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A Study on LCC Analysis by Floor Finishing Material to Reduce NOx in Urban Areas

- Focusing on the photocatalytic pavement and cement pavement -

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Abstract : In South Korea, NOx emissions are a major concern, leading to acid rain and smog, harming both the atmosphere and human health, particularly in urban areas. This study seeks to determine the most advantageous pavement material for NOx reduction in urban areas and assess whether photocatalytic pavement blocks, proven to reduce NOx emissions, can serve as a viable alternative to conventional cement pavement blocks. To achieve this, a comparative life cycle cost (LCC) analysis was conducted between photocatalytic pavement blocks and conventional cement pavement blocks installed for their NOx reduction capabilities. The cost-saving benefits of NOx reduction were monetized for photocatalytic pavement blocks. The analysis period was based on the least common multiple of the replacement cycles of both pavement materials: 30 years. The results revealed that while photocatalytic pavement blocks initially produce higher installation costs than cement pavement blocks, they offer greater cost savings in terms of total cost and net present value due to their NOx reduction effect over the life cycle. Additionally, the cost-saving effects of photocatalytic pavement blocks are even more pronounced because their replacement period is 5 years longer than that of cement pavement blocks. This study holds significance in performing an LCC analysis of the previously unanalyzed photocatalytic pavement blocks while also demonstrating their potential as substitutes for cement pavement blocks.

Keywords : Life cycle cost, Photocatalytic pavement, NOx, Urban park

1. Introduction

1.1 Background and purpose of research

1.1.1 Background of research

The increase in nitrogen oxide (NOx) emissions due to rising energy consumption is causing severe air pollution. NOx accounts for a significant proportion of various air pollutants, including carbon monoxide, sulfur oxides, total suspended particles, fine dust, ultrafine particles, black carbon, volatile organic compounds (VOCs), and ammonia. The most significant issue is that NOx not only has a substantial impact on human health, causing symptoms such as coughing, sputum, and respiratory disorders, it is also a pollutant that adversely affects the overall environment by contributing to the formation of photochemical smog and acid rain.

According to the NOx emission statistics released by the National Air Emission Inventory and Research Center of the Ministry of Environment in 2023, the total amount of NOx emitted across South Korea in 2021 was 884,454 tons[1]. The region with the highest NOx emissions was

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the Seoul metropolitan area, which includes Seoul Special City (62,209 tons), Gyeonggi Province (143,928 tons), and Incheon Metropolitan City (42,553 tons), collectively accounting for 28.12% of the total emissions with 248,690 tons (National Air Emission Inventory and Research Center of the Ministry of Environment, 2023). This indicates that areas with higher levels of human activities that lead to energy consumption tend to have more severe pollution levels. The increase in NOx emissions in areas with high human activity results in a vicious cycle where NOx produces harmful effects on human health.

Table 1. NOx emissions in South Korea in 2021

Region	NOx emissions (ton)	Proportion (%)
Nationwide	884,454	100.00
Seoul	62,209	7.03
Busan	41,945	4.74
Daegu	19,948	2.26
Incheon	42,553	4.81
Gwangju	10,016	1.13
Daejeon	11,923	1.35
Ulsan	42,427	4.80
Sejong	3,956	0.45
gyeonggido	143,928	16.27
Gangwondo	55,060	6.23
Chungcheong buk-do	47,893	5.41
Chungcheong nam-do	69,902	7.90
Jeolla buk-do	30,377	3.43
Jeolla nam-do	80,973	9.16
Gyeongsang buk-do	69,953	7.91
Gyeongsang nam-do	49,980	5.65
Jeju island	13,267	1.50
ocean	88,143	9.97

Data source: National Air Emission Inventory and Research Center of the Ministry of Environment (https://www.air.go.kr/capss/emission/sido.do?menuId=31)

As of 2021, when the nationwide NOx emissions in South Korea were converted into air pollutant conversion costs (23,927 KRW/kg), the social damage costs due to NOx amounted to approximately 21.1623 trillion KRW[2]. This amount is about 4% of the government budget of 558 trillion KRW for 2021 (based on the announcement by the Ministry of Economy and Finance), indicating that the social damage costs due to NOx are significant.

