Development and Application of Urban Micro-Climate Management System for Creating Low-Carbon and Green City

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1 ABSTRACT

The Republic of Korea has established a diversity of strategies to cope with the climate change through a new policy paradigm called 'low-carbon green growth' since the past 2008, and it is being realized. This new paradigm suggested a far-reaching developmental guideline of low-carbon and green city creation, and for its concrete realization appeared the very Urban Renaissance Project.

This study is the result drawn through this Project, and its ultimate purpose is to develop a system that can compare & analyze the degree of micro-climate change consequent upon diverse planning elements in a project target site. Actually, it's true the elements belonging to micro-climate are really diverse. However, this study carried out its research by confining the micro-climate to wind and temperature for the sake of realizable possibility and concreteness. As a case target site for system evaluation, this study set the Urban Renaissance Zone in Gwangju Metropolitan City of central district of Korea. The developmental contents of the system and system evaluation results are summed up as follows:

First, this study designed the urban micro-climate management system so that macro-scale analysis module and micro-scale analysis module can be interlocked on the basis of the 3-dimensional virtual machine, through which it's possible to analyze cold wind formation & its flow at a wide area level and also to analyze the wind flows at a microscopic level.

Second, this study designed the system composition by dividing it roughly into data sector, analysis sector and expression sector for making it possible for its users to handle with ease.

Third, this study dealt with system management process. In all planning process, this study preferentially conducted the analysis of cold wind formation and wind flows at a wide area level, on the basis of which this study conducted the analysis of wind flows at a microscopic level, and then finally drew the optimum alternative for creating low-carbon and green city.

Fourth, this study drew the results of Pilot Study for evaluating the urban micro-climate system. First, there increased the wind by 0.6 m/s, and decreased the temperature by 0.4 °C through the creation of Traditional Theme Street. In case of Streamlet Street, there increased the wind 0.12 m/s, and decreased the temperature by 0.3 °C. In addition, in case of Central Square, there increased the wind by 0.26 m/s, and decreased the temperature by 1.0 °C. Additionally, through the creation of Waterfront Park, there appeared the greatest increase in the wind by 0.99 m/s while the temperature was found to decrease the most by 0.7 °C, showing that green space combined with waterfront creation was the most effective in improving micro-climate.

Through the results mentioned above, this study was able to understand the potential for the stability & applicability of the Urban Micro-Climate Management System. Nevertheless, this research thinks that should the reliability in the drawn result value and speed for drawing the analysis value back up, it could be a system with higher practical use, and additionally, if the practical function like the analysis of greenhouse gas emissions should be added, the effective value of this system would be more augmented.

2 INTRODUCTION

The microclimatic environmental change has recently caused the problems, such as wind flow impediment and heat island phenomenon due to the high-rise/high-density centered urban development, and this has been recognized as the reason that impedes the residential environment in the surrounding areas, as well as the developing areas themselves. Therefore, the environment factors (securing wind road and enhancement of heat island) have been truly proposed as the planning considerations in the legislation system related to the urban plan, in recent. However, it is true that it is never enough to evaluate and reflect these urban microclimate environmental factors by linkage with the actual planning process. Especially, as the effects by the change of urban microclimate should be sufficiently reviewed and considered in the planned/comprehensive manner prior to implemetation of urban development project, the effective enhancement can be expected due to its nature. Because of this, it can be said that the sufficient effects can be seen only if the relevant factors of the urban microclimate should be predicted/evaluated and controlled in advance in the systematic/comprehensive manner when establishing all types of the urban regeneration projects.

Therefore, this study has an ultimate purpose of developing the technologies that can be generally operated in the process of applying this to each type of urban regeneration project by building the system that can control and manage the relevant problems related to urban microclimate due to urban regeneration projects perfectly and comprehensively, and is intended to contribute to building the low-carbon and green city with creating the pleasant urban environment as the environmental factors related to the urban microclimate are sufficiently reflected on the plan through this.

3 URBAN MICRO-CLIMATE MANAGEMENT SYSTEM (UMCMS)

3.1 System Concept and GUI

3.1.1 System Concept

The urban microclimate management system is a system to expand the liquidity of wind by predicting/analyzing the wind environment and the heat environment in priority among various urban microclimate factors and to focus on evaluating and designating the planning technique and the related factors necessary for this that can lower the strength of the heat island. This system has been interlocked with Macro-Model for wind flow analysis in the macroscopic level, Micro-Model for wind flow analysis in the microscopic level, and Thermal-Analysis Model for heat environment analysis in the microscopic level, based on the 3-dimensional virtual machine, and has been drawn up to allow various thermal maps to be drawn up through this.

