
An evaluation and enhancement approach of the carbon footprints-based environmentally sustainable service competitiveness for coffee shops

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Abstract: This paper develops an evaluation and enhancement approach of the carbon footprints (CFs) based environmentally sustainable service competitiveness for coffees shops. Firstly, the proposed approach uses the service blueprint to analyse the service process of coffee shops and the working times of the required direct facilities and the supporting facilities to estimate the amounts of greenhouse gas (GHG) emissions. By using data envelopment analysis, the holistic performance evaluation model of environmentally sustainable service operation for coffee shops is created to find the non-benchmark environmentally sustainable service coffee shops. To improve environmentally sustainable service performance of the non-benchmark coffee shops, this paper evaluates the environmentally sustainable performance evaluation models of the meal-ordering and cooking areas and dining areas. Finally, this research gives an in depth analysis to comprehend the decreasing amount of the CF of each facility in the non-benchmark environmentally sustainable service areas.

Keywords: carbon footprints; CFs; evaluation and enhancement approach; environmentally sustainable service competitiveness; service blueprint; data envelopment analysis; coffee shops.

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1 Introduction

In recent years, numerous human activities have caused environmental degradation and severe climate change. Therefore, many countries begin to promote the concept of green consumption and specific policies to fix human over-consumption and poor manufacturing efficiency, as well as to reduce the usage of nature resources and environmental damage. Since the eco-service issue has attracted worldwide attention, how to improve environmentally sustainable service in many countries has become a hot spotlight. Therefore, some studies have discussed and studied environmentally sustainable service performance evaluation. From a customer satisfaction perspective, Olaru et al. (2010) employed a questionnaire-based method on small and medium-sized enterprises (SMEs) in Romania to understand the status of the environmentally sustainable performance evaluation. The study showed that 43% of SMEs monitored the impact of processes on environment. Wang et al. (2011) used quality function development (QFD) method to evaluate new service performance to understand whether the new service process meets the customer requirements. Zhokhova (2013) took the price, quality, safety and ecology of service as the evaluation indices of eco-tourism service competitiveness. The customers gave the score of each evaluation index and then the weights of the indices were used to obtain the performance of the final eco-tourism service competitiveness. Sellitto et al. (2011) utilised the analytic hierarchy process (AHP) to synthesise the six experts' opinions to assess environmentally sustainable service performance for the transportation and warehousing service. Teng et al. (2012) performed the semi-structured interviews to identify and prioritise the energy conservation and carbon reduction (ECCR) indicators for the hotel industry in Taiwan. The hotel operators can improve their environmental performance competitiveness by initiating ECCR practices based on the proposed ECCR indicators. Oreja-Rodríguez and Armas-Cruz (2012) applied the Rasch model to analyse the questionnaires of interviewing the hotel's environmental managers to evaluate the environmentally sustainable service performance of the Western Canary Islands' hotel sector. Because the above works are based on experts' subjective judgment or customers' feelings, the different experts or customers may produce different environmentally sustainable service performance. To solve the above-mentioned problem, some studies directly use the quantitative environmental impact values to assess the environmental sustainable service competitiveness. Watanabe et al. (2012) utilised the integration definition for function

