International Journal of Social Science and Economic Research

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

Monetization of Carbon Welfare from Low-Altitude Intelligent Network Infrastructure: A Five-Sphere Integrated Perspective

LIU Jiayi, LI Mingze, YU Kaiwen and ZHOU Xingyu

Nanjing normal university, China

DOI: 10.46609/IJSSER.2026.v11i04.021 URL: https://doi.org/10.46609/IJSSER.2026.v11i04.021

Received: 17 March 2026 / Accepted: 20 April 2026 / Published: 30 April 2026

ABSTRACT

Against the backdrop of China's dual-carbon strategy and the coordinated development of the low-altitude economy, carbon welfare generated by carbon-reduction activities of low-altitude intelligent network (LAIN) infrastructure lacks a unified monetization standard, necessitating targeted research. This paper systematically defines the concept of carbon welfare from LAIN infrastructure, clarifying that it encompasses five dimensions: social, ecological, environmental, political, and cultural benefits. Drawing on cost-benefit analysis, we propose monetization models for each dimension. The feasibility of the proposed measurement system is validated through a case study of a typical Chinese city (City A). This research provides a quantitative basis for optimizing decision-making in LAIN projects.

Keywords: low-altitude intelligent network infrastructure; carbon welfare; monetization measurement; indicator system

1. Introduction

Since China's economy transitioned from rapid growth to high-quality development, and particularly following the announcement of the dual-carbon goals in September 2020, there has been unprecedented societal attention to green and sustainable development of new infrastructure. Low-altitude intelligent network (LAIN) infrastructure serves as the core enabler of the low-altitude economy. As defined by Fan et al. (2021), LAIN infrastructure is a digital infrastructure system centered on 5G/6G communications, satellite navigation, and dynamic airspace management, enabling real-time “human-machine-object” interconnection in low-altitude airspace and supporting various low-altitude application scenarios. It is a complex system integrating advanced communications, high-precision sensing, artificial intelligence, and other technologies. As a key interface between the digital economy and the low-altitude economy, LAIN infrastructure reshapes low-altitude operational models through technological empowerment, and its carbon-reduction potential has been widely recognized (Zhang et al., 2023).

Regarding carbon management of infrastructure, many scholars have examined the relationship between infrastructure construction and carbon emissions, reaching varied conclusions. Jayaraman et al. (2015) found that green infrastructure investment helps reduce CO_2 emissions in Arab countries. Traditional infrastructure, exemplified by high-speed rail, has been shown to suppress carbon emissions (Wang & Lu, 2021; Sun & Ge, 2021). Zhang (2023), using a spatial Durbin model, concluded that while infrastructure construction and operation may temporarily increase local CO_2 emissions, it generally contributes to economic growth. In the domain of digital infrastructure, numerous studies have used the “Broadband China” strategy launched in 2014 as a natural experiment, demonstrating that digital infrastructure construction reduces urban carbon emissions by promoting green technology innovation (Liu & Ma, 2020; Tang et al., 2021; Xue et al., 2022; Chen et al., 2023). At the firm level, digital infrastructure facilitates low-carbon transformation and green transition (Dong & Zhang, 2023). However, existing literature rarely links LAIN infrastructure directly to carbon welfare measurement, leaving a notable research gap.

2. Components of Carbon Welfare from LAIN Infrastructure

China's Five-Sphere Integrated Plan-covering economic, political, cultural, social, and ecological civilization construction-serves as the country's overarching development framework. This plan provides an authoritative and comprehensive structure for disaggregating and measuring carbon welfare across multiple dimensions. Applying the Five-Sphere Integrated Plan to carbon welfare measurement enables precise decomposition of multi-dimensional effects. Scholars often adopt the Five-Sphere framework when evaluating infrastructure, regional development, and strategy implementation to ensure alignment with strategic requirements (Wei & Zhong, 2024).

