A Study on Carbon-neutral Parks based on the Functions of urban park to solve urban problems

By

KIM, Taewoo

CAPSTONE PROJECT

Submitted to

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ABSTRACT

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The recent increase in global average temperature is causing various global problems such as water scarcity, the risk of starvation, and degradation of biodiversity. It is mainly attributable to the emission of greenhouse gases due to population growth and industrialization. Especially, since 92% of Korea's population is concentrated in cities that account for 17% of the country's land, urban parks are very important not only in solving urban problems, but also in acting as a carbon sink for the cities.

According to urban problems, urban parks are classified into landscape improvement and leisure, environmental welfare, environmental pressure reduction, and social function in this study. In order to confirm the carbon absorption capacity of urban parks, the basic unit of carbon emission based on materials was calculated through the review of previous studies and the carbon absorption model depending on the type of trees was applied. Among Sihwa MTV neighborhood parks that are closely related to urban problems, three types of parks that have been completed were selected as target sites. Neighborhood Park No. 46 is a leisure-use park with a land area of 10,789 m2 and a green area ratio of 61%, and various types of facilities have been introduced. Assuming that the life cycle of the neighborhood park is 30 years, it is estimated that the park release about 91.4 tons of carbon. Neighborhood Park No. 63 is an environmental welfare type park with a land area of 10,115 m2 and a green area ratio of 71.4%, and it is estimated that the park emits about 86.5 tons of carbon even though few facilities were introduced. The main part of the park consists of green areas centered on grass, and pines and shrubs with low carbon absorption capacity. Neighborhood Park No. 67 is an

environmental welfare type park with a land area of 12,684 m2 and a green area ratio of 85.1% and was estimated to absorb about 46.9 tons of carbon. The park's carbon absorption capacity seems to be due to the introduction of many small-sized trees with high carbon absorption capacity.

Through the above case study, I would like to suggest the following as a guideline for carbon neutral parks. Firstly, considering that carbon emissions from the manufacturing process of packaging facilities account for more than half of the park's carbon emissions, the government and ordering departments should encourage the active development and use of Environmental Product Declaration product, and natural materials such as clay and wood with low carbon emission should be used as packaging materials. Secondly, since lawn maintenance has a lot of carbon emissions, it is necessary to avoid introducing a wide area of lawn. finally, medium and small sized trees with high carbon absorption capacity should be planted together, and the planting density should be adjusted for future growth, and active management should be accompanied to prevent dead trees.

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1. Introduction

1.1 Background and purpose

Recent climate change is a global phenomenon. The people in North America are constantly experiencing extreme heatwaves and the people in Western Europe have been experiencing massive flood damage every year. In addition, the number of heatwave days in Seoul, the capital of Korea, increased four times in 2016 and five times in 2018 compared to the average number of heatwave days (5.9 days) in the past 30 years. According to the special report of global warming of 1.5℃ published by the Intergovernmental Panel on Climate Change (IPCC) in 2018. It warned that if the surface temperature rises by more than 2°C, it will be impossible to stop the global climate change due to biodiversity loss, glacier loss, and sea level rise. And it required countries around the world to take immediate action to limit the increase in global temperature to within 1.5°C. According to a United Nations research report, it tells us 200 million people in the world will be at risk of starvation, and more than 1 billion people will suffer from water problems if the global average temperature increases by 2°C.

Because of this background, the Paris Agreement has been proposed as a new climate agreement to be applied after 2020. Under this agreement, 195 countries have signed an agreement to phase out greenhouse gas emissions so that the global average temperature does not exceed 2°C. Korea aims to reduce it by 37% compared to its forecast for 2030. The U.S. has set a goal of carbon neutrality by 2050 and China, the world's largest emitter of carbon, has also declared a goal of carbon neutrality by 2060. Along with the global awareness of the global crisis, the quantitative economic feasibility of carbon reduction became effective. The company's carbon emission trading scheme was first introduced in the EU in 2005, and Korea has been enforced since 2015 when the Paris Agreement was adopted. The price of the emission rights which was 8,640 won/ton on January 12, 2015, rose more than 4 times over the four years to 38,000 won/ton at the end of ‘19 and formed a price of around 42,000 won/ton, up about 5 times in April 2020. Moreover, according to the National Greenhouse Gas Inventory Report published by the Greenhouse Gas inventory and research Center of the Ministry of Environment, Korea’s total greenhouse gas emissions in 2017 are 6th among the UNFCCC Annex I countries, behind the United States, Russia, Japan, Germany, and Canada, which emit very high levels of greenhouse gases. For this reason, the Korean government has declared to achieve carbon reduction rate of 37% compared to the 2030 projection and carbon neutrality by 2050. The Korean version of the Green New Deal policy was announced to create 660,000 jobs at a cost of 73.4 trillion won by 2025 around July 2020 in order to comply with the Paris Agreement.

To reduce carbon, we need to reduce carbon emissions, replace energy sources, or increase carbon sinks. In Korea, forests occupy 64% of the country, and cities account for only 17% of the country. Moreover, Korea ranks third in world population density among countries with a population of more than 10 million. Therefore, considering the domestic conditions, it seems relatively suitable to create an efficient carbon sink for carbon reduction in korea. In particular, urban parks can solve various urban problems as well as serve as a pleasant carbon sink in the city. In general, urban parks introduced carbon sinks into the city to improve the health and comfort of citizens and pursue leisure use. Nevertheless, solving urban problems and the role of carbon sinks are not always proportional. According to Park (2020) examining the carbon balance of the entire process of urban parks, 4 out of 30 urban parks had more carbon emissions than carbon absorbers. Since this excludes the carbon emissions of facilities, carbon emissions are actually expected to be higher. McPherson et al. (2015) quantified 50-year lifecycle carbon balance for the willow tree planting in Los Angeles. Surprisingly, the emissions outweighed the stocks in the high-emission scenario. Therefore, the purpose of this study is to solve urban problems through urban parks, and they fulfill the role of a carbon sink at the same time. To achieve this, the carbon balance of urban parks was evaluated based on existing studies, and it was intended to present guidelines for the composition of urban parks on the premise of carbon sinks.

1.2 Research Process

This research project makes sense in reducing the carbon emitted by the facilities, pavement, and vegetation introduced in urban parks, and increasing the carbon absorption of the trees in the park without abandoning the traditional value of urban parks. Therefore, firstly, I described the history and function of urban parks, and mentioned inappropriate park facilities. And then, I classified the types of urban parks according to the purpose prescribed by the law, and classified the parks into 4 types according to the function of green areas based on these. Secondly, the basic unit of carbon emission based on materials was calculated through the review of previous studies in order to evaluate the carbon emission of urban parks. Then, the carbon uptake of each major tree species was calculated for 30 years, the life cycle of the park, by applying the carbon absorption model of trees previously studied. Thirdly, three parks that have been completed were selected for research among the neighborhood parks in Sihwa MTV that are closely related to urban problems. Then, the type and purpose of the park were described, and facilities and vegetation introduced into the park were analyzed. Moreover, the carbon absorption and emissions amount of the park were evaluated through the carbon balance evaluation tool, and a plan to improve the park's carbon balance was suggested while maintaining the values pursued by the traditional park. Finally, I presented guidelines such as spatial composition, introduction facilities and vegetation for improving the carbon balance of urban parks with reference to the analysis results and methods to improve the carbon balance of urban parks.

Research Background and Purpose	➜	Review of previous studies	➜	Development of Carbon balance assessment tool	➜
Development of Carbon balance assessment tool	➜	Analysis of park types, vegetation, and introduction facilities	➜	Selection of parks for study	➜
Carbon balance assessment	➜	Park Guidelines for Carbon balance Improvement			

Table 1 Research performance system diagram

2. Urban Parks Overview

2.1 History of Urban Parks and Park Facilities

Urban parks are stipulated in the Park & Green Act as urban planning facilities designed to protect the natural landscape of the city and to improve the health, recreation and emotional life of citizens. The beginning of the park was to open the gardens of the ruling class to the public on special days such as festivals. The first public park was Birkenhead Park, established in 1847 to improve the quality of life and maintain health of urban workers after the Industrial Revolution in England in the 19th century. Under the influence of this park, the Central Park with a size of 341 hectares was built in 1856 in Manhattan, New York, the most expensive land in the United States.

The origin of the park system in Korea was that the Urban Planning Act of 1961 stipulated that it was designated as a public facility in terms of preserving natural landscapes, and a separate Urban Park Act was enacted in 1980. In 2005, the Park & Green Act was enacted as a complete revision of the Urban Parks Act. According to Article 5 of the amended Park & Green Act, the mayor is required to establish a basic urban park plan every 10 years. Article 3 of the Enforcement Rule in the same law specifies the types of park facilities that can be introduced into urban parks (Table 2). However, there are many facilities that overlap with the Building Act or the Act about the installation of sports facilities or do not fit the actual situation. Fishing grounds, large marts, shopping centers, players-only lodgings, bowling alleys, etc. do not meet the purpose of urban parks, and it is necessary to install in separate sites as building or sports facilities. In addition, the heterogeneous use may cause discomfort to park users, and it is also negative in terms of carbon absorption in the park. However, large parks such as national city parks and metropolitan area parks have sufficient buffer space, so it seems possible to accommodate limitedly large buildings or sports facilities.

Park Facilities	Species
Landscaping Facilities	Lawns, drinking fountains, hedgerows, shade trunks, nails, waterfalls, etc.
Recreation Facilities	Camping Ground, Pathway Party, Senior Welfare Hall, Arboretum, etc.
Entertainment Facilities	Seesaw, jungle gym, ladder, adventure playground, circular turn, amusement park, foot playground, boat playground, fishing ground, etc.
Sports Facilities	Basketball court, billiards court, racquetball court, volleyball court, bowling alley, wrestling court, baseball field, golf course, artificial rock closet, soccer field, gymnastics court, fitness center, sleigh shop, horse riding ground, etc.
Liberal arts facilities	Library, Reading Room, Greenhouse, Outdoor Theater, Art Museum, Children's Home, Kindergarten, Celestial Facilities, Performance Hall, etc.

Park Management Facilities	Warehouses, garages, bulletin boards, signs, lighting facilities, closed circuits, garbage disposal sites, trash cans, water tap, solar energy facilities, etc.
convenience facilities	Post boxes, public telephone rooms, restaurants, pharmacies, luggage depository offices, observation decks, clock towers, drinking fountain, bakeries, photo studios, youth hostels, players' accommodation, shopping centers, etc.
Urban Agricultural Facilities	Gardens, greenhouses, hotbeds, compost fields, watering and water supply facilities, washbasins, washing farms, etc.
Other facilities	Burial facilities, animal playgrounds, historical facilities, Veterans Hall, unmanned power training grounds, etc.

Table 2 Types of park facilities (Enforcement Regulations of the Park and Green Act)

2.2 Recent trends in urban parks and types of urban parks to be studied

The Enforcement Rules of the Urban Parks Act stipulates that the park area per person is 6m^2 or more, and the OECD recommends 9m^2. As of the end of 2016, the park area per capita in developed countries was 26.9 m^2 in the UK (London), 27.9 m^2 in Germany (Berlin), and 18.6 m^2 in the United States (New York), which is significantly higher than that of developing countries. In Korea, as shown in Table 3, the area of urban parks per capita has been increasing since 2010. Surprisingly Parks in large cities with high population density and sensitive property rights of city residents are showing a tendency to be expanded (Kim, 2021). Therefore, it is necessary to efficiently utilize the expanded urban parks to not only solve traditional urban problems, but also contribute to carbon neutrality in the city.

Table 3 Per Capita Urban Park space (National and Metropolitan City)

administrative division	2016	2017	2018	2019
Nationwide	9.2	9.6	10.1	10.5
Seoul	8.0	8.1	8.3	8.4
Busan	5.7	6.6	6.9	12.2
Daegu	4.9	4.9	5.0	5.1
Incheon	11.3	11.2	11.7	10.8
Kwangju	6.2	6.1	7.4	6.9
Taiden	8.6	10.3	12.2	10.9
Ulsan	9.1	9.4	9.4	10.6
Sejong	102.2	84.1	76.2	69

Note: Integrated data of the Ministry of Land, Transport, and Maritime Affairs

Urban parks are divided into national urban parks, living area parks, and theme parks by Article 15 of the lex of the Park & Green Act according to their purpose, and further subdivided according to function and theme. Their attraction distance and size are determined by Article 6 of the Enforcement Rule of the Park Green Act for urban park types classified in detail (Table 4). Some of these parks are not suitable to be developed as carbon sinks. Instead of making large green spaces in small urban parks, it is efficient to arrange appropriate facilities for local residents to relax, cultivate emotions, and form a community. Theme parks for specific purposes are also not suitable as carbon sinks. It is not easy to use them as a carbon sink since specific facilities must be introduced in accordance with the scale for children's parks, cemetery parks and urban agricultural parks, etc. On the other hand, national urban parks and greater area parks should actively use as carbon sinks because of their large area. However, since various carbon emission sources are arranged and it is difficult to quantify the carbon balance, they were excluded from this study. Therefore, the scope of urban parks as the research object includes neighborhood parks (10,000 m^2 ~ 100,000 m^2), historical parks, cultural parks, and waterfront parks. For this reason, the actual study objects were three neighborhood parks with an area of about 10,000 m^2.

Park Division	Purpose of installation	Attraction distance	scale
1. National Urban Parks	The preservation of history, culture, national memorial project, natural landscape.		More than 3,000,000㎡
2. Life Zone Park			
A. Small Park	Rest and emotional development of urban citizens	No limit	No limit
B. Children's Park	Children's Health and Emotional Life	Less than 250m	More than 1,500㎡
C. Neighborhood Park	Health, recreation, emotional life		
1) Neighborhood life zone Neighborhood Park	Use of nearby residents	Less than 500m	More than 10,000㎡
2) Walking zone Neighborhood Park	Use of Walking zone residents	Less than 1,000m	More than 30,000㎡
3) Urban Area zone Neighborhood Park	Comprehensive use of all residents in urban areas	No limit	More than 100,000㎡
4) Greater area zone Neighborhood Park	Wide use beyond one urban area	No limit	More than 1,000,000㎡
3. Theme Park			

A. Historical Park	Relaxation and education of urban citizens	No limit	No limit
B. Cultural Parks	Relaxation and education of urban citizens	No limit	No limit
C. Waterside Park	Use of waterside space, leisure and relaxation for urban citizens	No limit	No limit
D. Cemetery Park	Mixing cemeteries and park facilities in natural green areas	No limit	More than 100,000㎡
E. Sports Park	Cultivating a healthy body and mind	No limit	More than 10,000㎡
F. Urban Agricultural Park	Purifing your emotions and developing the sense of community	No limit	More than 10,000㎡
G. Disaster Prevention Park	Evacuation and relief in the event of disasters	No limit	No limit

Table 4 Purpose and Scale of Urban Parks (Park and Green Act and Enforcement Regulations of the same Act)

3. Review of Previous Research

3.1 The pluralistic function of green space to solve urban problems

Urban problems arise due to urban industrialization and concentration, and research on green spaces to solve urban problems should focus on the functions of green spaces. Therefore, I intend to classify urban parks by function through the review of previous studies.

Huh (2001) classified the functions of green spaces into relaxation and entertainment, social and aesthetic functions, ecological and environmental preservation functions, safety maintenance and disaster prevention functions, and central functions. Kim (2021) described the pluralistic functions of trees, such as air purification, adsorption of fine dust, improvement of microclimate, noise reduction, provision of habitat for wild animals, enhancement of landscape beauty, and provision of well-being and healing functions. According to a study (Park, 2018) that investigated the relationship between the health promotion of the elderly and the park, satisfaction with the park's walking path environment had an effect on the number of walking days and total walking time, and walking accessibility was inversely related to chronic disease. Seong (2020) investigated the stress index, blood pressure, and pulse rate to analyze the healing effect after walking activities under different walking environments. As a result, the decrease in the stress index was highest in the water and forest coexistence boardwalk (10.8%), and the decrease in systolic blood pressure was the highest in the forest boardwalk (10.3%). Pulse variability and RMSSD were only effective on water and forest trails. Water and forest trails also had the highest psychological response index, and this result was similar to that of Lee (2009)'s previous study. As a result, walking activity reduced stress and blood pressure, induced a sense of physiological relaxation, and had the effect of decreasing psychologically negative emotions and increasing vitality. Wang (2020) attempted to analyze the price according to the distance between Central Park and nearby apartments in Pyeongchon New Town in Anyang, Gyeonggi-do. In multiple regression analysis, time to park, number of households, the age of the building, time to school, and time to subway were analyzed as dependent variables. If it takes one more minute from the apartment to the park, the apartment price decreases by 576,000 won/m2, which is showing the high economic value of the urban parks. Yoon and Ahn (2009) confirmed that there is an average difference of 0.78℃ in temperature between green areas and general urban areas. Jin (2020) evaluated the seasonal changes in leaf microstructure and fine dust removal amount of five kinds of roadside trees such as Bamboo-leaf oak, Ring-cup oak, Willow-leaf evergreen oak, Yoshino cherry and Camellia in southern Korea., The absorption rate of fine dust for Willow-leaf evergreen oak was high since it had grooves and hairs on the leaf surface and has a lot of wax. On the other hand, the glossy camellia and Yoshino cherry tree with soft leaves had a low absorption rate. The absorption rate was about 54.4% higher in January than in May. According to the study about roadside trees along s in Yong-san city by Jo and Ann (2001) on the air purification effect of trees, the absorption of SO_2 was 1.0±0.4 kg/ha/yr, and the absorption of NO_2 was 2.0±0.4 kg/ha/yr in commercial and industrial area. Kwon (2019) had studied the plan to improve the water balance of urban parks through the calculation of the outflow coefficient by land cover type. Each outflow coefficients of vegetation ground, permeable block (permeable pavement), and clay block (semi-permeable) were 0.963, 0.583, and 0.245. Water permeable packaging included compaction of coarse sand, sand laying, grass protection block, and colored permeable asphalt concrete. Lee (2018) suggested zelkova, ginkgo, yellow-poplar, and oyster oak as fire-resistant species for earthquake and fire prevention. Lee (2018) suggested zelkova, ginkgo, yellow-poplar, and oyster oak as fire-resistant species for earthquake and fire prevention. Kim (2020) analyzed how much green space reduces non-point pollution sources for the Han River ecological Learning Center, Gwangju and Yongin restoration areas in Gyeonggi-do, etc. Each regions showed reduction effects in the range of 31.3~47.3%, 27.0~56.9%, and 34.8~100% based on BOD standards.

