetation ditch	1,000.00	1.47	0.10	3.69	56.75	101.65
Vegetation rooftop	1,000.00	2.00	1.00	14.00	56.75	401.63
Plant box	1,000.00	0.00	0.00	0.00	122.58	163.44
Rainwater box	1,000.00	0.00	0.00	0.00	122.58	163.44
Rainwater utilization facility	1,000.00	0.00	0.00	0.00	0.00	40.86
Infiltration pond	1,000.00	3.31	0.62	0.16	0.00	40.86

Rainwater retention and permeation tank	1,000.00	0.00	0.00	0.00	0.00	40.86

On the other hand, KL-SWMM of K-water shows the effluent coefficient by land type like table 5 and 6. Estimating the runoff effects through land use and LID scale data will make it easier to use this data.

Table 5. Runoff coefficient of rational formula by land use (River design standard, 2005)

Land use		**Runoff coefficient**	**Land use**			**Runoff coefficient**
Commerce	Urban area	0.70 ~ 0.95	Pedestrian road			0.75 ~ 0.85
Commerce	Neighborhood	0.50 ~ 0.70	Roof			0.75 ~ 0.95
Residence	House	0.30 ~ 0.50	Grass	Sandy soil	Flat (Under 2%)	0.05 ~ 0.10
Residence	Independent housing complex	0.40 ~ 0.60	Grass	Sandy soil	Normal (2~7%)	0.10 ~ 0.15
Residence	Tenement housing complex	0.60 ~ 0.75	Grass	Sandy soil	Slope (Above 7%)	0.15 ~ 0.20
Residence	Suburban area	0.25 ~ 0.40	Grass	Middle soil	Flat (Under 2%)	0.13 ~ 0.17
Residence	Apartment	0.50 ~ 0.70	Grass	Middle soil	Normal (2~7%)	0.18 ~ 0.22
			Grass	Middle soil	Slope (Above 7%)	0.25 ~ 0.35
Industry	Distributed area	0.50 ~ 0.80	Agriculture	Normal	Normal	0.30 ~ 0.60
Industry	Dense area	0.60 ~ 0.90	Agriculture	Normal	Rough	0.20 ~ 0.50
Park		0.10 ~ 0.25	Agriculture	Plow	Sandy soil – In crops	0.30 ~ 0.60
Stadium		0.20 ~ 0.35	Agriculture	Plow	Sandy soil – No crops	0.20 ~ 0.50
Railway		0.20 ~ 0.35	Agriculture	Plow	Middle soil – In crops	0.20 ~ 0.40
			Agriculture	Plow	Middle soil – No crops	0.10 ~ 0.25
Un-developed area		0.10 ~ 0.30	Agriculture	Plow	Farming	0.70 ~ 0.80

Road	asphalt	0.70 ~ 0.95		Grass	Sandy soil	0.15 ~ 0.45
	concrete	0.80 ~ 0.95			Middle soil	0.05 ~ 0.25
	brick	0.70 ~ 0.85		Forestry	Scarp	0.40 ~ 0.80
					Mild	0.30 ~ 0.70

Table 6. LID facility runoff correction coefficient (K-water, 2016)

Div.	**Artificial wetland**	**Infiltration pond**	**Rainwater utilization facility**	**Vegetation rooftop**	**penetration trough**	**Permeable packing**	**Vegetation ditch**	**Penetration trench**
Coefficient	0.7	0.6	0.6	0.5	0.2	0.2	0.6	0.4

Park (2007) classifies the characteristics of the water cycle by types of green spaces and proposes to consider them in the planning of green parks in the “Improvement of urban green space function considering water cycle.”- This study shows that water cycle may vary depending on the type of green space. In addition, she insists that the BMP (Best Management Practice) facility, where rainwater is moved along the canal and discharged to the river, causes problems of maintenance cost and future facility efficiency. Moreover, it creates adverse effects that lead to an increase in pollution and a fundamental change in the hydrological system. This emphasizes the importance of unstructured techniques such as green space urban plan and land use of the permeable layer.

