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Analyzing the Optimal Level of Biotope Quality and Cost Planning for Sustainable Development in Regional Tourism: Study of B&B Houses in Taiwan

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Abstract

This study explores the optimal relation between biotope quality and cost planning for sustainable development in regional tourism, utilizing cases of bed and breakfast (B&B) houses with real data in a national scenic area in central Taiwan to demonstrate the empirical validity of this study. We adopt the Biotope Area Factor (BAF) to measure a B&B environment's biotope quality and then analyze the optimal combination of B&B total surface by material planning and minimum cost through multiple objective programming (MOP). Results reveal that B&B houses without outdoor space and cost investment can hit the lower limit of a BAF target at low cost, but the cost increases by two times if they further raise their BAF target to a high level.

Key words: sustainable development, Biotope Area Factor, multiple objective programming, bed and breakfast (B&B)

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1. Introduction

Many national parks and scenic areas face challenges regarding sustainable development in tourism with the development of industry and transportation. These shifting trends have drastically lowered scenic areas' biotope quality due to the significant number of tourists, leading to a rapid increase in the demand and supply of lodging, within which the bed and breakfast (B&B) and guesthouse industry is the most significant. However, current studies regarding sustainable development in tourism mainly focus on technological innovation and transportation improvement (Chiesa & Gautam, 2009; Cabrini et al., 2009). The antecedent discussion that supports the biotope evaluation for sustainable development in a scenic area remains underdeveloped.

The conventional biotope evaluation for assessing and rating green buildings and the environment currently adopt nine key indicators: biodiversity, greenness, water reserves, energy savings, reduction of CO_2 emissions, reduction of waste disposal, indoor environment, water resources, and improvement of sewage and garbage disposal. Every qualified green building must fulfill four out of the nine criteria. These indicators can aid the management of buildings and construction sites, but they are hard to quantify and are not suitable for assessing an area's overall environmental quality. The Biotope Area Factor (BAF), developed in Berlin, is profoundly appropriate for use on buildings and overall areas, and the results can serve as a basis for developing general environment management strategies (U.S. Senate Department for Urban Development, 1990). BAF can quantify air and water permeability in outdoor spaces, vertical greenery on buildings, and various surface types. This factor contributes to the management of total greenery in a three-dimensional site and improves the simplicity at enhancing environmental quality.

Installation cost is usually the first consideration for businesses attempting to improve the quality of their ecological environment and retain functionality of the original space. Nine types of surfaces and twenty-one different materials can help improve the BAF values of outdoor spaces, vertical greenery on buildings, and greenery on rooftops, but different materials incur different costs. Accordingly, investigating how to calculate as well as obtain the optimal surface type and material combination at minimal cost while achieving the target BAF values is necessary. Such findings can help persuade B&B businesses to strive toward the goal of improving ecological quality. B&B businesses are an important part of the lodging industry that strongly rely on natural resources and biological environment in scenic areas. However, the prime cost is usually the first consideration for B&B owners. The effort from a biotope study involves striking a balance between ecological quality and the acceptable cost for businesses.

Given the importance of this topic on sustainable development, this research studies how to best improve the quality of the environment of B&B businesses at the lowest cost by selecting B&B enterprises in Sun Moon Lake National Scenic Area of central Taiwan. Our research target is to analyze nine B&B houses in three types, depending upon their current BAF value and outdoor space. The BAF value measures the biological quality of the environment using nine surfaces with 20 materials. The cost of improving environmental quality depends on the surfaces and materials being used. Multiple objective programming methods can help analyze the best combination of the surfaces and the materials to obtain the BAF target at the lowest cost.

2. Literature Review

2.1 Concept of Sustainable Development

The words “sustainable development” frequently encompass different dimensions. Sustainable development is most commonly described in the economic debate as the need to maintain permanent growth as well as progress for society and is generated from non-declining capital. The International Union for Conservation of Nature and Natural Resources (United Nations, 1987) is the first to coin the term sustainability as a form of development that meets the demand of society without compromising the ability of future generations.

Given the development of manufacturing and environmental threats, a framework has arisen to integrate environmental protection and economic development. Sustainable development is the key guideline to devise industry and environmental policies at a sectoral level (Koroneos & Rokos, 2012). However, disagreement over this definition and functionality persists. Many arguments define sustainable development as an integrated concept that considers economic development, ecological conservation, and social justice (Lélé, 1991; Perrings, 1991; Carley & Spapens, 1998; Sachs, 1999). Spangenberg (2005) proposes that every society comprises economic, social, environmental, and institutional dimensions, and each one is a dynamic and self-organizing entity that makes the whole system sustainable. Therefore, each subsystem must maintain its capability and enable the co-evolution of their interlinkages to achieve sustainable development.

The concept of sustainable development recently has taken on considerable importance in tourism policy and industry, as the current development of tourism is environmentally unsustainable. While other sectors are reducing their greenhouse gas emissions, the impact of tourism on climate change is increasing. The contemporary tourism theory also fails to clearly describe this sustainable development issue; thus, developing effective policies to mitigate environmental impacts is difficult (Peeters & Landré, 2012). Several investigations have proved that tourism-related greenhouse gas emissions are larger than global emissions (Scott et al., 2010). Some current discussions regarding sustainable development in tourism mainly focus on technological innovation, which includes energy efficiency improvement, the design of accommodations as well as transportation styles, and the use of low carbon fuel (Chiesa & Gautam, 2009; Cabrini et al., 2009). Discussions of sustainability in tourism from the biotope view have also emerged.