Based on the previous studies, the functions of green spaces can be divided into landscape improvement and leisure utilization, environmental pressure reduction, environmental welfare, and social roles. If landscape improvement and leisure utilization are traditional functions of urban parks, recently, environmental pressure reduction and environmental welfare are being emphasized as functions of urban parks.

3.2 Weighing of carbon emissions

The domestic official methods for quantifying carbon emissions are the national greenhouse gas inventory report and EPD (environmental Product Declaration). The GIR (Greenhouse gas Inventory and Research center) was established in 2010 under the Ministry of Environment and is carrying out systematic support work about the management of the national greenhouse gas emission list and setting of greenhouse gas reduction goals. And, GIR has been issuing national greenhouse gas emission and absorption coefficients and national greenhouse gas inventory reports for major fields from 2012. The EPD is a system that quantifies and displays the environmental impact of products through specialized institutions. It started to be implemented in 2001. The status of certified products with EPD including the carbon footprint is announced every month through the life cycle evaluation. As a result of national efforts to reduce greenhouse gas, the status of certified products is increasing rapidly, including some landscaping facilities used in parks.

On the other hand, researches to quantify carbon emissions have been conducted in domestic and overseas academic fields. The studies on carbon emissions for major construction materials has been mainly conducted in the field of architecture, and in the field of landscaping, research on carbon emission quantification for introduced trees and landscaping facilities has been conducted in connection with urban parks. The previous studies on major construction materials have been begun in earnest from when the KICT (Korea Institute of Civil engineering and building Technology) created the basic units of carbon emission for 404 major construction materials in 2004. The main carbon emission basic units include 0.001 kg/kg for sand, 0.073 kg/kg for gypsum board, 0.088 kg/kg for cement, and 0.956 kg/kg for rebars. Kim et al. (2004) investigated plastics, phenolic resins, rubber sheets, crushed stone, etc. Lee and Yang (2009) investigated packaging materials, major building materials, and management materials using the industry-related analysis method. They used the same method in 2010 to investigate construction materials such as polypropylene. Six materials of concrete, rebar, glass, gypsum board, insulation, and concrete bricks accounted for more than 95% of the RC group on average (Lee, 2017), Seven materials of ready-mixed concrete, rebar, steel frame, paint, glass, insulation, and concrete products emitted more than 95% of greenhouse gases in the SRC structure apartment house and the S structure Seongnam City Hall (Noh, 2013). In 2018, Thompson and Sorvig conducted a comparative study on major construction materials such as steel and wood.

The study of carbon balance in the landscape field is considered the first step in a full-scale study by Jo (1999b), who quantified carbon emission about vegetation management such as lawn mowing and pruning. As for the study of carbon balance in the landscape field, it is considered as the beginning of a full-fledged study that Jo (1999b) quantified carbon emission from vegetation management. In this study, it was investigated that 96.8% of carbon emission by vegetation management had been emitted from pruning, and more than 91.9% of turf management had been emitted from lawn mowers. The annual dry weight of grass mowed, which is major factor in carbon emission, was calculated as 7.4g/m2 for single residence, 20.6g/m2 for public land, 25.0g/m2 for multi-family residence, and 69.3g/m2 for resort area, and the carbon absorption amount of grass roots was presented as 47.1 g/m2. Choi (2014) had studied about carbon emissions according to the transplantation of large-scale trees. As a result, he had suggested that transplantation should be avoided because of the high mortality rate, as well as emission of a lot of carbon based on the use of equipment fuel and reducing the potential carbon absorption. Kim (2015) confirmed the CO2 emissions of major construction materials such as wood, concrete, steel and aluminum were 15kg/m3, 120kg/m3, 5,320kg/m3 and 22ton/m3, respectively. Among the wooden landscaping facilities, the average carbon emissions of pergolas, chairs, and decks were 180.9kg/ea, 22.8kg/ea, and 0.9kg/m2, respectively. Park (2021) presented a carbon balance life cycle evaluation and ecological design for production, transportation, construction, management, and disposal for 30 parks across the country. She had claimed that vegetation offset 0.4 to 3.6 times carbon emissions, grass emitted 2.7 times the amount absorbed due to management, and carbon emissions was higher in order of 31.9% from packaging materials, 17.5% from management, and 17.4% from grass production. Carbon emission by packaging material was in the order of 1.2 kg/kg for rubber, 0.9 kg/kg for stainless steel, 0.5 kg/kg for aluminum plate, and 0.1 kg/kg for clay brick. Depending on the waste treatment method, the carbon emission was in order of 0.017kg/kg for landfilling, 0.004kg/kg for recycling and 0.003kg/kg for incineration. Based on these results, ecological design such as reduction of lawn space, application of multi-layered group planting, reduction of impervious pavement, and preservation of existing trees was presented.

3.3 Carbon absorption amount of trees

Park and Kang (2010) calculated the amount of carbon dioxide storage and absorption using accumulated biomass carbon for 9 types commonly used as roadside trees. As for the amount of storage, a tulip tree was the highest at 518kgC, and a pine was the lowest at 41kgC, and the absorption amount of carbon dioxide absorbed was in the order of lily trip, metasequoia, and birch trees. Jo and Ahn (2012) presented carbon storage and absorption quantitative models for maple, zelkova, Yoshino cherry, and ginkgo. Kim (2013) suggested species with high carbon absorption rate over the mid to long-term in the following order, Tulip Tree, Metasequoire, platanus, ginkgo, zelkova, chinese scholar tree. Jo, Kim, and Park had presented a quantitative model for estimating the amount of carbon storage and absorption for pine and nut pine in 2013 and for Chinese Fringe tree, Apricot tree, Fir, Japanese cornlian cherry, Yew through the direct harvesting method in 2014. The carbon storage capacity of single tree with the diameter of 10 cm at chest height was 20kg per a Chinese Fringe Tree, 17.5 kg per an Apricot tree, and 13.2 kg per a fir. However, fir trees had more storage than pines and nut pines at 10 cm in diameter at chest height, but less than those in diameters over 14 cm. Jo and Park (2017) analyzed changes in annual diameter growth rate, biomass ratio and the amount of carbon uptake for major landscape tree species. As a result, the amount of carbon uptake up to 25 years of age was in the order of 198.3 kg per a zelkova, 121.7 kg per a Yoshino cherry, and 117.5 kg per a nut pine. Jo, Kim, and Park (2019) presented a carbon storage and absorption quantification model for camellia, Crape myrtle, and Bamboo-leaf oak which are species in the southern regions. Kim (2021) presented the guideline for the net carbon absorption service and planting and management of roadside trees. The amount of carbon uptake for representative tree species at 20cm in diameter at chest height was in the order of 16.5 kg per a tulip tree, 16.2 kg per a bambu-leaf oak, 14.5 kg per a thunberg’s bay, and 12.1 kg per a zelkova, 11.9 kg per a birch, and 9.9 kg per a Chinese Fringe Tree.

4. How to evaluate urban parks

4.1 Assessment Coverage

In order to create urban parks as a carbon sink based on the premise of solving the city problems, the functional status and carbon balance of the urban parks which are the research objects were analyzed and the improvement direction of the target parks was suggested. Because the functions of urban parks for solving urban problems were classified into 4 types based on the previous studies, I classified the function of urban parks into one of four types. And then, after evaluating whether the functions were properly performed, the amount of carbon absorption and emission of the park were evaluated.

Prior to the evaluation, I determined the scope of the study for the reliable evaluation of the research target park. Firstly, the scope of urban parks which are the study objects was determined as neighborhood park in neighborhood life zone referring to the urban parks overview. Secondly, the life cycle of urban parks was assumed to be 30 years, taking into account the Park & Green Act, the lifespan of trees, and the life cycle of wooden facilities. Thirdly, the carbon balance evaluation was carried out through the carbon emission basic unit according to the production of materials for the facilities introduced, carbon absorption quantitative model with tree diameter as independent variable, and the mortality rate by tree species, etc. Fourth, factors that are indirect, variable, or have a small effect on the carbon balance change were excluded among the carbon absorption and emission factors of urban parks.

4.2 Calculation of carbon emission basic unit

To prepare the basic unit of carbon emission of facilities in urban parks, I applied the results of previous studies that had presented carbon emission, national greenhouse gas emission and absorption coefficients, and LCI DB of KEITI (Korea Environmental Industry & Technology Institute). The basic unit of carbon emission of major construction materials in Table 5 was constructed by applying the arithmetic average of the basic units of the same material among the results of previous studies. The survey results of Park (2021) were applied to make basic units of carbon emission for partial construction and disposal., the carbon balance survey results of ready-made products were excluded because the differences in carbon emission among them was large depending on the shape and density even if they are made of the same materials. And, in the case that there is no basic unit in the results of previous studies, the basic unit of eco-friendly products was supplemented through the basic unit of carbon emission in EPD. Meanwhile, in the field of carbon emission according to the introduction of vegetation, the carbon emission amount for the production and management of introduced trees, the production and management of grass, the treatment of dead trees, and the input of compost and soil conditioners were reflected. The average value of the 27 landscaping farms investigated by Park (2020) was used to calculate the amount of carbon emission for tree production, and the average value of 7 landscaping farms was used to calculate that for shrub production. Unlike the case of roadside trees, pruning was not very required for trees in urban parks, so it was excluded. The carbon emission from lawn production followed the survey results of Park (2020), and the carbon emission from lawn management was calculated as the dry weight of grass mowed. According to Jo and McPherson (1995), the annual dry weight of grass mowed for residential areas in Chicago was 265 g/m2. The average annual dry weight of grass mowed in 30 parks which had been surveyed by Park (2020) was 270 g/m2 in case of mowing the lawn 6.8 times a year, which is the average number of mowing the lawn. Therefore, the research results of Park (2020), which are the most recent data, was applied to calculate carbon emission amount for lawn management. The disposal of dead tree was evaluated by applying 50% of landfill and 50% of recycling after logging the trees above ground, and the amount of waste and fuel consumption for logging was calculated by applying the Standard item count of the Korean Landscape history institute (2016).

Division	Carbon Emissions (Equivalent)	Division	Carbon Emissions (Equivalent)
Gasoline	0.594kg/l	Concrete tile	0.3kg/kg
Diesel	0.708kg/l	Concrete brick	0.04879kg/ea
Lubricant	0.746kg/l	Ggravel	2.24kg/㎥
Ready-mixed concrete (210-12)	111.54kg/㎥	Sand	1.4kg/㎥
Ready-mixed concrete (210-15)	114.27kg/㎥	Urethane paint	2.56kg/kg
Paint (water-soluble water system)	0.325kg/kg	Pruning	0.71kg/㎡
Concrete products	0.554kg/kg	Cutting &filling the ground	0.1kg/㎥
Cement	0.289kg/kg	Boundary Stone	2.2kg/m
Iron	1.2kg/kg	Granite	0.123kg/kg
Wood	0.082kg/kg	Aluminum Plate	2.305kg/kg
Plastic	1.24kg/kg	Demolition of pavement	0.11kg/㎡
Plastic tube	3.9kg/kg	Stainless steel bar	2.9kg/kg
Polypropylin	0.77kg/kg	Stainless steel	0.9kg/kg
Phenolic resin	1.6kg/kg	EPDM	1.2kg/kg
Clay Blocks	0.11kg/kg	Rubber sheet	0.9kg/kg
Crushed stone	3.67kg/㎥	Mortar	0.077kg/kg
Concrete tile	0.3kg/kg	Lawn production	4.1kg/㎡
Waste wood (Landfill)	0.017kg/kg	Mowing Lawn	0.149kg/㎡/year
Waste wood (recycle)	0.004kg/kg	Shrub production	78 g / tree
		Tree production (B 7cm)	1.7kg/ tree

Table 5 The basic unit of carbon emission of major construction materials

4.3 Quantitative model for carbon absorption

4.3.1 Preconditions

Vegetation absorbs and stores atmospheric carbon through photosynthesis, and the part of carbon flows into the soil, which is the basis for growth. Photosynthesis is the process of converting carbon dioxide and water into carbohydrates and oxygen using the chloroplasts which converts light energy into chemical energy. Urban parks are composed of green areas, pavements, and facilities, and so on. Generally, green areas absorb most of the carbon in the target area. Therefore, the results of previous studies that had been presented carbon uptake models for main trees in cities were applied to estimate the amount of carbon uptake in urban parks, and the planting density to ensure sufficient light intensity was premised. Moreover, additional preconditions are required to apply the carbon uptake quantitative model. Firstly, the amount of carbon uptake of grass and shrubs, which are difficult to calculate with a carbon uptake quantitative model, was applied as shown in Table 6, reflecting the results of previous studies. Secondly, the model by direct harvest by Jo et al. was applied as the quantitative model to reduce the variables caused by environmental factors. Thirdly, according to the results of previous studies, the carbon uptake and storage quantitative model for trees was significant within 0.1% in the case the tree diameter growth rate was assumed as independent variables. Therefore, the diameter growth rate of trees investigated by Jo and Park (2017) was applied to the quantitative model to calculate the carbon uptake and carbon storage of trees. Among the research data of Jo and Park (2017), the average value of the diameter growth rate was applied to the period when there was no data on the diameter growth rate, and the diameter growth rate was supplemented and applied through linear interpolation for old trees whose growth rate was gradually decreases. The diameter growth rate investigated by Jo et al. (2019) was applied to camellia, Crape myrtle, and Bamboo-leaf oak. The carbon absorption and disposal of trees at the end of the park's life cycle were assumed to be excluded from the carbon balance analysis of the parks.

Division	Carbon uptake	Division	Carbon uptake
A Tree (B 7cm) cumulative uptake amount	6.2kg	A Tree (B 7cm) cumulative uptake amount	14.7kg
A Shrub (H 30cm) cumulative uptake amount	48.5g	Korean Grass	0.047kg/㎡/year

Table 6 Cumulative carbon uptake amount of trees before introduction into the park & Basic unit of carbon uptake of grass

4.3.2 Defect rate of introduced trees

For the reliable calculation the amount of carbon uptake in the target park, the mortality rate of the introduced trees should be considered. Kim (2018) investigated tree defects on 10 large-scale landscaping construction sites completed between 2000 and 2015 in Gwangju Metropolitan City. They showed high defect rates of over 20%, including 61.6% for pine and 80% for Korean dogwood. Meanwhile, Im and Kim (2001) investigated the defects of landscaping trees in an apartment complex. The average defect rate was 10.1%, but the defect rate of white birch was higher than 35%.

I applied the defect rates in this study to the arithmetic means of the defect rates in the two studies as shown in <Table 7>. Moreover, the average tree defect rate of the LH (Land and Housing Institute) was applied in this study.

Species	Defect Rate			Species	Defect Rate		
	Apartment Complex	construction sites	Applicable Value		Apartment Complex	construction sites	Applicable Value
White birch	36.2		36.2	Tulip Tree	13.5	35	24.3
Metasequoire	27.1	15	21.5	Himalayan cedar	12.4	20	16.2
Fir tree	27.1		27.1	Snowbell tree	10.2	19	14.6
Nut Pine	27.7		27.7	Yoshino cherry	8.8	12	10.4
Christmas Berry	25		25	East Asian hackberry	8.7	6	7.4
Crape myrtle	24.2	12	18.1	Sea pine	7.8	11	9.4
White magnolia	21.4	9	15.2	Flower apple	7.54	12	9.8
rattan	20		20	ginkgo	7.2	28	10.4
Yew	19.7	17	18.4	bambu-leaf oak	5.0	30	10.4
Dogwood	19.4	50	19.4	Japanese cornlian cherry	4.96	24	10.4
Apricot	19.3	53	19.3	chinese scholar tree	4.17	18	10.4
Pine	18.9		18.9	Chinese Fringe Tree	3.05	15	9
Blue maple	17.4	16	16.7	Camellia	0	25	10.4
Silk tree	15.2	23	19.1	Japanese apricot	0	7	10.4
zelkova	14.7	14	14.4	East Asian ash	0	12	10.4
Strobe pine	14.6	15	14.8				
Average defect rate				10.4%	Land and Housing Institute (2018)		

Table 7 Tree defect rate (mortality rate)

4.3.3 Application of carbon absorption quantitative model for each species

The quantitative model for carbon absorption of vegetation is presented in Table 8. They are quantitative models that have been previously studied from 2001 to the present for the carbon uptake. The carbon absorption quantitative model was applied to evaluate how much trees affect the carbon balance of the park because the carbon storage quantitative model was suitable for evaluating the current carbon uptake of trees. The average values of deciduous and evergreen trees were applied to unirradiated trees except for the main trees investigated in previous studies (Jo, 2019). For shrubs, the values suggested by Jo (2001) were used. Since most of the shrubs had planted in groups, only 40% of the quantitative model value presented in previous studies was applied in consideration of the overlap rate between trees and the growth restriction due to overlap. Small shrubs and herbaceous plants have very little carbon uptake amount during their life cycle and are often planted on just one-shot basis in parks, so they were excluded from calculation of the carbon uptake amount.

When it is assumed that all trees introduced into the urban parks have the diameter of chest height of 7 cm, the carbon uptake amount for 30 years of the quantitative model was compared with the storage amount. Chinese Fringe Tree, apricot tree, and Japanese cornlian cherry had more than twice as much carbon absorption as carbon storage. On the other hand, there was almost no difference in the amount of storage and absorption for Crape myrtle, Zelkova, and Ginkgo. The storage amount of yew was higher than the uptake amount. Among the trees to which the quantitative model was applied, the amount of carbon uptake of zelkova and bambu-leaf oak was the highest for 30 years at 565 kg and 528 kg, respectively, and among the small trees, the amount of carbon uptake of apricot and camellia was relatively high at 493 kg and 458 kg, respectively. Maple tree absorbed 113 kg of carbon, which was the lowest among the surveyed tall trees. Although deciduous trees have high carbon storage, their carbon uptake is lower than that of evergreen trees, which is considered as an important analysis for the selection of tree species for carbon absorption in the parks.

