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Full Length Research Paper

An environmental performance assessment of the hotel industry using an ecological footprint

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Environmental management research on the hotel industry has touched little upon the topic of environmental performance assessment. This study uses ecological footprint models to assess natural resource consumption in the hotel industry and the burden it puts on the environment. Findings of the study indicated that: (1) As the star rating goes up, hotels tend to consume greater amounts of resources, leave larger ecological footprints and have greater impacts on the environment; (2) Consumption categories in the order of the size of their ecological footprints are food, energy, construction land, textile and waste; (3) The types of biologically productive land used in accounting for the geological footprint in order of size are fossil fuel land, cropland, grazing land, water area, construction land, and forest land; (4) As the ratings of hotels go up, the contribution of the catering sector to the total ecological footprint shrinks while that of accommodation increases; (5) The higher the star rating of a hotel, the larger the average ecological footprint of per bed.

Key words: Ecological footprint, hotel industry, environmental management, performance evaluation

INTRODUCTION

According to statistics provided by the World Tourism Organization (UNWTO), the world tourist industry is growing at an annual rate of 4%. Participation of the industry in the economy has become a global trend. However, as the tourist industry flourishes, those activities have also created environmental impact issues, such as traffic congestion, over- exploitation of natural resources, and issues created by inappropriate tourist behaviors. Apart from the effects on human, natural, and culture heritages, these create a lot of pollution (Wu, 2003). With the ongoing rise of environmental protection philosophies, "green consumption" is gradually from being a mere concept into real action. The hotel and restaurant industries, in particular, are closely related to environmental protection (Kuo, 2000). The International Tourism Partnership (ITP) and Green Hotels Association, founded in 1992 and 1993, respectively, hold that green hotels or the management of such hotels should hold to the saving of water and energy and reducing unnecessary waste (International Hotels Environment Initiative, 1995; Green Hotels Association, 2004).

Apart from the steadily increasing number of hotel buildings consequential to the development of tourism, huge amounts of water are required to meet the need of hotel guests. In terms of energy, electricity alone constitutes 70.8% of the energy consumption in hotels (Kuo et al., 2005). A survey conducted by the CTCI Foundation (2004) on 84 hotels showed that hotels account for 0.32% of the total electricity consumption in Taiwan. All such data indicate that the hotel industry is a major consumer of both water and energy resources. Further, the Fourth Climate Change Assessment Report by Intergovernmental Panel on Climate Change (IPCC, 2007) shows that the “commercial residential construction" sector has the biggest potential for greenhouse gas emissions reduction. Therefore, cost reduction through more thorough environment management measures and

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energy saving should be the goal of hotel managers everywhere in the 21 century (Frabotta, 1999).

It is a pressing task for the hotel industry to improve its business efficiency through more efficient utilization of resources and cost reductions and thus ensure sustainable development of the tourism industry while still fostering sustainable ecologic systems. Environmental management research on the hotel industry has touched little upon the topic of environmental performance assessment. In the trend toward sustainable development, tools and standards are being developed around the world for sustainability assessment so as to reflect truthfully and reasonably the current ecological environment, analyze the depletion status of resources, and explore the interrelationships between different environmental impacts (Chen et al., 2009). Among these tools is the ecological footprint (EF), a concept put forward by Wackernagel and Rees in the 1990s. It measures the actual load on the environment in land area terms. Its simple and comprehensive quantification indexes have been widely applied to sustainable development research in various fields. Gössling et al. (2002) state that the ecological footprints pertaining to the accommodation component of the hotel industry are those that deals with construction land occupation and energy consumption. Pattersona et al. (2008) indicate that the ecological footprints of water and waste disposal as also pertaining to the accommodation sector. Peeters and Schouten (2006) conducted a survey on a range of local accommodation providers in Amsterdam, the Netherlands, that ranged from youth hostels to five-star hotels, studying the individual ecological footprints in such categories as energy, water, food and commodity consumption, waste disposal, and construction land use.

To sum up, the existing research concerning the ecological footprint of the hotel industry is still unsystematic and incomplete. The research does not examine the hotel industry alone as a subject of study, thus rendering only rather rough calculation results and analyses. For this reason, this paper attempts to use the ecological footprint calculation model and structural analysis approach and assess the consumption of natural resources by the hotel industry. It also uses the model to examine the load the consumption puts on the environment, and thereby provides theoretical support as well as specific practical recommendations for environmental management and sustainability of the hotel industry.

LITERATURE REVIEW

The ecological footprint theory

The ecological footprint model was proposed by a Canadian ecological economist, William Rees, in 1992, and it became gradually complete after being improved by relevant researches (Wackernagel and Rees, 1996; Wackernagel et al., 2004 a, b). EF uses corresponding biological productive land to estimate the resource consumption and waste absorption area of a specific population or economy. Wackernagel and Rees (1996) believe that the size of ecological footprints is the direct proportion of environmental impact, the larger the ecological footprint the larger the environmental impact; the size of ecological footprints is the inverse proportion of biological productive land per person, the larger the ecological footprint the smaller the biological productive land per person. The calculation of ecological footprints can measure the different types of biological productive land (and water) a specific population requires to support its energy and resource consumption and to absorb the waste it produces. If countries, regions and cities can monitor load capacity and ecological footprint each year and announce GDP at the same time, they will be able to understand economic trends and ecological changes, implementing nature conservation and sustainable development concepts into the society's overall operation and feedback mechanism, and further providing a judgment standard and action direction for the future of mankind.