The flow of system for the microclimate analysis is shown as following. Firstly, the analysises in the regional level, such as cold wind forming analysis, cold wind flow analysis, and cold wind velocity analysis, have been conducted, based on the land cover and the geographical data. Next, the wind analysis is conducted, here with needs of building structures, building materials and meteological data. Based on these data, analysis of wind flow and pollutants distribution within the specific object site is to be conducted. Finally, the system has been comprised of the system that can propose the plan for building the optimal green city through linkage with the wind environment by conducting the heat environment analysis. However, the heat environment analyzing function has been in the status of showing only possibility of realizing the function, as a testing phase, and in the status with substantially little reliability on the results.

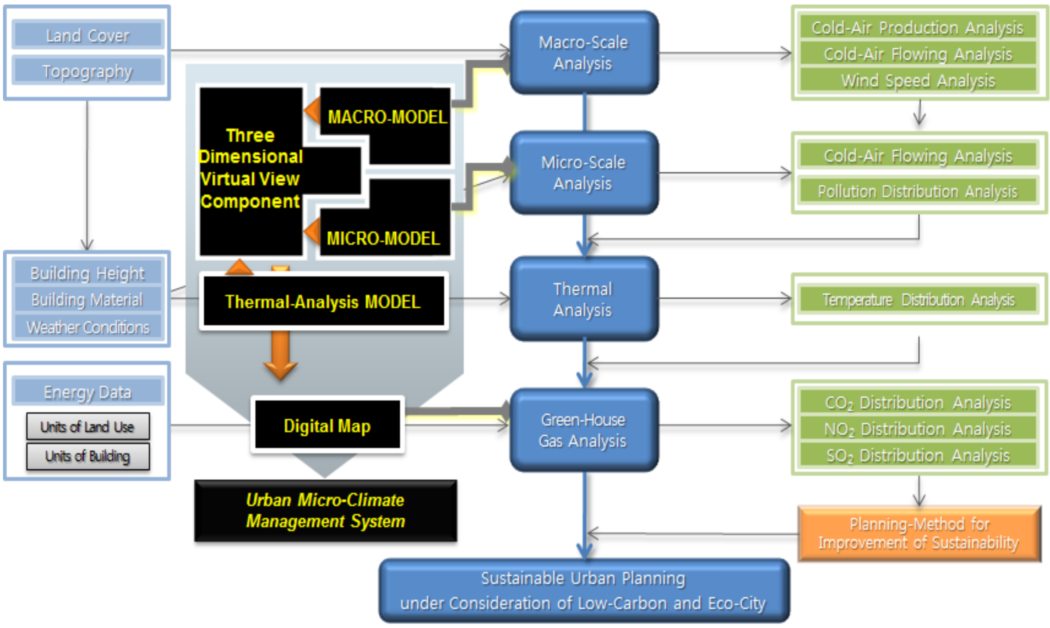

Fig. 1: System Concept and Workflow

3.1.2 System GUI

The most important matter in the urban microclimate management system is that the convenience should be provided to the users by top priority when utilizing the system. Therefore, the urban microclimate management system has a merit that it has been designed to enable all the functions to be implemented in the single platform with removing the difficulties that various models should be utilized in turn according to the necessary functions.

The main screen has been intuitively and simply comprised of Menus, Layer Control Window, and Map Display Window to improve convenience and identification. The menu for improving convenience of the system has been simply comprised of File, Data, Analysis and Display.

File Menu has been consisted of Submenu, such as Open and Save, which is the menu that all the programs have in common, generally. Data menu is largely divided into creation and extraction of data, and submenu below this has been consisted to create and extract the topography, image, land cover, and building data.

In Analysis Menu, the submenu has been composed to analyze wind environment, heat environment, and green house gasses emissions. In other words, we have comprised a submenu for separate analysis of cold wind flow and pollution sources below the wind environment menu, a submenu for analysis of temperature distribution below the heat environment menu, and sub/submenu for analysis of green house gasses emissions. We have divided the analyzed results into sectors of land status, wind environment, thermal environment, and status of green houses emission, as expressing parts, and consisted of the sub/submenu to draw up the specific thematic map related to each below it.

