A STUDY OF A RESIDENTIAL ENVIRONMENT RISK ASSESSMENT METHOD FOR NATURAL GREEN AREAS WITH UNPLANNED FACTORIES IN KOREA USING THE CLIMATE CHANGE RISK ASSESSMENT MODEL - THE CASE OF SAWOL TOWN, INCHEON

[1]HONG, MYUNG-GI, [2]BAN, YONG-UN, [3]BECK, JONG-IN

[1,2,3]Department of Environmental Urban Chemical Engineering, Chungbuk National University, 1 ChunDae-ro, Seowon-gu, Cheongju, Republic of Korea
Email: [1]christian_zior@naver.com, [2]byubyu@chungbuk.ac.kr,[3]yahoback@gmail.com

Abstract - The South Korean government eased construction regulations to facilitate the construction and extension of factories even in nonurban green areas as well as industrial areas, and this accelerated the establishment of more factories. As a result, unwanted facilities including factories have continuously increased in nonurban areas such as natural green areas. The residential environment was further deteriorated due to the emissions of chemical substances, dusts, noise, and odor from such facilities. Existing studies of residential environment risks mainly focused on facility expansion and infrastructure improvement projects using residential environment improvement index and residential management index. Therefore, existing assessment frameworks are unable to properly estimate residents' health and the safety of environmentally unwanted facilities. Considering this, the present study developed a Residential Environment Risk Index based on the Climate Change Risk Assessment Model provided by the UNISDR and IPCC. Sawol Town, which once came to much public attention for the serious damages caused by the environmental impact of various unplanned workplaces such as factories, was selected as study receptor. The Residential Environment Risk Index of the town was calculated using ArcGIS, and the correlation between the index and the prevalence of diseases for the past 12 months was investigated. Residential environment risks were assessed in reference to the start point of thyroid disorders which are mainly caused by stress.

Keywords - Natural green areas, unplanned factories, Residential Environment Risk Index, residential environment suitability

I. INTRODUCTION

The lexical definition of residential environment is an environment closely related to housing life. Humans have long been interested in establishing a reliable residential environment to ensure a high quality of life from ancient times. For the same reason, numerous researchers have endeavored to objectively assess the residential environment. The conventional academic definition of residential environment refers to the entirety of conditions for living environment, namely the entire urban residential area which include individual housings within the defined area. This approach sets its focus on the comprehensive residential environment which incorporates both physical and nonphysical elements such as social, economic, cultural and natural environment, and emphasizes that a good residential environment must take safety, health, convenience, and comfort into account (Sangyeong Shin, Indicators and Evaluations of the Quality of Residential Environments in Seoul, 2008). Here, safety, health, convenience, and comfort are four basic concepts presented by the WHO as qualitative requirements for living environments. Each of them means 'to economically ensure the convenience of living', 'to provide a sufficient degree of esthetics and amenities', 'to facilitate the maintenance of physical and mental well-being', and 'to protect human lives and properties from natural disasters, fire, and crime' (1961, WHO). A number of existing studies established indices for residential environment on the basis of these concepts, and diagnosed the livability, and weaknesses in residential environment infrastructures through these indices.

On the other hand, the trends of past studies in South Korea on the diagnosis and assessment of residential environments mainly focused on deterioration and convenience such as accessibility to transportation and facilities and on renovation of residential environments based on housing safety such as crime prevention facilities. For this reason, existing studies were unable to properly assess the most fundamental basis of living – such as residents' health and environmental safety from unwanted facilities including unplanned factories near housings.

To this end, the present study selected Sawol as a receptor among various natural green areas as the town was brought to public attention for its environmental problems caused by unplanned factories. Based on the basic risk assessment model suggested by the UNISDR and IPCC, an index for residential environment suitability tailored to environmental aspects was developed through risk mapping and analysis of hazardous facilities in Sawol. The study ultimately aimed to assess the residential environment of the receptor Sawol through the developed index

II. PREVIOUS WORKS ON RESIDENTIAL ENVIRONMENT ASSESSMENT

Existing residential environment studies suggested various definitions of residential environment. Jutaek Lee (1993) defined it as general components of living within a given residential area. He maintained that residential environment is not only limited to clothing, food, and housing, but also covers physical, physiological, and psychological aspects of living such as physical and mental health, work efficiency, parenting, education, and protection of human emotion. JeongsuJin and Jongtaek Park (1998) claimed that residential, educational, and labor environments are subsets that comprise a natural environment, and the natural environment comprises all types of environments. Of these, residential environment is a set of tangible and intangible conditions including economy, society, and other physical conditions for housing.