2.2 Green Infrastructure and Biotope Area Factor (BAF)

The discussion about sustainable development by a uniform environmental condition that provides a living place for a specific assemblage of plants and animals in a biological community has gained increasing interest. Haeckel's "General Morphology" (1866) is the first to advocate the concept of biotope in sustainability, which explains that environmental factors and the interaction among living things shapes one ecosystem's biota, and this ecological system is generally defined as a "biotope" (Baghdadi and Desha, 2016; Casella et al., 2016; Dennis and James, 2016; Huang et al., 2015; Iwasawa, 2005). In 1980, Germany proposed BAF as a policy tool to emphasize environmental issues. Berlin's landscape program formulates basic goals and measures to promote high-quality urban development with respect to the ecosystem, the protection of biotopes and species, the appearance of the landscape, as well as recreational use (Senate Department for Urban Development, 1990). The program for the protection of the landscape and of species states that an important goal of urban development in Berlin is the reduction of any environmental impact on the city, such as gross floor area, the site occupancy index, and the floor space index, which regulate the dimensions of use structures. BAF expresses the area portion of a plot of land that serves as a location for plants or assumes other functions for the ecosystem in order to contribute to standardizing and putting into concrete terms the following environmental quality goals (Baghdadi and Desha, 2016; Beatley, 2009; Carter & Fowler, 2008; Casella et al., 2016; Dennis and James, 2016; Huang et al., 2015).

BAF is similar to other calculation tools developed for urban planning. Improving the ecosystem's functionality and promoting the development of biotopes, while maintaining the current land use, are central to this endeavor. BAF's goals are to create and preserve the quality of habitat for creatures in urban areas, safeguard urban greenery standards, ensure the quality of urban aesthetics, and provide citizens with opportunities to enjoy leisure as well as entertainment in green areas. Ngan (2004) argues that, similar to the urban planning parameters used in development planning, BAF can measure the ecologically effective land area, which is defined as the area of a development that contributes to the functioning of an ecosystem through stormwater drainage or habitat.

2.3 Calculation of BAF

BAF in an area represents the ratio of the ecologically effective surface area to the total land area. The formula for calculating BAF is:

BAF = Ecologically-effective Surface Areas × Ecological Weighting

The use of BAF can provide quantified data on nutrients' different types of surfaces, their energies, and their biological classification. BAF can help calculate the suitability of different surfaces as habitats for animals and plants by using a variety of determining factors, such as transpiration efficiency, dust reduction, permeability, rainwater storage, and soil protection. Surfaces with high water permeability and greenery cover are highly suitable as habitats for animals and plants. Different types of surfaces have differing ecological effectiveness. Therefore, they are individually given an ecological effectiveness weighting factor. Table 1 shows the weighting factor of different surface types.

Table 1. Ecological Effectiveness Weighting of Each Surface Type

Surface type	Description	Weighting factor
Sealed surface	Surface that is impermeable to air and water and has no plant growth	0.0
Partially sealed surface	Surface that is permeable to water and air; as a rule, has no plant growth	0.3
Semi-open surface	Surface that is permeable to water and air, infiltration, and plant growth	0.5
Surface with vegetation, unconnected to soil below	Surface with vegetation on cellar covers or underground garages with less than 80 cm of soil covering	0.5
Surface with vegetation, unconnected to soil below	Surface with vegetation that has no connection to the soil below, but with more than 80 cm of soil covering	0.7
Surface with vegetation, connected to soil below	Vegetation connected to the soil below; available for the development of flora and fauna	1.0
Rainwater infiltration per m^2 of the roof area	Rainwater infiltration for the replenishment of groundwater; infiltration over a surface with existing vegetation	0.2
Vertical greenery up to a maximum of 10 m in height	Greenery covering walls and outer walls with no windows; the actual height, up to 10 m, is taken into account.	0.5
Greenery on the rooftop	Extensive and intensive coverage of the rooftop with greenery	0.7

Source: Senate Department for Urban Development (1990).

BAF covers urban forms of residential, commercial, and infrastructural uses, formulates ecological minimum standards for structural changes and new development, and includes all potential green areas, such as courtyards, roofs, walls, and firewalls. Table 2 lists the target BAF values applicable to various development and use structures and reveals that the target BAF values established for construction sites in Berlin for building residential units are a minimum of 0.3, that the next target BAF value is 0.45, and that a newly constructed structure should achieve a BAF value of 0.6.

Table 2. Target BAF Value of Various Land Uses

Land use			Target BAF value	Related guideline
Residential units	Degree of coverage	Up to 0.37	0.60	▪ BAF must be at least 0.6 with respect to undeveloped sites on which new structures are to be built.
		0.38 to 0.49	0.45	
		Over 0.50	0.30	
		Mixed use with commercial use	0.30	▪ Mixed structures for commercial usage within key areas are an exception. Their BAF must be at least 0.3. ▪ In the case of building coverage in excess of 0.4, rainwater infiltration through existing vegetation soakaways is generally no longer meaningful.

Source: Senate Department for Urban Development (1990).