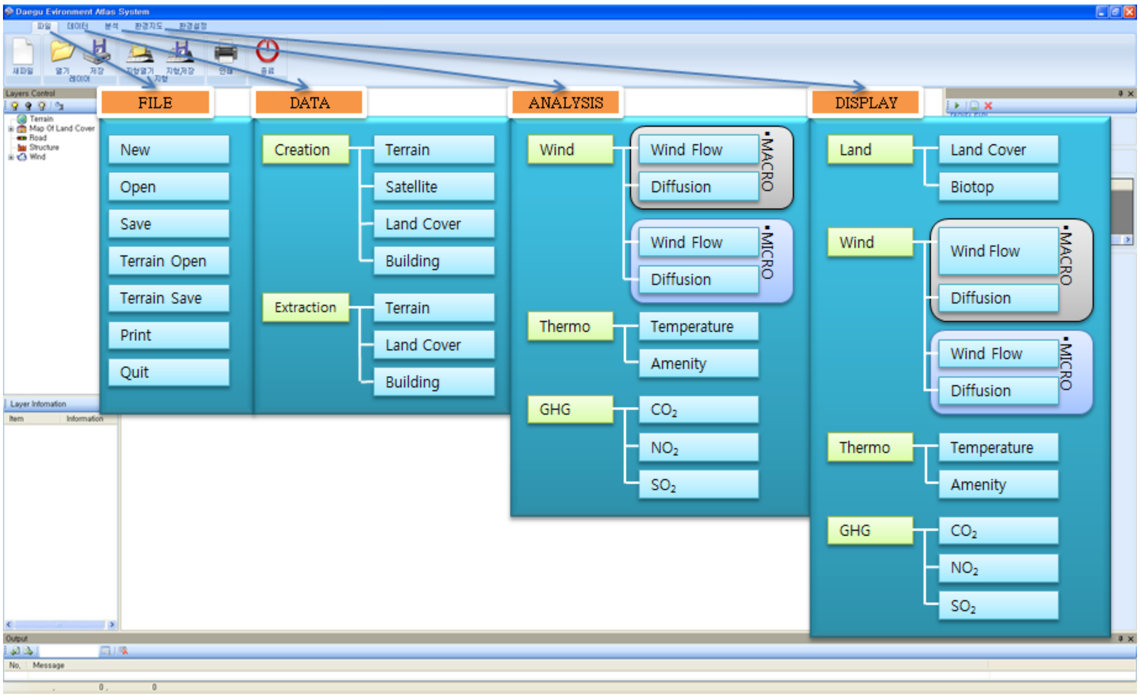

Fig. 2: System GUI

3.2 System Workflow

As aforementioned, the analyzing process of the system is substantially important to operate the microclimate system efficiently and draw the optimal result through this. Therefore, we intend to mention the specific details related to this in this chapter.

3.2.1 Cold-Wind Flow Analysis (Macro Scale)

As a first process for analysis of the microclimate, this means the process of analyzing the occurring areas and flows of the cold or fresh wind in the regional level. The cold wind blows to downtown ordinarily with forming in the mountain areas in the vicinity of downtown at night. As this cold wind has a crucial role in solving various environmental problems that the existing city has, the analysis of creation and flow should be conducted by top priority. Along with this, the results of analysis are utilized as the basic data for analysis of the optimal wind flow in the microscopic level that will be conducted in the next phase.

To analyze the creation and flow analysis of the cold wind in the regional level, the data related to topography on the object site, land cover and buildings, and the analysis of where the cold wind creates and flows in, is conducted based on this.