Other than the definition of residential environment, a wide of range of studies offer various concepts of residential environment suitability in an effort to determine the suitability of a residential environment for living. Dongyang Yang (1994) defined the suitability of a residential environment using the concept of livability. He defined 'livability' in architecture and city as the minimum standards for artificial or natural residential environment for humans to lead a healthy life, or 'quality of life' in the physical environment which a city offers as a place for living. The residential environment suitability is represented by the degree of general satisfaction with the lifestyle in a given residential area, and various components of the physical space which comprises housing and life. Therefore, the degree varies depending on one's environment, life pattern, and values. Similarly, the concept of minimum housing standards provided in the Housing Act (Article 5, Clause 2) requires to establish minimum housing standards necessary to lead a healthy and comfortable life.

The standards of the Act stipulate that a housing shall have basic living facilities including water, sewage, kitchen, and toilet; meet the legal standards for environmental factors such as the strength of a structure for safety, sound absorption, ventilation, lighting, heating and cooling system, noise, vibration, and odor; and feature disaster prevention functions against unexpected natural and man-made disasters. In the discussion of quality of life, Mina Gang et al. (2014) defined the concept of housing welfare as 'enjoyment of life in a housing in which every member of society is able to pursue health and happiness.' Hyeongok Hong et al. (2008) claimed that the definition of the concept of housing welfare, its scope of application, and support measures vary depending on specific aspects of focus.

Existing studies on residential environment assessment established indices based on safety, health, convenience, and comfort suggested by the WHO, and developed assessment methods. Sangyeong Shin (2008) selected safety, convenience, comfort, and resource saving as 4 dimensions indicating outcomes of a residential environment. He used z-score for simple preliminary assessment which did not consider relative weight between assessment items and assessed the quality of the residential environment of the study site. In this study, data related to living environment such as noise were replaced with the ratio of roads of minimum 20m in width, ratio of manufacturing facilities, and separation distance from bars and clubs as it was not easy to obtain such data in the neighborhood under the Framework Act on Environmental Policy. However, this approach did not take potential pollution and the degree of environmental pollution caused by these facilities into account. Mina Gang, JeongsuJin (2014) established amenity, payability (housing), community safety (residential environment), convenience, health, and safety as components of housing and residential environment in their discussion of the concept of universal housing welfare. They selected Seoul, Cheongju city, and a rural area as study sites each representing a metropolitan city, small and medium-sized city, and village; and conducted a public opinion survey to estimate the public perception of the quality of housing welfare in each region. This survey identified factors lacking welfare through Important Performance Analysis (IPA). Unfortunately, this study selected only a few assessment items through multiple selection processes, and did not include crucial component of living environment such as noise, odor, water quality, and soil contamination as provided in Framework Act on Environmental Policy. As discussed, environmental indices were either missing in most of residential environment studies except for a few ones, or little has been investigated with respect to residential environmental assessment according to hazardous facilities although residential environment studies have been conducted intensively. This study defined residential environment suitability as a reciprocal number of residential environment risks in reference to existing studies. This concept should satisfy legal requirements for residents' rights to housing and environment. It is defined as a space that protects residents from the environmental impacts of hazardous facilities based within the residential environment, and a comfortable space that reduces fatigue and stress to ensure a high quality of life for residents.

III. DATA AND ASSESSMENT METHODS

3.1. Analysis data

Ageographic survey map using an unmanned aerial vehicle (UAV) was used to analyze the status of

Sawol, a green area inundated with unplanned factories. Attribute data required for mapping included disease prevalence data collected over the past 12 months, and residents' tolerance level data concerning noise, odor, and air pollution present in the residential environment and housing environment – which are part of the 'Environmental Pollution and Residents' Health Survey in Sawol, Seo-gu, Incheon' implemented by Dongguk University. Industrial workplace survey data collected by Dongguk University, and data provided by the Seo-gu Office were used in order to obtain the exact addresses of housings and industrial classification of factories. The health impact assessment manual for hygiene and public health, provided in the environmental impact assessment report (Ministry of Environment, 2013) was used to assign the degree of risk to each factory which were examined through the industrial workplace survey. Precisely, the separation distance and separation grading standards of Germany and Australia provided in the manual were used for reference.