Vernon (2009) classified the LID facility (structural element technique) related to water sensitive urban design into water balance, quality and conservation. Table 8 shows the results in relation with the place's value.

Table 7. Ranking the success of water sensitive urban design techniques in contributing to place-making (Vernon & Tiwari, 2009)

Score	Technique	Div.*	Score	Technique	Div.
6	Swales	WB	4	Retention Existing Vegetation	WB
6	Living stream	WB	4	Xeriscaping	WC
6	Stream Rehabilitation	WQ	3	Permeable Surfaces	WB
5	Dry Compensation Basin	WB	3	Infiltration Retention Basin/Sump	WB
5	Wet Compensation Basin	WB	3	Regulated Self-Supply	WC
5	Constructed Wetland	WQ	3	Storm water Re-use	WC
5	Natural Wetland	WB	3	Hydro zones	WC
5	Turfing	WQ	3	Windbreaks	WC
4	Extended Dry Compensation Basin	WB	2	Grey water Re-Use	WC
4	Urban Forestry	WB	2	Water Harvesting	WC

*) WB : Water Balance / WQ : Water Quality / WC : Water Conservation

This study will present a model to determine the health of the urban water cycle by compiling the studies and systems related to water cycle. However this study will not be consider central concentrated rainwater discharge facilities or pollution prevention facilities, since they do not represent the overall solution of water cycle health. Furthermore land use can include various areas such as agriculture and forest area outside urban area, but this study is limited to element evaluation connected with land use plan in urban area without consideration of all these areas. This is because the model is intended to determine the integrity of the water circulation for new urban development projects. The calculation model proposed for consideration of these factors comprehensively is shown in Table 8.

Table 8. Urban water cycle health index item and calculation method

Div.	Detail content	Equation	Calculation method
Water Balance	Utilization of water	$\frac{Rain\ water / Sewage\ reuse}{Water\ usage}$	- Rainwater reuse : Rainwater Reuse Rate per House / Building - Sewage reuse: sewage reuse plan - Water usage: Urban planning Total water demand
	Spill suppression	1 − Leakage index	- Leakage index: Σ (runoff coefficient for land use × LID facility correction coefficient × LID area ratio)
		Ecological area	- According to the Guideline for Estimating Ecological Area Rate of the Ministry of Environment,
Water Quality	Reduced nonpoint pollution	$\frac{Non\ point\ pol\text{-}suppression}{Non\ point\ pol\text{-}generation}$	- Non-point pollution suppression amount: Area by LID facility × Non-point pollution abatement unit by facility - Non-point pollution generation amount: area by land use × non-point pollution source unit by land
Water Value	Land use	$\frac{LID\ land\ use\ value}{LID\ total\ facility} / 10$	- LID land use value: LID capacity by facility × place value by facility - Total LID Facility: Sum of Capacity by LID Facility

*) The land runoff coefficient for each land use is applied to the KL-SWMM land runoff coefficient

**) The unit of nonpoint source for each facility is the unit of the multivariate impact assessment (KEI)

***) Place value by facility is applied by Place-Making through Water Sensitive Urban Design (Vernon, 2009)

3. Analysis and findings

3.1 Application of analysis model

In order to review the evaluation results of this analysis model, we decided to select and compare two projects in progress. The target business is selected as Bu-yeo Geu-am water friendly district development project and Na-ju No-an water friendly district development project, which are similar in scale to the special law on the utilization of water friendly zone besides river, and the land use plan is as followed table 9. The two projects are a similar purpose public undertaking for the prevention of disorderly development around the rivers and eco-friendly utilization, unlike the general land development project for the supply of houses. In addition, it is considered that it is easy to apply this model as a relatively small scale business.