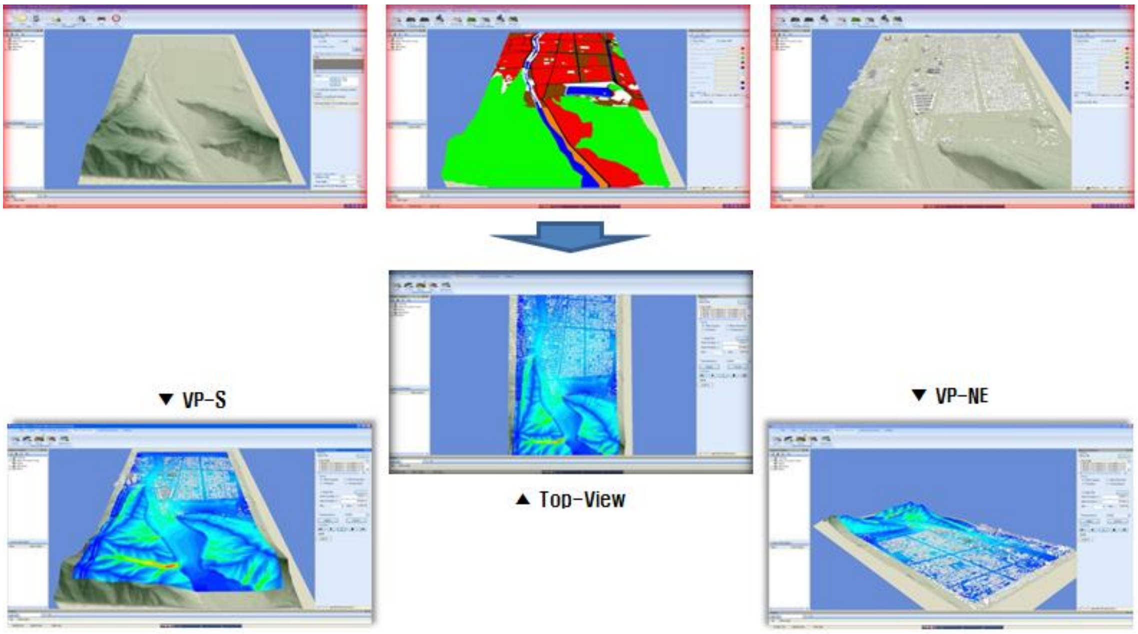

Fig. 3: Cold-Wind Flow Analysis (Macro-Scale)

3.2.2 Wind Flow Analysis (Micro Scale)

This is a phase of conducting an analysis of wind flow in the microscopic level, as the second process of the urban microclimate management system. To analyze the wind flow in the microscopic level, the data that are previously built in the macroscopic level can be utilized as they are. However, a step to set the main wind direction as the initial input values considering the cold wind flow results that have been drawn in the macroscopic level and the specific scope that is intended to be analyzed are necessary in addition.

We can draw the results of wind flow analysis in the microscopic level through this process, and can observe and assess the specific wind flow within the complex as shown in below picture.

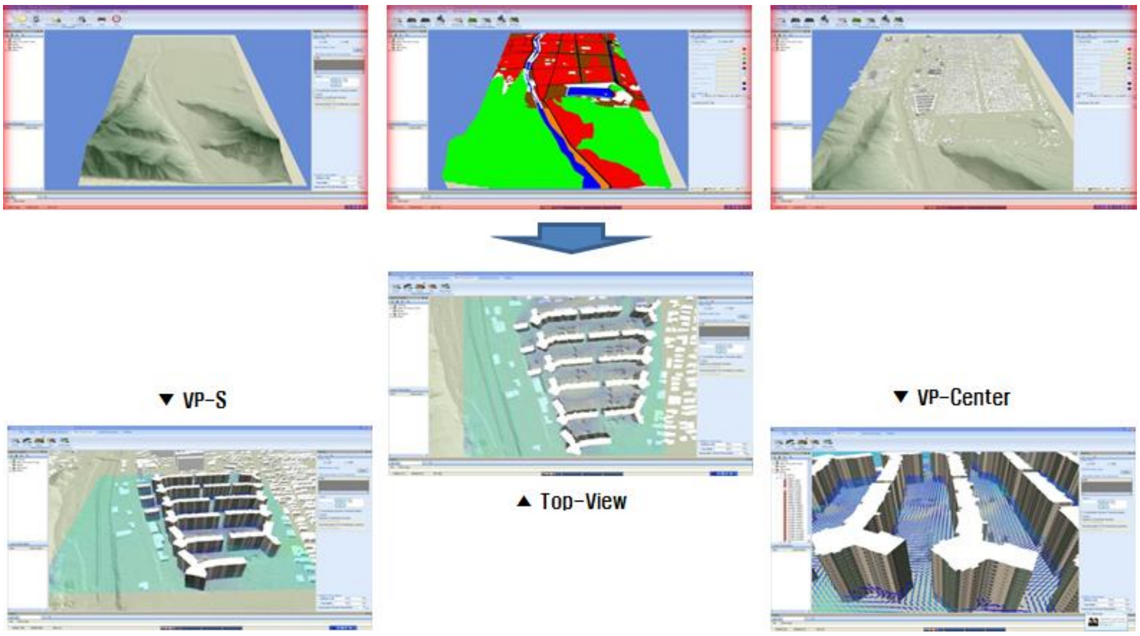

Fig. 4: Wind Flow Analysis (Micro-Scale)

3.2.3 Thermal Environment Analysis (Micro Scale)

Next is the thermal environment analysis phase. The analysis in this study is a phase of testing the possibility of further expansion of the system functions as aforementioned, and we intend to mean that we have checked the linking possibility with other modules up to now and mention that the analysis results still have a low reliability in advance.