modelling (IDEF 0) to describe the service process and then to evaluate the environmental load for each service activity. Because the emission of CO₂ is accelerating to significantly increase the atmospheric concentration of CO₂ to cause global warming, carbon footprints (CFs) have become an important index of environmentally sustainable service competitiveness. Hertwich and Peters (2009) studied the carbon emissions of 73 countries and 14 regions. They found that the service industry in these countries has the higher CFs. Such a phenomenon also occurs in Taiwan. Until 2011, the carbon emission of the service industry had risen to 13.6%. Because the service industry produces a great influence on the greenhouse effect, how to effectively reduce the CF of the service industry has become a crucial issue. Hu et al. (2012) investigated the carbon emissions of self-service laundries and took CFs as the evaluation index of environmentally sustainable service performance. They found that the environmentally sustainable service performance of self-service laundries is better than that of the traditional laundry practice. Liqin (2011) also used the CFs to evaluate environmentally sustainable service performance of the high-star hotels. That study showed the highest CF for the hotels is 5.56 times as the lowest CF and then gave the subjective improvement suggestions. Martínez and Silveira (2012) employed the data envelopment analysis (DEA) to analyse energy use, energy efficiency and CO₂ emissions in Swedish service industry to assess the energy efficiency-based sustainable service performance for 19 sub-service sectors. That research's result showed that Swedish services industries had increased energy consumption and CO₂ emissions in the period 1993–2008. However, this model is appropriate for the sector-level sustainable service performance evaluation. Hui and Wong (2010) investigated the energy consumption of the hotels in Hong Kong and set three grades for energy consumption to evaluate environmentally sustainable service performance and gave the practical guidelines to reduce the carbon emissions for guest rooms of the business hotels. In that work, the proposed evaluation model directly transfers the energy consumption per unit area to the energy efficient rating. Hence, the hotel managers cannot obtain an accurate environmentally sustainable service performance values. In addition, that model cannot be utilised to analyse which service facility can be improved to reduce the CFs. At the same time, that model cannot consider the output variables, for example, the order number. However, the order number is an important factor to affect the amount of the carbon emission. Moreover, that model cannot simultaneously compare several hotels to assess the relative environmentally sustainable service competitiveness.

Through the above literature review, we can understand that few studies focus on environmentally sustainable service performance assessment for coffee shops. However, the coffee shop managers need a scientific analytical method to analyse the carbon emissions and objectively assess the environmentally sustainable service performance and provide the managers with concrete improvement suggestions to boost the environmentally sustainable service competitiveness. Therefore, this study proposed an evaluation and enhancement approach of the CF-based environmentally sustainable service competitiveness. First, a service blueprint is employed to analyse the service process, in order to understand the use of facilities required for each activity and the carbon emissions generated by each facility. Afterwards, using a holistic evaluation model of environmentally sustainable service operations, this study identified the non-benchmark environmentally sustainable service coffee shops. In order to help enterprises identify the reasons for poor performance, this study develops the environmentally sustainable performance evaluation models of the meal-ordering and

cooking areas and the dining areas to evaluate the environmentally sustainable performance of the two service areas. In addition, through the profound analysis, this research acquires that the quantity of the CF of each facility in the different service areas should be reduced. These objective and specific improvement directions and suggestions can help coffee shop managers understand how to strengthen the performance of the non-benchmark environmentally sustainable service coffee shops so as to significantly promote eco-service competitiveness of these coffee shops.

The remainder of this paper is organised as follows: Section 2 is the literature review. Section 3 elaborates on the evaluation and enhancement approach of the CFs-based environmentally sustainable service competitiveness for coffees shops. Section 4 discusses a case study on coffee shops. Finally, Section 5 offers the conclusion remarks.

2 Literature review

In this section, the literature review is divided into three parts, including the service blueprint, the application of DEA (data envelopment analysis) in service performance evaluation, and the environmentally sustainable service, as explained below.

2.1 Service blueprint

In recent years, there have been a number of applications relating to the service blueprint. Berkley (1996) proposed a random service procedure to extend the representation and analysis method of the service blueprint. This method analysed the economic benefits and operational results of the service blueprint. Holdford and Kennedy (1999) applies the service blueprint to help drug store managers to identify and correct problems of the service process and provide drug store employees with service planning and feedback opportunities. That article verified that the design of the service blueprint of the drug store is a valuable tool. Chuang (2007) combined the service blueprint and the failure mode and effects analysis (FMEA) to help service designers with the design of faultless service systems. The method can identify potential fault points for the front stage and back stage operations and then the necessary actions are taken to ensure the performance of the process design of the services. In recent years, the concept of the product-service system (PSS) has received increasing attention. Geum and Park (2011) suggested that the service blueprint should represent the entire product life cycle from the perspective of customer service management, as well as the relationship between product and service. In addition, they used the service blueprint to help managers and researchers promote the benefits of the integration of products and services. Eichentopf et al. (2011) used the service blueprint to build a holistic process image to show that the customer side is equally important for the overall success of value creation. Zehrer (2009) explored the relationship between service experience and service design among SMEs in the tourism industry. That article employed the service blueprint to undertake service design in a holistic manner that is embedded in the organisational culture of the service provider for achieving long-term competitiveness.