Species (scientific name)		**carbon absorption quantitative model**	Cumulative uptake amonut	Sources
Deciduous	Lagerstroemia indica	ln Y = -3.2160 + 1.4838 lnDg	91kg	Jo et. al (2019)
	Chionanthus retusa	ln Y = -2.2695 + 1.7554 lnDbh	425kg	Jo, Park and Kim (2014)
	Purnus armeniaca	ln Y = -2.8278 + 1.8824 lnDbh	285kg	
	Cornus officinalis	ln Y = -3.1622 + 1.8844 lnDg	366kg	
	Acer palmatum	Y = 0.9608 + 0.1535 Dbh	113kg	Jo and Ahn (2012)
	Zelkova serrata	ln Y = -2.8177 + 1.7715 lnDbh	565kg	
	Purnus yedoensis	ln Y = -3.0939 + 1.7702 lnDbh	367kg	
	Ginkgo biloba	ln Y = -3.6471 + 1.8287 lnDbh	191kg	
Evergreen	Camellia japonica	ln Y = -5.6582 + 2.8731 lnDg	458kg	Jo et. al (2019)

	Quercus myrsinaefolia	ln Y = -2.7303 + 1.8411 lnDbh	528kg	
	Abies holophylla	ln Y = -3.1386 + 1.6158 lnDbh	154kg	Jo, Park and Kim (2014)
	Taxus cuspidata	ln Y = -4.7726 + 1.8554 lnDg	35kg	
	Pinus koraiensis	ln Y = -4.4881 + 2.2262 lnDbh	373kg	Jo and Kim (2013)
	Pinus densiflora	ln Y = -2.6720 + 1.5251 lnDbh	192kg	
Deciduous species		ln Y = -2.6119 + 1.5686 lnDbh	210kg	Jo (2020)
Evergreen species		ln Y = -3.7807 + 1.9347 lnDbh	200kg	
Deciduous shrubs		$Ys = e^{(2.7694+0.9729\ \ln DAG)} \times 12/44$	0.362kg	Jo (2001)
Evergreen shrub		$Ys = e^{(2.8203+1.2262\ \ln DAG)} \times 12/44$	0.401kg	

Table 8 Tree carbon absorption quantitative model for trees

5. Contents of the study

5.1 Research Subject Park`

Figure 1 Sihwa MTV (Multi Techno Valley) District Status

Urban parks in the Shihwa Multi-Techno Valley were selected as the target parks. Sihwa MTV have been building across Siheung City and Ansan City, with a project area of 3.03million square pyeong and the scale of 6,800 households and 14,000 people. The southern part of the site is facing the sea, and the Ansan Smart Hub (Banwol Complex) and Sihwa Industrial Complex are in the northern part. In the west, the Baegot New town with global education and medical infrastructure is under construction. The eastern area has the character of a residential complex as the central area of Ansan City.

The target site is adjacent to a dense residential complex that must accommodate the diverse needs of people as an industrial complex where pollutants are scattered. In addition, as it is in contact with the natural environment of the sea, it is an area that must overcome restrictions such as sea wind, and salt damage. Therefore, Sihwa MTV was an area that should act as a carbon sink while maintaining the pluralistic functions of urban parks, it was consistent a region with the topic of the thesis. Accordingly, seven urban parks corresponding to neighborhood parks were selected out of total 32 parks in Sihwa MTV, and carbon balance evaluation was conducted for neighborhood parks No. 46, No. 63, and No. 67, which were completed.

5.2 Carbon balance survey

5.2.1 Neighborhood Park No. 46

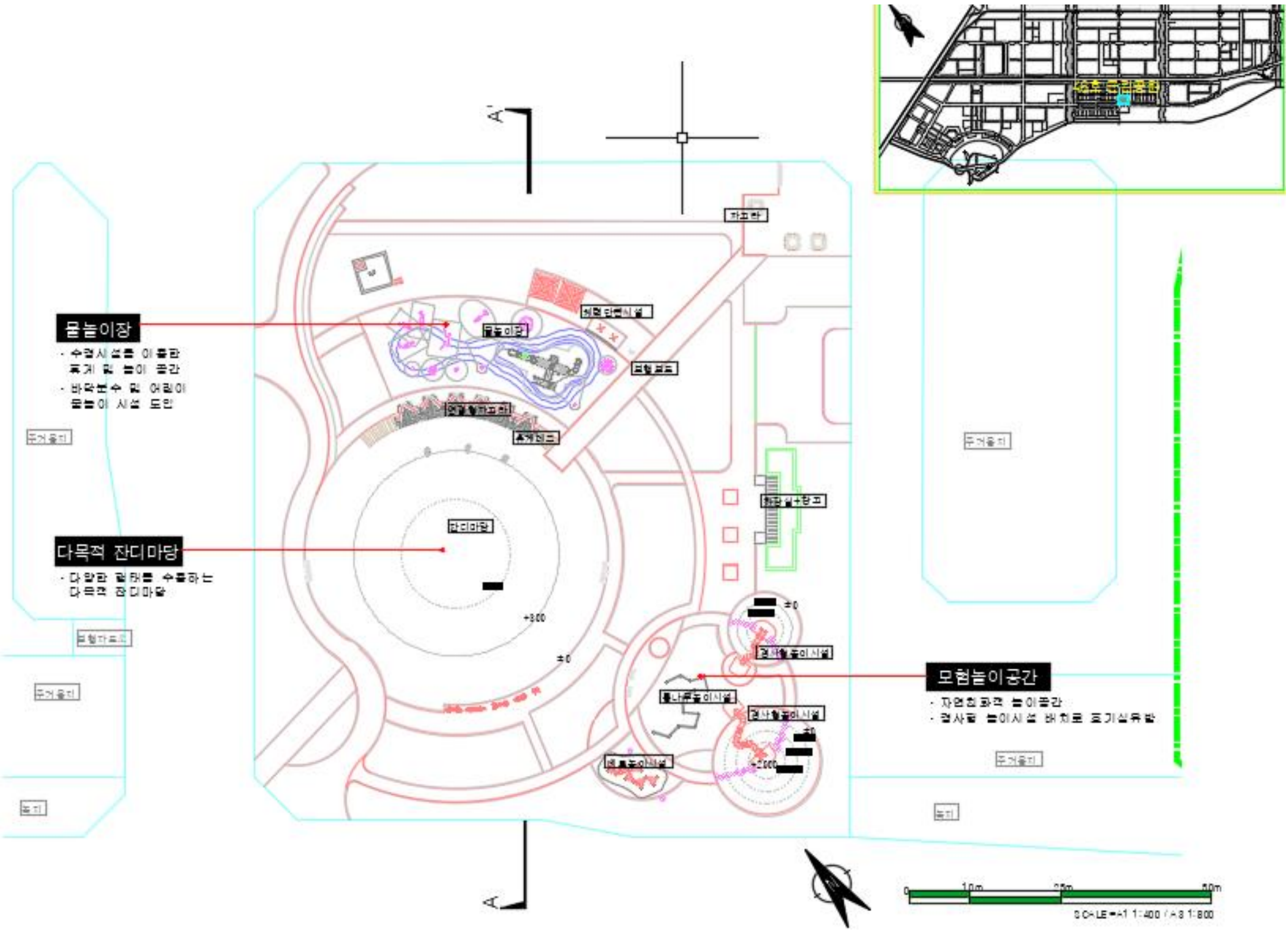

Figure 2　No. 46 Neighborhood Park Location and Floor Plan

Neighborhood Park No. 46 in Sihwa MTV is a leisure-use park located on the site of a detached house land. It is a facility-oriented water amusement park with a site area of 10,789㎡ and a green area of 61.03%. There is a lawn yard in the center, and experiential and theme playground were introduced around the lawn yard to accommodate the users in residential areas efficiently, but the density of facilities was the highest among the 32 parks.

First, emission sources were classified into facilities, pavements, and vegetation to identify the major influencing factors of the park's carbon balance. The cumulative carbon emission from facilities and pavements in the park was calculated as shown in Table 9 by apprehending the main materials in the drawing and applying the average value of basic unit coefficients previously investigated. The information facilities had the lowest carbon emission at around 30kg/ea, and the rest facilities also discharged small amount of carbon at around 50kg/ea. The reason for the low carbon emission seems to be because wood is used as the main material and small amount of ready-mixed concrete is used as just basic parts. Unit type sports facilities, convenience facilities, and amusement facilities emitted carbon in the range of 100 to 300 kg/ea. Although metals such as aluminum and stainless steel were used for sports facilities and convenience facilities to increase corrosion resistance, the amount of carbon emissions was low because of their small scale. Except for some facilities, even though the amusement facilities were large in size, they used wood as their main material, so their carbon emissions were low. The water play facilities used limited wood to prevent corrosion, and a mixture of stainless steel and plastic was mainly used. The water play facilities used limited wood to prevent corrosion, and a mixture of stainless steel and plastic was mainly used. The cooperative play facilities or cooperative rest facilities emitted a large amount of carbon. As a result of examining the carbon emission of the water play facilities, which are the combination of sculptures and five amusement facilities, the carbon emission of infrastructure such as machine room and foundation piping was much higher than that of playground equipment, and the main materials of the facility were stainless steel, steel, ready-mixed concrete, plastic mixture, and aluminum. The total carbon emission of facilities and structures in the neighborhood park was 31.6 tons.

Division	Quantity	Main Facilities	Carbon emissions
Amusement Facilities	7EA	Log-bridge Playstand (274kg) 1EA, Spider Netting stand(326kg) 1EA, Sloping Slide A(1,385kg) 1EA Sloping Slide B (2,140kg) 1EA, Turtle Sculpture (46.5kg) 3EA	4,265kg
Information Facilities	3EA	Park nameplate(28kg) 1EA, Usage information board (16.4kg) 2EA	61kg
Rest Facilities	36EA	Connected Pergola (3,497kg) 1EA, Pergola F (726 kg) 2 EA, Back chair F (51 kg) 6EA, Square chair (183 kg) 3EA, Flat chair F (45 kg) 24EA	6,883kg
Sports Facilities	5EA	Warming arm (110 kg) 1 EA, Leg extension (112 kg) 1 EA, Full weight (231 kg) 1 EA, Step cycle (135 kg) 1EA, Twin twist (91 kg) 1EA	679kg
Convenience Facilities	4EA	Water supply C (138 kg) 1 EA, Bicycle rack (110 kg) 1 EA, Outdoor shower (226.6kg) 2EA	701kg

Water Play Facilities	1 place	Ellis Water Exploration (2,443kg), Machine Room (10,735kg), Equipment and Foundation (6,272 kg) 1 Type	19,450kg

Table 9 The amount of Carbon Emissions for Landscape facilities in No. 46 Neighborhood Park

The scope of application of pavement facilities included all artificial facilities covering the target site except for green areas. Even the same type of pavement facilities had different the amount of carbon emission owing to different shape and composition, etc. So, emission amount was calculated by applying the basic unit of carbon emission for the main materials constituting the packaging. The Table 10 shows calculated value of carbon emission for each pavement facility in the park. Carbon emissions from transportation and construction were not reflected owing to the Variability and eager amount of emissions. Contrary to the results of previous studies, pavement facilities including concrete and rubber chips emitted the very high amount of carbon. The total carbon emission of pavement facilities in Neighborhood Park No. 46 was 161 tons. The pavements emitted five times more carbon than the facilities.

Species	Standard	Quantity	Carbon emissions	Species	Standard	Quantity	Carbon emissions
Timber Deck	L 34m × W 2.4m	1 place	2,305kg	Rubber chip Pavement	T 100	593㎡	57,649kg
Road Boundary Stone	200×250	74.8m	2,349kg	Grass Blocks Pavement	T 150	249.5㎡	12,133kg
Green Boundary Stone	150×150	1,123.6m	11,404kg	Granite Slabstone Pavement	T 30	17㎡	430kg
Pavement Boundary Stone	150×150	148.5m	1,391kg	Lawn Protection Pavement	T 72	24.8㎡	310kg
Clay Block Pavement	T 55	1,579.4㎡	13,098kg	Stepping Deck	T 450	78 places	209kg
Stone Block Pavement	T 60	956.4㎡	37,704kg	Sand block	D 100	137.7m	2,324kg
				Braille Blocks		21.2㎡	886kg

Table 10 The amount of Carbon Emissions for Pavement facilities in No. 46 Neighborhood Park

Urban park's infrastructure includes earthworks and drainage facilities for site maintenance. The basic unit of earthworks was taken from the research result of Park (2020), which averaged the results of 31 domestic parks. The amount of carbon emission from infrastructure in the neighborhood park was calculated as shown in Table 11. The 18 tons of carbon were emitted from the infrastructure, and the double-walled perforated pipe used for the drainage of rainwater emitted 10.7 tons of carbon, accounting for about 60% of the infrastructure carbon emission.

Division	Main Facilities	Carbon emissions
Earthworks	Pilling up soil (2,251㎡, 225kg), Flattening the surface of mound (2,233㎡, 1,585kg)	1,810kg
Rainwater Drainage Facilities	Collecting well (15places, 2,064kg), Outlet pipe (8.8m, 73 kg) Double-wall PE tube (432.8m, 10,715 kg), Trench (206 kg) 1EA Dummy ditch (96 m, 2,139 kg), PE collector (7 places, 82.6 kg)	15,280kg
Sewage, waterworks	Water supply pipe (274.6m, 346kg), GRP sewage pipe (13.2m, 566kg), sewage manhole (2EA, 573kg)	1,485kg

Table 11 The amount of Carbon Emissions for Infrastructure facilities in No. 46 Neighborhood Park

The total carbon emission of the neighborhood park except for green areas, was 211.2 tons, including 161 tons of pavement facilities, 31.6 tons of landscaping facilities and structures, and 18.6 tons of infrastructure. The pavement facilities emitted about 76% of carbon out of total carbon emissions.

The carbon emission of trees was calculated as shown in <Table 12>. The cumulative carbon absorption and emission of trees before introduction were excluded since they are variable. Carbon emission from dead wood and compost during planting, which can determine it, were calculated. The dead tree quantity was calculated by reflecting the tree defect rate in <Table 7> out of the quantities designed in the neighborhood park. The input of compost and improvement agents was targeted at the total quantity. The method of treating dead trees was assumed to landfill after crushing the above-ground part of the tree cut with the chainsaw. According to Park (2021), the amount of carbon emitted when crushing a tree with diameter of 40 cm at chest height is predicted to be 9.9 kg per a tree. According to the landscaping construction standard (2016), the amount of waste from above-ground parts with a diameter of 40 cm at chest height was 633 kg, so the basic unit of carbon emission in the case of crushing a tree is calculated as about 0.0156 kg/kg.

It was assumed that the shrub was buried by cutting both the above-ground and underground parts at the same time. The soil improvement agent was applied by dividing it into compost and sandy soil depending on whether it was ripe or not. As a result, the amount of carbon emission from soil improvement in the park was estimated to be 653 kg. There are previous research results that the huge amount of carbon was emitted by the disposal of dead large trees. Meanwhile, in the case of chanagin their shape and recycling them, the amount of carbon emission was relatively quite low. After proper action, the amount of carbon emission from the treatment of dead trees was estimated to be just 545kg. On the other hand, the amount of carbon emission by lawn production and management was calculated as shown in <Table 13> for the lawn covered in the park, excluding the amount of carbon absorption. As a result of the conversion of carbon emissions during the life cycle of the park, it was estimated that a large amount of carbon would be emitted as much as 38 tons.

Division	Size	Design Quantity	Equivalent Quantity	Dead tree Processing	Compost and improver agents
Trees	R 30	10	1.44	58kg	17.5kg
	R 25	13	2.46	51.4kg	22.7kg
	R 20	29	2..89	58kg	17.5kg
	B 15	50	5.2	99.7kg	58kg
	B 12	17	3.66	21.5kg	9.9kg
	R 12	125	17.54	97.8kg	72.6kg
	R 8	196	25.14	84.7kg	56.9kg
Shrubs	W 0.3	1,700	176.8	7.8kg	55.4kg
	W 0.4	7,300	759.2	51.9kg	318kg
Total				545kg	653kg

Table 12 The amount of Carbon Emissions for the trees &shrubs in No. 46 Neighborhood Park

species	Quantity	Production Basic Unit	Annual Carbon Emissions	Annual Carbon absorption	Annual Net carbon absorption	Carbon Emissions (30 years)
Korean Grass	5,345㎡	4.1kg/㎡	0.149kg/㎡	0.047kg/㎡	0.102kg/㎡	38,270kg

Table 13 The amount of Carbon Emissions for the lawn in No. 46 Neighborhood Park

Finally, the carbon uptake of trees to offset the carbon emission was calculated as shown in <Table 14>. The regression equation in <Table 8> was used to measure the amount of carbon uptake of trees. Moreover, since the only independent variable is the diameter of the tree, the rate of change in diameter growth by age in the appendix was applied. The carbon absorption rate of apricot tree was used for Japanese apricot and Mountain hawthorn tree because it is the same rosaceae and deciduous small tree with them. The carbon uptake rate of Japanese cornlian cherry was used for korean dogwood because it is the same dogwood family and deciduous small tree with it. The carbon uptake rate of general deciduous trees was applied for the Metasequoire because there was no regression data on carbon uptake. According to figure 3 of Park and Kang (2010) and the study of Jo and Park (2017), most of the tree species converged on the regression equation until the age of 15 to 20 years, but the metasequoia did not conform to the regression equation. Therefore, the average diametric growth rate suggested by Park and Kang (2010) was applied up to a diameter of 26.685 cm, which is the constant of the regression equation of their thesis, and the lowest diametric growth rate was applied for the subsequent period.

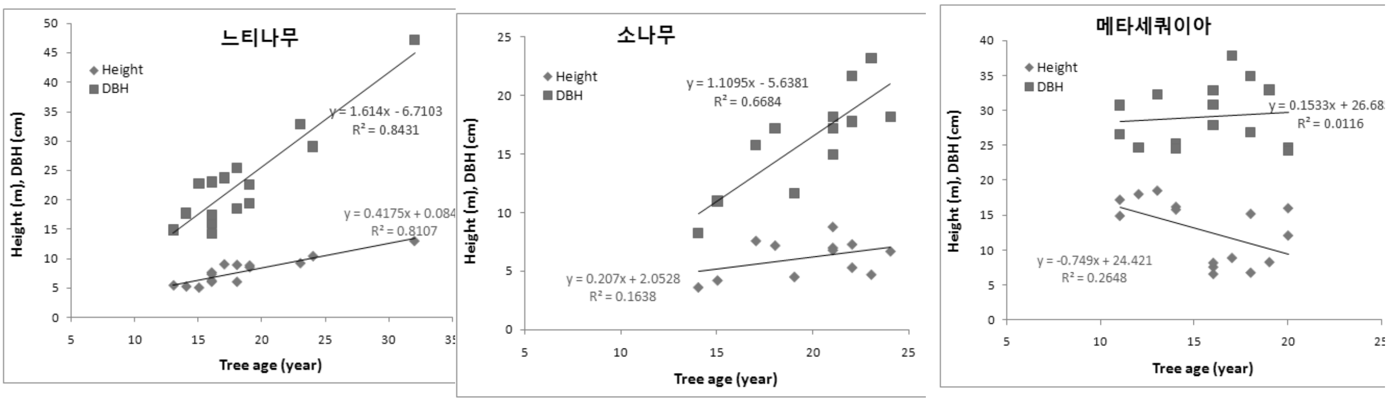

Figure 3 height and DBH distribution by age

The basic unit of shrubs was calculated by excluding the amount of carbon emission due the production of shrubs to the carbon absorption corrected due their group in <Table 8>.