For the thermal environment analysis, the data built in the microscopic level can be utilized as they are, and we can add the data related to the building materials more here. We can conduct the thermal environment analysis in the microscopic level through this. The results are shown as the below figure, and we can estimate and assess the change of the thermal environment according to the array of complex and type and materials of buildings.

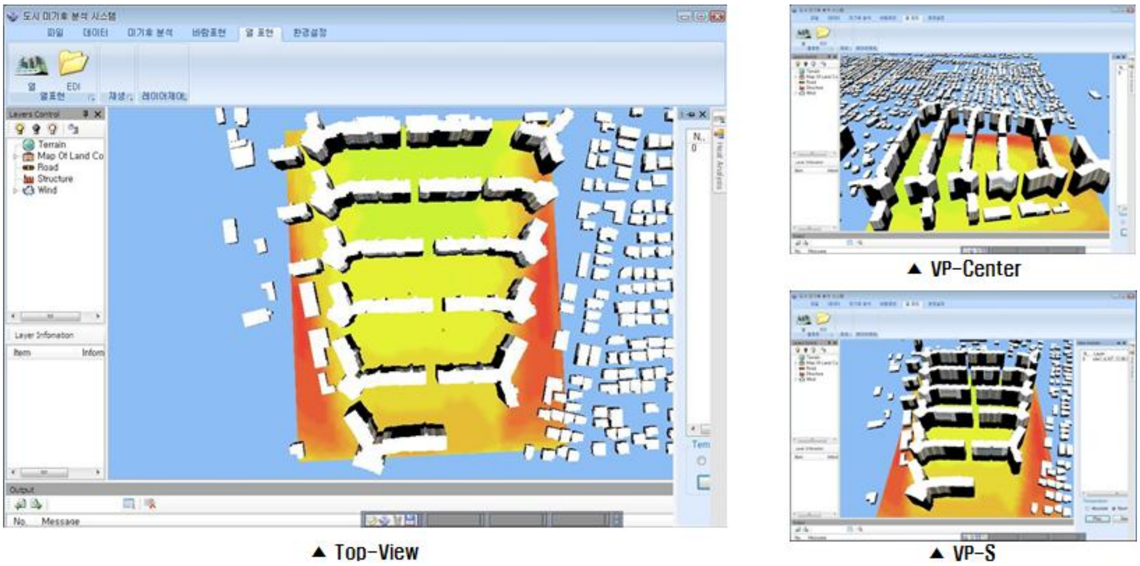

Fig. 5: Thermal Environment Analysis (Micro-Scale)

4 PILOT STUDY WITH UMCMS

In this chapter, we deal with the contents related to the Pilot Study to see the possibility of utilizing the previously developed microclimate management system, and intend to explain with focusing on the general status, planning details, and the results of the Pilot Study for the exampled site.

4.1 Outline of Study Area

4.1.1 Location

The exampled site is a regeneration project district within Gwangju Metropolitan City when has played a central role in the southwest areas, as one of 6 metropolitan cities in Korea. The details are shown in the below table, and this site is a place where the city regeneration project has been propelled after being designated as the demonstration project for residential environment enhancement from Ministry of Land, Transport And Marine Affairs with the reason of the quality declination of the residential areas due to the enhancement of the current decrepit buildings and the poor infrastructures.

Articles	Details
Location	Whole Area of No.202-27, Yangnim-Dong, Namgu, Gwangju Metropolitan City
Area	128,873m^2
Population	2,420 People
Household	1,133 Houses

Table 1: Summary of Study Area

Fig. 6: Location Map of Study Area

4.1.2 Climates Status

As to the detail climates in the exampled areas, the average temperature is 14.6 °C for one year in the object site and the vicinity of it, and the main wind is indicated as blown from north-northwest and south. As to the wind velocity, the blown wind in 0.5 m/s to 2.0 m/s velocity has taken up the largest portion by 54.3% of total.