1.1.2 Purpose of research

NOx causes significant social damage annually, but it can be mitigated through Pre-Combustion Technologies and Post-Combustion Technologies. This study aims to explore effective strategies for removing NOx emissions in urban areas from an architectural perspective. Specifically, the purpose of this study is to analyze the effectiveness of NOx removal and the life cycle costing (LCC) of different pavement materials used in urban parks, and to propose viable alternatives. To this end, this study compares and analyzes the LCC and NOx reduction effectiveness of installing 'photocatalytic paving blocks that promote NOx reduction' versus 'conventional cement paving blocks' in urban parks.

Photocatalytic paving blocks refer to paving blocks that utilize photocatalytic properties to purify air pollutants. When titanium dioxide (TiO_2) absorbs light and triggers a photochemical reaction, atmospheric NOx is oxidized and converted into nitrate ions (NO_3-) and calcium ions (Ca^{2+}), thereby being removed (Decopave, 2022). According to patent data from a photocatalytic paving block manufacturer, the NOx reduction effectiveness of photocatalytic paving blocks is 21.7%[3].

1.2 Literature review

Several studies have been conducted on the economic feasibility and performance of pavement materials, with the contents and limitations of each study as follows. First, LCC analyses of pavement materials include the study on the LCC analysis of maintenance and management of concrete road pavements in Malaysia (Ahmad Jasmi et al., 2018) and the study on the economic and environmental analysis of highway pavement

1) The domestic air pollutant emission information statistics provided by the National Air Emission Inventory and Research Center of the Ministry of Environment take about two years to collect and verify basic data.

2) The social damage costs due to NOX were calculated by applying the conversion cost for NOx air pollutants of 21,040 KRW (Lee, M.H. (2018). "Social cost-benefit analysis case study." The Korea Institute of Public Administration, p.34.) with an average inflation rate of 1.62% over the past ten years, as announced by Statistics Korea.

3) When measured in a full-scale environmental chamber, the NOx reduction rate of photocatalytic concrete paving blocks was approximately 22% at an average light intensity of 564W/㎡ (Lee et al., 2022).

maintenance scenarios (Choi, 2019). While these studies differ in their subjects and analysis targets, they share a focus on analyzing the economic feasibility of road pavement maintenance. However, Choi (2019) differs in that it attempts an environmental analysis to reduce carbon dioxide emissions in addition to economic feasibility. Jung et al. (2014) conducted an LCC analysis based on the pavement methods of flooring materials in residential complexes to analyze the economic feasibility according to the pavement methods of flooring materials. Although this paper does not consider environmental factors, it is significant in that it suggests that the maintenance cycle is a factor influencing the selection of pavement materials.

Existing studies on photocatalytic pavements have focused more on the NO_X reduction performance and durability of the products rather than LCC analysis. Representative studies on photocatalytic paving materials include research that proposed photocatalytic asphalt pavement as a measure to reduce automobile exhaust gases (Li et al., 2023) and a study that quantified and compared the pavement durability of TiO_2-treated concrete and asphalt (Osborn et al., 2014). While these studies are significant in concluding that photocatalytic paving materials are excellent in both efficiency and durability, they have the limitation of not presenting their economic effectiveness.

The summary of the findings from existing studies is as follows. Some research on photocatalytic paving blocks has been conducted to prove the efficiency, durability, and environmental performance of the products themselves. However, LCC analysis of photocatalytic paving blocks has not been conducted, nor has there been sufficient research that translates the air purification effectiveness of photocatalytic paving blocks into economic benefits. Therefore, this study aims to comprehensively compare and analyze the LCC of photocatalytic paving blocks, which have been proven to be effective in removing NO_X, as an alternative to the commonly used cement paving blocks, assessing their environmental performance and cost-saving effects.