Having advantages such as easy and comprehensive approach, lively expression and comparable outcome etc, ecological footprint can be adopted as an assessment indicator of sustainable development of ecology. At present, directions in the research of ecological footprint mainly consist of balance factors, rational adjustment of output factors(Erb, 2004; Venetoulis and Talberth, 2008), increase of syndrome count accounts(Jenerette and Larsen, 2006), computation of greenhouse emission (Lenzen et al., 2007; McGregor et al., 2008), calculation of ecological footprint of environmental pollution(Song et al., 2005; Bai et al., 2008), time sequence footprint model (van Vuuren and Bouwman, 2005; Wackernagel et.al., 2004a, b; Yue et al., 2006), footprint model combining context model(Senbel et al., 2003; van Vuuren and Bouwman, 2005), input-output footprint model(Bicknell et al., 1998; McGregor et al., 2008; Moran et al., 2008; Sánchez-Chóliz et al., 2006), life cycle footprint model(Monfreda et al., 2004), footprint model combining emergy analysis (Chen and Chen, 2007; Zhao et al., 2005) and land interference footprint model(Lenzen and Murray, 2001; Lenzen et al., 2007) etc. The above models have promoted and developed the theories and calculation method of ecological footprint in different levels. However, the accuracy and completeness of the computation of ecological footprint still need further improvement. Many literatures have explored the theoretical hypotheses, basic concepts, calculating methods, empirical applications and deficiency improvements of ecological footprint model, so this paper will not go further on these topics here. (Chen and Chen, 2007; Cuadra and Bjrklund, 2007; Gu et al., 2007; Li et al., 2008; Nguyen and Yamamoto, 2007; Turner et al., 2007; Wiedmann and Manfred, 2007; Wiedmann et al., 2007; Zhang and Zhang, 2007).

Wackernagel and Yount (1998) show that the tourism industry accounts for 10% of the world's total ecological footprint. Murray Mas (2000) analyzed the environmental impact of tourist activities in Balears, Spain, in an attempt to construct a time sequence for local ecological footprint. Hunter (2002) was the first to put forward the concept of tourist ecological footprint, its categorization, and its application to the sustainable development of tourism. Gössling et al. (2002) then constructed an ecological footprint calculation model for tourist destinations, using Seychelles, Africa, as its example. A study by the World Wide Fund for Nature (WWF, 2002) shows that one same vacation product generates three times the per capital ecological footprint in Cyprus as it does in Majorca; therefore, Majorca is obviously a better choice than Cyprus for a vacation. Cole and Sinclair (2002) conducted an analysis of the ecological footprint of tourists in the Indian Himalayas and discuss in their paper strategies for sustainable development in the future; these include waste processing, reducing fossil fuel consumption, developing ecotourism and instilling environmental awareness among tourists. Johnson (2003) analyzed and compared the tourist consumption of biological resources in Lake Ontario. Bagliani et al. (2004) calculated the ecological footprint of Venice, presenting findings that suggest that tourism is an important contributor to the expansion of a city's ecological footprint. Using ecological footprint standards, Pattersona et al. (2007) conducted an analysis of the environmental pressures that local residents and tourists put on the local area and on the global environment. Based on that information, they discuss the topics of biological efficiency and fair trading between communities in order for them to be informed on policy-making regarding tourism.

These aforesaid empirical research studies touched little on the topic of environmental performance assessment. Gössling et al. (2002) in their research on tourist ecological footprint in Seychelles points out that the ecological footprints pertaining to accommodation include those related to the use of construction land and from energy consumption. They calculate construction land use and energy consumption (per bed night in MJs (heat of combustion) identify) of various types of accommodations to provide important reference data for later research. Pattersona et al. (2008) point out that the ecological footprint of the accommodation sector also comes from water and waste disposal. These researches thus treat accommodation as an element of tourist activities. Further, catering is singled out and put aside, thus neglecting to examine the comprehensiveness of the overall hotel businesses operations in lodging, food and beverage and entertainment facilities.

If we regard hotels as independent and fully functional entities (rather than constituents of tourist activities), we can refer to the research by WWF (2002). It cover the ecological footprint of energy consumption, construction land use, waste recycling, and water consumption of hotels and provides a basis for building a hotel ecological footprint calculation model, despite the fact that WWF (2002) treats hotel consumptions as tourist activities and regards the ecological footprint of hotels as a part of the ecological footprint of all vacation products. The pity is that while the study tries to summarize all ecological footprint categories and estimate the aggregate ecological footprint for two different hotels as well as their per-bed per night ecological footprints, the study makes no attempt to summarize or discuss the ecological footprint of hotels as separate entities. Further there are only a limited number of samples and certain data are missing. Some of the completeness findings (example, counting and calculation of waste) also warrant further discussion.

When discussing the ecological footprint of in-bound tourists in Amsterdam, Peeters and Schouten (2006) define the ecological footprint of hotels as one of "accommodation”, which encompasses energy consumption, water consumption, food and commodity consumption, waste disposal, and use of construction land. Researchers conducted a survey on seven local accommodation providers, ranging from youth hostels to five-star hotels. Their results show that the per- room night ecological footprints of these accommodations ranged between 0.003 and 0.011 hm^2, with the gap indicating different classes and ratings of the various accommodations. Their research paper deals with hotels more directly as a subject of study, compared to all other studies in the existing literature. However, just as Peeters and Schouten (2006) mentioned, they tend to be conservative or even doubtful of the calculation results due to the difficulty of obtaining the data. Since the focus of this study is in-bound tourist activities in Amsterdam, analysis of the ecological footprint of the hotels appears to be quite rough.

To sum up, the existing literature on the ecological footprint of hotels is unsystematic and incomplete and fails to treat hotels as a stand-alone subject of study, thus as an outcome, rendering only rough calculations and analyses. It is, therefore, necessary to undertake further research in greater detail to render precise conclusions on the EF of hotels that are more convincing and provide a more exact reference for future studies.