Articles	Details
Average Temperature	14.6℃
Relative Humidity	68%
Main Wind Direction	NNS, S
Frequency of Wind Velocity	0.5-2.0 m/s: 54.3%
Frequency of Non Windy Condition	11.34%

Table 2: Climates Status of Study Area

4.2 Urban Regeneration Planning of Study Area

4.2.1 Purpose of Planning

The exampled site is a typical urban residence, in which is located in Nam-gu of Gwangju Metropolitan City, with the lining of decrepit buildings in current. Because of this, it is a district where a variety of programs have been propelled to promote the urban regeneration as the downtown of Gwangju Metropolitan City has been depressed. Also, the qualitative enhancement of the residence environment has been required as all the infrastructures necessary for the residential life have been substantially appalled. Besides, as there are many facilities that have substantial values historically in the object site and the vicinity of it, the necessity of their preservation has been also suggested. Therefore, it is a ultimate purpose of the urban generation project for this exampled site to improve the qualitative enhancement of residential environment by enhancement of the appalled infrastructure and improvement of decrepit buildings, and further to promote the urban regeneration through the linkage with the facilities that have historical and cultural values.

4.2.2 Details of Plan

Various specific plans for the exampled site have been established and propelled to achieve the purpose of the plan. If the details of the plan related to this study among them are put together, they are shown as followings.

Traditional Theme Street: The planning factor for utilizing the natural materials in the existing asphalt-centered street and realizing the traditional street by planting the street trees in the surroundings.

Streamlet-Street: The planning factor for providing the water-friendly space by building water-friendly space in the existing dreary street, especially, a small stream in the middle or at the edge of street.

Central Square (Community Center): The planning factor for restoring the center point and symbolism for local communities by using the environment-friendly or natural coating materials.

Traditional Parking Lot: The planning factor for restoring the traditionality by installing the traditional fence with using the pavement materials with permeability in the existing concrete-centered parking lots.

Waterfront Park: The planning factor for providing space where the residents can have an easy access and enjoy the rest as improving the space around the existing river.

Pocket Park: The planning factor for providing various resting space for residents within the object site.

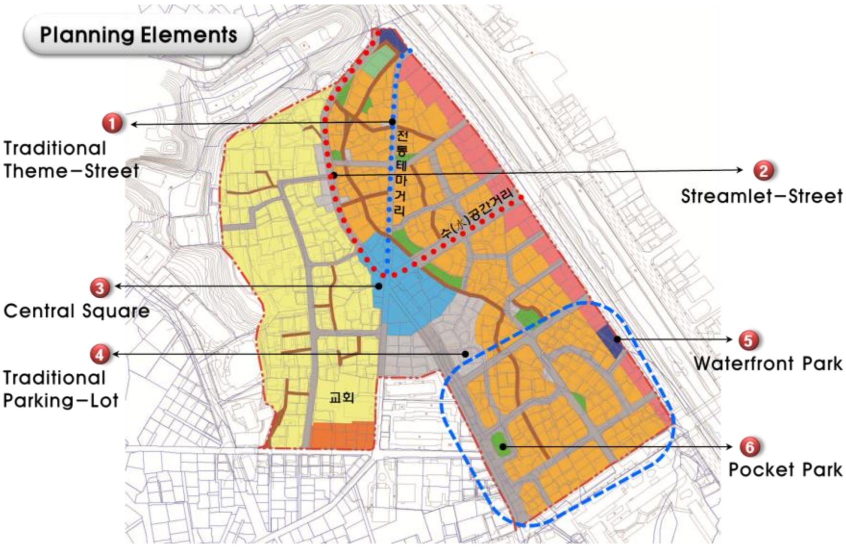

Fig. 7: Planning Details of Urban Regeneration Project for Study Area

4.3 Evaluation of Micro-Climate according to Urban Regeneration Planning

In this chapter, we intend to introduce the results of analyzing and assessing the degree of urban microclimate change according to the major planning factors related to the urban microclimate among various planning details of the urban regeneration project for the exampled site.

4.3.1 <u>Planning Element 1: Traditional Theme-Street</u>

The traditional theme street has a feature that the Korea beauty has been added by using stones, which is a natural material, not an artificial material for the materials for existing road pavement, and building the street trees and flower garden around it. It is a specialized street planned with 230m in total length and 10m in width(Fig. 9).