Species		Size	Quantity	Conversion Quantity	Bacic Unit	Carbon Absorption
Evergreen tree	Pine	R25	13	10.5	370kg	3,885kg
	Pine	R20	11	9.7	314kg	3,046kg
Deciduous Tree	Zelkova	R20	18	15.4	700kg	10,780kg
	Zelkova	R30	10	8.6	828kg	7,121kg
	Japanese apricot	R8	56	45.4	285kg	12,939kg
	Metasequoire	B12	17	13.3	618kg	8,219kg
	White magnolia	R12	12	10.2	223kg	2,275kg
	Korean dogwood	R8	62	55.5	355kg	19,702kg
	Mountain hawthorn tree	R8	49	43.9	285kg	12,511kg
	Japanese cornlian cherry	R8	29	26	355kg	9,230kg
	Yoshino cherry	B15	50	44.8	523kg	23,430kg
	Chinese Fringe Tree	R12	41	37.3	454kg	16,938kg
	Blue maple	R12	72	60	120kg	7,197kg

Evergreen shrub	Korean Boxwood	W0.3	1,000	896	0.106kg	95kg
Deciduous shrub	Royal azalea	W0.4	1,600	1,434	0.078kg	112kg
	Christmas Berry	W0.4	2,000	1,792	0.078kg	140kg
	Leather-leaf viburnum	W0.4	2,000	1,792	0.078kg	140kg
	Korean azalea	W0.3	700	627	0.067kg	42kg
	Burning bush spindle Tree	W0.4	1,700	1,523	0.078kg	119kg
Total						158,669kg

Table 14 The Carbon uptake amount of the trees in No. 46 Neighborhood Park

The total amount of carbon absorbed by vegetation during the 30 years was estimated to be about 159 tons. The amount of net carbon uptake might be lower if trees were considered logging for growth during the park's life cycle. The total carbon emission of the park was estimated to be 31.6 tons for facilities and structures, 161 tons for pavement facilities, and 18 tons for infrastructure. On the other hand, the amount of net carbon uptake after excluding the carbon emission from vegetation was estimated to be 119.2 tons. Putting the carbon balance in the park together, it was estimated that this park would emit 91.4 tons of carbon during 30 years.

5.2.2 Neighborhood Park No. 63

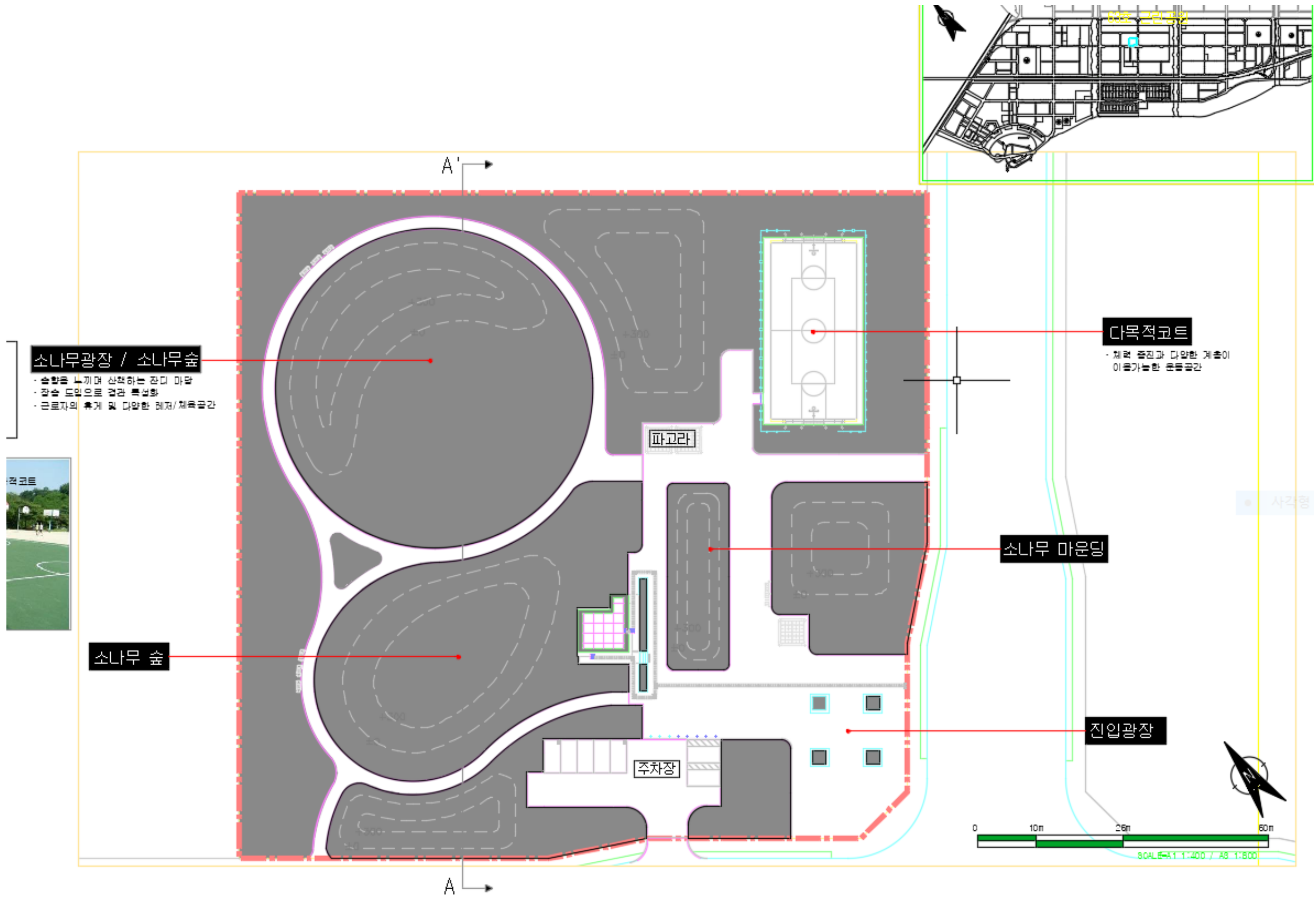

Figure 4 No. 63 Neighborhood Park Location and Floor Plan

Neighborhood Park No. 63 in Sihwa MTV is a welfare type park located in the new material industrial district. It is a recreational sports park for workers with a site area of 10,115㎡ and a green area of 71.4%. The forest shelter has been reproduced with pine trees as the main vegetation, and there are relatively simple sports facilities with multi-purpose courts, entrance square, parking lots, and walking trails. In addition, it was estimated that the park would play an appropriate role as a carbon sink due its high green rate.

The amount of carbon emission from facilities in the park was calculated as shown in <Table 5-7> by applying the average value of the surveyed basic unit coefficients. Among the facilities in the park, the main factors of carbon emission were multi-purpose courts, pergolas, and sitting walls, and the main materials causing carbon emission were iron and concrete. Among the facilities in the park, toilets were excluded as they were recognized as separate areas in accordance with related laws such as zero buildings. The total carbon emission of the park facilities was 7.7 tons. Since the main constituent material of the facilities in the park were wood, the carbon emission was calculated to be low.

Division	Quantity	Main Facilities	Carbon emissions
Information Facilities	3EA	Park nameplate(28kg) 1EA, Vehicle control panel (470 kg) 1EA Usage information board (16.4kg) 1EA	514kg

Rest Facilities	18EA, 64.2m	Pergola A (545 kg) 3EA, Sitting wall (34 kg) 38.4 m, Back chair A (30 kg) 6EA, Planter B (30 kg) 25.8m, Flat chair A (23kg) 9EA	4,114kg
Sports Facilities	5EA	Mesh fence B (33.4 kg) 37.5 span, Multipurpose Post (45 kg) 1set Mesh Entrance Gate (69 kg) 1EA, Bollard (30.3 kg) 8 places, Multipurpose Goal post (802 kg) 2 places,	3,213kg
Convenience Facilities	10EA 1place	Bicycle storage rack B (13.5kg) 10EA, Toilet access staircase (111kg) 1 place	246kg

Table 15 The amount of Carbon Emissions for Landscape facilities in No. 63 Neighborhood Park

The amount of carbon emitted by the pavement facilities reached 96.9 tons as shown in <Table 16>. Although the pavement area of the park was relatively small compared to other parks, the carbon emission was quite high. Pavement facilities emitted 12 times more carbon than facilities and structures. In particular, the I.L.P(InterLocking Pavement) blocks for the rest area was made of concrete blocks, and it discharged 51 tons of carbon.

Species	Standard	Quantity	Carbon emissions	Species	Standard	Quantity	Carbon emissions
I.L.P type C	T60	1,095.8㎡	41,884kg	I.L.P type E	T80	184.5㎡	9,266kg
Road Boundary Stone	200×250	89.4m	2,805kg	Grass Blocks Pavement	T150	310.5㎡	15,099kg
Green Boundary Stone	150×150	281.5m	2,857kg	Urethane Pavement	T7	428.6㎡	14,114kg
Soil concrete pavement	T120	599.5㎡	9,647kg	Entry point pavement	asphalt concrete	1 place	268kg
Braille Blocks		22.6㎡	945kg				

Table 16 The amount of Carbon Emissions for Pavement facilities in No. 63 Neighborhood Park

Urban park's infrastructure included earthworks, drainage facilities sewage and water supply for site maintenance. The basic unit of earthworks was taken from the research result of Park (2020), which averaged the results of 31 domestic parks. The amount of carbon emission from infrastructure in the neighborhood park was calculated as shown in <Table 17>. Although the park excluded most of the rainwater through the topography of the green area, the amount of carbon emission was counted as 29.9 tons. The circular water pipe for the drainage of rainwater in the multi-purpose playground emitted 20.4 tons of carbon, accounting for about 68% of the infrastructure carbon emission. Although the park excluded most of the rainwater through the topography of the green area, the amount of carbon emission was counted as 29.9 tons.

Division	Main Facilities	Carbon emissions
Earthworks	Pilling up soil (5,565㎡, 557kg), Flattening the surface of mound (1,364㎡, 968kg)	1,525kg
Rainwater Drainage Facilities	Collecting well (3 places, 413kg), Outlet pipe (15.6 m, 1,807kg) Double-wall PE tube (25.5 m, 1,904 kg), Circular water pipe (82.9 m, 20,446 kg)	24,570kg
Sewage, waterworks	Water supply pipe (386.6m, 1,468kg), GRP sewage pipe (41.2m, 1,767kg), Sewage manhole (2EA, 573kg)	3,808kg

Table 17 The amount of Carbon Emissions for Infrastructure facilities in No. 63 Neighborhood Park

The total carbon emission of the neighborhood park except for green areas, was 134.5 tons, including 96.9 tons of pavement facilities, 7.7 tons of landscaping facilities and structures, and 29.9 tons of infrastructure. The pavement facilities emitted about 72% of carbon out of total carbon emissions. Among the main materials, the I.L.P block emitted 51 tons of carbon, accounting for about 38% of the total carbon emission. Compared to Neighborhood Park No. 46, despite having very few facilities, the carbon emission was very high. This result shows how much impact pavement facilities with high carbon emissions amount have.

The carbon emission of trees was calculated as shown in <Table 18>. The amount of carbon emission from the treatment of dead trees in the park was estimated to be 407kg though applying of the converted quantity, and the carbon emission by soil improvement agent was estimated to be 714kg by applying the design quantity. On the other hand, the amount of net carbon emission by lawn was estimated to emit a high amount of carbon reaching 42.7 tons as shown in <Table 19>. As a result of the conversion of carbon emissions during the life cycle of the park, it was estimated that a large amount of carbon would be emitted as much as 38 tons. The net carbon emission of lawn reached 24% of the park's total carbon emission of 178.3 tons.

Division	Size	Design Quantity	Equivalent Quantity	Dead tree Processing	Compost and improver agents
Trees	R 40	9	1.7	39.6kg	21kg
	R 30	16	3.02	30.5kg	28kg
	R 25	28	5.29	37kg	49kg
	R 20	25	4.73	20.7kg	36kg
	R 15	82	11.81	26.6kg	71kg
	R 12	46	6.91	9.5kg	27kg

Shrubs	W 0.3	1,700	176.8	7.8kg	55.4kg
	W 0.4	7,300	759.2	51.9kg	318kg
	W 0.8	300	31	6kg	52kg
Total				407kg	714kg

Table 18 The amount of Carbon Emissions for the trees &shrubs in No. 63 Neighborhood Park

species	Quantity	Production Basic Unit	Annual Carbon Emissions	Annual Carbon absorption	Annual Net carbon absorption	Carbon Emissions (30 years)
Korean Grass	5,962㎡	4.1kg/㎡	0.149kg/㎡	0.047kg/㎡	0.102kg/㎡	42,687kg

Table 19 The amount of Carbon Emissions for the lawn in No. 63 Neighborhood Park

The amount of carbon uptake by trees to offset carbon emission was calculated as shown in <Table 20>. To measure the carbon uptake of trees, the rate of change in diameter growth by tree age was applied to the regression equation. Red maple and Three-flowered Maple are deciduous broad-leaved trees of the Mapleaceae, so the carbon absorption rate of Blue maple was used to apply to the regression equation. Among the shrubs, Smooth-cranberrybush viburnum was planted as a single tree, so the 40% reduction in diameter growth due the overlapping of trees was not applied.

Species		Size	Quantity	Conversion Quantity	Bacic Unit	Carbon Absorption
Evergreen tree	pine	R40	9	7.3	685kg	5,000kg
	pine	R30	16	13	529kg	6,877kg
	pine	R25	28	22.7	370kg	8,339kg
	pine	R20	25	20.3	314kg	6,374kg
	Strobe pine	R6	36	30.7	152kg	4,666kg
Deciduous Tree	zelkova	R15	82	70.2	661kg	46,402kg
	Three-flowered Maple	R8	23	18.7	108kg	2,020kg
	Japanese cornlian cherry	R10	10	9	398kg	3,582kg
	Chinese Fringe Tree	R12	10	9	454kg	4,086kg

	Red maple	R12	36	30	120kg	3,600kg
Deciduous shrub	Red royal azalea	W0.4	1,000	896	0.15kg	134kg
	Smooth-cranberry bush viburnum	W0.8	300	269	0.87kg	234kg
	Korean early lilac	W0.4	700	627	0.15kg	94kg
	Pink royal azalea	W0.4	1,600	1,434	0.15kg	215kg
	Burning bush spindle Tree	W0.3	1,000	896	0.134kg	120kg
	Simple bridal wreath spiraea	W0.4	500	448	0.15kg	67kg
	Purple beautyberry	W0.4	500	448	0.15kg	67kg
	Kerria	W0.4	300	269	0.15kg	40kg
	Korean azalea	W0.3	1,870	1,676	0.134kg	225kg
Total						92,142kg

Table 20 The Carbon uptake amount of the trees in No. 63 Neighborhood Park

The total amount of carbon absorbed by vegetation was estimated to be about 92tons, and the amount of net carbon absorption except for carbon emission by vegetation was only about 48tons. The total carbon emission of the park was estimated to be 134.5 tons. Putting the carbon balance in the park together, it was estimated that this park would emit 86.5 tons of carbon during 30 years.

The reason for the high carbon emission in the park despite the high percentage of green space and few facilities is as follows. Firstly, despite the small pavement area, the carbon emission density of the pavement facilities was too high by using concrete blocks as the main material. Secondly, by constructing the green area centered on lawn, the annual carbon emission due grass management increased. Thirdly, more shrubs with lower carbon uptake capacity than trees were introduced.

5.2.3 Neighborhood Park No. 67

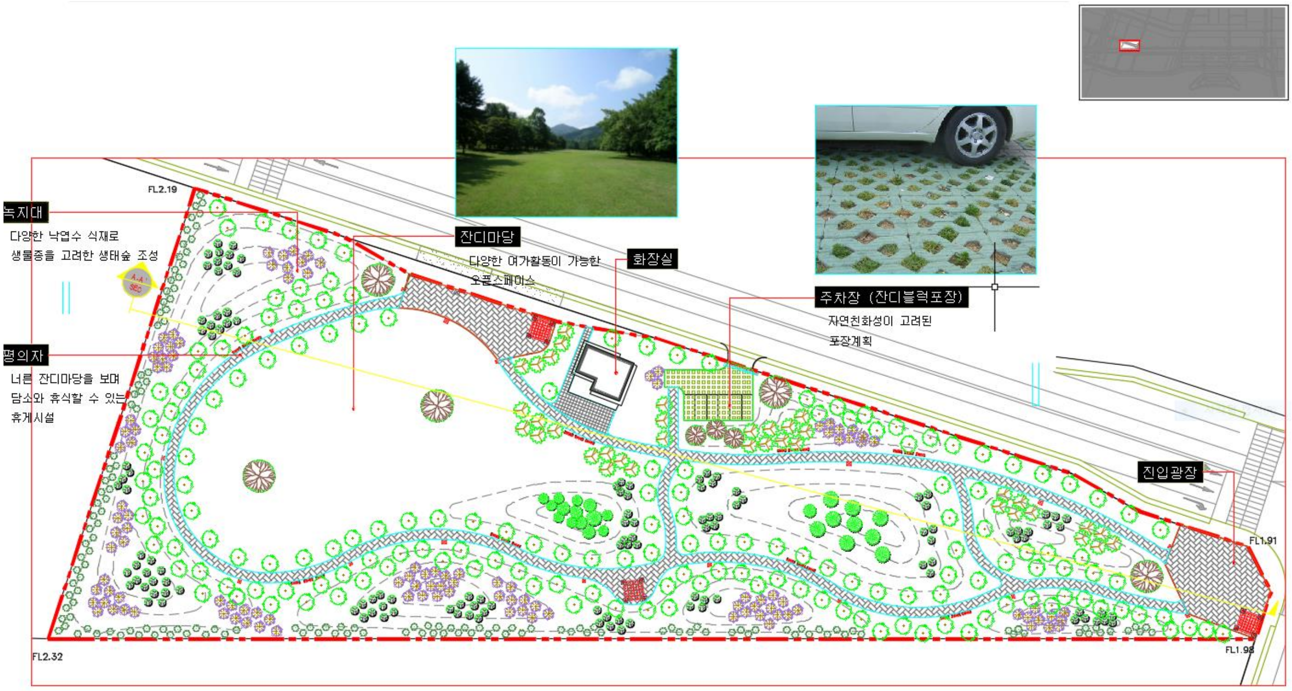

Table 21   No. 67 Neighborhood Park Location and Floor Plan

Neighborhood Park No. 67 in Sihwa MTV belongs to the environmental welfare type park located in the high-tech facilities cluster. It is a recreational park with the forest theme with a site area of 12,684㎡ and a green area of 85.1%.