1.3 Research Method and Scope

1.3.1 Research Method

This study conducts an LCC analysis of different pavement materials by applying cost information over their life cycle to an urban park case study. First, the types of pavement materials are selected, and cost information over their life cycle is established, including initial investment costs, maintenance costs, demolition and reinstallation costs, conversion of NO_X reduction effects into monetary value, inflation rates, and discount rates. Second, the LCC analysis is conducted for the pavement materials in the case study area. The LCC analysis focuses on two types of pavement materials: conventional cement paving blocks and photocatalytic paving blocks. Scenario #1 involves installing conventional cement paving blocks as the pavement material in the urban park while Scenario #2 involves installing photocatalytic paving blocks with high NO_X reduction effectiveness as the pavement material. In Scenario #2, since the NO_X reduction effect occurs over the life cycle, this is converted into monetary value for cost analysis. Third, Based on the analysis results, the total costs are calculated using the Net Present Value (NPV) as shown in Equation (1) for comparative analysis. This comprehensive comparison and analysis will identify the superior pavement material in terms of effectiveness and cost, and the implications drawn.

$$NPV = IC + \sum_{K=1}^{N} \frac{FC_K}{(1+i)^k} \qquad (1)$$

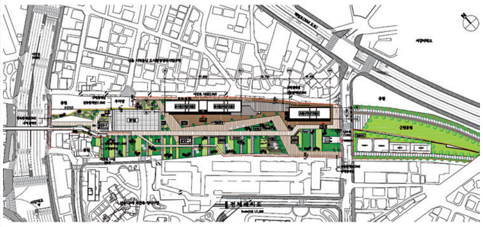
IC : Initial Cost, the cost incurred in the first year
FC : Future Cost, the cost incurred annually after the first year
i : Discount rate
K : Period

1.3.2 Research Scope

The spatial scope of this study is the park development site in Mapo-gu, Seoul, with a total site area of 17,356 ㎡, a building area of 4,931㎡, and an analysis target area of 12,425㎡. The analysis target area refers to an outdoor space within the project site where pavement materials can be installed.

The analysis period is set at 30 years, based on the least common multiple of the replacement cycles and durability periods of cement paving blocks and photocatalytic paving blocks[4)].

Table 2. Spatial Research Scope

Category	Content
Layout	
Location	Park at Seogang University Station on the Gyeongui Line, located in Mapo-gu, Seoul
Land size	17,356㎡
Building area	4,931㎡
Area of analysis	12,425㎡

2. Selection of Items and Basic Data Analysis

2.1 Selection of Pavement Materials

This study aims to conduct an LCC comparative analysis of photocatalytic paving blocks, which are effective in NO_x removal, and conventional cement paving blocks. The pavement materials are selected as follows.

First, for cement paving blocks, 'H' concrete materials were selected from the company with the highest sales among those registered with the Public Procurement Service for pedestrian and vehicular concrete blocks. In this study, impermeable paving blocks with a thickness of 60mm and a flexural strength of at least 4N/㎟ were selected for analysis.

Second, for photocatalytic paving blocks, materials from 'D' company were chosen. 'D' has the highest market share and sales for photocatalytic paving blocks among the air-purifying paving block companies registered with the Public Procurement Service. The study will analyze impermeable paving blocks with a thickness of 60mm and a flexural strength of at least 4N/㎟.

2.2. Basic Data Analysis

2.2.1. Initial Investment Cost

The initial investment cost is estimated based on material costs and construction costs. According to the Korea ON-line E-Procurement System, the material cost for cement paving blocks is 33,000 KRW/㎡, which is approximately 4,500 KRW/㎡ cheaper than the material cost for photocatalytic paving blocks at 37,500 KRW/㎡. However, when comparing the construction costs based on the standard market unit prices for construction work in the second half of 2023, the construction cost for both types of paving blocks is the same at 8,051 KRW/㎡. Therefore, it is confirmed that the initial investment cost is lower for cement paving blocks due to their cheaper material cost.

2.2.2. Maintenance Costs

Maintenance costs are divided into repair costs and replacement costs. For the pavement blocks under analysis, both are impermeable, so there are no repair costs such as percolation tests or cleaning costs for improving the permeability performance of the pavement blocks.