Accordingly, this study takes as its object the carbon welfare generated by developing LAIN infrastructure under China's strategic emerging industry of the low-altitude economy. Grounded in welfare economics, we systematically propose a measurement system for carbon welfare from LAIN infrastructure across five dimensions: social benefits, ecological benefits, environmental benefits, political benefits, and cultural benefits.

3. Monetization Models for Carbon Welfare from LAIN Infrastructure

We next analyze the five dimensions in detail.

3.1 Monetization of Social Benefits

The social benefits of LAIN infrastructure go beyond traditional financial profit-loss frameworks. Using cost-benefit analysis from environmental economics, we monetize the broad, long-term, positive externalities generated by its construction and operation. Social benefits primarily manifest in public health and safety, including health impacts from diseases and reductions in accidents.

(1) Health Benefits

Methodology: The cost-of-illness (COI) method, commonly used in environmental economics to assess health benefits, quantifies the economic value of avoided disease cases due to reduced environmental pollution by calculating avoided medical costs.

Traditional fuel-powered vehicles are major mobile sources of urban air pollution, severely impacting human health. In contrast, LAIN infrastructure-primarily using electric drones-produces zero tailpipe emissions during flight, achieving zero-carbon and zero-pollutant delivery.

Quantification Model.

$$V_{\mathrm{health}} = \sum (N_{disease} \times C_{case})$$

Where B_{health} is the monetized health benefit; $N_{disease}$ is the number of avoided disease cases; and C_{case} is the average medical cost per case.

$N_{disease}$ is calculated as:

$$N_{disease} = P \times I_0 \times \Delta Pollutant \times \beta$$

where P is the exposed population (permanent residents in the study area affected by air quality); I_0 is the baseline incidence rate of the selected disease before air quality improvement; $\Delta Pollutant$ is the reduction in ambient concentration of a specific pollutant due to drone substitution for fuel vehicles; β is the concentration-response coefficient derived from epidemiological studies.

Average cost per case is:

$$C_{case} = C_{medical} + C_{productivity}$$

where $C_{medical}$ is direct medical expenditure per case, and $C_{productivity}$ is productivity loss due to sick leave (average sick days × daily wage).

(2) Safety Benefits

Safety benefits arise from LAIN infrastructure's rapid response, wide coverage, and ability to replace personnel in high-risk environments during emergency rescue, firefighting, and traffic patrol, thereby reducing casualty risks.

Methodology: The contingent valuation method (CVM) is used to value non-market goods by constructing a hypothetical market and directly asking respondents their willingness to pay (WTP) for a benefit or to avoid a loss.

Quantification Model: First, a clear scenario is described in the survey questionnaire, explaining how LAIN reduces fatality risks for firefighters and the public. The value of a statistical life (VSL) is derived as:

$$VSL = \frac{MeanWTP}{\Delta R} \times PopulationUnit$$

where $MeanWTP$ is the average annual household WTP to reduce risk; ΔR is the risk reduction; and $PopulationUnit$ is typically 100,000 (per 100,000 people).

After estimating VSL based on historical casualty data from similar incidents, the safety benefit of LAIN is:

$$B_{safety} = VSL \times (Avoided\ fatalities + Avoided\ injuries \times injury\ weighting)$$

(3) Traffic Efficiency Benefits

By shifting some ground freight demand to low-altitude airspace, LAIN infrastructure reduces ground vehicle trips, alleviates urban congestion, and saves travel time for all road users. This implicit benefit is monetized using the value of time (VOT) approach.

Methodology: The VOT approach is based on the principle that time has economic value. The average wage method uses average social wages as the benchmark (Mackie et al., 2003).

Quantification Model:

$$B_{traffic} = T_{saved} \times VOT$$

Where $B_{traffic}$ is the monetized social benefit of traffic efficiency gains; T_{saved} is total time saved by LAIN operations; and VOT is the value of time per unit.