The abovementioned research shows that the service blueprint is a systematic service process planning and design tool. Therefore, this research uses the service blueprint to analyse the service process of coffee shops and comprehend the carbon emissions of the

direct facilities and support facilities for achieving the environmentally sustainable service of a coffee shop.

2.2 Application of DEA in service performance evaluation

In recent years, the application of DEA in service performance evaluation mainly involves the medical industry and the hotel industry. Yang (2008) applied DEA in the analysis of the operational efficiency of service institutions for the elderly people and found that the output could be added by about 8.2% for better operational efficiency. Moreover, the operational efficiency of the medical institutions is significantly correlated to the assessment achievement. Gao et al. (2009) applied a modified DEA model to analyse the medical service efficiency of 31 provinces and municipalities in China in 2006, and discussed the causes of the low efficiency of some provinces. Based on the condition of unchanged inputs in that case, the ideal output values in 2007 are inferred. Finally, according to the analysis of the ideal output and actual values, a number of suggestive alternatives were proposed for decision makers. Wu and Hung (2009) developed an integrated evaluation method with 54 amusement parks in Taiwan as the research subjects. They used the five evaluation indicators, i.e., the land area, the number of employees, the total assets, the total expenditures and total income to evaluate the performance of amusement parks by applying the DEA method. The research's results show that the operational efficiency of different types of amusement parks had significant differences, and that the efficiency of amusement parks with natural landscapes would be better.