However, after the initial installation, the replacement period for pavement blocks will be reached due to damage, color fading, and subsidence. According to Jung et al. (2014) and the Engineering Journal (2019), the replacement cycles for cement paving blocks and photocatalytic paving blocks are 10 years and 15 years, respectively[5)]. Thus, over the 30-year life cycle analysis period, it is considered that cement paving blocks will undergo full replacement twice (in the 11th and 21st years), while photocatalytic paving blocks will undergo full replacement once (in the 16th year). The costs incurred include the removal cost of the existing paving blocks, the material cost of the replacement

4) The replacement cycle for cement paving blocks is 10 years (Jung et al., 2014), whereas the durability period for photocatalytic paving blocks is 15 years (Engineering Journal, 2019). Since the replacement cycles of the two types of paving blocks do not currently align, a 30-year analysis period, which is the least common multiple of the replacement cycles and durability periods of both paving materials, is applied to determine the point at which simultaneous replacement would occur after the initial installation.

5) The replacement cycle for cement paving blocks is 10 years (Jung et al., 2014), whereas the durability period for photocatalytic paving blocks is 15 years (Engineering Journal, 2019).

paving blocks, and the reinstallation construction cost. The removal cost is set at 2,379 KRW/㎡, based on the standard market unit prices for construction works in the second half of 2023. The replacement material costs are based on the material costs provided by the Korea ON-line E-Procurement System[6]. The reinstallation construction cost is set at 8,051 KRW/㎡, based on the standard market unit prices for construction works in the second half of 2023. The removal cost, replacement material cost, and reinstallation construction cost are all adjusted for inflation[7] at the time of replacement.

2.2.3. Demolition Cost

It is assumed that all pavement materials will be demolished in the final year of the analysis period, which is the 30th year. In this case, the demolition cost is set at 2,379 KRW/㎡, based on the standard market unit prices for construction works in the second half of 2023. The demolition cost is calculated by reflecting the inflation rate at the time of demolition (30th year) for restoration purposes.

2.2.4. Conversion of NOx Reduction Effects to Economic Benefits

To calculate the value of converting the NO_X reduction effects into economic benefits (T), the following Equation (2) is used. The detailed criteria are as follows.

$$T = AA \times AG \times C \times E \qquad (2)$$

T: Value of converting NO_X reduction effects into economic benefits(KRW)
AA: Analysis area(㎡)
AG: NO_X emission per unit area(kg/㎡)
C: Cost of NO_X damage(KRW/kg)
E: NO_X reduction effectiveness of photocatalytic paving blocks(%)

First, the analysis target is a part of the park development site, with an analysis area (AA) of 12,425 ㎡. Second, the NO_X emission per unit area (AG) is set at 0.10 kg/㎡, which is the emission rate for City of Seoul. This value is consistently applied over the analysis period based on the most recent NO_X emission data for 2021, released by the National Air Emission Inventory and Research Center of the Ministry of Environment. Third, the cost of NO_X damage (C) is 24,314 KRW/kg. This value is the current value calculated by applying the inflation rate to the social damage cost of air pollutants (21,040 KRW/kg)[8]. This study applies the average inflation rate of 1.62% over the past 10 years, as announced by Statistics Korea. Fourth, the NO_X reduction effectiveness (E) of photocatalytic paving blocks is set at 21.70% of the emission amount, based on previous studies and patent data.

2.2.5. Inflation Rate and Discount Rate

The inflation rate is set at an average of 1.62%, as applied in Equation(1) for converting NO_X reduction effects into economic benefits. This average value is calculated based on the most recent 10-year data from 2013 to 2022 (Statistics Korea). The discount rate is calculated based on the base interest rates announced by the Bank of Korea over the past 10 years from 2013 to 2022, and the value is 1.58%.

3. Research Analysis Results

This research secured basic data on photocatalytic and cement paving blocks and conducted an LCC analysis over a 30-year period.