3.2. Assessment method

The impact of each unplanned factory on the residential environment was quantified based on the basic model for climate change risk assessment developed by the UNISDR and IPCC. The risk model of this study consists of multiplicative estimation methods for hazard, exposure, and vulnerability. This study defined the Residential Environment Risk Index as follows:

$$RERI = \sum (H \times E) \times V$$

-H: Unique Potential Hazard of Workplaces
-E: Distance between residence and individual workplace
-V: Endurance Degree of affected Residents from workplaces

In the assessment of risks on the residential area, hazards presented by factories are defined as the potential of environmental impacts which an unplanned factory can have on the residential area in question. Germany and Australia established separation distance and grading standards to protect receptors which are sensitive to factories of different industrial categories. Industrial sectors of factories were categorized according to these data, and the hazard of a factory was classified into 7 grades accordingly.

Exposure is the physical distance between each residential area and the factory in question, and indicates how far the two are apart from each other. There are currently no suitable standards available in Korea. Therefore, separation distance and grading were established based on the odor intensity at which residents complained most.

Table1: 6-stage in bad odor intensity

Degree of odor	Odor intensity
0	None
1	Threshold
2	Moderate
3	Strong
4	Very Strong
5	Over Strong

source: KR Application

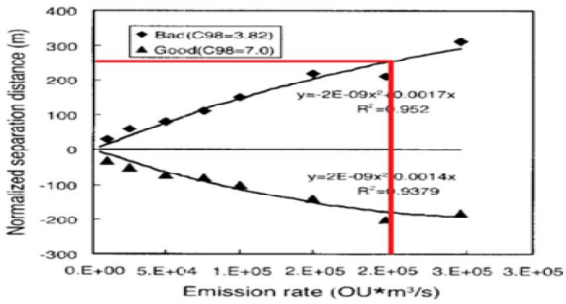

Fig.1. Computed emission rates as a function of selected measurement odor concentration
source: Sang JinJeong, 2002

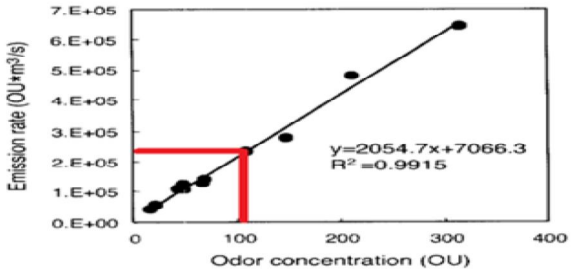

Fig.2. Effect of hedonic quality to annoyance distance
source: Sang JinJeong, 2002

The reference was 100 ou/m which people normally perceived as a moderate odor. The odor intensity 100 ou/m becomes unrecognizable when the air in the area is diluted 100 times with odorless air. In this case, thedegree of odor is 2 (SangyeongAn, Seongu Choi, 2006). SangjinJeong (2002) estimated that the mean measured odor concentration 100OU as $250000 OU \cdot m3/s$ of odor emission for a same unit area using the AUSPLUME model. The required separation distance for this level is 250m. Based on this, the separation distance was divided into 5 grades with a 50m interval from 0m to 250m, starting from the outer wall of each factory. Finally, vulnerability was estimated by subjective evaluation of residents affected by unplanned factories, and was defined as tolerance level according to the impact. Tolerance level here is a scale representing how unbearable the impact is. It was estimated with the 5-point Likert scale of our survey questionnaire.
Unplanned factory and residential area data from the Seo-gu Office and the industrial workplace survey were converted to spatial point data, and again to spatial polygon data through geocoding using the address information. This is used to calculate separation distance to assess the impact of factors

including noise and odor. The spatial data were then projected on the UAV-based geographic survey map. Industrial sectors were categorized using the German and Australian separation distance and grading standards according to sensitive receptors and factories by business sector. Hazard scores for unplanned factories were assigned to each grade from grade 1 to grade 7. A higher grade indicates a factory with a higher level of environmental impact. Welding factory is categorized as grade 1; wood processing factory as grade 2; heat treating and stone processing factories as grade 3; compost factory using earthworms as grade 4; chemical waste treatment plant as grade 5; aluminium smelter and animal carcass disposal plant as grade 6. Factories with furnace is grade 7 but does not exist within the receptor.