There are relatively simple resting and leisure space with lawn yards, entrance square, parking lot, and walking trails. In addition, it was estimated that the park would play an appropriate role as a carbon sink due its high green rate. Except for toilets, rest facilities are the only facilities in the park. The main constituent material was wood and the amount of carbon emission was very low. Among the facilities in the park, the toilet was recognized as a separate area and excluded. The amount of total carbon emission for landscaping facilities was only 2.84tons as shown in <Table 21>

Division	Quantity	Main Facilities	Carbon emissions
Information Facilities	3EA	Park nameplate(28kg) 1EA, Vehicle control panel (470 kg) 1EA Usage information board (16.4kg) 1EA	514kg
Rest Facilities	33EA	Pergola A (545 kg) 3EA, Flat chair A (23kg) 30EA	2,325kg

Table 22   The amount of Carbon Emissions for Landscape facilities in No. 67 Neighborhood Park

The amount of carbon emitted by the pavement facilities was 35.4 tons as shown in <Table 23>. Not only was the paved area of the park relatively smaller than other parks, but the main paved trail was designed as the clay block pavement, so the pavement facilities emitted the lower carbon amounts than other parks. Although the clay block pavement used as the walkway was about 10 times larger than the grass block pavement used in the parking lot, the clay block pavement emitted just 12.8 tons of carbon and the grass block pavement emitted 7.6 tons of carbon. It showed an interesting result that the carbon emission of grass block pavement, which is considered an eco-friendly paving material, was significantly higher than that of other pavement materials.

Species	Standard	Quantity	Carbon emissions	Species	Standard	Quantity	Carbon emissions
Road Boundary Stone	200×250	58.6m	1,840kg	Alvedge		963.1m	8,946kg
Green Boundary Stone	150×150	65.9m	669kg	Grass Blocks Pavement	T150	156.5㎡	7,610kg
Pavement Boundary Stone	150×150	18.6m	174kg	Entry point pavement	asphalt concrete	1 place	233kg
Clay Block Pavement	T55	1,550.7㎡	12,860kg	Braille Blocks		5.9㎡	247kg
Stone Block Pavement	T60	73㎡	2,878kg				

Table 23 The amount of Carbon Emissions for Pavement facilities in No. 67 Neighborhood Park

The amount of carbon emission from infrastructure in the neighborhood park was calculated as shown in <Table 24>. The park excluded through the Hume concrete pipe after inducing the rainwater to the collecting well through the topography of the green area. The main material was the Hume tube, and the total carbon emission was calculated to be 27.3 tons.

Division	Main Facilities	Carbon emissions
Earthworks	Pilling up soil (4,716㎡, 472kg), Flattening the surface of mound (4,732㎡, 3,360kg)	3,832kg
Rainwater Drainage Facilities	Collecting well (17 places, 2,330 kg), Hume concrete tube (431.8m, 20,189 kg)	22,519kg
Sewage, waterworks	Water supply pipe (5.4m, 6.8kg), GRP sewage pipe (7.4m, 317kg), Sewage manhole (2EA, 573kg)	3,808kg

Table 24 The amount of Carbon Emissions for Infrastructure facilities in No. 67 Neighborhood Park

The total carbon emission of the neighborhood park except for green areas, was 65.5 tons, including 35.4 tons of pavement facilities, 2.84 tons of landscaping facilities, and 27.3 tons of infrastructure. The pavement facilities emitted about 54% of carbon out of total carbon emissions except for green area and vegetation. Among the main materials, the boundary material emitted 11.6 tons of carbon, and the pavement material emitted 23.8 tons of carbon. Although the clay block pavement accounted for about 85% of the total paved area, it emitted 12.8 tons of carbon, which is 54% of the carbon amount of total pavement facilities. Although Neighborhood Park No. 63 is the park centered on green area of a similar type with Neighborhood Park No. 63, the amount of carbon emission was much lower than No. 63 Park. This result was presumed to be due to the use of materials with low carbon emission as the main material for pavement facilities.

The carbon emission of trees was calculated as shown in <Table 25>. The amount of carbon emission from the treatment of dead trees in the park was estimated to be 225kg, and the carbon emission by soil improvement agent was estimated to be 667kg. On the other hand, the amount of net carbon emission by lawn was estimated to emit a high amount of carbon reaching 63.2 tons as shown in <Table 26>, which accounts for 49% of the total carbon emission of the park. It seems to be due to the grass coverd area was very high, reaching 70% of the target site.

Division	Size	Design Quantity	Equivalent Quantity	Dead tree Processing	Compost and improver agents
Trees	R 30	15	2.61	26.5kg	26.3kg
	R 20	6	1.13	5kg	8.7kg
	R 15	11	1.94	3.53kg	7.9kg
	R 10	37	6.18	4.07kg	21kg
	B 8	165	17.16	11.3kg	47.9kg
	R 6	387	44.95	17.25kg	112.2kg
Shrubs	W 0.3	2,000	208	26.9kg	49.7kg
	W 0.4	7,700	801	107.1kg	335kg
	W 0.6	1,000	104	23.4kg	58kg
Total				225kg	667kg

Table 25 The amount of Carbon Emissions for the trees &shrubs in No. 67 Neighborhood Park

species	Quantity	Production Basic Unit	Annual Carbon Emissions	Annual Carbon absorption	Annual Net carbon absorption	Carbon Emissions (30 years)
Korean Grass	8,827㎡	4.1kg/㎡	0.149kg/㎡	0.047kg/㎡	0.102kg/㎡	63,201kg

Table 26 The amount of Carbon Emissions for the lawn in No. 67 Neighborhood Park

The amount of carbon uptake by trees to offset carbon emission was calculated as shown in <Table 27>. Mountain ash is the deciduous broad-leaved small tree and Rosaceae family, so regression equation of the apricot tree which was the same member of the Rosaceae was applied. Chinese maple is also the deciduous broad-leaved tree of the Mapleaceae family, so the regression equation of blue maple was applied. Many small trees were planted in the target site, and the number of shrubs was relatively small compared to the No. 63 Neighborhood Park.

Species		Size	Quantity	Conversion Quantity	Bacic Unit	Carbon Absorption
Evergreen tree	Pine	R30	10	8.11	529kg	4,290kg
	Pine	R20	6	4.87	314kg	1,529kg
	Pine	R15	8	6.49	292kg	1,895kg
	Strobe pine	R6	147	125.2	152kg	19,037kg
Deciduous Tree	zelkova	R30	5	4.28	828kg	3,544kg
	zelkova	R15	3	2.568	661kg	1,697kg
	Mountain ash	R6	114	102	264kg	26,928kg
	Yoshino cherry	B8	165	147.84	438kg	64,753kg
	Chinese Fringe Tree	R6	126	114.67	378kg	47,628kg
	Chinese Maple	R10	37	30.8	122kg	3,760kg
Deciduous shrub	Red royal azalea	W0.4	700	628	0.15kg	94kg
	Korean early lilac	W0.6	1,000	896	0.2kg	179kg
	Purple beautyberry	W0.4	2,400	2,150	0.15kg	323kg
	Korean azalea	W0.4	4,600	4,122	0.15kg	618kg
	Border privet	W0.3	2,000	1,792	0.134kg	240kg
Total						176,515kg

Table 27 The Carbon uptake amount of the trees in No. 67 Neighborhood Park

The total amount of carbon absorbed by vegetation was estimated to be about 176.5tons, and the amount of net carbon absorption except for carbon emission by vegetation was only about 112.4tons. The high amount of carbon uptake was judged to be due to the planting of a large number of small trees. However, since the high planting density by the growth of trees was not considered, the actual amount of carbon uptake was judged to be rather lower. Putting the carbon balance in the park together, it was estimated that this park would absorb 46.9 tons of carbon during 30 years.

6. Conclusion

6.1 Improvement plan for each target site

6.1.1 Neighborhood Park No. 46

In terms of the park's function to solve urban problems, the target park was configured to faithfully perform the purpose of the park by arranging rest and convenience facilities around them, along with water play facilities, adventure play facilities, and sports facilities as the target park is a leisure-use park located on the site of a detached house complex. However, the multi-purpose lawn square located in the center of the park had the disadvantages in that there was no shade as a resting space and no sense of comfort from the surroundings. In particular, since the lawn yard has room for low utilization and unclear purpose due to overlapping of rest, exercise, and event functions, it is necessary to improve the sense of comfort and provide shade to take a rest by introducing independent trees. Each facilities seemed to lack functional linkage of space, and it seemed necessary to provide additional facilities for the convenience of users. In addition, it is judged that supplementary facilities and movement lines need to be supplemented.

In terms of the park's role in reducing carbon in cities, this park seems not to play a role as a carbon sink since it is expected to emit about 90.6 tons of carbon. The park is estimated to emits 31.6 tons of carbon from landscaping facilities, 161 tons of carbon from pavement facilities, and 18 tons of carbon from infrastructure for 30 years. The amount of net carbon absorption for vegetation is estimated to be 120 tons. Therefore, the use of pavement facilities with a high carbon emission rate and a large lawn area appears to be the main causes of carbon emission. The pavements with high emissions per unit area were rubber chip pavement (97.2kg/m2), grass block pavement (48.7kg/m2) and stone block pavement (39.4kg/ m2), etc. It was estimated to discharge 57.6 tons of carbon for rubber chip pavement, 37.7tons of carbon for stone block pavement, and 12.1tons of carbon for grass block pavement. The lawn area was 5,345㎡, and emitted about 38.3 tons of carbon. If rubber chip pavement and stone block pavement are replaced with clay block pavement, and grass block pavement is replaced with soil concrete pavement, it is possible to turn the current park into a carbon neutral park. In addition, if zelkova trees(R20) were planted at intervals of 15m for rest in 2,700㎡, which is about 1/2 of the grass area, No. 46 park would secure carbon reduction of about 10.8 tons without impairing the original function of the park, it seemed possible to act as a carbon sink for the city.

6.1.2 Neighborhood Park No. 63

In terms of the park's function to solve urban problems, the target park was configured to play a role as an environmental welfare type park in the new urban industrial district by installing multi-purpose courts and creating pine forests. However, the main design concept of the park, centered on the pine forest, seemed to be insufficient to achieve the original purpose of resting and physical training of nearby workers. For the welfare of workers, seasoned broad-leaved trees that provide sufficient well-shade should be arranged to provide a refreshing walking trails and resting spaces to cool off after exercise. The lawn space, which occupies about 60%, also seemed to need to be repurposed. It is necessary to create resting spaces that can provide sufficient well-shade and are harmonious with the surrounding landscape by introducing flower trees in the lawn yard. reinforce the resting function by supplementing resting and convenience facilities in the lower part. It is also necessary to reinforce the resting function by supplementing resting and convenience facilities under the trees.

In terms of the park's role in reducing carbon in cities, this park seems not to play a role as a carbon sink since it is expected to emit about 86.5 tons of carbon. The park is estimated to emits 7.7 tons of carbon from landscaping facilities, 96.9 tons of carbon from pavement facilities, and 29.9 tons of carbon from infrastructure for 30 years. The amount of net carbon absorption for vegetation is estimated to be 48 tons. Therefore, the use of pavement facilities with a high carbon emission rate, excessive drainage facilities, and a large lawn area appears to be the main causes of carbon emission. The pavements with high emissions per unit area were I.L.P blocks (40kg/m2), grass block pavement (48.7kg/m2). It was estimated to discharge 51.1 tons of carbon for I.L.P blocks and 15.1tons of carbon for grass block pavement. The main drainage facility was a circular water pipe, which emitted 20.4 tons of carbon when installed pipe 82.9m. The lawn area was 5,962㎡, and emitted about 42.7 tons of carbon. If I.L.P blocks are replaced with clay block pavement, and grass block pavement is replaced with soil concrete pavement, it is possible to reduce carbon emissions by 50.6 tons. And, if the circular water pipes are replaced with a double wall PE pipe, 14.2 tons of carbon emission can be reduced. In addition, if zelkova trees(R15) were planted at intervals of 10m for rest in 3,000㎡, which is about 1/2 of the grass area, No. 63 park would secure carbon reduction of about 25.9 tons without impairing the original function of the park. it seemed possible to turn the current park into a carbon neutral park. After all these measures were over, Putting the carbon balance in the park together, it was estimated that this park would absorb 4.2 tons of carbon for 30 years.

6.1.3 Neighborhood Park No. 67

In terms of the park's function to solve urban problems, the target park was configured to play a role as an environmental welfare type park around high-tech and landfill facilities by arranging many small trees. The park was intended to be the space for workers to rest and to buffer the pressure of the surrounding environment. The target site has a high green rate of 85.1%, and if it is maintained well in the future, it is expected to become the space that can buffter environmental pressure by implementing faithfully the concept of an urban forest park. However, it seemed not to be easy to meet the purpose of resting for workers due to the wide-open space and a few rest areas. To secure the rest area, it seemed to be necessary to introduce medium-sized trees that provide well-shade in an open space, and to provide sufficient rest facilities. In addition, the square and lawn yard were judged to have low usability because there are no differentiated facilities to attract workers and pedestrians in the street, so Creating an exercise space or city forest that can be linked with a rest space in the site seems to be a way to perform the original functions of the park.

In terms of the park's role in reducing carbon in cities, this park seems to play a role well as a carbon sink since it is expected to absorb about 46.9 tons of carbon. The park is estimated to emits 2.8 tons of carbon from

landscaping facilities, 35.4 tons of carbon from pavement facilities, and 27.3 tons of carbon from infrastructure for 30 years. The amount of net carbon absorption for vegetation is estimated to be 112.4 tons.
Planting the many small trees with high carbon uptake rates appears to be the main causes of the amount of high carbon absorption. However, Since the planting density increases as the tree grows, it is judged that the carbon absorption might be reduced than figures calculated in this study due to the high planting density. Therefore, it is necessary to secure a long-term plan for maintenance, timely implementation of management, and secure idle space for future transplantation to maintain the carbon absorption of trees as planned. In terms of carbon reduction, the lawn section that continuously emits carbon according to management seems appropriate for the area to secure the idle space.

6.2 Urban Parks Guidelines

6.2.1 Composition of the space

At the beginning of the introduction of urban parks, they tended to be installed as urban planning facilities for Improving the landscape or cultivating the health and emotions of urban residents. However, recently, they have been installed for the purpose of solving various urban problems, and accordingly, the functions of urban parks are diversifying. In this study, it was judged that the composition of space should be considered according to the main functions of urban parks, and the functions of urban parks were divided into leisure use, environmental welfare, environmental pressure reduction, and social roles. In addition, I suggest some ideas for the spatial composition through the consideration of the research target park.

Firstly, in order to achieve the function of leisure use, the spaces including amusement facilities, rest facilities, and convenience facilities should be closely connected by the user's movement system in the park. Moreover, it is necessary to secure multi-layered green spaces to increase the comfort of the park and the efficiency of the space. Secondly, walking trails and physical training facilities should be arranged around rest areas for environmental welfare. The trails should be closely connected to the rest area and physical training facilities, and should provide sufficient well-shade and pleasant. Thirdly, in order for the park to buffer the environmental pressure, the sufficient size of green space must be secured. Fourthly, the shorter the trails in the park for leisure and social functions are, the better the accessibility is. On the other hand, since the trail is the main facility of the park for environmental pressure and environmental welfare, the appropriate distance must be provided and the surrounding environment must be pleasant. Finally, among the elements introduced into the park, the lawn yard has high management requirement and lack of shade. Therefore, it is reasonable to introduce wide lawn yard only when the role in the park is clear.

6.2.2 Introduced vegetation to improve carbon balance

The carbon emission factors from trees management were assumed only for the recycling of dead trees and input of compost and improvement agent. The emission amount was relatively low. On the other hand, the carbon emission amount from lawn accounted for 95% of the emission amount of vegetation. In addition, the lawn may need additional management depending on the occurrence of pests or complaints from users. Therefore, it is necessary to avoid creating a large area of lawn.

The best arboreal trees with high carbon uptake rate were selected as Zelkova and Chinese Fringe Tree. As the secondary preferred trees for carbon reduction, Yoshino cherry and Chinese scholar tree were suggested. The small tree for multi-layered planting with these trees was selected as apricot tree and Camellia. Their defect rate was near average. However, not only metasequoias and bambu-leaf oak with high defect rates, but also Tulip Tree and Birch trees, which are fast-growing trees, may be introduced depending on the situation such as tree management.

The planting forms of trees for carbon reduction are multi-layered planting through mixing arboreal trees and small trees, or planting arboreal trees with high carbon uptake rate when their sizes are small. In addition, in order to strengthen the function of the park as a carbon sink, it is necessary to continuously discover tree species with a high carbon absorption rate and study methods for lowering the defect rate for each species.

6.2.3 Introduced facilities to improve carbon balance

More than 50% of the carbon emissions of parks 46, 63, and 67 in Sihwa MTV were emitted from pavement facilities. In particular, the carbon emission amount of pavement facilities using concrete in areas requiring high durability such as parking lots and pavement facilities using rubber chips for safety was very high. The infrastructure facilities using large amounts of concrete and rebar also emitted large amounts of carbon. Meanwhile, landscaping facilities and structures exposed to the outside had low carbon emission amount. Moreover, carbon emissions from the construction, transportation, and management of the facilities introduced in the park were also low. Therefore, the following measures are necessary to minimize carbon emissions by facilities introduced in urban parks.