3.1. LCC Analysis Results for Each Pavement Material

3.1.1. Photocatalytic Paving Blocks

〈Table 3〉 presents the LCC analysis results for the installation of photocatalytic pavement blocks in an urban park, which have a NO_X reduction effect. The total cost over a period of 30 years for the installation of these blocks is estimated at 1.11 billion KRW. The cost distribution includes initial costs at 50.8% (570 million KRW), maintenance costs at 44.9% (500 million KRW), and demolition costs at 4.3% (50 million KRW). Notably, the maintenance costs account for the economic

6) The material cost for cement paving blocks is 33,000 KRW/㎡, while the material cost for photocatalytic paving blocks is 37,500 KRW/㎡.
7) Although the inflation rate varies each year, for the convenience of analysis, the average inflation rate over the past 10 years (1.62%) is applied in the calculations.
8) Lee Min-ho (2018). "Social cost-benefit analysis case study." The Korea Institute of Public Administration, p. 34. (The analysis used the social damage cost of NO_X from 2014, which is 21,040 KRW/kg, as cited in this previous study.)

Table 3. Life Cycle Cost (LCC) Analysis Results of Photocatalyst Pavement Case

Category		Photocatalyst Pavement Case	
		Amount (KRW)	Proportion (%)
Initial Cost	Installation Material Cost	465,946,875	41.82%
	Installation Cost	100,035,688	8.98%
	Subtotal	565,982,563	50.80%
Maintenance Cost	Replacement Material Cost	592,958,449	53.23%
	Replacement Demolition Cost	37,617,284	3.38%
	Replacement Cost	127,304,226	11.43%
	NOx Reduction Effect	- 257,685,648	-23.13%
	Subtotal	500,194,311	44.90%
Demolition Cost		47,871,308	4.30%
Total Cost		1,114,048,182	100.00%
Total Cost NPV		991,848,115	
Cumulative Cost Increase Rate Average		4.7%	

Table 4. Life Cycle Cost (LCC) Analysis Results of Cement Pavement Case

Category		Cement Pavement Case	
		Amount (KRW)	Proportion (%)
Initial Cost	Installation Material Cost	410,033,250	21.18%
	Installation Cost	100,035,688	5.17%
	Subtotal	510,068,938	26.35%
Maintenance Cost	Replacement Material Cost	1,046,977,586	54.08%
	Replacement Demolition Cost	75,477,566	3.90%
	Replacement Cost	255,430,804	13.19%
	NOx Reduction Effect	-	0.00%
	Subtotal	1,377,885,957	71.18%
Demolition Cost		47,871,308	2.47%
Total Cost		1,935,826,203	100.00%
Total Cost NPV		1,625,440,077	
Cumulative Cost Increase Rate Average		6.6%	

benefits of the NO_X reduction, valued at 260 million KRW. The annual NO_X emissions from the park are 1,277 kg Applying the 21.7% reduction effectiveness of the photocatalytic blocks, the monetary benefit is then calculated. Considering an analysis period of 30 years, the annual average monetary benefit from the NO_X reduction by the photocatalytic blocks is approximately 9 million KRW. Furthermore, the demolition costs in the final year of the analysis period amount to 50 million KRW, constituting 4.3% of the total costs. When discount rates are applied to present-value total costs, the NPV of the total costs is estimated at 990 million KRW. The cumulative cost increases annually at an average rate of 4.7%.

3.1.2 Cement Paving Blocks

〈Table 4〉 presents the LCC analysis results for the installation of cement pavement blocks within an urban park. According to the LCC analysis, the total cost amounts to 1.94 billion KRW. The costs are distributed as follows: initial costs at 26.4% (510 million KRW), maintenance costs at 71.2% (1.38 billion KRW), and demolition costs at 2.5% (50 million KRW). The relatively low initial costs are due to the lower material costs. However, maintenance costs are comparatively high, partly because the NO_X reduction benefit cannot be excluded from consideration, and partly because the replacement cycle is relatively short. Cement blocks have a replacement cycle of 10 years compared to 15 years for photocatalytic blocks, necessitating two replacements during the analysis period. The shorter replacement cycle significantly influences the costs of materials, construction, and demolition, thereby increasing maintenance expenses. Additionally, in the final year of the analysis period, year 30, demolition costs amount to 50 million KRW, which is about 2.5% of the total cost. When applying discount rates to current-value the total costs, the NPV of the total costs for cement pavement blocks is estimated at 1.63 billion KRW. The cumulative cost of cement blocks is analyzed to increase annually by an average of 6.6%.