Table 9. Land use plan (K-water, 2016&2017)

Div.		Geu-am district		No-an district		Ref.
		Area(㎡)	Ratio(%)	Area(㎡)	Ratio(%)	
Total		110,553	100.0	105,494	100.0	
House		4,711	4.3	37,848	35.9	
Accomodation		32,000	28.9	10,553	10.0	
Leisure/culture		20,208	18.3	8,405	8.0	
Amusement		3,344	3.0	-	-	
Commerce		3,457	3.1	6,139	5.8	
Park		5,318	4.8	7,285	6.9	
Green area	Landscape	18,249	16.5	-	-	
	Buffer	9,875	8.9	10,695	10.1	
Parking lot		1,652	1.5	1,296	1.2	
Pedestrian		96	0.1	532	0.5	

Road	11,081	10.0	22,241	21.1	
Agricultural waterway	562	0.5	-	-	
Community	-	-	500	0.5	

The following results were derived using the land use plan, the district unit plan, the environmental impact assessment, the business plan based on the disaster impact preview, and the above calculation method.

Table 10. The result of analysis about water cycle health

<table>
<tr><th>Div.</th><th>Detail content</th><th>Equation</th><th colspan="3">Geu-am district</th><th colspan="3">No-an disitrict</th></tr>
<tr><td rowspan="3">Water Balance</td><td>Utilization of water</td><td>$\frac{Rain\ water/Sewage\ reuse}{Water\ usage}$</td><td colspan="3">0.04</td><td colspan="3">0.01</td></tr>
<tr><td rowspan="2">Spill suppression</td><td>1 – Leakage index</td><td colspan="3">0.390</td><td colspan="3">0.453</td></tr>
<tr><td>Ecological area</td><td colspan="3">0.258</td><td colspan="3">0.209</td></tr>
<tr><td rowspan="2">Water Quality</td><td rowspan="2">Reduced nonpoint pollution</td><td rowspan="2">$\frac{Nonpoint\ pol\text{-}suppression}{Nonpoint\ pol\text{-}generation}$</td><td>T-N</td><td>T-P</td><td>BOD</td><td>T-N</td><td>T-P</td><td>BOD</td></tr>
<tr><td>0</td><td>0.04</td><td>0.01</td><td>0.01</td><td>0.06</td><td>0.02</td></tr>
<tr><td>Water Value</td><td>Land use</td><td>$\frac{LID\ land\ use\ value}{LID\ total\ facility}/10$</td><td colspan="3">0.3</td><td colspan="3">0.35</td></tr>
</table>

However, all the above projects were small-scale projects aimed at preventing the development of the surrounding river areas in accordance with the needs of the local governments. As a result, there was not much progressive plan in terms of water circulation such as reuse of water. In other words, LID facilities are constrained by the beneficial limitations of small - sized projects. Therefore, in order to derive the analytical data, the analysis result of the water utilization field is estimated by assuming that about 5% of the planned water supply plan of the accommodation and resort areas will be supplied through water reuse. In general, according to the law on reuse and promotion of water, this is taken into account in the case of public facilities or commercial facilities over a certain scale.

Based on the assumption results, the Geu-am district development, which has a high rate of accommodation and recreation facilities, showed a higher score in terms of water utilization than No-an district. In the case of the Geu-am district project, the ratio of ecological area, an indicator of leakage index, was higher than that of No-an district in proportion to the high green zone rate. However, if you look at the water penetration index in connection with land use plan and LID facility plan, No an district development is recognized as an efficient plan in terms of water balance.

In case of pollution reduction rate, non - point pollution source was treated as concentrating facility in two business districts. Therefore, the pollutant reduction rate is not high in this model index that mainly concerns the LID facility as a distributed facility. However, as a result of the calculated indicators, the pollution reduction rate is higher in the No-an district project. In connection with this, the No-an district project, which reflects various LID facilities, also showed higher value in terms of land use value. Overall, the Geu-am district project showed a higher score in terms of water balance, and the No-an district has a high water cycle health index in terms of water quality and value. On this dataset, we can safely argue that the No-an district project is ahead of the Geu-am district project .

