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Cost-Benefit Analysis of Urban Green Spaces: A Case Study on Air Quality and Public Health

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Abstract

Urban green spaces have emerged as critical infrastructure for fostering sustainable urban development, mitigating environmental degradation, and enhancing public health. This research paper presents a comprehensive cost-benefit analysis of urban green spaces, focusing on their impact on air quality improvement and public health outcomes. Using a mixed-methods approach involving empirical data from a mid-sized urban locality, satellite-derived vegetation indices, and air quality sensors, the study evaluates the economic viability of green space investments. Benefits measured include reductions in airborne pollutants, incidences of respiratory illness, and healthcare costs. The study also incorporates non-market valuations such as improved mental well-being and aesthetic value through contingent valuation methods. The analysis reveals those although the initial and maintenance costs of urban green spaces is significant, the accrued benefits—especially long-term health savings and ecosystem services—vastly outweigh the expenditures. The results underscore the importance of integrating green infrastructure into urban planning as both an environmental and economic necessity.

Keywords: Urban green spaces, air quality, public health, cost-benefit analysis, environmental economics, ecosystem services, healthcare cost reduction

I. Introduction

The rise of urbanization has introduced numerous environmental challenges, among which deteriorating air quality is particularly severe [1]. Rapid industrialization and the expansion of urban infrastructure have led to an exponential increase in air pollutants, thereby escalating the public health burden. In this context, urban green spaces have gained attention for their potential to mitigate the adverse effects of urban living. However, the implementation and maintenance of green spaces require significant investment, and urban policymakers often grapple with the question of economic justification [2]. This paper explores the economic rationale for urban green spaces by performing a cost-benefit analysis that focuses on air quality improvement and public health enhancement. The analysis contributes to a growing body of literature emphasizing the multifunctionality of green infrastructure in urban settings. Urban green spaces include parks, gardens, green belts, and tree-lined streets, which are instrumental in filtering pollutants such as particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). Additionally, they modulate urban heat islands, enhance biodiversity, and offer psychological and recreational benefits. Although the environmental advantages of urban green spaces are well-documented, quantifying these benefits in economic terms remains a challenge [3]. This study seeks to bridge that gap by evaluating the air quality improvements and subsequent health benefits provided by green spaces in a selected urban locality.

Using a case study methodology, this paper focuses on a moderately polluted city experiencing rapid urban growth [4]. The study utilizes both secondary air quality data and primary data from field surveys, including interviews with healthcare professionals, urban planners, and residents. Furthermore, it quantifies reductions in morbidity rates attributable to improved air quality near green spaces. The analysis includes capital investment, operation, and maintenance costs of green spaces, set against the economic valuation of health benefits and environmental services [5]. The rationale for using cost-benefit analysis (CBA) lies in its capacity to guide evidence-based policymaking. CBA provides a quantitative framework for evaluating whether the benefits of a public project outweigh its costs. In this context, it serves as a robust tool to assess the economic feasibility of expanding green infrastructure [6]. The findings from this study offer actionable insights into urban planning, environmental health, and sustainable development goals (SDGs), especially those linked to good health and well-being (SDG 3) and sustainable cities and communities (SDG 11).

This paper is structured as follows: the next section discusses the methodology used for data collection and analysis [7]. This is followed by a detailed examination of the experimental setup, including air quality monitoring and public health assessment techniques. Results are presented thereafter, including quantitative and qualitative findings. The paper concludes with a synthesis of the insights gained and policy recommendations [8].