Seen the results of analyzing the degree of the urban microclimate change due to building this traditional theme-street, the wind velocity has increased as the wind velocity prior to the plan was indicated as 0.87 m/s of daily mean temperature, and the one after planning was indicated as 1.47 m/s of daily mean temperature. The temperature has been analyzed as reduced by 0.4 °C in average, as it is 26.8 °C of daily mean temperature prior to building the traditional theme-street, and 26.4 °C of daily mean temperature after building it. These velocity improvement and temperature falling effect can be said as the result that gives an awareness of importance of the road pavement materials and road width when improving the urban microclimate.

	Average Wind-Speed(m/s)	Average Temperature(℃)
Before	0.87	26.8
After	1.47	26.4

Table 3: Effect of Enhancing Urban Microclimate According to Building Traditional Theme-Street

4.3.2 <u>Planning Element 2: Streamlet-Street</u>

The streamlet-street is a planning factor that has been built to provide the more pleasant water front space to residents who live within the exampled site. The street has been planned with 250m in length and 6m in width along with Korean traditional floor pattern considering the traditional style(Fig. 10)

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Seen the degree of urban microclimate change according to building the streamlet-street, the wind velocity has been indicated as increased by 0.25 m/s in daily average, and the temperature change as reduced by 0.3 °C in daily average.

	Average Wind-Speed(m/s)	Average Temperature(℃)
Before	1.13	26.6
After	1.25	26.3

Table 4: Effect of Enhancing Microclimate According To Builing Streamlet-Street

Fig. 8: Example of Traditional Theme Street

Fig. 9: Example of Streamlet-Street

4.3.3 Planning Element 3: Central Square

The central square established to play a central point role in the community of residents and to impose the symbolism within the exampled site, is due to be built as 5,950 m2 in total areas and is planned to equip with fountains, resting spaces, playgrounds and community centers as detail facilities(Fig. 11).

Seen the effect of improving the urban microclimate through these central squares, the velocity has been indicated as increased by 0.26 m/s in daily average, and the temperature as reduced by 1.0 °C. Especially, when comparing the temperature change with other planning factors, it has shown the relatively high reduction effect. This can be concluded as the areas where the natural coating materials have taken up are relatively larger. Eventually, it is judged that the natural coating materials should be positively introduced to improve the temperature.

	Average Wind-Speed(m/s)	Average Temperature(℃)
Before	1.20	26.8
After	1.46	25.8

Table 5: Effect of Enhancing Microclimate According To Builing Central Square

4.3.4 Planning Element 4: Traditional Parking-Lot

This is a traditional parking lot planned to restoring traditionality by using the traditional fence and the floor pattern along with using the pavement materials with permeability in the existing concrete-centered parking lot(Fig. 11). The degree of urban microclimate change according to this is shown as followings. 6,070m2 of the total areas have been planned by being divided into 3 places within the exampled site. However, to conduct the specific and accurate analysis, we have conducted the analysis by selecting one traditional parking lot located in the center within the exampled site that has taken up 2,960m2 areas. Firstly, the wind velocity has indicated the improvement effect by 0.18 m/s, showing 1.22 m/s after applying the plan to the previous 1.04 m/s, and the temperature has indicated the temperature falling effect by 0.3 °C, showing 26.3 °C after applying the plan to the previous 1.04 m/s.

	Average Wind-Speed(m/s)	Average Temperature(℃)
Before	1.04	26.6
After	1.22	25.3

Table 6: Effect of Enhancing Microclimate According To Builing Traditional Parking-Lot

