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Knowledge-Graph Intelligent Auxiliary Decision-Making Tool for Zero-Waste Design of Urban Green Spaces Based on Multi-Source Sensing Data

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1 Calculation of Ecological Performance

1.1 Ecological Performance

Ecological performance is used to measure the extent to which a design scheme achieves waste reduction and resource recovery within the project boundary. It is calculated as:

$$Eg = \frac{\sum_{i=1}^{n} T_{reduced-i}}{T_{initial}} \times 100\% = \frac{T_{reduced-1} + T_{reduced-2}}{T_{initial}} \times 100\% \quad , \quad \text{(S1)}$$

where:

Eg: ecological performance;

$T_{reduced-1}$: reduced trunk quantity (t);

$T_{reduced-2}$: reduced concrete quantity (t);

i: zero-waste design strategy for urban green spaces;

$T_{initial}$: total waste generated (t) (i.e., the sum of all generated waste).

1.2 Calculation Basis

In this study, ecological performance is defined as the proportion of waste effectively diverted from conventional disposal pathways (such as landfilling and incineration) through reduction and recovery-oriented design strategies, relative to the total waste generated within the project boundary. For the initial design scheme, the recycling term may be zero; for the optimized scheme, both reduction and recycling are included. This definition is consistent with the original calculations for the initial and optimized schemes.

1.3 Data Sources

The relevant data were derived from site investigation, waste quantity statistics, design quantity take-off, material inventories, construction and operation records, and scheme-based simulation statistics on waste diversion pathways. The reduced and recycled quantities in both the initial and optimized schemes were compiled on this basis.

2 Calculation of Overall Zero-Waste Performance

Overall zero-waste performance is used to represent the combined ecological and economic performance of a design scheme. In this study, ecological performance and the sigmoid-normalized economic performance are integrated with equal weights:

$$E = \frac{1}{2}E_g + \frac{1}{2} \times \frac{1}{1 + e^{-(E_m - 1)}} \times 100\% \quad , \quad \text{(S2)}$$

where:

E: the overall zero-waste performance;

E_g: ecological performance;

E_m: economic performance.

Here, economic performance E_m is defined as the ratio of total benefits to total costs of the adopted zero-waste design strategies within the same project boundary. The benefits include, for example, material substitution benefits, savings in transport costs, and savings in disposal costs; the costs include processing, transport, labor, equipment, and material inputs. The same definition of economic performance was used for both the initial and optimized schemes in the original calculations.

2.2 Calculation Basis

This study gives equal weight to ecological and economic performance. Economic performance is first normalized using a Sigmoid function to reduce dimensional inconsistency and is then combined with ecological performance to obtain the overall zero-waste performance. This treatment is consistent with the original overall performance calculations for both the initial and optimized schemes.

2.3 Data Sources

The data used for economic performance were obtained from market surveys of material prices, transport price surveys, official waste-disposal charging standards, equipment rental and labor-cost records, and quantity estimates of each zero-waste strategy in the design scheme. The overall zero-waste performance was then derived from the combined ecological and economic results.

NOTE

This Supplementary Material only provides the two core equations and their basic explanatory information for Table 2, to support the interpretation of the results in the main text and facilitate editorial checking. A more detailed derivation of the evaluation model, parameter expansion, and extended case-based analysis will be published in related research article.