II. Methodology

This study employed a mixed-methods approach combining quantitative data analysis and qualitative field assessments. The central objective was to perform a cost-benefit analysis of green spaces by evaluating their impact on air quality and public health outcomes. The primary site for the study was a rapidly urbanizing city with significant pollution levels and multiple green zones of varying sizes. Data collection occurred over a 12-month period to account for seasonal variations in air quality and health data [9]. The use of multiple data streams ensures the validity and reliability of the results. Air quality data were obtained from both government monitoring stations and portable low-cost air sensors placed near selected green and non-green zones. The pollutants monitored included PM2.5, PM10, NO_2, CO, and O_3. Satellite imagery from Sentinel-2 and Landsat 8 was used to derive vegetation indices such as NDVI (Normalized Difference Vegetation Index) to map and classify green cover. Health data were sourced from local hospitals and clinics, focusing on the prevalence and frequency of respiratory and cardiovascular diseases. Additionally, a contingent valuation survey was conducted among 500 residents to capture non-market benefits such as mental health, aesthetic appreciation, and recreational use [10].

Costs were calculated using budgetary data provided by the municipal authorities and supplemented by interviews with urban planners. These included initial capital investments, operational costs, land acquisition, and maintenance expenditures. Benefits were quantified in monetary terms using the Avoided Cost Method for healthcare savings and the Hedonic Pricing Method to estimate the impact of green spaces on property values. Furthermore, Willingness-To-Pay (WTP) measures were derived from the contingent valuation survey to assess public valuation of green spaces. The benefit-cost ratio (BCR), net present value (NPV), and internal rate of return (IRR) were used as indicators of economic feasibility. Sensitivity analysis was also conducted to account for uncertainties in the valuation models. This included adjusting the discount rate, extending the analysis period, and varying pollution abatement efficiencies of green spaces. By employing these financial metrics, the study ensures robust economic evaluation that accounts for both direct and indirect benefits.

Qualitative data were collected through focus group discussions and in-depth interviews with urban residents, environmental activists, and local authorities. The themes explored included perceptions of air quality, mental health, social cohesion, and environmental awareness. These data were analyzed using thematic coding techniques to identify recurring patterns and sentiments regarding green infrastructure [11]. By integrating economic, environmental, and social dimensions, the methodology ensures a holistic understanding of the role of green spaces. The study not only quantifies tangible benefits such as healthcare savings but also captures the intrinsic and relational values of nature in urban life. This comprehensive approach is essential for informing urban policies that are both environmentally sustainable and economically sound [12].

III. Experimental Setup and Data Analysis

The experimental setup was designed to capture real-time air quality improvements associated with the presence of urban green spaces and their linkage to public health metrics. Three primary zones were selected: a high-density residential area with minimal green cover (Control Zone), a moderately greened park-centric neighborhood (Test Zone 1), and an extensively green zone with interconnected parks and tree-lined streets (Test Zone 2). Each of these zones was monitored for air pollutant levels over a 12-month period using calibrated air quality sensors. Air pollutants were measured at three distinct times of the day—morning, noon, and evening—to capture diurnal variations [13]. Data was aggregated weekly and analyzed using statistical tools including ANOVA and regression analysis to determine the correlation between green cover and air quality. Vegetation indices derived from satellite data were cross-validated using groundtruthing methods like tree counts and leaf area index (LAI) measurements. These indices were then used to create spatial overlays in GIS to map pollution reduction efficacy [14]. Health data included records of outpatient visits for asthma, bronchitis, COPD, and cardiovascular symptoms. These were anonymized and geo-tagged to patients' residential addresses to allow spatial correlation with green coverage. Statistical tests such as Pearson correlation and logistic regression were used to assess the relationship between proximity to green spaces and the likelihood of developing respiratory issues. The analysis showed statistically significant reductions in disease incidence among populations living within 500 meters of green spaces [15].

Economic analysis involved calculating the direct costs of developing and maintaining green spaces, which included land preparation, planting, irrigation, and upkeep. These were compared to the monetized benefits from reduced healthcare costs and increased property valuations. The Avoided Cost Method estimated the monetary value of reduced hospital visits, while hedonic pricing assessed the appreciation in property values attributable to proximity to green zones. Benefit-cost ratios for the three zones were calculated, with Test Zone 2 showing the highest BCR of 3.5:1, indicating strong economic justification [16]. Test Zone 1 had a BCR of 2.1:1, while the Control Zone predictably yielded a BCR below 1, indicating net economic loss. Additionally, public surveys indicated that 78% of respondents were willing to pay a modest increase in municipal tax if the revenue was earmarked for green infrastructure development. This reflects a high degree of public support for such initiatives.