3.2. Comparison and Analysis

A comprehensive examination of the LCC analysis results for photocatalytic and cement pavement blocks is as follows.

Comparing the total costs over a 30-year period as shown in 〈Table 3〉 and 〈Table 4〉, photocatalytic pavement blocks are found to be 630 million KRW cheaper than cement pavement blocks. This is because, although the initial cost of cement blocks was approximately 50 million KRW cheaper, the maintenance costs of photocatalytic blocks were about 880 million KRW lower. To analyze the reasons in detail, it is necessary to examine the cumulative total cost per year for each type of pavement material over their lifecycle 〈Fig. 1〉.

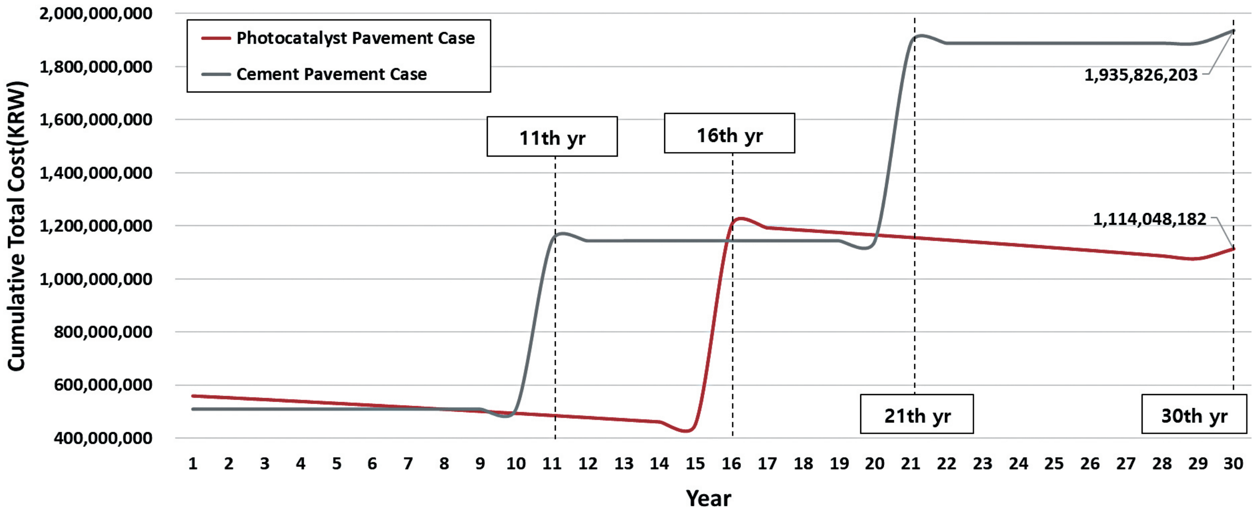


Fig. 1. Cumulative Total Cost Graph by Floor Finishing Material

For the first 8 years after installation, photocatalytic blocks show higher cumulative total costs due to more expensive material costs. However, in the 9th year, the cumulative cost graph for photocatalytic and cement blocks reverses. This reversal results from the accumulated NOx reduction effect of the photocatalytic blocks, which have reduced maintenance costs by approximately 260 million KRW over their lifecycle.

Moreover, for most of the period, cement blocks exhibit higher total costs. This difference in total costs arises from the differing replacement cycles of the two types of blocks. Photocatalytic blocks are replaced once 15 years after installation, in the 16th year, whereas cement blocks require replacements twice: once 10 years after installation, in the 11th year, and again 20 years after installation, in the 21st year. Consequently, the shorter 10-year replacement cycle for cement blocks leads to more frequent replacements and significantly higher maintenance costs.

While the cumulative cost for cement blocks increases at an average annual rate of 6.6%, the increase for photocatalytic blocks is limited to an average annual rate of about 4.7%. The difference in replacement cycles and the accumulation of NOx reduction benefits result in a lower rate of increase in cumulative costs for photocatalytic blocks compared to cement blocks. Consequently, photocatalytic blocks can be considered a viable alternative to cement blocks, offering not only environmental but also economic advantages.