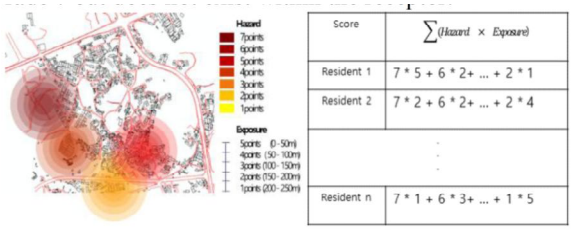

Fig.3. Risk Exposure Score Calculation Method

As suggested in Fig 3, buffer was applied to each factory based on the established data set, and the impacts of each unplanned factory on the residential area were quantified. These two types of values were then added up. Values acquired through this process were multiplied by the grade score of tolerance level per household which had been obtained through the survey. For the grading of tolerance level, the environment was divided into internal and external housing environments, and the maximum value per household was used among mean values of the 5-point scale tolerance level data for the items of living environment. Tolerance level items include air quality, exposure to odor and hazardous chemicals, water quality, soil, noise, vibration, light pollution, reduction of green area, indoor air quality, and indoor odor, noise, vibration, and lighting.

The final index of exposure to residential environment risks was graded with certain intervals. Correlation analysis was conducted on the Residential Environment Risk Index, and the prevalence of diseases in residents over the last 12 months in order to estimate the correlation between these two factors. Thyroid disorders mainly occur when fatigue and stress are not reduced as residents are not guaranteed the rights to proper housing within a residential area. The index score of exposure to residential environment risks of households with family members with thyroid disorders was categorized into grade 3.

IV. ANALYSIS RESULTS

4.1. Quantitative mapping of facility hazard

The locations of factories and 51 households with 114 residents were visualized by hazard score using ArcGIS. Buffers were applied to exposure scores, and the score of impact on residence was calculated therewith. As shown in Fig 4, light green points represent 51 housings. Unplanned factories were indicated with 6 colors from scarlet to ivory yellow on the map. As the industrial workplace survey of the upper area on the map was incomplete, impact scores of the upper area were calculated based on 36 housings and factories situated in the lower area of the map in order to conduct the assessment based on accurate values. 37 factories were categorized as hazard score grade 1; 13 as grade 2; 9 as grade 3; 1 as grade 4; 2 as grade 5; and 1 as grade 6. Blue dots indicate factories which were left without categorization during the industrial workplace survey, or due to lack of information. The orange area in the left and lower areas on the map are 4 recycled aggregate factories of the same category. These were considered as two large factories because each two factories are closely located from one another and belong to the same industrial category. The mapping results of exposure to each unplanned factory by the degree of hazard is shown in Fig 5.

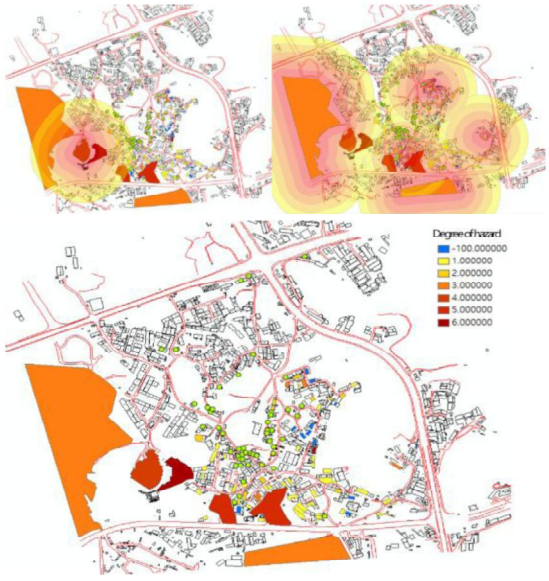

Fig.4. Map of hazard quantification

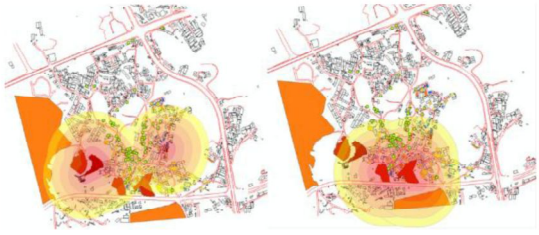

Fig.5. The mapping of the degree of exposure by risk to individual sites for housing