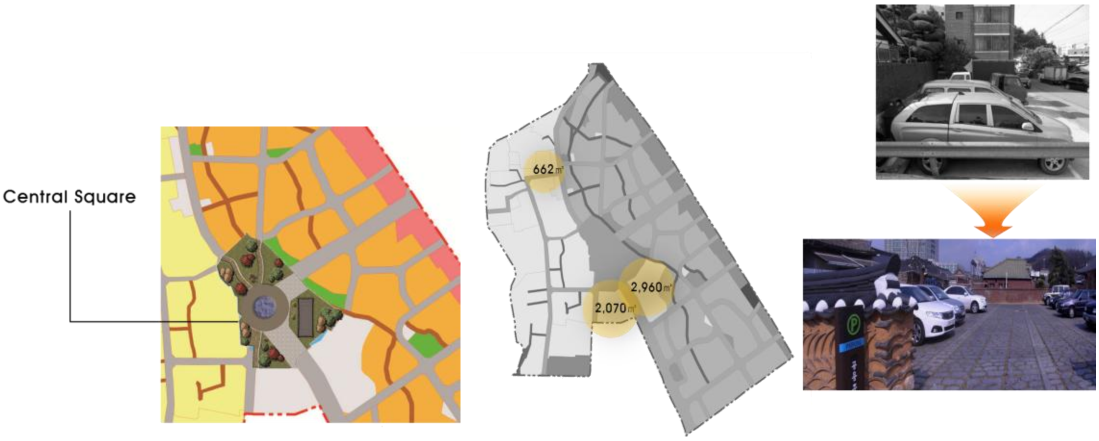

Fig. 10: Example of Central Square (Left) / Allocation and Example of Traditional Parking-Lot (Right)

4.3.5 Planning Element 5: Waterfront Park

The waterfront park planned to provide an easy access and space for enjoying rests to residents is a substantially important planning factor to residents when improving the spaces around the existing stream located in the east side of the exampled site. Therefore, it can be expected that the expecting effect for the degree of urban microclimate change is substantially huge in general, according to building the water front park. The analysis result according to this has also shown the degree of enhancement relatively better than other planning factors. Seen the result, the wind velocity has shown the enhancement effect by 0.99 m/s in daily average and the temperature has shown the one by 0.7 °C. In other words, it can be judged that the results are showing the biggest enhancement effect in wind velocity and the second biggest effect next to the central square in temperature.

	Average Wind-Speed(m/s)	Average Temperature(℃)
Before	0.36	26.9
After	1.35	25.2

Table 7: Effect of Enhancing Urban Microclimate According to Building Waterfront Park

4.3.6 Planning Element 6: Pocket Park

The result of the degree of the urban microclimate change according to the pocket park planned to provide various resting spaces to residents within the exampled site is shown as followings.

Firstly, the wind velocity has shown the enhancement effect by 0.77 m/s, changing from 0.34 m/s to 1.11 m/s, and the temperature has shown the same enhancement effect as the waterfront park, changing 27.0 °C to 26.3 °C. They can also be the result of empasizing the importance of the natural coating materials or nature-friendly structures more and more.

	Average Wind-Speed(m/s)	Average Temperature(℃)
Before	0.34	27.0
After	1.11	26.3

Table 8: Effect of Enhancing Urban Microclimate According to Building Pocket Park

If summarizing by putting together the degree of urban microclimate change according to various planning factors within the exampled site as above, it is shown as followings.

The common features of the planning factors, such as traditional theme-street, streamlet-street, central square, traditional parking-lot, waterfront park, and pocket park, is to replace and use the artificial coating materials actively to natural coating materials and to recommend the proper density. With the result of analyzing the urban microclimate within the exampled site utilizing the microclimate management system through these common features, it has been assessed that the average wind velocity has shown as increased by 0.2 m/s in daily average, changing from 0.82 m/s before the project to 1.12 m/s after the project, the average temperature has the temperature reducing effect by 0.57 °C, changing from 26.78 °C before the project to 26.21 °C after the project.

5 CONCLUSION

The construction of the low carbon and green city is a strategy established by the urban development policy due to the policy paradigm of low carbon and green growth in Korea, and one of the projects suggested to realize this specifically is a very urban regeneration project. However, it is the current status that there is lack of quantative assessment tools for the enhancement effect according to the urban regeneration projects, especially the assessment tools for urban microclimate. Therefore, we have developed the tools for assessing the urban microclimate comprehensive, and further percussed a possibility of utilizing the assessment tools by designating the actual exampled site.

With the result of it, it has been shown that there are enhancement effects in urban microclimate, such as wind and temperature, according to various planning factors, and that utilization of natural coating materials rather than artificial materials and securement of the waterfront have substantial effects on enhancement of the urban microclimate. It has been also assessed that the quantative results shown through utilizing the system have shown the enhancement effect by about 0.2 m/s in daily average for wind and the temperature falling effect by 0.57 °C in daily average for temperature.

We could acknowledge the possibility of stability and utilizability of the urban microclimate management system through these case studies. However, it is suggested that this system can have a higher utilizabilty if immediacy for drawing the analyzed values and reliability for the drawn result values can be backed up. Beside of this, if the practical functions, such as the emission analysis of green house gasses, are added more, the effective values of the system is expected to be expanded more and more.

6 ACKNOWLEDGEMENT

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