METHODOLOGY

Based on the literature review above, we construct a calculation model by consumption categories as shown in Figure 1. The model has six parts: Food, energy, textile, paper, waste, and construction land. Various resource or energy consumption items are converted into biologically productive land areas. There are six basic types of biologically productive land: Cropland, grazing land, forestland, construction land, fossil energy resource land, and water (marine) area. Since biocapacity varies with land types, the biologically productive land area figures must be converted to reflect the same biocapacity before being totaled. In other words, the ratio between the consumption of a certain type of goods and the yield per unit of

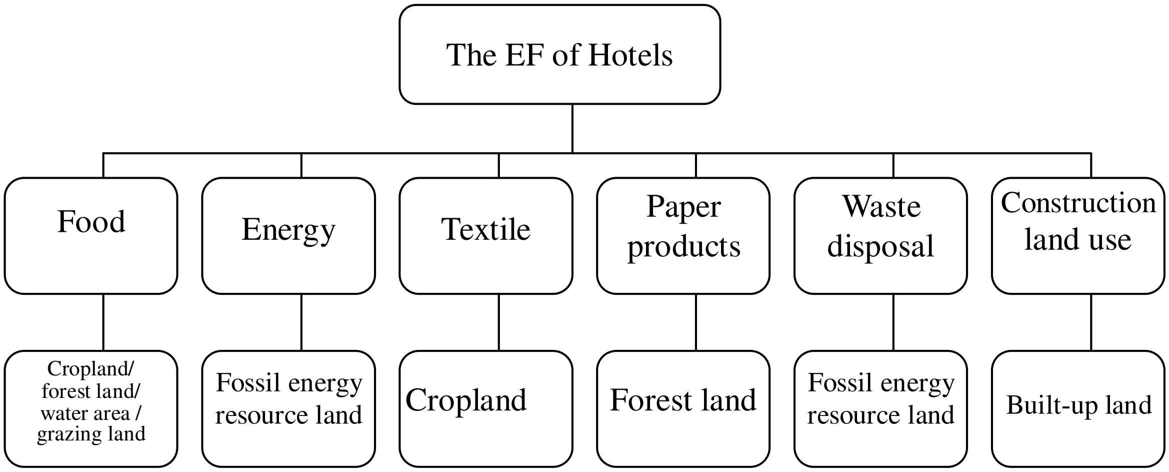

Figure 1. The framework of the ecological footprint of hotels.

such goods on a certain type of land is the biologically productive land area required for that type of land. Multiply the figure by the corresponding equivalent factor, and we have the required area for this type of land under local or international standards. See Formula (1):

$$EF_1 = \frac{Q_1}{P_1} \times E_1 \quad (1)$$

Wherein:
EF_i: represents the ecological footprint of a certain category, normally expressed in units of global hectares (ghm^2).
Q_i: represents the total consumption of a certain type of goods, normally expressed in units of kilograms (kg) or tons (t).
P_i: represents the world average yield of this type of goods, normally expressed in units of kilograms/hectare (kg/hm^2).
E_i: is the equivalent factor for the type of the land which produces this type of goods. And, the value of the coefficient varies with land type.

Calculation of the ecological footprint of energy consumption

The type of land demanded for energy consumption is fossil energy resource land. It is also the land required to absorb the CO_2 from any consumption of energy. The ecological footprint of energy consumption is usually calculated as the ratio between the energy consumption amount and the land area. The consumption of gas varies with hotels. Findings from this research show that guest rooms account for 40% of the gas consumption in hotels and catering activities account for 60%. It is a bit difficult to obtain the actual volume of sewage to be disposed of. Estimation is used instead based on the volume of clean water used. The sewage rate is normally assumed to be 0.8, that is, out of every single ton of clean water comes 0.8 ton of sewage. At water treatment facilities, it usually takes 0.2 kw.h of electricity on average to treat 1 ton of sewage. Hence, the ecological footprint of water disposal is calculated using Formula (2) as follows:

$$F_{ef} = \frac{E_p}{P_i} . \sum_{i=1}^{N} Q_i . A_i \quad (2)$$

wherein:
E_{ef} : represents the aggregate ecological footprint of all types of energy consumed (ghm^2).
P_i: represents the world average yield of energy Type i, expressed in units of heat productivity (GJ/hm^2).
Q_i: represents the consumption of energy Type i (t), and in the case of electricity, it is expressed in units of kWh. It is normally an annual amount. A_i is the conversion coefficient for energy Type i (GJ/t), and in the case of electricity, it is in GJ/ kWh.
E_p: is the equivalent factor for the type of biologically productive land required, which in this case is land that provides fossil energy resources.

Calculation of the ecological footprint of food consumption

By food type, food consumption can be categorized into crops, fruit and vegetables, meats, drinks, oils, eggs, and aquatic products. From viewing the flow of food, all hotel departments, from guest room, catering to leisure and entertainment services, require a food supply. In this study, all food consumptions are regarded as pertaining to the catering sector. These are calculated using Formula (3) as follows:

$$F_{ef} = \frac{E_f}{P_i} . \sum_{i=1}^{N} Q_i \quad (3)$$

wherein:
E_{ef} : represents the aggregate ecological footprint of all types of food consumed (ghm^2).
P_i: represents the world average yield of food type i (kg/hm^2).
Q_i: represents the consumption of food Type i. This is normally an annual amount.
E_f: is the equivalent factor for the type of land required to produce food (resource) Type i. The types of land required for food consumptions include forests, croplands, grazing lands, and water areas.

Calculation of the ecological footprint for waste disposal

The types of waste covered in this research include food leftovers, paper products (all kinds, example, napkins, paper rolls, office paper supplies, and paper slippers) and textile scraps. Because it is difficult to count the actual amount of food waste, estimation through mathematic conversion is used. Normally the food waste rate is 5%. The calculation for Formula (4) is as follows:

$$W_{ef} = \frac{E_w}{P_a} \cdot \sum_{i=1}^{N} Q_i (q_i^{CO_2} + q_i^{CH_4} \cdot X) \quad (4)$$

wherein:
W_{ef}: represents the aggregate ecological footprint of all types of waste disposal (ghm^2).
Q_i: represents the disposal amount of a certain type of waste (t). This is normally an annual amount.
$qiCO_2$ represents the CO_2 production rate of waste Type i (normally set at 0.5).
$qiCH_4$: represents the CH_4 production rate of waste Type i (normally set at 0.5).
x: is the GWP coefficient for CH_4 (normally set at 23).
P_a: is the amount of CO_2 a hectare of forest land can absorb a year (normally 5.2 t/hm^2).
E_w: is the equivalent factor for lands that provide fossil energy resources.