First of all, materials with low carbon emission should be used for all facilities. Materials with low carbon emissions in the manufacturing process were clays and woods. Although the durability of wood was inferior, the durability showed a tendency to be strengthened when the shape was changed and used in combination with other materials. Another way to reduce carbon emissions is to use products certified on EPD for facilities requiring durability, which emit much less carbon than the same facility. Urban problems can be effectively solved by using facilities in various ways according to the surrounding landscape, usage, and aesthetics. Therefore, it is not a good idea to use only materials with low carbon emission. Finally, natural materials that do not emit carbon in the manufacturing process, such as sand, gravel, and soil, should be in pavement and landscaping facilities. Recently, there is a tendency to create ecological facilities using natural materials in parks, and to make up spaces such as ecological playgrounds that introduce them. These parks work to cultivate the emotions of users and reduce stress of users by introducing nature in the city

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8. Appendix

1. Vegetation-related carbon absorption and emission basic unit

Division	Specification	Details	Related coefficient	Source
Japanese larch		Corrosion grade 1, Dry mass	0.5t C/t. d.m. (Carbon Conversion Factor)	Greenhouse Emission coefficient (2020)
Pine			0.51C/t. d.m	
Nut Pine			0.47 C/t. d.m	
Needleleaf tree			0.5 C/t. d.m	
Sawtooth oak			0.46 C/t. d.m	
Broadleaf tree			0.49 C/t. d.m	
tree production Ⅰ	DBH 7cm	Seeding, seedling production & transport, seedling transplantation & tree production, excavation	1.7kg	Park, Hye-mi (2020)
Introduction tree	DBH 7cm	Cumulative uptake	6.2kg	
tree production Ⅱ	DBH 10cm	〃	2.6kg	
Introduction tree	DBH 10cm	Cumulative uptake	14.7kg	
tree production Ⅲ	DBH 13cm	〃	3.4kg	
Introduction tree	DBH 13cm	Cumulative uptake	27.6kg	
Shrub production	H 30cm		78g	
Introduction shrub	H 30cm	Cumulative uptake	48.5g	
lawn production	Korean grass		4.1kg/㎡	
Lawn management	Korean grass	Mowing volume; 0.27kg/year Number of mowering plants; 6.8times / year Lawn spray; once/ year	0.149kg/㎡/ year	
Lawn	Korean grass	carbon uptake	0.047kg/㎡/year	Jo and McPherson (1995)
Transplantation of trees	DBH 35cm	Pine Tree (Gangwon → Seoul)	118.1 kg	Choi Yoo (2014)
Disposal	DBH 10cm	22kg above ground, 13kg underground		Korean Landscaper society

Tree removal	DBH 10cm	Gasoline 0.094ℓ, Lubricant 0.039ℓ		(2016)
Compost			0.058kg/kg	National Academy of Agricultural Sciences (2020)
Compound fertilizer, Weedkiller		Use of the PASS program of the Ministry of Commerce, Industry and Energy	0.235kg/kg	Lee, Jong-sik et al. (2018)
Timber tree		Larch Lumber Production	42.9kg/㎥	Land and Housing Research Institute (2018)

NOTE: Transportation is based on a full load in a 4.5 ton truck. Medium distance is calculated based on 200km

2. Fuel consumption per a tree due chainsaw operation during tree removal (Korea Landscaper Society, 2016)

Chest height diameter	Fuel (L/a tree)	
	Gasoline	Lubricant
≦ 8cm	0.065	0.026
10cm	0.094	0.039
15cm	0.218	0.09
20cm	0.412	0.17
25cm	0.730	0.302
30cm	1.176	0.487
35cm	1.744	0.722
40cm	2.923	1.211
45cm	3.910	1.619

3. Amount of forest waste per a tree by chest height diameter (Korea Landscaper Society, 2016)

Chest height diameter	Forest waste (kg/a tree)	
	Ground Division	Underground
10cm	22	13
15cm	63	44
20cm	124	105
25cm	194	206
30cm	279	327
35cm	380	591
40cm	633	952

45cm	915	1,268

4. Carbon Emissions for Major Construction Materials

Division	Details	Carbon Emissions (Equivalent)	Sources
Gasoline	0.930 (conversion factor) × 32.7(Total Calorific Value) ×19,548/10^6	0.594kg/l	Greenhouse emissions Coefficients (2018)
Diesel	0.931×37.8×20,111/10^6	0.708kg/l	
Lubricant	0.933×40.0×19,979/10^6	0.746kg/l	
Ready-mixed concrete	Ready-mixed concrete 25-210-12	111.54kg/m^3 (≒0.044kg/kg)	(Roh Seung-joon, Tae Sung-ho Tae-hyung, Kim Nak-hyun, 2013) KEITI LCI DB
	Ready-mixed concrete 25-210-15	114.27kg/m^3	
	Ready-mixed concrete 25-240-12	112.9kg/m^3	
	Ready-mixed concrete 25-240-15	117kg/m^3	
Steel	ㄱ,ㄷ,I - shaped steel	0.11kg/kg	
	H-shaped steel	0.108kg/kg	
Paint	Unsaturated polyester system	0.783kg/kg	
	Water-soluble water system	0.325kg/kg	
	Amino-Altide	0.228kg/kg	
	Water-soluble emulsion system	0.088kg/kg	
Glass	Plate glass	0.215kg/kg	
	PP Glass Door	0.11kg/kg	
Concrete products	Cement	0.289kg/kg	
	Portland cement (1,2 types)	0.258kg/kg	
	Goroslag cement	0.056kg/kg	
Insulation	Foamed polystyrene plate	0.561kg/kg	
Clay brick		0.49kg/kg	Lee Kang-hee, Yang Jae-hyuk (2009)
		0.108kg/kg	KEITI (2019)
		0.109kg/kg	Thompson and sorvig(2018)

Iron material		1.21kg/kg	Thompson and sorvig(2018)
		0.956kg/kg	KICT (2004)
	Industry Association Analysis	1.2kg/kg	Lee Kang-hee, Yang Jae-hyuk (2009)
		0.374kg/kg	BSRIA (2011)
Wood		0.06kg/kg	Thompson and sorvig(2018)
		0.082kg/kg	BSRIA(2011)
		0.125kg/kg	Hammond and Jones(2008)
plastic		0.69kg/kg	Hammond and Jones(2008)
		1.79kg/kg	Kim Jong-yop, Kim Sung-wan, and Son Chang-yeol (2004)
Plastic Tube		3.9kg/kg	Kim Jong-yop, Kim Sung-wan, and Son Chang-yeol (2004)
Polypropylene		0.77kg/kg	Lee Kang-hee, Jaehyuk Yang (2010)
Granite		0.123kg/kg	Bae Eun-suk (2013)
		0.1kg/kg	Lee Kang-hee, Lee Ha-sik, and Yang Jae-hyuk (2010)
Zinc Steel Sheet		0.417kg/kg	Lee Kang-hee, Lee Ha-sik, and Yang Jae-hyuk (2010)
Aluminum Plate		2.25kg/kg	Hammond and Jones (2008)
		2.36kg/kg	Lee Kang-hee, Lee Ha-sik, and Yang Jae-hyuk (2010)
Aluminum Plate	Pavement Materials	0.5kg/kg	KEITI (2019)
Stainless Steel bar		2.9kg/kg	Lee Kang-hee, Jaehyuk Yang (2010)
Stainless Steel		0.9kg/kg	KEITI (2019)
Phenolic resin	Industry Association Analysis	1.58kg/kg	Lee Kang-hee, Jaehyuk Yang (2010)
		1.28kg/kg	Kim Jong-yop, Kim Sung-wan, and Son Chang-yeol (2004)
Rubber sheet		0.9kg/kg	
Clay Blocks		0.11kg/kg	KEITI (2019)
EPDM		1.2kg/kg	KEITI (2019)
Concrete tile		0.3kg/kg	Lee Kang-hee, Yang Jae-hyuk (2009)
Concrete brick		0.04879kg/pcs	Lee Kang-hee, Lee Ha-sik, and Yang Jae-hyuk (2010)
Gravel		1.4kg/㎥	Lee Kang-hee, Yang Jae-hyuk (2009)
		3.08kg/㎥	KEITI (2019)

Sand	Industry Association Analysis	1.45kg/㎥	Lee Kang-hee, Yang Jae-hyuk (2009)
		1.7kg/㎥	KICT (2004)
		1.05kg/㎥	KEITI (2019)
Crushed stone		4.08kg/㎥	Kim Jong-yop, Kim Sung-wan, Son Chang-yeol (2004)
		3.25kg/㎥	Bae Eun-suk (2013)
Urethane painting		2.56kg/kg	Lee Kang-hee, Yang Jae-hyuk (2009)
Earthworks	readjusting the land	0.71kg/㎡	Hye-Mi Park (2021)
	cut and fill the land	1.0kg/㎥	
	Soil import and export	0.9kg/㎥ (within 5km)	
Boundary Stone	150×150, T200 (Remicon)	2.2kg/m	
	Medium-haul transportation	0.37kg/m	
Demolition of green area		0.83kg/㎡	
Demolition of pavement		0.11kg/㎡	
Wood crushing	Waste, Measuring Value	0.0156kg/kg	
Plasterboard		0.073kg/kg	KICT (2004)
Cement		0.088kg/kg	KICT (2004)
		0.258kg/kg	KEITI (2019)
		0.199kg/kg	BSRIA (2011)

5.EPD Certification Status for Construction Materials (2021.6)

Business Name	**Certified Product Name**	**Carbon Emissions (Equivalent)**
Daeduck Wood	Timber Deck Merbau	36.81kg/㎥ (approx. 0.05kg/kg)
	Design Fence	8.54kg/span
Intelligent Industry Development	Waterway type collector (1000*600)	65.45kg/ea
Halla Encom	Ready-mixed concrete (25-30-150)	67.6kg/㎥
PPI	DH Drainpipe	0.695kg/kg
KCC	Plasterboard (9.5T)	0.305kg/㎡
Hyundai L&C	Wooden floor	1.1kg/㎡

	Hyundai Tiles	0.7kg/㎡
	Window Profile	0.385kg/kg
SWH Industry	Ready-mixed concrete (25-40-150)	72.82kg/㎥
Asia Cement	Ready-mixed concrete (25-30-150)	87kg/㎥
	Ready-mixed concrete (25-27-150)	75.82kg/㎥
	Ready-mixed concrete (25-24-150)	67.9kg/㎥
	Ready-mixed concrete (25-21-150)	66.5kg/㎥
Prime Enertech	Low-emission composite insulation	26.51kg/㎥
Daeheung resin	Foamed polystyrene insulation	16.01kg/㎥
Dongcheon	Semi-non-combustible hard polyurethane foam insulation	51.81kg/㎥
Dasco	2 types of hard polyurethane foam insulation	51.81kg/㎥
SungEun	Light bubble concrete block (0.6 articles)	73.09kg/㎥
Sampyo construction	Dry cement mortar (high strength)	0.077kg/kg
LG hausys	Interior Film	0.428kg/㎡
Sandul maru	River Floor (7.5 mm)	1.65kg/㎡
Young-Jong industry Co., Ltd.	Heated asphalt concrete	26.7kg/ton

6. Tree age & Diameter

Scientific name	**Introduction tree age (B=7cm)**	**Diameter after 30 years of introduction**	**Sources**
Acer palmatum	0.42×5+0.59×5+0.63×3= 6.94 (13 years)	6.94+0.89×5+0.63×25 ≒ 27cm	Jo Hyun-kil, Hye-Mi Park (2017)
Chionanthus retusus	0.46×5+0.60×5+0.55×3= 6.95 (13 years)	6.95+0.55×2+0.62×5 +0.54×23 ≒ 24cm	
Cornus officinalis	0.57×5+0.68×5+0.84×1= 7.09 (11 years)	7.09+0.84×4+0.98×5 +0.69×21 ≒ 30cm	
Ginkgo biloba	0.5×5+0.77×5+0.92 =7.27 (11 years)	7.27+0.92×4+0.78×10 +0.74×5+0.73×11≒30cm	
Purnus armeniaca	0.39×5+0.6×5+0.63*3 = 6.84 (13 years)	6.84+0.63×2+0.65×5+0.43×5+0.41×5+0.39×5+0.21×8 ≒19cm	

Purnus yedoensis	0.65×5+0.98×4 = 7.17 (9-year)	7.17+0.98+1.24×5+0.97×5 +0.89×19 ≒ 36cm	
Zelkova serrata	0.65×5+1.08×3.5 = 7.03 (8.5 years)	7.03+1.08×1.5+1.26×5+1.16 ×5+1.17×5+13.5 ≒ 40cm	
Abies holophylla	0.47×5+0.68×5+0.95 = 6.7(11 years)	6.7+0.95×4+0.8×5+ 0.7×21 ≒ 29cm	
Pinus densiflora	0.68×5+1.02×3.5 = 6.97 (8.5 years)	6.97+1.02×1.5+0.84×5+0.82×5 +0.72×5+0.67×13.5 ≒ 29cm	
Pinus koraiensis	0.74×5+1.11×3 = 7.03 (8 years)	7.03+1.11×2+0.98×5+0.91 ×5+0.95×5+0.93×13 ≒ 36cm	
Taxus cuspidata	0.27×5+0.42×5+0.49×5+ 0.49×2 = 6.88 (17years)	6.88+0.49×3+0.52×5+0.47 ×5+0.39×17 ≒ 20cm	
Lagerstroemia indica	0.52×5+0.73×6 = 6.98 (11-year)	6.98+0.73×30 ≒ 29cm	Jo Hyun Kil et al. (2019) survey
Camellia japonica	0.65×11 = 7.15 (11 years)	7.15+0.65×30 ≒ 27cm	
Quercus myrsinaefolia	0.65×5+0.83×5 = 7.4 (10-year)	7.4+0.83×30 ≒ 32cm	
Deciduous trees	0.86×5+0.9×3 = 7(8 years)	7+0.9×2+0.75×5+0.74×5+0 . 62×5+0.61×5+0.58×8≒27cm	Jo Hyun-kil, Hye-Mi Park (2017)
Evergreen trees	0.77×5+0.67×5= 7.2(10-year)	7.2+0.66×5+0.68×5+0.72×5 +0.8×5+0.8×5+0.72×5 ≒29cm	
shrubby deciduous trees	0.42×2.5=1.05(2.5years)	1.05+0.42×30=13.65	Jo Hyun-kil (1999)
shrubby evergreen trees	0.26×4=1.04 (4 years)	1.04+0.26×30=8.84	

7. Carbon Storage Quantitative Model for Trees

Scientific name		**Quantitative Model (B=7cm)**	**Carbon storage (During 30 years)**	**Sources**
Deciduous	Lagerstroemia indica	ln Y = -3.2502 + 2.3199 lnDg	91kg	Jo Hyun-kil, Kil Seung-ho, Hye-mi Park, and Kim Jin-young (2019)
	Chionanthus retusa	ln Y = -2.7512 + 2.4952 lnDbh	162kg	Jo Hyun-kil, Hye-mi Park, and Kim Jin-young (2014)
	Purnus armeniaca	ln Y = -2.4307 + 2.2999 lnDbh	213kg	
	Cornus officinalis	ln Y = -3.3110 + 2.4057 lnDg	125kg	

	Acer palmatum	Y = -23.2064 + 4.8538 Dbh	98kg	Jo Hyun-kil, Ahn Tae-won (2012)
	Zelkova serrata	ln Y = -2.4708 + 2.3862 lnDbh	557kg	
	Purnus yedoensis	ln Y = -2.8265 + 2.4181 lnDbh	339kg	
	Ginkgo biloba	ln Y = -2.8428 + 2.3862 lnDbh	196kg	
Evergreen	Camellia japonica	ln Y = -4.9154 + 3.1833 lnDg	249kg	Jo Hyun-kil, Kil Seung-ho, Hye-mi Park, and Kim Jin-young (2019)
	Quercus myrsinaefolia	ln Y = -2.4849 + 2.4593 lnDbh	418kg	
	Abies holophylla	ln Y = -2.2126 + 2.0814 lnDbh	117kg	Jo Hyun-kil, Hye-mi Park, and Kim Jin-young (2014)
	Taxus cuspidata	ln Y = -3.7842 + 2.4407 lnDg	65kg	
	Pinus koraiensis	ln Y = -4.4489 + 2.8942 lnDbh	356kg	Jo Hyun-kil, Kim Jin-young, and Kim Jin-young (2013)
	Pinus densiflora	ln Y = -3.1140 + 2.4430 lnDbh	167kg	
Deciduous species		ln Y = -2.5274 + 2.3431 lnDbh	173kg	Jo Hyun-kil (2020)
Evergreen species		ln Y = -3.3130 + 2.5098 lnDbh	167kg	
Deciduous shrubs		ln Y = 5.1929+1.9494 lnDAG×12/44	0.215kg	Jo Hyun-kil (2001)
Evergreen shrub		lnY = 5.0801+2.1892 lnDAG×12/44	0.17kg	

8. The Plan for the Creation of Sihwa MTV Park

시화MTV 공원 조성계획

■ 공원현황

- 공 원 : 총 32개소, 면 적 : 738천㎡
  [생활권 11개소] 근린 7, 어린이 3, 소 1개소
  [주 제 21개소] 수변 12, 체육 3, 문화 5, 도시농업 1개소
- 광 장 : 총 7개소(교통광장 2개소 미포함), 면 적 : 35천㎡