For the implication of BAF, whether surfaces are in outdoor spaces or on building rooftops, different materials affect air and water permeability as well as plants' and animals' ability to adapt to the habitat. Their impact may lead to a higher building cost and a change in the BAF value given that different types of surface materials have their own corresponding cost expense. This scenario leads to B&B houses having a lack of motivation to increase the BAF value of their building, because they may need to reallocate the surface material and area in outdoor and indoor architectures.

3. Methods

This section introduces the research method and sample selection. We provide a research design to explain the research target and framework and define the numerical model of multiple-objective programming. We also present three scenarios for analyzing our three B&B types.

3.1 Research Design

This research selected Sun Moon Lake National Scenic Area in central Taiwan, a famous national scenic park, as our research scope. This scenic area has built old and emergent B&B houses around the lake in the last twenty years. The study chose

69 B&B houses registered in the official yearbook and collected 57 useful B&B samples after surveys and interviews from October 2010 to June 2011. Nine B&B enterprises were further selected as calculated cases to conduct a complete area measurement of the B&B environment. We divide these nine B&B cases with detailed numerical data into three types based on their current BAF value and outdoor space and utilize a multi-objective programming method (Kuhn & Tucker, 1951; Johnson, 1968; Roy, 1971; Hwang et al., 1980) to explore an optimization problem that concerns the achievement of their target BAF values at a minimum cost.

We now explain the research process as follows. First, we conducted a field investigation using a 1/5000 colored orthophoto map and surveyed the current outdoor space as well as the vertical surface of buildings and building rooftop materials to understand the types of surfaces used by these B&B buildings. Second, this study used the Geography Information System to calculate the area of the surface types used in the B&B houses. We calculated the current BAF values that the B&B houses demonstrate and categorized the surveyed B&B houses into three types according to their BAF values and whether they had outdoor space.

Using the expert method, this research assessed and determined the minimum cost of each of the 21 materials for the nine types of surfaces and used these figures for calculating the cost of each unit of the surface for improving ecological quality. After assessing the current condition and situation through consulting experts, we adjusted the list of materials. One originally listed material, waterproof plastic coating (under the type of “sealed surfaces”), is not used on its own as a surface material in Taiwan. This material is generally applied in a waterproofing project of artificial ground that later has vegetation planted on it. Accordingly, the experts suggested deleting this material from our list. Another originally listed material, mosaic coating (under the type of “partially sealed surfaces”), is not water-permeable given the conditions in Taiwan. The experts hence suggested reassigning this material to the “sealed surfaces” category. Table 3 (following the amendment) exhibits 9 types of surfaces, 20 materials, the variable value, and the minimum cost of each material.

Table 3. Surface Type and Minimum Cost

Surface type	Material	Minimum cost
	Y_{11} concrete	2100/m^2
	Y_{12} asphalt	4000/m^2
Y_1 sealed surfaces	Y_{13} brick paving	2400/m^2
	Y_{14} ceramic paving	800/m^2
	Y_{15} mosaic paving	9000/m^2
	Y_{21} rock-block paving	1200/m^2
	Y_{22} wood-block paving	2800/m^2
	Y_{23} concrete paving with sand/gravel slot	1600/m^2
Y_2 partially sealed surfaces	Y_{24} ceramic paving with sand/gravel slot	850/m^2
	Y_{25} slab with a sand subbase	350/m^2
	Y_{26} slab with a gravel subbase	670/m^2
	Y_{27} infiltration	150/m^2
	Y_{28} grass subbase	150/m^2
Y_3 semi-open surface	Gravel with grass coverage	350/m^2
Y_4 surface with vegetation, unconnected to soil below	Surface with vegetation on cellar cover or underground garage with less than 80 cm of soil covering	500/m^2 Planting bush
Y_5 surface with vegetation, unconnected to soil below	Surface with vegetation that has no connection to soil below, but with more than 80 cm of soil covering	2000/m^2 Planting bush
Y_6 surfaces with vegetation, connected to soil below	Vegetation connected to soil below	1500/m^2
Y_7 rainwater infiltration per m^2 of roof area		0/m^2
Y_8 vertical greenery up to a maximum of 10 m in height		4500/m^2
Y_9 greenery on rooftop		4500/m^2

3.2 Multiple-objective Programming

We adopt multiple-objective programming methods to discuss the optimal approach, while considering the dual objectives of the cost and BAF value, and use the results as a reference for the B&B business. We specifically employ Lingo 12.0 as our analytical tool to set the surface area of different building surface types as variable Y_i. Subsequently, we set the minimal total cost as an objective and the minimum required BAF values as the other objective. The two objectives are under the constraint of variable Y_i combinations (building surface types), where Y_i

combinations are the constraints in this multi-objective programming. We express the total cost for each of the B&B houses as follows.

Total cost =

$2180*Y_{11}+300*Y_{12}+2400*Y_{13}+800*Y_{14}+600*Y_{15}+9000*Y_{21}+1200*Y_{22}+2850*Y_{23}+1630*Y_{24}+850*Y_{25}+350*Y_{26}+670*Y_{27}+165*Y_{28}+367*Y_{3}+350*Y_{4}+1900*Y_{5}+1560*Y_{6}+0*Y_{7}+4500*Y_{8}+4500*Y_{9}$

The BAF value of each B&B house is set up as follows, wherein the total area changes along with the B&B house.