Calculation of the ecological footprint for paper products

Paper consumptions include use of napkins and paper, (wooden) dishware (within the catering sector of hotels), and consumption of paper rolls, paper slippers and some office paper supplies (within the accommodation sector). The calculation for the ecological footprint for paper products is as follows:

$$P_{ef} = \frac{Q_P \times q_w}{P_w} . E_p \quad (5)$$

wherein:
P_{ef}: represents the aggregate ecological footprint of all paper products (ghm^2).
Q_p: represents the total consumption of paper. This normally is an annual amount.
q_w: represents the per unit timber consumption in paper manufacturing. (Normally it takes $4m^3$ of timber to produce 1 ton of paper.)
P_w: represents the average per hectare timber yield of forest lands (m^3).
E_p: is the equivalent factor for the forest lands required for paper product consumption.

Calculation of the ecological footprint for textile products

Textile products are those used in hotel guest rooms, including bed sheets and covers, blankets, quilt covers, pillow cases, facial towels, towels, bath mats, bath towels, and bathrobes. Therefore, textile consumptions are listed under the accommodations sector. The calculation formula for the ecological footprint for textile products is as follows:

$$T_{ef} = \frac{Q_t}{P_t} . E_t \quad (6)$$

wherein:
T_{ef}: represents the ecological footprint of textile products (ghm^2).
Q_t: represents the aggregate textile consumption (m).
P_t: represents the textile yield per unit area (m/hm^2).
E_b: is the equivalent factor for the cropland lands required for textile consumption.

Calculation of the ecological footprint for construction land use

Construction land includes lands occupied by various hotel facilities and roads. The calculation for the ecological footprint for construction land use is as follows:

$$B_{ef} = Q_b \cdot E_b \quad (7)$$

wherein:
B_{ef} : represents the aggregate ecological footprint of all types of construction lands (ghm^2).
Q_b: represents the construction area of a hotel (hm^2).
E_b: is the equivalent factor for the built-up land type required for construction.

Calculation of the ecological footprint for hotels

As mentioned earlier, the total ecological footprint of a hotel is the sum of the ecological footprints of all the resources and goods consumed by the hotel and the waste that hotel produce. The calculation for the ecological footprint for hotels is as follows:

$$H_{ef} = \sum_{i=1}^{n} ef_i \quad (8)$$

wherein:
H_{ef}: represents the total ecological footprint of a hotel (ghm^2).
Efi: represents the ecological footprint of various types of consumption and waste in the hotel (ghm^2).

Calculation of the average ecological footprint per bed per night

Apart from calculating and analyzing the ecological footprint of all hotels industry as a whole, further analysis is necessary to obtain a per- bed ecological footprint. The per- bed, per- night ecological footprint figures (ghm^2/bed•night) reveals more about the actual consumption level and efficiency of different hotels with different ratings and sizes. The calculation formula for the average ecological footprint per bed per night is as follows:

$$R_{ef} = \frac{H_{ef}}{n \times r \times 365} \quad (9)$$

wherein:
R_{ef}: represents the average per bed, per night ecological footprint (ghm^2/bed•night)
H_{ef}: represents the total ecological footprint of hotels
n: represents the total number of beds in the hotel (bed)
r: represents the annual average occupancy rate of the hotel

EMPIRICAL ANALYSIS

This study assesses empirically the environmental performance of the hotel industry in Taiwan. A performance assessment model is built on the basis of the afore-described ecological footprint method. The environmental performance of the hotels is then reviewed by

Table 1. The hotels and their star rating average management scale.

Star rating	Hotel	Management scale		Average management scale	
		Number of room	Number of bed night	Number of room	Number of bed night
Five-star	A	300	118347.02	275	85864.135
	B	250	53381.25		
Four-star	C	270	104136.70	235	84396.92
	D	200	64657.14		
Three-star	E	180	53357.04	165	58670.17
	F	150	63983.29		

examining the overall assessment values.

Subject of the assessment and the assessment approach

Two five-star tourist hotels, two four-star hotels and two three-star hotels in Taipei are assessed in this study. Both accurate values and empirical values acquired through in-depth interviews are adopted in the assessment. Energy consumption, as well as water consumption and disposal, are major contributors to the ecological footprint of hotel accommodations. These are also the key interest areas in this research. Therefore, accurate values are adopted, when dealing with these categories. Empirical values are used in other categories, such as food, disposable articles, and waste.

Parameters of the calculation

The calculation of the ecological footprint of these hotels mainly involves two types of parameters: Basic parameters and conversion factors. Basic parameters include the equivalent factors for various land types, the world average yield of these land types, energy conversion coefficients, and heat productivity. The data are obtained from the literature and relevant researches. Annual statistics reports and relevant websites are consulted to ensure accuracy of the data. The equivalent factors we adopt in this research for various land types are based on WWF (2004) statistics. They include 2.19 (cropland), 0.48 (grazing land), 1.38 (forestland), 0.24 (water area), 2.19 (built-up land), and 1.38 (fossil energy resource land). Conversion factors primarily include the following two factors:

Specs of goods

During the survey, respondents were asked to fill in the actual consumption amounts of items listed in the survey in units of kilograms. However, some of the hotels offered volumes or costs instead. Therefore, these values must be converted to reflect uniform specs to avoid inaccuracies of kilograms due to spec differences. Standardized spec items include density, unit price, standard volume, etc. For example, the standard sizes for liquor is 75 ml a bottle, 12 bottles a case for wine, 500 ml a bottle , 6 bottles a case for distilled spirits, and 630 ml a bottle , 12 bottles a case for beer. Conversion from volume to weight is based on a density of 1000 kg/m^3 for liquor.

Conversion ratios for consumption

Certain items are difficult to keep record of, or there is no accurate data that could be collected about them. Such data can only be estimated through mathematic conversion, using commonly adopted conversion ratios. For example, sewage disposal amounts are calculated using the sewage conversion ratio; waste disposal amounts are calculated using the waste production rate, and textile consumptions are calculated using a cloth width conversion ratio.

Calculation and analysis of the ecological footprint

Analysis and discussion is carried out from the following aspects: Aggregate ecological footprint of the hotels, use of different types of land, the ecological footprint of different consumption categories, the ecological footprint of the major business functions of the hotels.