By integrating spatial data analysis, health statistics, and economic valuation, the experimental setup provides a multidimensional assessment of the value of urban green spaces. The strong statistical correlations and positive economic indicators support the hypothesis that green infrastructure delivers significant, quantifiable benefits to urban populations. These findings provide a compelling case for prioritizing green spaces in urban development policies.

IV. Results and Discussion

The results of the study clearly indicate that urban green spaces contribute significantly to air quality improvement and public health enhancement [17]. Across the two test zones, there was

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an average reduction of 30% in PM2.5 and 24% in NO_2 compared to the control zone. These reductions were most pronounced during summer and early autumn when vegetation density was at its peak [18]. Moreover, the spatial correlation maps revealed a strong inverse relationship between green coverage and pollutant concentration, particularly in Test Zone 2, where vegetative density was highest [19]. Health data analysis showed a notable decline in the incidence of respiratory illnesses in the test zones. Residents in Test Zone 2 experienced a 37% lower rate of respiratory-related outpatient visits compared to the control zone. This translated into substantial healthcare cost savings, with an estimated reduction of $250,000 annually in direct medical expenses. The results also showed fewer school absences due to asthma attacks, indicating improved health outcomes among children, a particularly vulnerable group [20].

Economically, the study found a robust return on investment in green infrastructure. The Net Present Value (NPV) over a 20-year period was highest in Test Zone 2, exceeding $3 million, compared to $1.2 million in Test Zone 1. The Internal Rate of Return (IRR) in both zones exceeded 15%, demonstrating financial viability well above standard public project thresholds. Sensitivity analysis showed that even under conservative scenarios—lower pollution reduction rates and higher maintenance costs—the BCR remained above 1, reinforcing the resilience of the investment [21]. Qualitative feedback from residents underscored additional non-monetary benefits. Many reported increased recreational use of parks, higher levels of perceived mental well-being, and improved neighborhood aesthetics. Community cohesion was also noted, with green spaces serving as venues for social interaction, thereby reducing urban alienation. These intangible benefits, although not easily quantifiable, add to the holistic value proposition of urban green infrastructure [22].

Public sentiment strongly favored green investments, with 82% of surveyed residents indicating a preference for more green spaces even at the cost of reduced commercial development. This indicates a shift in urban priorities, where citizens value long-term environmental and health benefits over short-term economic gains [23, 24]. Local businesses also reported increased foot traffic near parks, suggesting indirect economic benefits not captured in traditional cost-benefit frameworks. Overall, the results demonstrate that urban green spaces are not only environmental assets but also economic and social multipliers [25]. They reduce pollution, enhance public health, and yield significant economic returns. These findings provide robust evidence to guide urban policymakers in allocating resources toward green infrastructure as a core component of sustainable city planning [26].

V. Conclusion

The comprehensive cost-benefit analysis conducted in this study underscores the indispensable role of urban green spaces in enhancing air quality and improving public health. Despite the upfront investment required for their development and maintenance, the long-term economic, environmental, and social benefits significantly outweigh the costs. Reductions in air pollution levels lead to measurable declines in respiratory illnesses and associated healthcare costs, while non-market benefits such as improved mental well-being and community engagement further strengthen the case for green infrastructure. The positive benefit-cost ratios, strong public support, and consistent health improvements across zones affirm that green spaces are not mere aesthetic enhancements but vital public assets that deliver multifaceted returns. Policymakers should, therefore, prioritize the integration of green spaces in urban planning frameworks to foster sustainable, healthy, and economically resilient cities.

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