$BAF = (0.3*Y_2+0.5*Y_3+0.5*Y_4+0.7*Y_5+1*Y_6+0.2*Y_7+0.5*Y_8+0.7*Y_9)$ / Total area

This multi-objective programming approach has three types of constraints. The first constraint is the upper limit of the variable "surface area." The B&B businesses that attempted to expand their building surface areas to help improve their BAF value are constrained by the upper limit of the surface area, which means that they could not expand their building's surface area indefinitely. We express the constraint in the equation below. Moreover, the upper limit of rooftop area B is also set to constrain the greenery on rooftop Y_9 and the rainwater infiltration of roof area Y_7. This constraint is also in the equation below. The surface area upper limits A and B vary from B&B businesses to B&B businesses.

$Y_1+Y_2+Y_3+Y_4+9*Y_5+9*Y_6$ = Upper limit of surface area A

Y_7+Y_9 = Upper limit of rooftop area B

The second constraint is the interrelation among variable Y_i of different surface areas in multi-objective programming. The variables are also affected by the following constraints that demonstrate the interrelation.

$Y_1 = Y_{11}+Y_{12}+Y_{13}+Y_{14}+Y_{15}$

$Y_2 = Y_{21}+Y_{22}+Y_{23}+Y_{24}+Y_{25}+Y_{26}+Y_{27}+Y_{28}$

The third constraint is the upper and lower limits of each variable Y_i. The lower limit of every variable Y_i is 0, but the upper limit of each variable differs. Bed and breakfast businesses that attempted to expand their building surface areas to help improve the BAF value could not expand their building's surface area indefinitely.

3.3 Scenario Writing

Given the multi-objective programming approach, we categorize the surveyed

B&B houses in this national scenic area into three types (Types I–III) according to their BAF values and whether they have outdoor space. We select two to four B&B houses from each of the three categories from all nine B&B cases with detailed survey data for analysis using the multi-objective programming approach. The first type is B&B houses without outdoor space and a BAF value smaller than 0.5 (four B&B houses). The second type is B&B houses with outdoor space and a BAF smaller than 0.5 (three B&B houses). The third type is B&B houses with an outdoor space and a BAF value larger than 0.5 (two B&B houses).

Table 4. Setting Conditions in Three Scenarios

Category	Type I without outdoor space BAF < 0.5	Type II with outdoor space BAF < 0.5	Type III with outdoor space BAF > 0.5
Case 1	Type I-1	Type II-1	Type III-1
Current BAF value	0	0	0.5319
Current cost	0	208,000	540,450
Case 2	Type I-2	Type II-2	Type III-2
Current BAF value	0	0.1015	0.6295
Current cost	0	141,900	1,069,000
Case 3	Type I-3	Type II-3	–
Current BAF value	0	0.1636	–
Current cost	0	184,000	–
Case 4	Type I-4	–	–
Current BAF value	0.1663	–	–
Current cost	0	–	–
Objective in Scenario I	Min cost BAF >= 0.3	Min cost BAF >= 0.3	Min cost BAF >= 0.65
Objective in Scenario II	Min cost BAF >= 0.4	Min cost BAF >= 0.4	Min cost BAF >= 0.7
Objective in Scenario III	Min cost BAF >= 0.5	Min cost BAF >= 0.5	Min cost BAF >= 0.75

The stipulated building coverage rate for the residential area in this national scenic area is 60%. The research sets the minimum target BAF value for B&B buildings as 0.3 based on the BAF literature. We develop three scenarios (Scenarios I, II, and III) for the analysis (Table 4). The objectives in Scenario I include minimal total cost and a BAF value equal to or larger than 0.3 or 0.65 (if the current BAF value is smaller than 0.5, then the objective BAF value is 0.3; if the current BAF value is larger than 0.5, then the objective BAF value is 0.65). Scenario II investigates the increase in total cost if B&B businesses wish to improve their BAF values. Consequentially, the objectives include minimal total cost and a BAF value equal to or larger than 0.4 or 0.7 (if the current BAF value is smaller than 0.5, then the objective BAF value is 0.4; if the current BAF value is larger than 0.5, then the objective BAF value is 0.7). Moreover, Scenario III investigates the increase in total cost if B&B businesses aim to further improve their BAF values. The objectives thus include minimal total cost and a BAF value equal to or larger than 0.5 or 0.75. Table 4 shows the settings and the current BAF value and spending costs in each of the nine B&B houses.

4. Results

This section discusses the optimal approach for B&B houses based on the calculations from multi-objective programming. Table 5 lists the calculation results in Scenario I, where the B&B houses look to raise their BAF values to the required minimum levels. The results corroborate that each B&B house in Types I and II only needs to invest less than 250,000 units for raising their BAF value to the basic standard of 0.3. In Type III B&B houses, a relatively higher cost would arise to further increase their BAF value to 0.65 given that their current BAF values are already larger than 0.5. Moreover, the analysis results verify that the optimal solution in multi-objective programming tends to occur in extreme situations. In Type I B&B houses, when the majority of the variables (surface area) equal 0, the few variables that do not have the value of 0 include rainwater infiltration (Y_7) and greenery on the rooftop (Y_9). In Type II B&B houses, the few variables that do not have the value of 0 include surfaces with vegetation, unconnected to soil below (Y_4), rainwater infiltration (Y_7), and greenery on the rooftop (Y_9). In Type III B&B houses, the aforementioned variables that involve surfaces with vegetation include unconnected to soil below (Y_4), rainwater infiltration (Y_7), vertical greenery (Y_8), and greenery on the rooftop (Y_9).