Analyzing the aggregate ecological footprint of hotels

Among the hotels surveyed, the five-star hotels have an average ecological footprint of more than 1000 ghm^2, the four-star hotels have an average ecological footprint of nearly 900 ghm^2, and the three-star hotels have an average ecological footprint of more than 500 ghm^2. These values are closely related to the size of the hotels. As far as the hotels surveyed, the average number of rooms and average annual bed night counts in the four-star and five-star hotels are about 1.4 to 1.7 times the counts for the three-star hotels (Table 1). Generally speaking, the higher the star rating and the bigger size the hotel, the larger its ecological footprint and environmental impact is.

Types of consumption categories in descending order of the size of their ecological footprint are: Food, energy, textile, construction land, waste, and paper products. On average, food and energy together account for over 90% of the total ecological footprint. Use of construction land varies a great deal with location and area. Yet it does not change over time and is, therefore, fairly irrelevant to the everyday operation of hotels. For this reason, the ecological footprint of construction land will not be discussed in detail in this paper. Further, the ecological footprint of paper products is not considerable in size and is therefore, not taken into account. Hence the order above should be changed to: food>energy>textile>waste.

Analyzing the demand for land typed

Analysis in this section will be carried out on six basic types of biologically productive lands, as categorized in the ecological footprint theory: Cropland, fossil energy resource land, grazing land, water area, forest land, and construction land. The order of their demand in terms of proportion is: cropland, fossil energy resource land, grazing land, water area, construction land, and forest land. The aggregate average demand for cropland, grazing land and water area exceeds 55% of the total demand, followed by fossil energy resource land which constitutes more than 30% of the total demand. Such findings are in line with the findings of the study, that is, “catering is the biggest contributor to the ecological footprint”, as croplands, grazing lands, and water areas are the primary types of land required for catering- related activities.

In addition, while the exact areas of cropland, grazing land, and water areas do increase with the star rating of hotels, the shares of these three land types in terms of total land demand shrink. The area required for fossil energy resource land and the share of this type of land in terms of total land demand varies dramatically with the ratings of the hotels. That is, as the star ratings go up, the area required for this land type and its share of the total land demand increases dramatically. The average areas required for fossil energy resource land in three-, four-, and five- star hotels are 122 ghm^2, 358 ghm^2 and 487 ghm^2, representing respectively a 25, 40 and 46% of the total land area required. It is worth mentioning here that in five-star hotels, both the average area of fossil energy resource land required and its share of the total land demand exceed that for cropland. Hence, fossil energy resource land constitutes the biggest share of total land demand in five-star hotels. In hotels of all other ratings, cropland has the largest average land area and the largest share of total land demand.

To sum up, four-star and five -star hotels do not differ much in certain basic consumptions (such as food). However, to maintain class and comfort of the overall environment, five-star hotels have a greater demand for energy (fossil energy resource land is basically required for energy consumption). The share of fossil energy resource land demand in terms of total land demand can serve as a criterion for distinguishing between hotels of different star ratings.

Analyzing the ecological footprint for food consumption

Broadly speaking, in hotels of every star rating, food types in descending order for the size of the ecological footprint are meats, aquatic products, eggs, oils, crops, liquors, and fruit and vegetables. Among these, meats, aquatic products, eggs and oils generate the majority of the ecological footprint, with their aggregate amount exceeding 95% of the total ecological footprint, as is shown in Table 2.

More specifically, although crops, liquor, and fruit and vegetable consumption is not smaller than the consumption of meats, aquatic products, eggs, and oils, their consumption ecological footprints are the result of significantly higher productivity of the lands on which these foods are produced, as shown in Table 2.

Analyzing the ecological footprint for energy consumption

Broadly speaking, the order between types of energy consumption and the size of their ecological footprints is: electricity > dieselfuel. The ecological footprint of energy consumption varies significantly with the star rating of hotels. Electricity accounts for more than 50% of the total ecological footprint, while diesel fuel accounts for nearly 30%. Together, the two energy types account on average for more than 80% of the total ecological footprint of hotel energy consumption. The average contribution of energy consumption to the total ecological footprint increases as the star-ratings of the hotels go up, leaving huge gaps between hotels of different ratings. The contribution of energy consumption to the total ecological footprint for five-star hotels is 1.20 times that for four-star hotels and 1.96 times that for three-star hotels. This finding is in line with the findings in the previous section. In other words, the contribution of energy consumption to the total ecological footprint of hotels can serve as a criterion for distinguishing between hotels of different ratings.

More specifically, the ecological footprints for electricity and diesel fuel vary significantly with the star ratings of hotels. The ecological footprint of electricity consumption in five-star hotels is 2.14 times that in four-star hotels and 3.89 times that in three-star hotels. The ecological footprint of diesel fuel consumption in five-star hotels is 1.93 times that in four-star hotels and 7.26 times that in three-star hotels. In this study electricity and diesel fuel consumption is accounted for under the accommodation sector, which explains why the ecological footprint of an accommodation business grows with the increase in star rating.

Analyzing the ecological footprint for catering and accommodation sectors of hotels

As discussed before, catering and accommodations are the primary functions of hotels. In all the hotels surveyed here, catering accounts for the majority of the total ecological footprint. Across the board, catering accounts for on average of more than 70% of the total ecological footprint. Among three-star hotels, it accounts on average for nearly 80% of the total ecological footprint. Among four-star hotels, it accounts on for average nearly 70% of the total ecological footprint. Among five-star hotels, it accounts on average for a little more than 65% of the total ecological footprint. Across the board, accommodation account on average for more than 25% of the total ecological footprint of hotels. However, the contribution of accommodations to the total ecological footprint changes in the opposite direction from that for catering. That is, the contribution of accommodations increases as the star ratings go up, being less than 20% in three-star hotels, nearly 30% in four-star hotels, and more than 33% in five-star hotels. The fact that the ecological footprint for catering and that for accommodations changes in opposite directions might be another clue to use to distinguish between hotels that have different star ratings.

The ecological footprint for catering comes mainly from food and from the energy used to process that food. Paper product consumption can be disregarded. Food is the biggest contributor in the catering sector, accounting for 85.265% of the ecological footprint for that sector. Energy used for food processing is next, accounting for 10.152%. These two items together account for 95.417% of the total ecological footprint. The ecological footprint of food consumption and that for energy consumption for food processing vary significantly with the star rating of the hotels. However, the total ecological footprint for the catering sector is similar in four- and five-star hotels, a finding that means that consumption amounts are not a criterion for distinguishing high star-rating hotels.