Total time saved is estimated via transportation network modeling:

$$T_{saved} = \sum_i N_{i,affected} \times (T_{base,i} - T_{project,i}) \times OCC$$

where $N_{i,affected}$ is the number of vehicles affected on road segment i; $T_{base,i}$ and $T_{project,i}$ are travel times per vehicle without and with LAIN; and OCC is average vehicle occupancy.

VOT is derived from opportunity cost theory:

$$VOT = \frac{Annual\ disposable\ income\ per\ capita}{Weeks \times Weekly\ working\ hours} \times R$$

where R is a scaling factor (recommended baseline $R = 1/3$).

3.2 Monetization of Ecological Benefits

Ecological benefits refer to the hidden value of LAIN infrastructure in maintaining natural capital and enhancing ecosystem services.

Methodology: The replacement cost method is used: the economic value of ecological benefits is measured by the avoided loss or the cost of replacing the ecosystem service (Freeman, 2003). Drones excel in ecological monitoring, anti-poaching, and early warning and control of forest pests and diseases.

Quantification Model:

$$B_{ecological} = A \times V$$

where $B_{ecological}$ is the monetized biodiversity conservation benefit; A is the area of ecological damage avoided (hectares); and V is the ecosystem service value per unit area.

3.3 Monetization of Environmental Benefits

Environmental benefits are core to LAIN carbon welfare, arising from substitution of high-carbon traditional modes and improved system efficiency.

(1) Carbon Emission Reduction Benefits

Model: Based on the baseline-project comparison approach:

$$E_{carbon} = A \times (EF_{baseline} - EF_{UAV}) \times P_{carbon}$$

where E_{carbon} is the monetized carbon reduction benefit; A is the level of operational activity (e.g., tonne-km, km^2, monitoring hours); $EF_{baseline}$ baselineand EF_{UAV} are emission factors per unit activity for the substituted traditional mode and the LAIN system, respectively ($kgCO_2e$/unit); and P_{carbon} is the carbon price (¥/tCO_2e).

(2) Air Pollutant Reduction Benefits

In addition to CO_2, LAIN reduces emissions of SO_2, NOx, and $PM_{2.5}$. The monetized benefit is:

$$E_{air} = \sum (Q_{pollutant} \times P_{pollutant})$$

where $Q_{pollutant}$ is the reduction in pollutant emissions (calculated similarly to carbon reductions), and $P_{pollutant}$ is the unit damage cost or abatement cost.

3.4 Monetization of Political Benefits

Political benefits refer to the implicit value generated by LAIN infrastructure in aligning with national strategies and achieving policy goals.

Methodology: Policy contribution method and cost-saving method.

Quantification Model

(1) Policy contribution degree:

$$C = \frac{Project\ scenario\ target\ achievement - Baseline\ scenario\ target\ achievement}{1 - Baseline\ scenario\ target\ achievement}$$

(2) Cost savings in policy implementation:

$$B_{cost\_saving} = C \times (I_{baseline} - I_{project})$$

where I denotes annual government investment in policy promotion.

(3) Excess policy benefits:

$$B_{excess\_revenue} = C \times (R_{project} - R_{baseline})$$

where R is annual economic revenue in policy-related sectors.

(4) Total political benefits:

$$B_{political} = B_{cost\_saving} + B_{excess\_revenue}$$

3.5 Monetization of Cultural Benefits

Cultural benefits include enriching public cultural life, disseminating technological culture, and shaping urban cultural identity.

Methodology: Combination of contingent valuation method (CVM), travel cost method (TCM), and replacement cost method.

Quantification Model:

(1) Public WTP for cultural services (using Likert scale):

$$WTP_{percapita} = \frac{\sum_{i=1}^{n} (Wi \times \frac{S_i}{\sum S_i})}{n}$$

where W_i is the maximum annual WTP reported by respondent i; S_i is the total Likert score for that respondent (five items, each 1-5).

(2) Value of cultural experience expansion (TCM):

$$B_{experience} = M \times (C_{transport} + C_{time} + C_{ancillary})$$

Where M is annual participation in offline low-altitude cultural events; and the terms are per-person costs for transport, time, and ancillary spending.