Table 6 lists the calculation results in Scenario II, where the B&B houses attempted to further raise their BAF values to high required minimum levels. Compared with the results in Scenario I, all three types of B&B houses must spend more to raise their BAF value to the new goal. Moreover, the results validate that the optimal solution in multi-objective programming tends to occur in extreme situations. In Type I B&B houses, when the majority of the variables (surface area) equal 0, the few variables that do not have the value of 0 include rainwater infiltration (Y_7) and greenery on the rooftop (Y_9). In Type II B&B houses, the few variables that do not have the value of 0 include surfaces with vegetation, unconnected to soil below (Y_4), rainwater infiltration (Y_7), and greenery on the rooftop (Y_9). In Type III B&B houses, the aforementioned variables that involve surfaces with vegetation include unconnected to soil below (Y_4), rainwater infiltration (Y_7), vertical greenery (Y_8), and greenery on the rooftop (Y_9).

Table 5. Results in Scenario I

Category	Type I without outdoor space BAF < 0.5	Type II with outdoor space BAF < 0.5	Type III with outdoor space BAF > 0.5
Case 1	**Type I-1**	**Type II-1**	**Type III-1**
Min cost	81,900	72,200	2,647,000
BAF value	0.3	0.3	0.65
Variable	$Y_7 = 72.8$ $Y_9 = 18.2$ Others = 0	$Y_4 = 52$ $Y_7 = 152$ $Y_9 = 12$ Others = 0	$Y_4 = 404$ $Y_7 = 484$ $Y_8 = 556.8$ Others = 0
Case 2	**Type I-2**	**Type II-2**	**Type III-2**
Min cost	221,436	186,750	2,977,250
BAF value	0.3	0.3	0.65
Variable	$Y_7 = 196.83$ $Y_9 = 49.21$ Others = 0	$Y_4 = 45$ $Y_7 = 242$ $Y_9 = 38$ Others = 0	$Y_4 = 715$ $Y_7 = 144$ $Y_8 = 315$ $Y_9 = 291$ Others = 0
Case 3	**Type I-3**	**Type II-3**	–
Min cost	211,500	119,600	–
BAF value	0.3	0.3	–
Variable	$Y_8 = 188$ $Y_9 = 47$ Others = 0	$Y_4 = 46$ $Y_7 = 184$ $Y_9 = 23$ Others = 0	–
Case 4	**Type I-4**	–	–
Min cost	90,900	–	–
BAF value	0.3	–	–
Variable	$Y_7 = 80.8$ $Y_9 = 20.2$ Others = 0	–	–

Table 6. Results in Scenario II

Category	Type I without outdoor space BAF < 0.5	Type II with outdoor space BAF < 0.5	Type III with outdoor space BAF > 0.5
Case 1	**Type I-1**	**Type II-1**	**Type III-1**
Min cost	163,800	266,600	3,046,600
BAF value	0.4	0.4	0.7
Variable	$Y_7 = 54.6$ $Y_9 = 36.4$ Others = 0	$Y_4 = 52$ $Y_7 = 108.8$ $Y_9 = 85.2$ Others = 0	$Y_4 = 404$ $Y_7 = 484$ $Y_8 = 645.6$ Others = 0
Case 2	**Type I-2**	**Type II-2**	**Type III-2**
Min cost	442,872	479,250	3,494,750
BAF value	0.4	0.4	0.7
Variable	$Y_7 = 147.6$ $Y_9 = 98.4$ Others = 0	$Y_4 = 45$ $Y_7 = 177$ $Y_9 = 103$ Others = 0	$Y_4 = 715$ $Y_7 = 29$ $Y_8 = 315$ $Y_9 = 406$ Others = 0
Case 3	**Type I-3**	**Type II-3**	–
Min cost	423,000	347,300	–
BAF value	0.4	0.4	–
Variable	$Y_7 = 141$ $Y_9 = 94$ Others = 0	$Y_4 = 46$ $Y_7 = 133.4$ $Y_9 = 73.6$ Others = 0	–
Case 4	**Type I-4**	–	–
Min cost	181,800	–	–
BAF value	0.4	–	–
Variable	$Y_7 = 60.6$ $Y_9 = 40.4$ Others = 0	–	–

Table 7 lists the calculation results in Scenario III, where the B&B houses attempted to raise their BAF values to high required minimum levels. Compared with the results in Scenario II, all three types of B&B houses must spend more to raise their BAF value to the new goal. The results corroborate that the optimal solution in multi-objective programming tends to occur in extreme situations. Each B&B house must invest more than 250,000 units to raise their BAF value to a high standard of 0.5.