Energy consumption is the main contributor to the ecological footprint of accommodations, accounting for more than 90% of the total amount. Types of energy in order of the size of their average ecological footprint across all hotels are electricity and diesel fuel. The ecological footprint varies significantly with the star ratings of hotels. The higher the star rating is, the larger the ecological footprint fir energy consumption becomes in the accommodations sector. The ecological footprint of accommodation thus increases dramatically as hotel ratings rise.

A comparative analysis

Here the findings of this study on the ecological footprint of hotels or certain hotels are compared with the findings available in foreign literature (Table 3). The comparison is made for three aspects: The heat value of the average per bed energy consumption, the per-bed- per night ecological footprint of the accommodations sector and the per bed per night ecological footprint of the hotels.

Average heat value analysis: The per bed per night heat value for three- star hotels in this research is very close to those found in

Table 2. The main food amount consumption, the ecological footprint and account for the proportion.

Item	Consumption (kg)	Average yield (kg/ hm^2)	EF (ghm^2)	Average contribution (%)	Total average consumption (kg)	Total EF (ghm^2)	Total ratio (%)
Meats	20413	129	382.01683	73.38	53902	494.82755	95.05
Aquatic products	9652	29	56.47753	10.85			
Eggs	7465	534	30.35641	5.83			
Oils	16372	1856	25.97678	4.99			
Crops	9588	2744	10.74662	2.06	68542	25.7858	4.95
Liquor	18492	7164	8.68453	1.67			
Fruit and vegetable	40462	18000	6.35465	1.22			

Table 3. Grouping of data found in foreign literature.

Compare item	Unit	Research sources	Star rating			
			Two star	Three star	Four star	Five star
Heat values	MJ	Gössling et al. (2002)	40	70	70	110
		This research	-	80.45	191.67	295.75
Accommodation	(Bed/night ghm^2	Gössling et al. (2002)	0.0005977	0.0011418		0.0029669
		This research	-	0.0011294	0.0026354	0.0038535
		WWF(2002)	Majorca		0.0103393(0.0034959)	
			Cyprus		0.0316515(0.0068317)	
The EF of hotels	(Bed/night ghm^2					
		Peeters and Schouten (2006)	Amsterdam		0.0030000-0.0110000	
		This research	-	0.0063866	0.0084517	0.0118972

Note: 1. Heat value: represents the heat converted from energy consumption in the accommodation sector, including electricity, diesel fuel, petrol and gas (partial). 2. The ecological footprint of the accommodation sector: data come from the same foreign source as the heat values. Data from our study: the ecological footprint of the accommodation sector = the ecological footprint figure converted from heat values (all converted into electricity) + the average per bed ecological footprint in the form of construction land occupation. 3. The data about Cyprus come from the same source as that about Marjorca. 4. Brackets suggest that waste is not considered in the calculation.

research done overseas (Gössling et al., 2002). However, there is a remarkable difference between the findings for four- star and five- star hotels, a finding that may have to do with how energy consumption in the accommodations sector is categorized. In this study, electricity falls completely under the accommodations sector (because it is difficult to obtain separate electricity data for both sectors). Diesel fuel, petrol, and gas (partially) are also listed under the accommodations sector. In the study by Gössling et al. (2002), energy consumption of the accommodations sector mainly included consumption of air conditioning, heating/freezing, food processing, lighting, cleaning, and desalination of seawater. Obviously, Gössling et al. (2002) overlooks the energy consumption of utility equipment, such as large volume water pumps and elevators.

Therefore, the findings concerning energy consumption are somewhat conservative just as the author claims. However, broadly speaking, the conclusions of this study coincide with those for the overseas researches. The higher the star rating, the greater for the per bed energy consumption; the divergence between hotels of different ratings is thus significant, which might be used as acriterion for distinguishing between hotels of different ratings.

The accommodations sector analysis: Except for four -star hotels for which the per bed per night ecological footprints are larger than those of similar hotels overseas, findings for the average ecological footprint of the accommodations sector in this study do coincide largely with those recorded in the foreign literature. The difference is fairly small, however. This finding means that hotels in Taiwan are the same level as foreign hotels of equal star ratings at least in terms of their ecological footprint for accommodations.

The ecological footprint of hotels analysis: The per–bed- per night ecological footprint figures of the hotels assessed in this study are within the range of those found by Peeters and Schouten (2006) for hotels in Amsterdam. (There are certain hotels with apparently higher results. The maximum value found in this study is 0.0165769 ghm^2/bed. night). However, the results here are remarkably lower than those found in the study on Cyprus. The reasons are discussed below:

(A) The hotels in Cyprus are holiday hotels while those assessed in this study are business hotels. Generally speaking, holiday hotels have higher ratings than business hotels and their guests tend to stay longer (according to the study, the normal stay of guests at that particular hotel was 7 to 14 days.). Total consumption is, therefore, much higher. In addition, the total number of bed nights in that hotel (121554 bed.night) is about 1.42 times the average number of bed nights in the four- and five-start hotels (85864 bed.night) assessed in this study. Yet its total ecological footprint is 3 times that of the four- and five-star hotels assessed in this study.
(B) In the studies of Majorca and Cyprus, hotels waste disposal is the biggest contributor to the ecological footprint of these hotels. WWF (2002) statistics show that hotels in these two areas produce 4.3 and 9.87 kg of waste per bed per night. Peeters and Schouten (2006) are skeptical about that finding. In our study, waste includes sewage, food waste, textile scrap, and waste paper. The amount of food waste is obtained through a mathematics conversion based on a 5% disposal rate. The estimation of the total waste amount is "conservative" and significantly lower than those recorded for the hotels in Majorca and Cyprus. However, even if we base our calculation on an annual waste amount of 500 tons, the variation in the per bed per night ecological footprint is between just 0.0005 and 0.001, still too small to bring the results up to the level of the hotels in Cyprus. What it does, however, is change the overall composition of the ecological footprint of the hotel-- the order between consumption categories of their contribution to the total ecological footprint change from food, energy, textile and waste to food, energy, waste and textile.