구 분	번호	면적 (㎡)	위 치	비고	구 분	번호	면적 (㎡)	위 치	비고
합 계	**32개소**	**737,693**			수변공원	83호	63,577	73호 녹지변	안산시
근린공원	**7개소**	**168,299**			수변공원	84호	1,468	상업업무용지변	시흥시
근린공원	46호	10,798	주거용지내	시흥시	수변공원	85호	3,000	남측지구계변	시흥시
근린공원	50호	90,123	상업업무용지내	시흥시	수변공원	86호	3,000	남측지구계변	시흥시
근린공원	55호	14,233	유통상업용지내	시흥시	**체육공원**	**3개소**	**108,849**		
근린공원	63호	10,044	신소재산업지구내	시흥시	체육공원	48호	38,552	제9 하천변	시흥시
근린공원	67호	12,703	중로1-89호선변	안산시	체육공원	52호	37,297	하수처리장 동측변	안산시
근린공원	74호	10,089	신소재산업지구내	안산시	체육공원	86호	33,000	14투취장	안산시
근린공원	75호	20,309	발전소 동측변	안산시	**문화공원**	**5개소**	**241,074**		
어린이공원	**3개소**	**6,516**			문화공원	53호	6,594	유통업무지구내	안산시
어린이공원	64호	2,266	주거용지내	시흥시	문화공원	79호	7,018	벤처기업지구내	안산시
어린이공원	66호	1,908	주거용지내	시흥시	문화공원	87호	42,687	중로 1-103 호선변	안산시
어린이공원	73호	2,342	주거용지내	시흥시	문화공원	88호	166,521	대로 2-19 호선변	시흥시
소공원	**1개소**	**720**			문화공원	89호	18,254	제11 하천변	안산시
소공원	76호	720	상업업무용지내	안산시	**도시농업공원**	**1개소**	**10,002**		
수변공원	**12개소**	**202,234**			도시농업공원	81호	10,002	제9 하천변	시흥시
수변공원	45호	32,710	제8 하천변	시흥시	**광 장**	**7개소**	**34,783**		교통광장제외
수변공원	47호	13,750	제9 하천변	시흥시	일반광장	1호	2,480	상업업무용지내	시흥시
수변공원	49호	10,079	제11 하천변	안산시	일반광장	2호	2,750	상업업무용지내	시흥시
수변공원	51호	31,114	제12 하천변	안산시	일반광장	3호	3,632	상업업무용지내	시흥시
수변공원	60호	3,858	대로 2-19 호선변	시흥시	일반광장	4호	1,997	상업업무용지내	시흥시
수변공원	65호	22,477	제13 하천변	안산시	경관광장	5호	16,877	상업업무용지내	안산시
수변공원	68호	8,199	중로 1-103 호선변	안산시	일반광장	6호	3,524	상업업무용지내	안산시
수변공원	80호	9,002	철새서식지내	시흥시	일반광장	7호	3,524	상업업무용지내	안산시

9. The carbon emissions for Landscape Facilities in No. 46 Neighborhood Park

Species		quantity	Material Composition					Carbon Outflow
			Item	Quantity	Unit weight	Basic Unit	Carbon Outflow	
Amusement Facilities	Log Bridge Playstand	1EA	Wood	1.067 m^3	750kg/ m^3	0.089kg/kg	71.2kg	274kg
			Oilstain	5.69ℓ	0.6kg/ℓ	0.325kg/kg	11.1kg (1 time/3 years)	
			Ready-mixed concrete	1.68 m^3		114.27kg/ m^3	191.9kg	
	Spider Netting stand	1EA	Wood	0.875 m^3	750kg/ m^3	0.089kg/kg	58.4kg	326kg
			Oilstain	4.58ℓ	0.6kg/ℓ	0.325kg/kg	8.9kg (1 time/3 years)	
			Ready-mixed concrete	1.68 m^3		114.27kg/ m^3	191.9kg	
			Wrought iron	0.0073 m^3	7,800kg/ m^3	1.02kg/kg	57.7kg	
			Plastic	0.0073 m^3	980kg/ m^3	1.24kg/kg	8.8kg	
	Sloping SCovere A	1EA	Wood	0.106 m^3	750kg/ m^3	0.089kg/kg	7.1kg	1,385kg
			Ready-mixed concrete	0.117 m^3			13.4kg	
			Iron (steel)	0.0088 m^3	7,850kg/ m^3	1.02kg/kg	70.9kg	
			Plastic	1.066 m^3	980kg/ m^3	1.24kg/kg	1,294kg	
	Sloping SCovereB	1EA	Wood	0.155 m^3	750kg/ m^3	0.089kg/kg	10.3kg	2,140kg
			Ready-mixed concrete	0.143 m^3		114.27kg/ m^3	16.4kg	
			Iron (steel)	0.012 m^3	7,850kg/ m^3	1.02kg/kg	98.8kg	
			Plastic	1.657 m^3	980kg/ m^3	1.24kg/kg	2,014kg	
	Turtle Sculptures	3EA	Granite	0.142 m^3	2,650kg/ m^3	0.123kg/kg	46.5kg	140kg (46.5)
Information Facilities	Park nameplate (columnar)	1EA	Wood	0.081 m^3	900kg/ m^3	0.089kg/kg	6.5kg	28kg
			Ready-mixed concrete	0.113 m^3		114.27kg/ m^3	12.9kg	
			Iron (steel)	8.48kg		1.02kg/kg	8.64kg	
	Usage information board	2EA	Stainless steel	0.002 m^3	7,900kg/ m^3	0.9kg/kg	14.6kg	33kg (16.4)
			Ready-mixed concrete	0.016 m^3		114.27kg/ m^3	1.8kg	
Rest Facilities	Connected Pergola	1EA	Wood	0.34 m^3	700kg/ m^3	0.089kg/kg	16.9kg	3,497kg
			Frame Sheet	0.099 m^3	5,280kg/ m^3	1.361kg/kg	714.4kg	
			Ready-mixed concrete	3.53 m^3		114.27kg/ m^3	403.1kg	
			Iron (steel)	1,970kg		1.02kg/kg	2,009kg	
			Plastic	0.29 m^3	980kg/ m^3	1.24kg/kg	354kg	

	Pagora F	2EA	Wood	0.53㎥	700kg/㎥	0.089kg/kg	26.5kg	1,452kg (725.9)
			Stainless steel	0.077㎥	7,900kg/㎥	0.9kg/kg	547.5kg	
			Ready-mixed concrete	0.256㎥		114.27kg/㎥	29.3kg	
			Aluminum	0.014㎥	2,710kg/㎥	2.305kg/kg	85.7kg	
			Plastic	0.03㎥	980kg/㎥	1.24kg/kg	36.9kg	
	Back chair F	6EA	Wood	0.034㎥	700kg/㎥	0.089kg/kg	1.7kg	305kg (50.8)
			Oilstain	0.78ℓ	0.6kg/ℓ	0.325kg/kg	1.5kg (1 time/3 years)	
			Aluminum	0.007㎥	2,710kg/㎥	2.305kg/kg	44.5kg	
			Ready-mixed concrete	0.027㎥		114.27kg/㎥	3.1kg	
	Square chair	3EA	Wood	0.084㎥	700kg/㎥	0.089kg/kg	4.2kg	549kg (183)
			Granite	0.036㎥	2,650kg/㎥	0.123kg/kg	12kg	
			Ready-mixed concrete	0.09㎥		114.27kg/㎥	10.3kg	
			Aluminum	0.012㎥	2,710kg/㎥	2.305kg/kg	77.7kg	
			Iron (steel)	0.01㎥	7,850kg/㎥	1.02kg/kg	78.8kg	
	Flat chair F	24EA	Wood	0.037㎥	700kg/㎥	0.089kg/kg	1.84kg	1,080kg (45kg)
			Oilstain	0.45ℓ	0.6kg/ℓ	0.325kg/kg	0.88kg (1 time/3 years)	
			Aluminum	0.006㎥	2,710kg/㎥	2.305kg/kg	39.3kg	
			Ready-mixed concrete	0.027㎥		114.27kg/㎥	3.1kg	
Sports Facilities	Warming arm	1EA	Iron (steel)	75.8kg		1.02kg/kg	78.8kg	110kg
			Aluminum	0.0011㎥	2,710kg/㎥	2.305kg/kg	7.2kg	
			Ready-mixed concrete	0.21㎥		114.27kg/㎥	24kg	
	Leg Extension	1EA	Iron (steel)	70kg		1.02kg/kg	71.4kg	112kg
			Aluminum	0.0011㎥	2,710kg/㎥	2.305kg/kg	6.8kg	
			Ready-mixed concrete	0.144㎥		114.27kg/㎥	16.5kg	
			Plastic	0.014㎥	980kg/㎥	1.24kg/kg	17.7kg	
	Full-weight	1EA	Iron (steel)	154.74kg		1.02kg/kg	157.8kg	231kg
			Aluminum	0.0013㎥	2,710kg/㎥	2.305kg/kg	8.2kg	
			Ready-mixed concrete	0.441㎥		114.27kg/㎥	50.39kg	
			Plastic	0.012㎥	980kg/㎥	1.24kg/kg	14.5kg	
	Step Cycle	1EA	Iron (steel)	85.45kg		1.02kg/kg	87.2kg	135kg

			Aluminum	0.0011㎥	2,710kg/㎥	2.305kg/kg	7.2kg	
			Ready-mixed concrete	0.441㎥		114.27kg/㎥	30.2kg	
			Plastic	0.008㎥	980kg/㎥	1.24kg/kg	10.1kg	
	Twin Twist	1EA	Iron (steel)	61.8kg		1.02kg/kg	63.1kg	91kg
			Aluminum	0.0011㎥	2,710kg/㎥	2.305kg/kg	6.8kg	
			Ready-mixed concrete	0.264㎥		114.27kg/㎥	16.5kg	
			Plastic	0.004㎥	980kg/㎥	1.24kg/kg	4.1kg	
Convenience Facilities	Water supply C	1EA	Wood	0.53㎥	700kg/㎥	0.089kg/kg	26.5kg	138kg
			Stainless steel bar	16.4kg		2.9kg/kg	47.6kg	
			Stainless steel	58.3kg		0.9kg/kg	52.5kg	
			Ready-mixed concrete	0.06㎥		114.27kg/㎥	6.9kg	
			Plastic	3.839kg		1.24kg/kg	4.7kg	
	Bicycle rack	1EA	Stainless steel bar	9.2kg		2.9kg/kg	26.7kg	110kg
			Stainless steel	50.3kg		0.9kg/kg	45.3kg	
			Ready-mixed concrete	0.04㎥		114.27kg/㎥	4.6kg	
			Iron (steel)	5.3kg		1.02kg/kg	5.4kg	
	Outdoor shower	2EA	Stainless steel bar	73.9kg		2.9kg/kg	214kg	453kg (226.6)
			Plastic	10.2kg		1.24kg/kg	12.6kg	
Water Play Facilities	Ellis Water Exploration	1EA	Hardwood	0.017㎥	900kg/㎥	0.089kg/kg	1.1kg	2,443kg
			Stainless steel bar	339kg		2.9kg/kg	983kg	
			Ready-mixed concrete	0.648㎥		114.27kg/㎥	74kg	
			Phenolic resin	0.346㎥	1,300kg/㎥	1.6kg/kg	721.5kg	
			Plastic	0.97㎥	980kg/㎥	1.24kg/kg	654.5kg	
			Wrought iron	0.001㎥	7,800kg/㎥	1.02kg/kg	7.8kg	
			P.P	0.001㎥	910kg/㎥	0.77kg/kg	0.7kg	
	Machine room	1 place	Ready-mixed concrete	36.7㎥		114.27kg/㎥	4,193kg	10,735kg
			Rebar	6,400kg		1.02kg/kg	6,528kg	
			Stainless steel bar	4.8kg		2.9kg/kg	13.9kg	
	Equipment & Foundation	1 place	Stainless steel bar	2,047kg		2.9kg/kg	5,936kg	6,272 kg
			Ready-mixed concrete	2.94㎥		114.27kg/㎥	336kg	

10. The carbon emissions for Pavement Facilities in No. 46 Neighborhood Park

Species	Specification	Quantity	Material Composition					Carbon Outflow
			Item	Quantity	Unit weight	Basic Unit	Carbon Outflow	
Timber Deck	L 34m× W 2.4m	1 place	Hardwood	2.19㎥	900kg/㎥	0.089kg/kg	175.4kg	2,305kg
			Rubble	15.04㎥		3.67kg/㎥	55.2kg	
			Ready-mixed concrete	9.28㎥		114.27kg/㎥	1,060.4 kg	
			Iron (steel)	920kg		1.02kg/kg	938.4kg	
			Oilstain	38.8ℓ	0.6kg/ℓ	0.325kg/kg	75.7kg (1 time/3 years)	
Road Boundary Stone	200×250 ×1,000	74.8m	Boundary Stone	1m	135kg/m	0.112kg/kg	15.1kg	2,349kg
			Ready-mixed concrete	0.146㎥		111.54kg/㎥	16.3kg	
Green Boundary Stone	150×150 ×1,000	1,123.6m	Boundary Stone	1m	60.8kg/m	0.112kg/kg	6.8kg	11,404 kg
			Ready-mixed concrete	0.03㎥		111.54kg/㎥	3.35kg	
Pavement Boundary Stone	150×150 ×1,000	148.5m	Boundary Stone	1m	60.8kg/m	0.112kg/kg	6.8kg	1,391kg
			Ready-mixed concrete	0.023㎥		111.54kg/㎥	2.57kg	
Clay Block Pavement	T55	1,579.4㎡	Clay Blocks	0.055㎥	1,300 kg/㎥	0.11kg/kg	7.87kg	13,098 kg
			Sand	0.04㎥		1.4kg/㎥	0.056kg	
			Mixed aggregates	0.1㎥		3.67kg/㎥	0.367kg	
Stone Block Pavement	T60	956.4㎡	Concrete tile	1㎡	130kg/㎡	0.3kg/kg	39kg	37,704 kg
			Sand	0.04㎥		1.4kg/㎥	0.056kg	
			Mixed aggregates	0.1㎥		3.67kg/㎥	0.367kg	
Rubber chips Pavement	T100	593㎡	EPDM	0.01㎥	870kg/㎥	1.2kg/kg	10.4kg	57,649 kg
			Rubber chips	0.09㎥	930kg/㎥	0.9kg/kg	75.3kg	
			Ready-mixed concrete	0.1㎥		111.5kg/㎥	11.15kg	
			Mixed aggregates	0.1㎥		3.67kg/㎥	0.367kg	
Grass Block Pavement	T150	249.5㎡	Upper of the grass block	0.033㎥	2,300kg/㎥	0.3kg/kg	22.8kg	12,133 kg
			Lower of the grass block	0.06㎥	1,300kg/㎥	0.3kg/kg	23.4kg	
			Sand	0.04㎥		1.4kg/㎥	0.056kg	

			Mixed aggregates	0.2㎥		3.67kg/㎥	0.734kg	
			Lawn	0.4㎡		4.1kg/㎡	1.64kg	
Granite Slabstone Pavement	T30	17㎡	Granite Slabstone	0.03㎥	2,650kg/㎥	0.1115kg/kg	8.9kg	430kg
			mortar	0.03㎥	2,100kg/㎥	0.077kg/kg	4.9kg	
			Ready-mixed concrete	0.1㎥		111.5kg/㎥	11.kg	
			Mixed aggregates	0.1㎥		3.67kg/㎥	0.367kg	
Lawn Protection Pavement	T72	24.8㎡	Lawn	0.9㎡		4.1kg/㎡	3.69kg	310kg
			Sand	0.05㎥		1.4kg/㎥	0.07kg	
			Plastic	0.0072㎥	980kg/㎥	1.24kg/kg	8.75kg	
Stepping Deck	T450	78 places	Wood	0.043㎥	700kg/㎥	0.089kg/kg	2.67kg	209kg
Sand block	D100	137.7m	Radieta Pine	0.0314㎥	420kg/㎥	0.089kg/kg	1.17kg	2,324kg
			Ready-mixed concrete	0.09㎥		111.5kg/㎥	10kg	
			Iron (steel)	5.6kg		1.02kg/kg	5.71kg	
Braille Blocks		21.2㎡	Concrete tile	0.06㎥	2,300kg/㎥	0.3kg/kg	41.4kg	886kg
			Sand	0.04㎥		1.4kg/㎥	0.056kg	
			Mixed aggregates	0.1㎥		3.67kg/㎥	0.367kg	

281. The carbon emissions for Infrastructuer Facilities in No. 46 Neighborhood Park

Division		Item	Quantity	Unit weight	Basic Unit	Carbon Conversion
Earthworks	Pilling up soil		2,251㎥		0.1kg/㎥	225kg
	Flattening the surface of mound		2,233㎥		0.71kg/㎥	1,585kg
Rainwater Drainage Facilities	Collecting well	Ready-mixed concrete	16.25㎥		111.5kg/㎥	1,812kg
		Cover	247kg		1.02kg/kg	252kg
	Double wall PE tube		432.8m	980kg/㎥	1.24kg/kg	10,715kg
	Dummy ditch	Gravel	19.2㎥		2.24kg/㎥	43kg
		HDPE pipe	1,690kg		1.24kg/kg	2,096kg
	PE collector	Cover	50.8kg		1.02kg/kg	52kg
		Plastic	0.025㎥	980kg/㎥	1.24kg/kg	30.6kg
	Outlet pipe		8.8m	6.7kg/m	1.24kg/kg	73kg
	Trench	Ready-mixed concrete	1.128㎥		111.5kg/㎥	126kg
		Rebar	78kg		1.02kg/kg	80kg
Sewage, waterworks	Water supply pipe		274.6m	980kg/㎥	1.24kg/kg	346kg
	Sewage Pipe (GRP)	D200	13.2m	11kg/m	3.9kg/kg	566kg
	sewage manhole	Cover	108kg		1.02kg/kg	110kg
		Ready-mixed concrete	3.712㎥		111.5kg/㎥	414kg
		Rebar	47.7kg		1.02kg/kg	49kg

12. The carbon emissions for Trees in No. 46 Neighborhood Park

Species		Specification	Quantity	Mortality Rate	Dead tree treatment	Compost and improver
Evergreen tree	Pine	R25	13	18.9%	51.4kg	22.7kg
	Pine	R20	11	18.9%	27.3kg	16kg
Deciduous Tree	Zelkova	R20	18	14.4%	44.6kg	26.2kg
	Zelkova	R30	10	14.4%	58kg	17.5kg
	Japanese apricot	R8	56	18.9%	24.2kg	16.3kg
	Metasequoire	B12	17	21.5%	21.5kg	9.9kg
	White magnolia	R12	12	15.2%	9.4kg	7kg
	Korean dogWood	R8	62	10.4%	26.8kg	18kg
	Mountain hawthorn	R8	49	10.4%	21.2kg	14.2kg
	Japanese cornlian cherry	R8	29	10.4%	12.5kg	8.4kg
	Yoshino cherry	B15	50	10.4%	99.7kg	58kg
	Chinese Fringe Tree	R12	41	9%	32.1kg	23.8kg
	Blue maple	R12	72	16.7%	56.3kg	41.8kg
Evergreen shrub	Korean BoxWood	W0.3	1,000	10.4%	4.6kg	24.9kg
Deciduous shrub	Royal azalea	W0.4	1,600	10.4%	7.9kg	70kg
	Christmas Berry	W0.4	2,000	10.4%	16kg	87kg
	Leather-leaf viburnum	W0.4	2,000	10.4%	16kg	87kg
	Korean azalea	W0.3	700	10.4%	3.2kg	30.5kg
	Burning bush spindle Tree	W0.4	1,700	10.4%	12kg	74kg
Total					545kg	653kg