Table 7. Results in Scenario III

Category	Type I without outdoor space BAF < 0.5	Type II with outdoor space BAF < 0.5	Type III with outdoor space BAF > 0.5
Case 1	**Type I-1**	**Type II-1**	**Type III-1**
Min cost	245,700	461,000	3,446,200
BAF value	0.5	0.5	0.75
Variable	$Y_7 = 36.4$ $Y_9 = 54.6$ Others = 0	$Y_4 = 52$ $Y_7 = 65.6$ $Y_9 = 98.4$ Others = 0	$Y_4 = 404$ $Y_7 = 484$ $Y_8 = 734.2$ Others = 0
Case 2	**Type I-2**	**Type II-2**	**Type III-2**
Min cost	664,308	771,750	3,898,250
BAF value	0.5	0.5	0.75
Variable	$Y_7 = 98.42$ $Y_9 = 147.62$ Others = 0	$Y_4 = 45$ $Y_7 = 112$ $Y_9 = 168$ Others = 0	$Y_4 = 715$ $Y_7 = 6$ $Y_8 = 315$ $Y_9 = 429$ Others = 0
Case 3	**Type I-3**	**Type II-3**	–
Min cost	634,500	575,000	–
BAF value	0.5	0.5	–
Variable	$Y_7 = 94$ $Y_9 = 141$ Others = 0	$Y_4 = 46$ $Y_7 = 82.8$ $Y_9 = 124.2$ Others = 0	–
Case 4	**Type I-4**	–	–
Min cost	272,700	–	–
BAF value	0.5	–	–
Variable	$Y_7 = 40.4$ $Y_9 = 60.6$ Others = 0	–	–

5. Discussion and Conclusion

5.1 Discussion

On the basis of the results of the multi-objective programming analysis using three scenarios, we further discuss the varying trend of cost in each type of B&B houses in a graph. Figures 1 to 3 show a four-step curve that represents the B&B houses' current cost to their minimum cost when they increase their BAF value from the current value to the target BAF value (from current status to Scenarios I, II, and III). The three figures also present the change rate of cost among these three types of B&B house.

Figure 1 exhibits that Type I B&B houses do not spend, because they have no outdoor spaces. These four case types I-1 to I-4 can achieve the BAF value in Scenario I (0.3) by spending less in material selection and area planning. This should be a worthy investment for B&B managers. However, the necessary cost increases soon if they plan to raise their BAF value to the level in Scenarios II (0.4) and III (0.5).

Figure 1. Cost Change and BAF Value in Type I B&B Houses

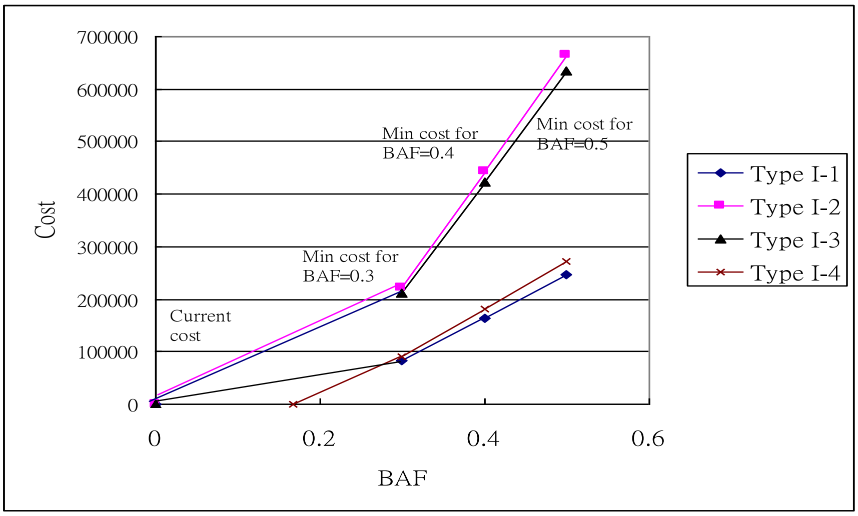
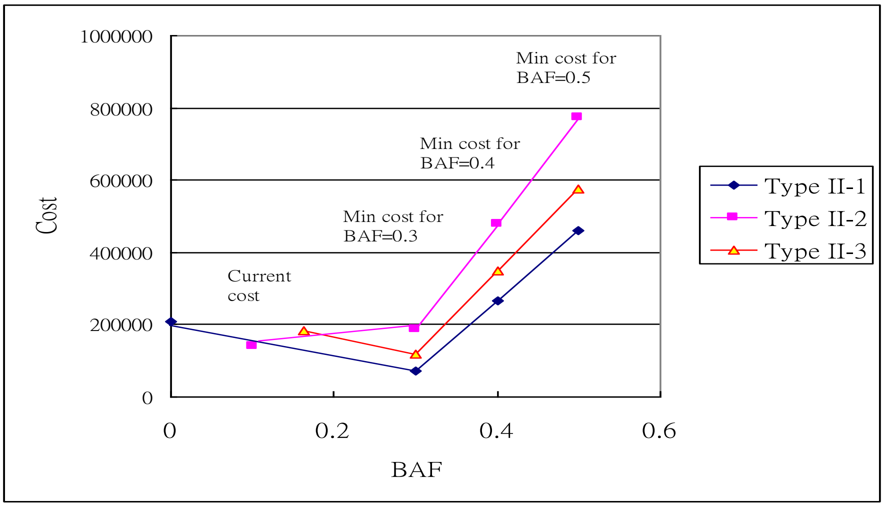