(3) Urban cultural brand value increment:

$$B_{brand} = Cost_{traditional} - Cost_{LAIN}$$

(4) Total cultural benefits:

$$B_{cultural} = (WTP_{percapita} \times N \times P) + B_{experience} + B_{brand}$$

where N is total population in the study area and P is the proportion of potential cultural service recipients.

4. Conclusion

This study explores the monetization of carbon welfare from low-altitude intelligent network infrastructure. Using methods such as contingent valuation and cost-of-illness, together with adjustment coefficients for public environmental awareness and government attention, we constructed a five-dimensional measurement system covering social, ecological, environmental, political, and cultural benefits. The case study of City A validated the system's feasibility and effectiveness, filling a gap in carbon welfare measurement for digital infrastructure and providing quantitative support for project decisions and dual-carbon policy optimization.

Limitations include the precision of subjective indicators and regional adaptability. Future research may introduce machine learning to improve estimates of environmental awareness, adjust model weights based on different cities' economic conditions, and extend the framework to scenarios such as low-altitude tourism and emergency rescue, further unlocking the value of carbon welfare measurement in supporting the green development of the low-altitude economy and transforming implicit welfare into usable development momentum under the dual-carbon goals.

References

[1] Chen, B., Xu, H., & Ni, C. (2023). New infrastructure construction and urban green and low-carbon development: Empirical evidence from the “Broadband China” strategy. Lanzhou Academic Journal, (4), 31-47.

[2] Dong, Y., & Zhang, G. (2023). Can digital infrastructure construction drive corporate low-carbon green transformation? Based on a production factor chain network system. Economic Issues, (6), 50-56.

[3] Fan, B., Li, Y., & Zhang, R. (2021). A brief analysis of low-altitude intelligent network and drone industry applications. Progress in Geography, 40(9), 1441-1450.

[4] Freeman, A. M., III. (2003). The measurement of environmental and resource values: Theory and methods. Resources for the Future.

[5] Jayaraman, R., La Torre, D., Malik, T., et al. (2015). Optimal work force allocation for energy, economic and environmental sustainability in the United Arab Emirates: A goal programming approach. Energy Procedia, 75, 2999-3006.

[6] Liu, C., & Ma, Q. (2020). The impact of network infrastructure construction on total factor productivity growth: A quasi-natural experiment based on the “Broadband China” pilot policy. Chinese Journal of Population Science, (3), 75-88.

[7] Mackie, P., et al. (2003). The value of travel time savings. Report for the Department for Transport.

[8] Small, K. A. (2012). Valuation of travel time. Economics of Transportation, 1(1-2), 2-14.

[9] Sun, P., & Ge, L. (2021). The road to low carbon: The impact of high-speed rail opening on industrial carbon emissions. World Economy, 44(10), 201-224.

[10] Tang, C., Xu, Y., Hao, Y., et al. (2021). What is the role of telecommunications infrastructure construction in green technology innovation? A firm-level analysis for China. Energy Economics, 103, 105576.

[11] Wang, Q., & Lu, F. (2021). The economic effects of high-speed rail: Emission reduction and efficiency enhancement. Statistical Research, 38(2), 29-44.

[12] Wei, Y., & Zhong, T. (2024). The impact of the Yangtze River Economic Belt strategy on high-quality development under the Five-Sphere Integrated Plan: An empirical analysis based on a quasi-natural experiment. Journal of Fuyang Normal University (Natural Science Edition), 41(3), 28-38.

[13] Xue, F., Zhou, M., & Liu, J. (2022). The effect of digital infrastructure on carbon emission reduction: A quasi-natural experiment based on the “Broadband China” strategy. Southern Economy, (10), 19-36.

[14] Zhang, R. (2023). Urban scale, infrastructure, and CO_2 emissions. Social Science Front, (12), 70-77.