3.2 Effect of analysis

As mentioned above, there are various analytical models such as SWMM in the analysis of urban water circulation, and this model is used to evaluate urban water circulation in previous studies. Most research models assessed urban areas mainly through hydrological approaches. However, for the multivariate impact assessment model, a water quality approach considering nonpoint source reduction through LID structural unit characteristics was considered exceptionally. The urban water cycle refers to the effects of water quality and quantity on the LID structural characteristics or the non-structural characteristics of the urban space plan and, the district unit plan. With the goal of evaluating a more comprehensive urban water cycle, it is able to secure execution power. Therefore, ecological area rate and water reuse that can be defined in the district unit plan can be evaluated, and the value of land use can be considered in urban water cycle. This analysis model was able to derive the items that are lacking in the urban planning design according to the characteristics of each item. It is meaningful to find a supplementary direction for constructing efficient urban water cycle system.

4. Policy recommendations

In a previous study, "Indicators and Techniques for Evaluating Water Circulation Integrity", Choi (2009) stated that the urban water cycle is formed by the combination of the natural water circulation and the artificial water circulation. Especially, as mentioned in the introduction, urban development or management policy depend on the expansion of urban area, and the factors of water circulation should be rigorously evaluated. If the urban water policy is narrowly concentrated on the hydrologic water cycle health index or the environmental water quality index, urban water cycle health would not be perfect in terms of sustainability and effectiveness. Therefore, it is necessary to synthesize the indicators related to various water cycles and to lay the foundation for the technique to improve the water cycle health.

Therefore, in this study, we propose a technique to evaluate the water cycle health in a comprehensive manner considering the spatial planning. However, this method has been devised an evaluation method for water cycle health based on the land use plan according to the green area ratio of the urban planning technique and the introduction scale of the LID element technique. However, the water recycling method can be more advantageous with various approaches if techniques are studied together. But, quantitative research on this issue was relatively not enough to reflect this. Neverthless, this evaluation method suggested a method to evaluate the water quality, quantity and place-ability in a comprehensive way, so that the city planning could be evaluated from a comprehensive viewpoint of water.

Also, in order to effectively evaluate water cycle health, there is a need for measures that can be linked to effectiveness such as the current environmental impact assessment or disaster impact preview. In particular, it is reasonable to proceed as a legal process before the development plan is set up, that will allow to assessment of the water cycle health at the land use planning stage.

In addition, in order to promote active participation of project developers, it will be necessary to find incentives linked to these. In fact, these structural and non - structural techniques are factors that can adversely affect maintenance and installation costs to developers, but they require a bold inducement when considering sustainability of urban area. To this end, it is possible to induce the active participation of the businesses by finding many cost or business incentives, for example the adjustment of the green area ratio scale and the budget subsidy. And many participating companies will help acquire technologies such as urban planning, design, development element related to water cycle.

Finally, a dedicated organization should be set up to study these evaluation methods and techniques. According to the integrated water management policy, the organization of the government is currently under adjustment with the ministry of environment. As mentioned in the introduction, there are several ministries of interest in urban water cycle, as urban water cycle is one of the detailed integrated water management policies. Therefore, it is necessary to establish an organization centered on the Ministry of Environment. In particular, it is necessary to consider the governance structure such as the water management committee as the water management is centered on the watershed-based local organizations. And water cycle should be linked with various factors such as land use value, energy value, ecosystem value together with water quantity and quality management, and it seems that a comprehensive organizational system would be able to control them.

In this study, we derived and applied a technique to evaluate the water cycle health in conjunction with the structural and non - structural techniques of land use planning and water cycle. By using this, it is possible to assess and bring water cycle healthy land use plan and urban design element. And if such a system is established, many developers will be able to actively utilize these planning elements and establish safe and clean urban planning in a water cycle. I think that the establishment of this system will contribute to the construction of a sustainable and livable urban environment that can adapt to nature.