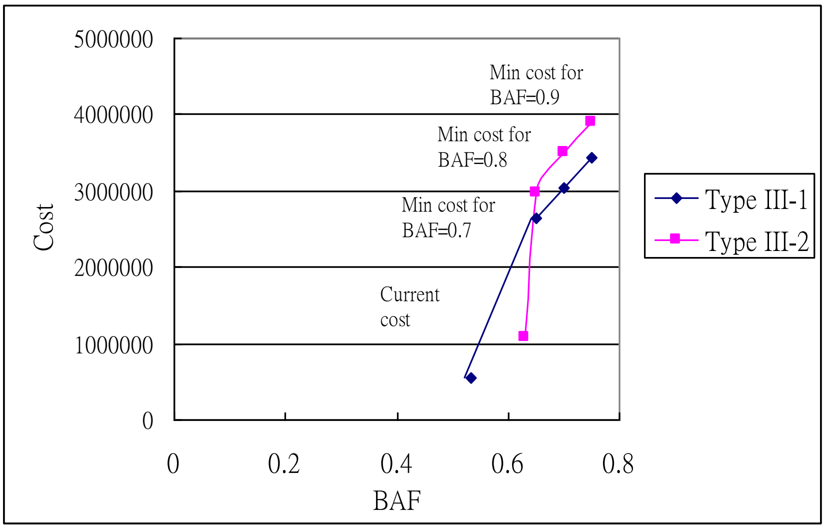
Figure 2 shows that three B&B case types II-1 to II-3 can achieve the BAF value in Scenario I (0.3) by only spending slightly less than the current cost. This scenario means that their current material selection and arrangement are not the optimal combination to maximize the BAF value. Moreover, the necessary cost also increases soon if they plan to raise their BAF value to the level in Scenarios II (0.4) and III (0.5).

Figure 2. Cost Change and BAF Value in Type II B&B Houses



For the Type III B&B houses in Figure 3, further raising their BAF value under limited cost is difficult, because this type of B&B houses has already paid a high price to invest in BAF value improvement. The changing rate of cost in the first stage needs a large amount of spending versus current spending.

Figure 3. Cost Change and BAF Value in Type III B&B Houses



Compared to the necessary cost of raising the BAF value between Scenarios I and II, Table 8 offers a change rate of cost to analyze the sensitivity. We discuss this result in order to evaluate the difficulty of the BAF improvement of each type of B&B house.

Table 8. Change Rate of Cost from Scenarios I to II in Each Type of B&B House

Category	Type I without outdoor space BAF < 0.5	Type II with outdoor space BAF = 0	Type III with outdoor space BAF > 0.5
Increase of BAF	0.3 → 0.4	0.3 → 0.4	0.65 → 0.7
Case 1	**Type I-1**	**Type II-1**	**Type III-1**
Increase rate of cost (%)	200%	369.2%	115.1%
Case 2	**Type I-2**	**Type II-2**	**Type III-2**
Increase rate of cost (%)	200%	256.6%	117.4%
Case 3	**Type I-3**	**Type II-3**	–
Increase rate of cost (%)	200%	290.4%	–
Case 4	**Type I-4**	–	–
Increase rate of cost (%)	200%	–	–

Compared to the necessary cost of raising the BAF value between Scenarios II and III, Table 9 also offers a change rate of cost to analyze the sensitivity. We discuss this result in order to evaluate the difficulty of the BAF improvement of each type of B&B house.

The results confirm that, to further increase the BAF values from Scenarios I to II or from Scenarios II to III, the costs of the Type I B&B houses would rise by over 200%, and this increasing rate remains fixed. The owners do not spend much for improving the biotope quality. Therefore, Type I B&B owners can set an appropriate BAF value for themselves in accordance with their budget and help improve ecological quality at their own pace. However, Type II B&B houses that raise their BAF value to 0.3 in Scenario I must increase the cost by over 300%. The amount may be a higher investment than the budget, and the B&B owners do not need to raise the BAF value as high as possible. For Type III B&B houses that raise their BAF value to 0.65 in Scenario I by investing a huge cost, the increasing rate of cost for further raising the BAF value is slow. Type III B&B owners can further invest in BAF improvement if they have raised the value to 0.65. Therefore, the owners of three types of B&B houses can refer to these findings to determine whether they should further improve their BAF value while considering their business strategies and cost structure.

Table 9. Change Rate of Cost from Scenario II to III in Each Type of B&B House

Category	Type I without outdoor space BAF < 0.5	Type II with outdoor space BAF = 0	Type III with outdoor space BAF > 0.5
Increase of BAF	0.4 → 0.5	0.4 → 0.5	0.7 → 0.75
Case 1	**Type I-1**	**Type II-1**	**Type III-1**
Increase rate of cost (%)	200%	172.9%	113.%
Case 2	**Type I-2**	**Type II-2**	**Type III-2**
Increase rate of cost (%)	200%	161.0%	102.9%
Case 3	**Type I-3**	**Type II-3**	–
Increase rate of cost (%)	200%	165.6%	–
Case 4	**Type I-4**	–	–
Increase rate of cost (%)	200%	–	–

The results of this study offer building surface combinations that B&B houses should consider, enabling house owners to understand how to project the ratio of different surfaces to improve the ecological environment. The results also confirm that, at the extreme point of the optimal solution, Type I B&B houses should have the smallest possible surface areas apart from the surface areas of rainwater infiltration (Y_7) and greenery on the rooftop (Y_9). Type II B&B houses should have the smallest possible surface areas in addition to the surfaces with vegetation, unconnected to soil below (Y_4), rainwater infiltration (Y_7), and greenery on the rooftop (Y_9). Type III B&B houses should have the smallest possible surface areas apart from the surface area of the surfaces with vegetation, unconnected to soil below (Y_4), rainwater infiltration (Y_7), vertical greenery (Y_8), and greenery on the rooftop (Y_9). Ecological quality can be improved by employing the approaches outlined here.