RESULTS, DISCUSSION AND CONCLUSION

Overall, the higher the star rating, the more resources a hotel consumes and the greater are its ecological footprint and environmental impacts. In the order of the size of their respective ecological footprints, the consumption categories that constitute the ecological footprint calculation model for hotels developed in this study are food, energy, construction land, textile, and waste. The contribution of food to the total ecological footprint decreases as the star ratings of hotels rises. The contribution of energy consumption, in contrast, increases as the star ratings of hotels go up. The types of biologically productive land in descending order of the area demanded of each type are fossil energy resource land, cropland, gracing land, water area, construction land, and forest land. From the viewpoint of hotel functions, the catering sector is accountable for a bigger proportion of the total ecological footprint of hotels than is the accommodations sector. The proportion between the ecological footprints of the two sectors varies drastically based on the star ratings of the hotel. Because food and energy are the key consumption types in catering and accommodations, respectively, the proportion between the ecological footprints for catering and that for accommodations varies in the same direction as the ratio between the ecological footprint for food and that for energy. In other words, as the star ratings of hotels go up, the contribution of the catering sector to their total ecological footprint decreases, while the contribution of the accommodations sector increases. The contribution of accommodations to the total ecological footprint varies distinctively between hotels of different ratings, a finding that may be used as a criterion for the rating of hotels. As for food, the main consumption types in order of the size of their corresponding ecological footprint are meats, aquatic products, eggs, oils, crops, liquors, and fruit and vegetables. (These food consumption combined account for more than 95% of the total ecological footprint for the food category). The first four consumption types, especially meats and aquatic products, contribute the most to the total ecological footprint.

In terms of energy, the order of different energy types in terms of the size of ecological footprint is electricity>diesel fuel. (These two, when combined, account for 80% of the total ecological footprint from the energy category.) Both the size of the ecological footprint for energy consumption and its contribution to the total ecological footprint of hotels increase as the star ratings of hotels go up. The average per- bed- per night ecological footprint varies significantly with the star ratings of hotels. The higher the rating, the larger the per-bed- per night ecological footprint for the type of hotel becomes.

This study tries to illustrate, through ecological footprint calculation and analysis, the consumptions involved in objects or activities and the impacts these have on the environment. The hope is to improve ecological awareness among hotel operators and users. Based on the findings of the study, we make the following recommendations:

(1) Taiwan is experiencing a weak economy currently. By implementing environmental performance management systems, the hotel industry can cope with this situation better through energy saving and expense reduction and achieve effective cost reductions.
(2) Hotels should endeavor to enhance employee recognition of the green management concept, develop employee-training guidebooks on green management,

educate employees regularly and enhance employee recognition regarding the value of green hotels. Only by making these changes can hotels build real environmental competitiveness.

(3) Hotel managers, when taking certain measures to implement environmental performance management systems, may consider giving guests discounts appropriate to increase the willingness of guests to become involved and eliminate ongoing resistance against the implementation of environmental management systems.

(4) Part of any environmental management system may involve activities that require considerable funding, example, the building of a water- cooling and recycling system. Hotel managers may find it to be beyond their capacity at times. Therefore, we suggest that the government offer tax rebates or tax exemption schemes or other favorable conditions that encourages hotel management to increase their desire to implement environmental management systems appropriately and consistently throughout the entire hotel industry.

REFERENCES

Bai Y, Zeng H, Wei JB, Zhang WJ, Zhao W (2008). Optimization of ecological footprint model based on environmental pollution accounts: a case study in Pearl River Delta urban agglomeration. Chinese J. Appl. Ecol., 19(8): 1789-1796.

Bagliani M, Da VE, Gattolin M, Niccolucci V, Patterson T, Tiezzi E (2004). The ecological footprint analysis for the Province of Venice and the relevance of tourism, in: CA Brebbia and N Marchettini (eds.), The Sustainable City III: Urban Regeneration and Sustainability, Wessex Institute of Technology, United Kingdom, pp. 123-131.

Bicknell KB, Ball RJ, Cullen R, Bigsby HR (1998). New methodology for the ecological footprint with an application to the New Zealand economy. Ecol. Econ., 27(2): 149-160.

Chen B, Chen CO (2007). Modified ecological footprint accounting and analysis based on embodied energy – a case study of the Chinese society 1981-2001. Ecol. Econ., 61(2-3): 355-376.

Chen YK, Chen CY, Hsieh T (2009). Establishment and applied research on environmental sustainability assessment indicators in Taiwan. Environ. Monit. Assess., 155(1): 407-417.

China Technical Consultants Incorporated (CTCI) (2004). The case of energy conservation. Taipei: CTCI. Retried http://www.ctciectdc.org.tw/success/NEW/index.htm.

Cole V, Sinclair AJ (2002). Measuring the ecological footprint of a Himalayan tourist center. Mt. Res. Dev., 22(2): 132-141.

Cuadra M, Bjrklund J (2007). Assessment of economic and ecological carrying capacity of agricultural crops in Nicaragua. Ecol. Indic., 7(1): 133-149.

Erb KH (2004). Actual land demand of Austria 1926-2000: a variation on Ecological footprint assessments. Land Use Policy, 21(3): 247-259.

Frabotta D (1999). New York hoteliers go green and save. Hotel and Motel Manage., 11: 3-36.

Gössling S, Hansson CB, Horstmerier O, Saggel S (2002). Ecological footprint analysis as a tool to assess tourism sustainability. Ecol. Econ., 43: 199-211.

Green Hotels Association (September 21, 2004). http://www.greenhotels.com.

Gu XW, Wang Q, Wang J (2007). Study of ecological press and ecological efficiency of a country. Resour. Sci., 27(1): 260-269.

Hunter C (2002). Sustainable tourism and the tourist ecological footprint. Environ. Dev. Sustain., 4: 7-20.

Intergovernmental Panel on Climate Change (IPCC) (2007). Climate change 2007: Mitigation of climate change- summary for policymakers, WGIII contribution to the IPCC Fourth Assessment Report. http://www.ipcc.ch/SPM040507.pdf.

International Hotels Environment Initiative (1995). Environmental action pack for hotels. London: IHEI. http://www.uneptie.org/pc/tourism/library/actionpack.htm.