4. Conclusions

NOx accounts for a significant proportion of air pollution, causing acid rain and photochemical smog, leading to the destruction of ozone and having a serious impact on global warming. It also acidifies soil and water, causing secondary damage. Considering the global efforts to solve environmental pollution, finding measures to reduce NOx emissions is essential. Additionally, NOx negatively affects individual health, causing respiratory and cardiovascular diseases, as well as conditions like dermatitis and hair loss. Accordingly, this study focuses on exploring effective ways to reduce NOx in everyday life.

As a result, this research turned its attention to the pavement blocks installed in urban parks. Urban parks have an inherent NOx reduction effect. However, to enhance this effectiveness, it is necessary to expand green spaces or use alternative materials capable of removing NOx. Excluding pathways that are covered with low grass or lawns, the commonly installed cement pavement blocks do not offer NOx removal. Therefore, replacing them with photocatalytic pavement blocks, which are effective at removing NOx, would enhance the effectiveness of NOx removal in urban areas. However, their economic feasibility as replacements has not yet been demonstrated.

For this reason, this study conducted an LCC analysis based on the assumption of installing both photocatalytic and cement pavement blocks in urban parks. The research targeted a park redevelopment site in Mapo-gu, Seoul, and performed an LCC analysis for the installation of both types of pavement blocks. The results showed that photocatalytic pavement blocks are 820 million KRW cheaper over a 30-year usage period. Considering the analysis period of 30 years, this amounts to an annual saving of about 27 million KRW. However, this indicates that the total cost of photocatalytic blocks is about 42.5% cheaper than that of cement blocks.

This trend is also confirmed in the present-value of the total costs. The NPV of the total costs for photocatalytic and cement blocks is 990 million KRW and 1.63 billion KRW, respectively, indicating that photocatalytic blocks are 39.0% cheaper. This outcome can be attributed to two main factors.

First is the maintenance cost reduction effect produced by the NO_X reduction. Photocatalytic blocks, unlike cement blocks, remove about 21.7% of atmospheric NO_X. This reduction can be converted into economic benefits, estimated to generate an annual economic gain of 8.59 million KRW at the study site. Although the total economic benefits may seem low due to the limited area of 12,425 square meters, expanding this to the entire city of Seoul could significantly increase the ripple effects. Considering the annual NO_X reduction and its socio-economic benefits in improving air quality, the effectiveness of photocatalytic blocks would be even greater.

The second factor is the cost difference due to the different replacement cycles of the pavement blocks. While cement blocks need to be replaced twice, costing 1.38 billion KRW, photocatalytic blocks only need to be replaced one, costing 760 million KRW, roughly half the amount. The replacement cost difference of about 620 million KRW is substantial. Normally, cement blocks must be replaced every 10 years, but photocatalytic blocks are replaced every 15 years. This 5-year difference in replacement cycles translates to a significant difference when considered in terms of frequency. Both types of blocks would need to be replaced simultaneously after 30 years. Increased replacement frequency due to durability issues leads to higher maintenance costs, including demolition, material, and construction costs.

In summary, although photocatalytic blocks are more expensive in terms of material costs and thus require more initial investment, their longer replacement cycle and economic benefits through NO_X reduction reduce maintenance costs. Especially as these cost-saving effects accumulate over time, the long-term perspective shows even greater cost reductions. Therefore, considering both environmental and economic aspects, photocatalytic blocks can be sufficiently considered as an alternative to cement blocks.

This study has confirmed the lifecycle cost-saving effects of photocatalytic blocks through an LCC analysis of different flooring materials in urban parks. However, this research is limited by its reliance on prior studies and patent data for the NO_X reduction effects of photocatalytic blocks, as well as by estimating NO_X emissions based on average data for Seoul rather than direct measurements at a study site. Despite these limitations, the significance of this study lies in its performance of an LCC analysis of previously unanalyzed photocatalytic blocks and in demonstrating their sufficiency as replacements for cement blocks. Future empirical research based on this study is expected to contribute to reducing atmospheric pollutants and improving air quality.

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