5.2 Implications

This research provides a theoretical analysis of the BAF value and minimum cost planning in B&B operations through multiple-objective programming. The findings offer implications for designing the mechanism of sustainable development in the environmental and tourism sectors. First, B&B businesses may not be able to apply the extreme optimal solutions - that is, setting some of the variables (surface area) as 0. Nevertheless, business owners can attempt to minimize the suggested types of surfaces in accordance with their needs and design. Although this approach does not achieve the optimal solutions offered by the calculations in this study, B&B

houses can still improve their BAF values by incurring a fraction more of the total cost. Therefore, B&B businesses will be able to achieve their individual BAF targets by applying the total cost formula as well as analyzing and determining ways to readjust the minimal surface area given their expected affordable cost.

The results also offer some practical suggestions for different types of B&B managers. The current BAF values of Types I and II B&B houses are not high. Moreover, the B&B houses must raise their BAF values to a minimum of 0.3, and they do not need to incur a great deal of cost, making it worth their investment. For Type I B&B houses that do not have outdoor space, the cost of increasing their BAF value is low. They could maintain ecological quality with inconsiderable effort. These guest house owners should be actively encouraged to invest in such building surfaces.

For Type III B&B houses that possess outdoor space and already have a BAF value larger than 0.5, the average amount they need to further increase their BAF value to 0.6 or higher is several million units. The return on investment would be relatively low, and thus persuading the business owners to improve their BAF values would be difficult. Type III B&B houses are mainly large in scale. Business owners in this category could still use the results from this study and make decisions to raise their BAF value to over 0.7 depending on their turnover and business strategies.

Some tourism or environmental policy suggestions for sustainable development can also be explored on the basis of this study's results. From the literature survey, Berlin has adopted BAF as the measurement standard in its urban landscape planning program. Malmö and Seattle have also incorporated green standards into their construction permit procedures. However, existing laws and regulations that apply to B&B houses in Taiwan's National Scenic Area only regulate the building coverage rate, interior design, and usage. The regulations lack principles and rules on the environmental quality of the sites. The results from the present study verify that raising BAF values to the minimum standards incurs inconsiderable cost and is feasible. Therefore, BAF standards should be incorporated into urban design review and deliberation to ensure that the green standards and aesthetic pleasantness of the national scenic area are not adversely affected by the development of the B&B sector. The government can establish minimum BAF values for buildings and construction sites in the regulations for the management of homestay facilities, under which B&B houses must comply. The government can adopt land use and zoning in the Urban Planning Act to dictate the minimum BAF values for different zones and areas (including areas such as residential areas, commercial areas, and land for public facilities) and also set appropriate BAF targets for the new urban development and old town renewal projects, as well as provide them with technical guidance.

The results of this study affirm that the various types of B&B houses can improve their BAF values to the minimum suggested standards without incurring substantial cost. Therefore, the government should provide addditional incentives and subsidies to increase the businesses' willingness to improve their BAF values. Green buildings are primarily built to save energy and resources, reduce pollution, and provide a comfortable, healthy, and environmentally friendly living environment. However, the living environment should not be restricted to indoor space given that outdoor space and the external environment are also essential in people's lives. Accordingly, outdoor spaces of construction sites should also be granted appropriate subsidies as incentives to encourage environmental greenery and the improvement of the overall ecological quality.

To obtain the optimal solution in this study and improve the BAF values of B&B houses, we have simplified the calculation process and sought to understand how to best project the ratio of different types of surfaces and improve ecological quality. Consequently, we only adopt outdoor space area and the existing conditions of the buildings as constraints in multi-objective programming. We further regard each B&B house as an empty space with a building and do not consider its existing type nor the function of the surfaces. Future research should also consider the cost of altering existing surfaces (cost of deconstruction, backfill work, and surface laying). Moreover, we only calculate the cost of the different surface type materials on the top layer of the surface. Experts suggest that future studies should adopt the concept of unit price analysis to improve accuracy. Taking "sealed surfaces" as an example, cost estimation should include the unit price of the top layer material and the steel reinforced concrete. The use of steel reinforced concrete results in "sealed surfaces", because it makes the surface water and air impermeable; thus, vegetation cannot grow on it. Taking "partially sealed surfaces" as an example, the base must be laid with gravel to achieve water infiltration and air permeability.

5.3 Conclusion

From the view of sustainable development, as an important part of the lodging industry B&Bs strongly rely on natural resource planning and the quality of the biological environment. However, the prime cost is generally the first consideration of B&B houses in start-up enterprises. The results corroborate that B&B houses without outdoor space and cost investment can reach the lower limit of a BAF target at a low cost. The cost increases intensely by two times if the B&B houses raise the BAF target to a high level. The increasing rate of the cost to reach the BAF target is comparatively lower in a B&B with high current cost investment and BAF value. The findings of multi-objective programming also offer a guideline for B&B owners to minimize the suggested types of surfaces in accordance with their needs and design. Although this approach does not achieve the optimal solutions offered by the calculations in this study, B&B houses can still improve their BAF values and thus contribute to sustainable development in scenic areas by only incurring a fraction more of the total cost.

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