Table2: Hazard Exposure Vulnerability Score

Residence	$\sum(Hazard \times Exposure)$	$vulnerability$	$\sum(Hazard \times Exposure) \times vulnerability$
1	141	4	564
2	193	5	965
3	142	5	710
4	101	4	404
5	137	5	685
6	141	5	705
7	176	5	880
8	91	5	455
9	136	5	680
10	174	5	870
11	169	5	845
12	168	5	840
13	159	4	636
14	154	5	770
15	179	5	895
16	156	5	780
17	174	5	870
18	132	4	528
19	109	5	545
20	103	4	412
21	153	4	612
22	103	4	412
23	118	5	590
24	162	5	810
25	174	4	696
26	151	5	755
27	103	5	515
28	164	4	656
29	157	4	628
30	122	5	610
31	110	4	440
32	123	5	615
33	189	4	756
34	118	5	590
35	177	5	885
36	103	5	515

4.2. Assessment of the residential environment risk index

Tolerance level represents the vulnerability of 36 households which were confirmed to be under the environmental impacts of factories based in Sawol. This index was calculated in this section according to the following method. As shown in Table 2, the mean value of survey scores was calculated according to internal and external housing environments per person. Residential environment risk score was produced by assigning a maximum value to each household, and multiplying it with the previously discussed value $\sum(Risk \times Exposure)$.

In order to enhance the reliability of assessment standards, a correlation analysis was conducted between the 12-month disease prevalence data from the 'Environmental Pollution and Residents' Health Survey in Sawol, Seo-gu, Incheon' conducted by Dongguk University, and the obtained residential environment risk scores. The correlation of the two factors was estimated as 0.3926, and the p-value 0.0001412. Thus the correlation was significant.

Based on the correlation of these two factors, the start point of a specific disease was used as a grading criterion. Namgil Kim, Jaemyeong Ha (1996) suggested that environmental stress caused by negative environmental factors present in a residential environment affects physical and mental health, which may manifest in the form of cardiac function decline, thyroid disorders, or dyspepsia.

Yonggu Yu (2010) claimed that 80% of thyroid disorders can be explained by mental stress. Based on these arguments, it was assumed that residents were unable to relieve stress within their residential area and developed diseases, affected by the environmental impacts of nearby factories. In case a resident acquired a thyroid disorder, the Residential Environment Risk Index score of his household rounded to the nearest tens place was set as grade 3, and score interval was set with 100 point intervals. The Residential Environment Risk Index grading scale is shown in Fig 7 below.

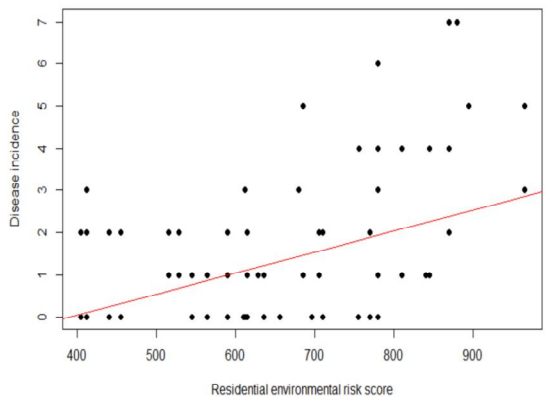

Fig.6. Residential environmental risk score - Disease incidence scatter plot

5(730 –)	Observation of deaths
4(630 – 729)	
3(530 – 629)	528 points- Observation of first thyroid disease patient (Rounds)
2(430 – 529)	
1(0 – 429)	

Fig.7. Residential Environmental Risk Index Scale

The residential environment risks of Sawol were assessed according to the grading scale of Fig 7. Of 35 households subject to the residential environment risk assessment, those with grade 3 (high risk) or higher were 27 accounting for about 97%; those with grade 4 (extreme risk) were 19, accounting for 54%.

CONCLUSIONS

Currently, the process of environmental impact assessment is often simplified in many development projects in South Korea. The South Korean government held the the first meeting for regulatory reform and national policy reform chaired by Prime Minister in July 2015. This largely eased constructional regulations to facilitate the construction and extension of factories in nonurban areas, which even included natural green areas, as well as industrial districts. Further, the deregulation resulted in a practice of simplifying or omitting environmental impact assessment. These measures accelerated the construction of unplanned factories, and the consequences are attested by the fact that 64.9% of newly constructed factories by June 2017 were unplanned (Industrial Land Service, 2017). Due to the regulatory reforms, nonurban areas including natural green areas had to accommodate an increasing number of unwanted facilities. Chemicals, dusts, noise, and odor emitted from such facilities deteriorated the residential environments at a remarkable speed. Nonetheless, existing studies of residential environment assessment failed to establish a reliable assessment framework for public health and the safety of environmentally unwanted facilities because they mainly focused on facility extension and infrastructure improvement projects using residential environment improvement index and housing management index.