Jenerette GD, Larsen L (2006). A global perspective on changing sustainable urban water supplies. Global Planet. Change, 50(3-4): 202-211.

Johnson PA (2003). Exploring the ecological footprint of tourism in Ontario. Unpublished doctoral dissertation, University of Waterloo, Ontario, pp. 23-37.

Kuo NW, Hsiao TY, Yu YH (2005). A Delphi–matrix approach to SEA and its application within the tourism sector in Taiwan. Environ. Impact Asses., 25(3): 259-280.

Kuo MS (2000). The performance and strategy analysis on promotion environmental management system in industry. Unpublished master disseratrial. National Cheng Kung University, Taiwan, pp. 3-5.

Lenzen M, Murray SA (2001). A modified ecological footprint method and its application to Australia. Ecol. Econ., 37(2): 229-225.

Lenzen M, Hansson CB, Bond S (2007). On the bioproductivity and land-disturbance metrics of the ecological footprint. Ecol. Econ., 61: 6-10.

Li GJ, Wang Q, Gu XW, Liu JX, Ding Y, Liang GY (2008). Application of the componential method for ecological footprint calculation of a Chinese university campus. Ecol. Indic., 8: 75-78.

McGregor PG, Swales JK, Turner K (2008).The CO_2 trade balance between Scotland and the rest of the UK: Performing a multi-region environmental input-output analysis with limited data. Ecol. Econ., 66(4): 662-673.

Moran DD, Wackernagel M, Kitzes JA, Goldfinger SH, Boutaud A (2008). Measuring sustainable development nation by nation. Ecol. Econ., 64(3): 470-474.

Monfreda C, Wackemagel M, Deumling D (2004). Establishing national natural capital accounts based on detailed ecological footprint and biological capacity assessments. Land Use Policy, 21: 231-246.

Murray Mas I (2000). The ecological footprint of Balears. The impacts of mass tourism. Unpublished doctoral dissertation, University of Edinborough, Edinburough, pp. 1-20.

Nguyen HX, Yamamoto R (2007). Modification of ecological footprint evaluation method to include non-renewable resource consumption using thermodynamic approach. Resour. Conserv. Recy., 51(4): 870-884.

Pattersona TM, Niccoluccib V, Bastianonib S (2007). Beyond "more is better": ecological footprint accounting for tourism and consumption in Val di Merse, Italy. Ecol. Econ., 62: 747-756.

Pattersona TM, Niccoluccib V, Marchettini N (2008). Adaptive environmental management of tourism in the province of Siena, Italy using the ecological footprint. J. Environ. Manage. 86(2): 407-418.

Peeters P, Schouten F (2006). Reducing the ecological footprint of inbound tourism and transport to Amsterdam. J. Sust. Tourism., 14(2): 157-171.

Rees WE (1992). Ecological footprints and appropriated carrying capacity: what urban economics leaves out? Environ. Urban., 4(2): 121-130.

Sánchez-Chóliz J, Duarte R, Mainar A (2006). Environmental impact of household activity in Spain. Ecol. Econ., 62(2): 11-22.

Senbel M, McDaniels T, Dowlatabadi H (2003). The eclological footprint: A monetary metric of human consumption applied to North America. Global Environ. Change., 13: 83-100.

Song WW, Liu NF, Xie HY (2005). Study on ecological impact of a project by total ecological footprint. J. Huazhong University of Sci. and Technology-Urban Sci., 22(1): 85-89.

Turner K, Lenzen M, Wiedmann T, Barrett J (2007). Examining the global environmental impact of regional consumption activities-Part1: A technical note on combining input output and ecological footprint analysis. Ecol. Econ., 62(1): 37-44.

Van-Vuuren DP, Bouwman LF (2005). Exploring past and future changes in the ecological footprint for world regions. Ecol. Econ., 52(1): 43-62.

Venetoulis J, Talberth J (2008). Refining the ecological footprint Environ. Dev. Sustain., 10(4): 441-469.

Wackernagel M, Rees W (1996). Our ecological footprint: reducing human impact on the earth. Gabriola Island, BC, Canada: New

Society Publishers, pp. 221-215.
Wackernagel M, Monfreda C, Erb KH, Haberl H, Schulz NB (2004a). Ecological footprint time series of Austria, the Philippines, and South Korea for 1961-1999: comparing the conventional approach to an actual land area approach. Land Use Policy, 21(3): 261-269.
Wackernagel M, Monfreda C, Schulz NB, Erb KH, Haberl H, Krausmann F (2004b). Calculating national and global ecological footprint time series: resolving conceptual challenges. Land Use Policy, 21(3): 271-278.
Wackernagel M, Yount JD (1998). The ecological footprint: an indicator of progress toward regional sustainability. Environ. Monit. Assess., 51: 511-529.
Wiedmann T, Lenzen M, Tumer K, Barrett J (2007). Examining the global environmental impact of regional consumption activities - Part 2: Review of input-output models for the assessment of environmental impacts embodied in trade. Ecol. Econ., 61(1): 15-26.
Wiedmann T, Manfred L (2007). On the conversion between local and global hectares in ecological footprint analysis. Ecol. Econ., 60(4): 673-677.
World Wild Fund (WWF) (2002). Holiday Footprinting: A Practical Guide for Responsible Tourism. World Wildlife Fund UK, pp. 1-38
World Wild Fund (WWF) (2004). Living planet report 2004, Morges, Switzerland, 2004.
Wu TC (2003).The influences of development stages and tourism dependency on tourism impact perceptions. J. Outdoor Recreation Stud., 16(1): 45-61.
Yue D, Xu X, Li Z, Hui C, Li W, Yang H , Ge J (2006). Spatiotemporal analysis of ecological footprint and biological capacity of Gansu, China 1991-2015: Down from the environmental cliff. Ecol. Econ., 58(2): 393-406.
Zhang JH, Zhang J (2007). Progress and implication in domestic research on ecological footprint model. Areal Res. Dev. 26(2): 90-96.
Zhao S, Li Z, Li W (2005). A modified method of ecological footprint calculation and its application. Ecol. Model., 185: 65-75.