Table 13. The carbon emissions for Landscape Facilities in No. 63 Neighborhood Park

Species		quantity	Material Composition					Carbon Outflow
			Item	Quantity	Unit weight	Basic Unit	Carbon Outflow	
Information Facilities	Park nameplate	1EA	Wood	0.077㎥	900kg/㎥	0.089kg/kg	6.2kg	28kg
			Ready-mixed concrete	0.113㎥		114.27kg/㎥	12.9kg	
			Steel	8.48kg		1.02kg/kg	8.64kg	
	User Information Board	1EA	Stainless steel	0.002㎥	7,900kg/㎥	0.9kg/kg	14.6kg	16kg
			Ready-mixed concrete	0.016㎥		114.27kg/㎥	1.8kg	
	Vehicle Control panel	1EA	Ready-mixed concrete	0.117㎥		111.54kg/㎥	162.6kg	470kg
			Stainless steel	301.3kg		1.02kg/kg	307.4kg	
Rest Facilities	Pergola A	3EA	Hardwood	0.54㎥	900kg/㎥	0.089kg/kg	43.2kg	1,635kg (545)
			Plywood	0.12㎥	560kg/㎥	0.089kg/kg	6kg	
			Ready-mixed concrete	0.17㎥		114.27kg/㎥	19.6kg	
			Polycarbonate	0.32㎥	1,200kg/㎥	1.24kg/kg	476.16kg	
	Flat chair A	9EA	Hardwood	0.025㎥	900kg/㎥	0.089kg/kg	2.0kg	203kg (23kg)
			Oil Stain	0.4ℓ	0.6kg/l	0.325kg/kg	0.78kg (1 time/ 3 years)	
			Aluminum	0.003㎥	2,710kg/㎥	2.305kg/kg	17.22kg	
			Ready-mixed concrete	0.023㎥		114.27kg/㎥	2.6kg	
	Back Chair A	6EA	Hardwood	0.04㎥	900kg/㎥	0.089kg/kg	3.2kg	180kg (30)
			Oil Stain	0.67ℓ	0.6kg/l	0.325kg/kg	1.3kg (1 time/3 years)	
			Aluminum	0.004㎥	2,710kg/㎥	2.305kg/kg	23.6kg	
			Ready-mixed concrete	0.023㎥		114.27kg/㎥	2.6kg	
	Sitting wall	38.4m	Mixed aggregates	0.104㎥		3.67kg/㎥	0.382kg	1,322kg (34)
			Ready-mixed concrete	0.084㎥		111.54kg/㎥	9.37kg	
			Cement brick	61 sheets		0.04879kg/piece	2.97kg	
			Clay brick	0.03㎥	2,100kg/㎥	0.11kg/kg	6.93kg	

			Granite	0.028㎥	2,650kg/㎥	0.123kg/kg	9.13kg	
			mortar	0.035㎥	2,100kg/㎥	0.077kg/kg	5.66kg	
	Planter B	25.8m	Mixed aggregates	0.108㎥		3.67kg/㎥	0.396kg	656kg (25)
			Ready-mixed concrete	0.058㎥		111.54kg/㎥	6.47kg	
			Cement brick	35 sheets		0.04879kg/piece	1.71kg	
			Clay brick	0.052㎥	2,100kg/㎥	0.11kg/kg	12.12kg	
			mortar	0.029㎥	2,100kg/㎥	0.077kg/kg	4.72kg	
Convenience Facilities	Bicycle storage rack B	10EA	Stainless steel bar	0.47kg		2.9kg/kg	1.37kg	135kg (13.5)
			Hardwood	0.006㎥	900kg/㎥	0.089kg/kg	0.47kg	
			Ready-mixed concrete	0.027㎥		111.54kg/㎥	3kg	
			Steel	0.001㎥	7,850kg/㎥	1.02kg/kg	8.66kg	
	Toilet access staircase	1 place (3steps, 1.8m width)	Mixed aggregates	0.478㎥		3.67kg/㎥	1.75kg	111kg
			Ready-mixed concrete	0.214㎥		111.54kg/㎥	23.87kg	
			Cement brick	423 sheets		0.04879 kg/piece	20.6kg	
			Clay brick	0.16㎥	2,100kg/㎥	0.11kg/kg	36.96kg	
			mortar	0.172㎥	2,100kg/㎥	0.077kg/kg	27.81kg	
Sports Facilities	Mesh fence B	37.5 Span	Stainless Steel	0.42kg		2.9kg/kg	1.22kg	1,252kg (33.4)
			Ready-mixed concrete	0.03㎥		111.54kg/㎥	3.35kg	
			Steel	0.0036㎥	7,850kg/㎥	1.02kg/kg	28.82kg	
	Mesh Entrance Gate	1EA	Ready-mixed concrete	0.05㎥		111.54kg/㎥	5.58kg	69kg
			Steel	0.0079㎥	7,850kg/㎥	1.02kg/kg	62.9kg	
	Bollard	8 places	Ready-mixed concrete	0.025㎥		111.54kg/㎥	2.79kg	243kg (30.3)
			Steel	25.74kg		1.02kg/kg	26.25kg	

			Plastic	0.0011㎥	980kg/㎥	1.24kg/kg	1.29kg	
	Multi-purpose Goal post	2 places	Wood	0.27㎥	700kg/㎥	0.089kg/kg	16.86kg	1,604kg (802)
			Steel	568.3kg		1.02kg/kg	579.67kg	
			Ready-mixed concrete	1.728㎥		111.54kg/㎥	192.74kg	
			Plastic	0.01㎥	980kg/㎥	1.24kg/kg	13.12kg	
	Multi-purpose Post	1 set	Steel	28.73kg		1.02kg/kg	29.3kg	45kg
			Ready-mixed concrete	0.144㎥		111.54kg/㎥	16.06kg	

14. The carbon emissions for Pavement Facilities in No. 63 Neighborhood Park

Species	Specification	Quantity	Material Composition					Carbon Outflow
			Item	Quantity	Unit weight	Basic Unit	Carbon Outflow	
Road Boundary stones	200×250×1,000	89.4m	Boundary stones	1m	135kg/m	0.112kg/kg	15.1kg	2,805kg
			Ready-mixed concrete	0.146㎥		111.54kg/㎥	16.28kg	
Green Boundary stones	150×150×1,000	281.5m	Boundary stones	1m	60.8kg/m	0.112kg/kg	6.8kg	2,857kg
			Ready-mixed concrete	0.03㎥		111.54kg/㎥	3.35kg	
I.L.P type C	T60	1,095.8㎡	ILP Block	1㎡	126kg/㎡	0.3kg/kg	37.8kg	41,884kg
			Sand	0.04㎥		1.4kg/㎥	0.056kg	
			Mixed aggregates	0.1㎥		3.67kg/㎥	0.367kg	
I.L.P type E	T80	184.5㎡	ILP Block	1㎡	166kg/㎡	0.3kg/kg	49.8kg	9,266kg
			Sand	0.04㎥		1.4kg/㎥	0.056kg	
			Mixed aggregates	0.1㎥		3.67kg/㎥	0.367kg	
Urethane Pavement	T7	428.6㎡	Urethane	0.007㎥	1,195kg/㎥	2.56kg/kg	21.41kg	14,114kg
			Ready-mixed concrete	0.1㎥		111.54kg/㎥	11.15kg	
			Mixed aggregates	0.1㎥		3.67kg/㎥	0.367kg	
Grass Blocks Pavement	T150	310.5㎡	Turf block top	0.033㎥	2,300kg/㎥	0.3kg/kg	22.8kg	15,099kg
			Lower Lawn	0.06㎥	1,300kg/㎥	0.3kg/kg	23.4kg	

			Block					
			Sand	0.04㎥		1.4kg/㎥	0.056kg	
			Mixed aggregates	0.2㎥		3.67kg/㎥	0.734kg	
			sod	0.4㎡		4.1kg/㎡	1.64kg	
Soil concrete pavement	T120	599.5㎡	cement	0.036㎥	1,500kg/㎥	0.289kg/kg	15,606kg	9,647kg
			Masato	0.084㎥		1.4kg/㎥	0.118kg	
			Mixed aggregates	0.1㎥		3.67kg/㎥	0.367kg	
Entry point pavement	asphalt concrete	1 place	Ascon	4.79㎥	2,350kg/㎥	7.28kg/ton	81.94kg	268kg
			Mixed aggregates	5.74㎥		3.67kg/㎥	21.07kg	
			Ready-mixed concrete	1.45㎥		111.54kg/㎥	161.73kg	
			Pavement Removal	30.4㎡		0.11kg/㎡	3.34kg	
Braille blocks		22.6㎡	Concrete tiles	0.06㎥	2,300kg/㎥	0.3kg/kg	41.4kg	945kg
			Sand	0.04㎥		1.4kg/㎥	0.056kg	
			Mixed aggregates	0.1㎥		3.67kg/㎥	0.367kg	

15. The carbon emissions for Infrastructuer Facilities in No. 63 Neighborhood Park

Species		Quantity	Material Composition				Carbon Outflow
			Item	Quantity	Unit weight	Basic Unit	
Earthworks	Pilling up soil	5,565m^3				0.1kg/m^3	557kg
	Flattening the surface of mound	1,364m^3				0.71kg/m^3	968kg
Rainwater Drainage Facilities	Circular water pipe	82.9m	Concrete Products	14.245m^3	2,300kg/m^3	0.554kg/kg	20,446kg
			Ready-mixed concrete	10.114m^3		111.54kg/m^3	
			rubber	1.387m^3	930kg/m^3	0.9kg/kg	
			Mixed aggregates	7.129m^3		3.67kg/m^3	
	Collecting well	3 places	Ready-mixed concrete	3.25m^3		111.54kg/m^3	363kg
			lid	49.4kg		1.02kg/kg	50kg
	Double wall PE tube	25.5m			940kg/m^3	3.9kg/kg	1,904kg
	Outlet pipe	15.6m	Double wall PE pipe	15.6m	940kg/m^3	3.9kg/kg	1.807kg
			Mixed aggregates	15.2m^3		3.67kg/m^3	
			Sand	8.8m^3		1.4kg/m^3	
			Ready-mixed concrete	3.84m^3		111.54kg/m^3	
			Ascon	8.5m^3	2,350kg/m^3	7.28kg/ton	
Sewage, waterworks	Water supply pipe	386.6m	PE pipe		940kg/m^3	3.9kg/kg	1,468kg
	GRP sewage pipe	41.2m	GRP(D200)		11kg/m	3.9kg/kg	1,767kg
	Sewage manhole	2EA	lid	108kg		1.02kg/kg	573kg
			Ready-mixed concrete	3.712m^3		111.5kg/m^3	
			Rebar	47.7kg		1.02kg/kg	

16. The carbon emissions for Trees in No. 63 Neighborhood Park

Species		Specification	Quantity	Mortality Rate	Dead tree treatment	Compost and improver
Evergreen tree	pine	R40	9	18.9%	39.6kg	21kg
	pine	R30	16	18.9%	30.5kg	28kg
	pine	R25	28	18.9%	37kg	49kg
	pine	R20	25	18.9%	20.7kg	36kg
	Strobe pine	R6	36	14.8%	4.1kg	10kg
Deciduous Tree	zelkova	R15	82	14.4%	26.6kg	71kg
	Three-flowered Maple	R8	23	18.9%	3.3kg	7kg
	Japanese cornlian cherry	R10	10	10.4%	0.8kg	17kg
	Chinese Fringe Tree	R12	10	9%	1.2kg	6kg
	Red maple	R12	36	16.7%	8.3kg	21kg
Deciduous shrub	Red royal azalea	W0.4	1,000	10.4%	10.2kg	44kg
	Smooth-cranberry bush viburnum	W0.8	300	10.4%	6kg	52kg
	Korean early lilac	W0.4	700	10.4%	14.1kg	30kg
	Pink royal azalea	W0.4	1,600	10.4%	18kg	70kg
	Burning bush spindle Tree	W0.3	1,000	10.4%	13.5kg	25kg
	Simple bridal wreath spiraea	W0.4	500	10.4%	7.8kg	22kg
	Purple beautyberry	W0.4	500	10.4%	10kg	22kg
	Kerria	W0.4	300	10.4%	5.4kg	13kg
	Korean azalea	W0.3	1,870	10.4%	19kg	47kg
Total					407kg	714kg

17. The carbon emissions for Landscape Facilities in No. 67 Neighborhood Park

Species		quantity	Material Composition					Carbon Outflow
			Item	**Quantity**	**Unit weight**	**Basic Unit**	**Carbon Outflow**	
Information Facilities	Park nameplate (Pillar type)	1EA	Wood	0.077㎥	900kg/㎥	0.089kg/kg	6.2kg	28kg
			Ready-mixed concrete	0.113㎥		114.27kg/㎥	12.9kg	
			Steel	8.48kg		1.02kg/kg	8.64kg	
	Usage information board	1EA	Stainless steel	0.002㎥	7,900kg/㎥	0.9kg/kg	14.6kg	16kg
			Ready-mixed concrete	0.016㎥		114.27kg/㎥	1.8kg	
	Vehicle control panel	1EA	Ready-mixed concrete	0.117㎥		111.54kg/㎥	162.6kg	470kg
			Steel	301.3kg		1.02kg/kg	307.4kg	
Rest Facilities	Pergola A	3EA	Hardwood	0.54㎥	900kg/㎥	0.089kg/kg	43.2kg	1,635kg (545kg)
			plywood	0.12㎥	560kg/㎥	0.089kg/kg	6kg	
			Ready-mixed concrete	0.17㎥		114.27kg/㎥	19.6kg	
			Polycarbonate	0.32㎥	1,200kg/㎥	1.24kg/kg	476.16kg	
	Flat chair A	30EA	Hardwood	0.025㎥	900kg/㎥	0.089kg/kg	2.0kg	690kg (23kg)
			Oil Stain	0.4ℓ	0.6kg/l	0.325kg/kg	0.78kg (1 time/3 years)	
			Aluminum	0.003㎥	2,710kg/㎥	2.305kg/kg	17.22kg	
			Ready-mixed concrete	0.023㎥		114.27kg/㎥	2.6kg	

18. The carbon emissions for Pavement Facilities in No. 67 Neighborhood Park

Species	Specification	Quantity	Material Composition					Carbon Outflow
			Item	**Quantity**	**Unit weight**	**Basic Unit**	**Carbon Outflow**	
Road Boundary stones	200×250×1,000	58.6m	Boundary stones	1m	135kg/m	0.112kg/kg	15.1kg	1,840kg
			Ready-mixed concrete	0.146m^3		111.54kg/m^3	16.3kg	
Green Boundary stones	150×150×1,000	65.9	Boundary stones	1m	60.8kg/m	0.112kg/kg	6.8kg	669kg
			Ready-mixed concrete	0.03m^3		111.54kg/m^3	3.35kg	
Pavement Boundary Stone	150×150×1,000	18.6m	Boundary stones	1m	60.8kg/m	0.112kg/kg	6.8kg	174kg
			Ready-mixed concrete	0.023m^3		111.54kg/m^3	2.57kg	
Clay Block Pavement	T55	1,550.7m^2	Clay Block	0.055m^3	1,300 kg/m^3	0.11kg/kg	7.87kg	12,860 Kg
			Sand	0.04m^3		1.4kg/m^3	0.056kg	
			Mixed aggregates	0.1m^3		3.67kg/m^3	0.367kg	
Stone Block Pavement	T60	73m^2	Concrete tiles	1m^2	130kg/m^2	0.3kg/kg	39kg	2,878kg
			Sand	0.04m^3		1.4kg/m^3	0.056kg	
			Mixed aggregates	0.1m^3		3.67kg/m^3	0.367kg	
Grass Blocks Pavement	T150	156.5m^2	Turf block top	0.033m^3	2,300kg/m^3	0.3kg/kg	22.8kg	7,610kg
			Lower Lawn Block	0.06m^3	1,300kg/m^3	0.3kg/kg	23.4kg	
			Sand	0.04m^3		1.4kg/m^3	0.056kg	
			Mixed aggregates	0.2m^3		3.67kg/m^3	0.734kg	
			sod	0.4m^2		4.1kg/m^2	1.64kg	
Braille blocks		5.9m^2	Concrete tiles	0.06m^3	2,300kg/m^3	0.3kg/kg	41.4kg	247kg
			Sand	0.04m^3		1.4kg/m^3	0.056kg	
			Mixed aggregates	0.1m^3		3.67kg/m^3	0.367kg	
Alvedge		963.1m	Aluminum	0.001487m^3	2,710kg/m^3	2.305kg/kg	9.29kg	8,946kg
Entry point pavement	Ascon	1 meal	Ascon	3.25m^3	2,350kg/m^3	7.28kg/ton	55.6kg	233kg
			Mixed aggregates	5.84m^3		3.67kg/m^3	21.4kg	
			Ready-mixed concrete	1.37m^3		111.54kg/m^3	152.8kg	
			Pavement Removal	27.5m^2		0.11kg/m^2	3,025kg	

19. The carbon emissions for Infrastructure Facilities in No. 67 Neighborhood Park

Species		Quantity	Material Composition				Carbon Outflow
			Item	Quantity	Unit weight	Basic Unit	
Earthworks	Pilling up soil	4,716m^3				0.1kg/m^3	557kg
	Flattening the surface of mound	4,732m^2				0.71kg/m^3	3,360kg
Rainwater Drainage Facilities	Hume concrete tube	431.8m	Concrete Products		84.4kg/m	0.554kg/kg	20,189kg
	Collecting well (600×600)	14EA	Ready-mixed concrete	13.91m^3		111.5kg/m^3	1,551kg
			lid	230.7kg		1.02kg/kg	235kg
	Collecting well (800×800)	3EA	Ready-mixed concrete	4.23m^3		111.5kg/m^3	471kg
			lid	72kg		1.02kg/kg	73kg
Sewage, waterworks	Water supply pipe	5.4m	PE pipe		980kg/m^3	1.24kg/kg	6.8kg
	GRP sewage pipe	7.4m	GRP(D200)		11kg/m	3.9kg/kg	317kg
	Sewage manhole	2EA	lid	108kg		1.02kg/kg	573kg
			Ready-mixed concrete	3.712m^3		111.5kg/m^3	
			Rebar	47.7kg		1.02kg/kg	