This study attempted to establish an assessment framework for areas where many unplanned factories are constructed. It defined residential environment suitability specifically for the Sawol Town in Incheon, and established a method for residential environment risk assessment based on the Climate Change Risk Assessment Model.

This study bears several limitations, and concludes by suggesting future study topics. First, the sample size was remarkably small due to the introduction of the new assessment tool. This made it difficult to draw significant results from the statistical analysis. It is

required to reinforce the sample through follow-up studies, which will improve the reliability of the assessment framework.

Second, it was not possible to survey the impact that each residential area received due to the incomplete factory data as some factories and individuals refused to cooperate for the workplace survey. A legal foundation for residential environment risk assessment should precede to facilitate follow-up studies on residential environment suitability assessment. Data collection and establishment in the future shall be supported by governmental authority.

Finally, it was not possible to test the explanatory power of the index of exposure to residential environment risks for the prevalence and status of diseases in residents living in housings within the town based on the correlation analysis alone. Therefore, future studies shall identify factors related to disease prevalence through a further theoretical discussion. It is recommended to conduct regression analysis to control various variables in order to better demonstrate the explanatory power of the index of exposure to residential environment risks for the prevalence and status of diseases in humans.

ACKNOWLEDGMENTS

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2016S1A5B6914198)

REFERENCES

[1] Lee, Joo-Taek, 1993. “A Study on Factor Structure of the Degree of Satisfaction with Residential Environment ”, Dongguk University graduate school, doctoral thesis

[2] Jeong-suJin· Jong-Taek Park. 1988.「Policies to improve the quality of residential environment」, KRIHS.

[3] Sang-Young Shin, 2008.「Indicators and Evaluations of the Quality of Residential Environments in Seoul」, The Seoul Institute.

[4] SeoMin-Ho·KimSei-Yong, 2012. “A Review of Ambiguous Concepts on the Urban Livability Discourse”,「JOURNAL OF THE ARCHITECTURAL INSTITUTE OF KOREA Planning & Design」, 28(4):211-222.

[5] YangDong-Yang·Yoo, SeungMoo·Park, Hyong-Suk·Nam, Young-Woo, 1994. “A study on the habitability in Mixed-Use Development ”,「 JOURNAL OF THE ARCHITECTURAL INSTITUTE OF KOREA 」, 10(10):145-158.

[6] The minimum housing standard in accordance with the Administrative Regulations, 2011, Ministry of Land Transport and Dwelling, Housing Welfare Policy Division

[7] Hong, Hyung-Ock·Chea, Hye-Won·Choi, Eun-Hee, 2008. “A Study on Development of the Objective Indicators of Housing Welfare”,「 JOURNAL OF THE KOREAN HOUSING ASSOCIATION」, 19(5):77-84.

[8] Mi-na Kang ·Jeong-suJin· Hong-giAhn·Mi-kyeong Yu. 2014.「A Study on the Housing Welfare Indices」, KRIHS.

[9] Sang-Young Ahn·Sung-Woo Choi, 2006. “Evaluation of Malodor Emissions Using the ISCST3 in Industrial Complex Area”,「Journal of Korean Society of Odor Research and Engineering」, 5(1):19-25.

[10] Sang JinJeong, 2002. “A Study on Separation Distance between Industrial Source and Residential Areas to Avoid Odor Annoyance Using AUSPLUME Model”,「Journal of Korean Society for Atmospheric Environment」, 18(5):393-400.

[11] Nan-Gil Kim·Ha, Jae-Myung. 1996. “Fundamental Study on Relationship between Perception of Environmental Stress and Healthy Behavior in Residential Environment”,「JOURNAL OF RHE KOREAN HOUSING ASSOCIATION」,7(2):9-17.

[12] Yu, Yong-gu, 2010. AUTO JOURNAL : Journal of the Korean Society of Automotive Engineers, 32(8):94-95.

[13] 2013, “Health Impact Assessment Manual for the Preparation of Hygiene and Public Health Items in the Environmental Impact Assessment”, Ministry of Environment, Environmental, Health Policy Office.

★★★