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Appendix A : Detailed analysis data

Div.	Detail content	Equation	Calculation method
Water Balance	Utilization of water	$\frac{Rain\,water/\,Sewage\,reuse}{Water\,usage}$	- Rainwater reuse : (Geu am) 306 / (No an) 130 - Sewage reuse: No data - Water usage: (Geu am) 12.365 / (No an) 1.5
	Spill suppression	1 − Leakage index	- Leakage index: Table d
		Ecological area	- Followed by EIA report each projects
Water Quality	Reduced nonpoint pollution	$\frac{Non\,point\,pol\cdot suppression}{Non\,point\,pol\cdot generation}$	- Non-point pollution suppression amount: Table b - Non-point pollution generation amount: Table b
Water Value	Land use	$\frac{LID\ land\,use\,value}{LID\ total\,facility}/10$	- LID land use value: Table c - Total LID Facility: Table c

Table a.

Div.	LID Area		T-N (kg/yr)	T-P (kg/yr)	BOD (kg/yr)	T-N (kg/yr)	T-P (kg/yr)	BOD (kg/yr)
	Geu am(㎡)	No an(㎡)	Geu am			No an		
Permeable Block	756.8	1050.4	0.00	0.76	3.03	0.00	1.05	4.20
Penetration trough	-	203.0	0.00	0.00	0.00	1.70	0.00	4.64

Table b: Nonpoint pollution data

Div.	LID Area	
	Geu am(㎡)	No an(㎡)
Land value	2270.4	4369.2
LID total fac.	756.8	1253.4

Table c. Land use data

Div.		Land use		Applied land use		Coefficient
		Geu am(㎡)	No an(㎡)	Geu am(㎡)	No an(㎡)	
Total		**110,553**	**105,494**	**67,485**	**57,742**	
House		4,711	37,848	1,884	15,139	0.4
Stay		32,000	10,553	19,200	6,332	0.6
Leisure/culture		20,208	8,405	12,125	5,043	0.6
Amusement		3,344	-	1,003		0.3
Commerce		3,457	6,139	2,074	3,683	0.6
Park		5,318	7,285	1,064	1,441	0.2
Green area	scape	18,249	-	13,687		0.75
	Buffer	9,875	10,695	7,406	8,021	0.75
Parking lot		1,652	1,296	106	83	0.8
Pedestrian		96	532	15	106	0.8
Road		11,081	22,241	8,865	17,793	0.8
Agri. waterway		562	-	56		0.1
Community		-	500		100	0.2

Table d. Leakage data each land use

Div.		T-N (kg/yr)	T-P (kg/yr)	BOD (kg/yr)	T-N (kg/yr)	T-P (kg/yr)	BOD (kg/yr)
		Geu am(㎡)			No an(㎡)		
Total		**197.3**	**19.6**	**518.3**	**227.4**	**16.9**	**432.5**
House		15.5	0.9	12.7	124.9	7.6	102.2
Stay		89.6	9.6	230.4	29.5	3.2	76.0
Leisure/culture		56.6	6.1	145.5	23.5	2.5	60.5
Amusement		9.4	1.0	24.1	0.0	0.0	0.0
Commerce		6.9	0.7	51.9	12.3	1.2	92.1
Park	scape	-	-	-	-	-	-
	Buffer	-	-	-	-	-	-
Green area		scape	-	-	-	-	-
Buffer		2.5	0.2	6.9	1.9	0.1	5.4
Parking lot		0.2	0.0	0.3	1.0	0.1	1.5
Pedestrian		16.6	1.1	46.5	33.4	2.2	93.4
Road							
Agri. waterway		0.0	0.0	0.0	0.9	0.1	1.4