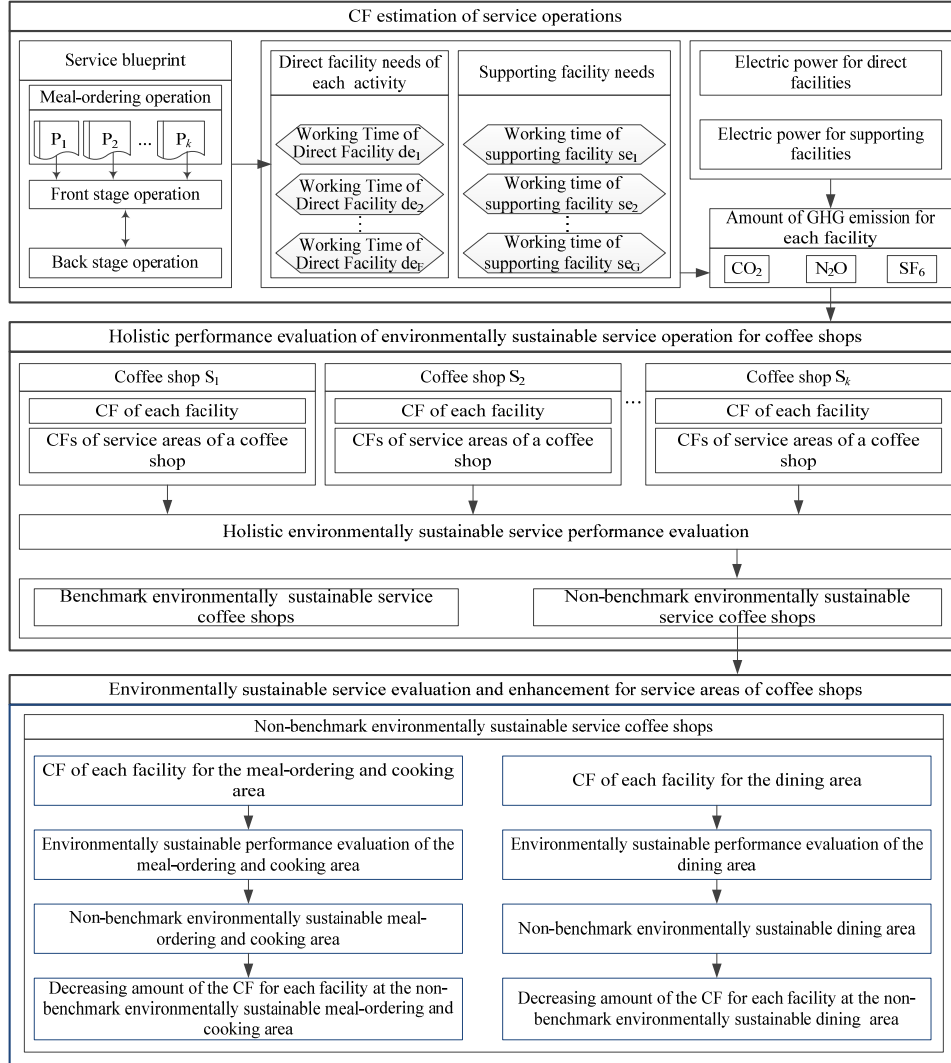
This study investigates coffee shops, which have the service-related characteristics that are similar to those of hotels. In recent years, there have been a number of applications relating to the service performance evaluation of the hotel industry. Hwang and Chang (2003) used DEA and Malmquist productivity index to evaluate the management performance in 1998 and the efficiency changes from 1994 to 1998 of 45 international tourism hotels in Taiwan. According to the management efficiency change, the hotel industry was divided into six groups, and the business operational strategies of each group were developed, respectively. Chiang et al. (2004) used DEA to evaluate the operational performance of international tourism hotels in Taipei. The input variables included the number of guest rooms, number of employees, operating expenses, the total number of floors, and the floor area of the food and beverage (F&B) department. The output variables included room revenue, F&B revenue and other revenue. The research results showed that not all the chain or franchised international tourism hotels are more efficient than Taiwan-funded international tourism hotels in the Taipei area. Yang and Lu (2006) studied 56 international tourism hotels in Taiwan in 2002 using the DEA method to evaluate management performance and measure the input congestion degree of inefficient international tourism hotels. It was found that about 40% of the international tourism hotels had not made full use of their employees or the floor area of the F&B department. Chain international tourism hotels that can make efficient use of other related facilities can easily become the benchmark of the industry. Hsu (2011) used DEA to analyse the relative efficiency of the input and output of 11 international tourism hotels in the Kaohsiung-Pingtung area of Taiwan in 2010 and discussed the directions and content of the improvements for inefficient hotels. By using slack variable analysis, the inefficient input item was the number of rooms, and thus the operators of the hotel managers should improve this performance index.

The hotel industry has similar characteristics as the coffee shop industry. In addition, the previous papers show DEA is a very appropriate method to evaluate the performance of the service industry. However, little research focuses on the evaluation of eco-service performance of coffee shops. Hence, this paper employs DEA to develop the performance evaluation model of environmentally sustainable service operation.

2.3 CF for the service industry and eco-service

In the small and open economic system of Singapore, Schulz (2009) calculated the direct CF emissions and trade-related indirect CF emissions. He found that direct emissions account for only 20% of the upstream emissions (domestic emissions plus the indirect emissions of imported commodities). According to Muthu et al. (2011), CFs are used to measure the impact of human activities on the globe, especially, the impact on the environment. It involves climatic change, the total amount of greenhouse gas (GHG) emissions, and carbon dioxide emissions. The literature argues that the efforts to reduce CFs are very important. The research results suggested that consumer concepts and behaviours as well as the policies are the key to the reduction of CFs. Yi (2011) pointed out that low-carbon service is the definite trends for the hotel industry. According to this survey for high class hotels in Jinan, the major direct sources of carbon emissions during the operational process of F&B include air-conditioning and lighting, which accounted for 99%. As for the six hotels with the most power consumption for F&B services, the carbon emissions of the hotel with the highest power consumption were 25 times that of the hotel with the lowest power consumption. Filimonau et al. (2011) discussed the potential LCA for the evaluation of tourism accommodation facilities and to propose some suggestions on how to further enhance the performance of energy and thereby reduce CF. According to the review of literature, we can understand that sustainable business operations have been the goal of each enterprise, especially in the highly competitive F&B service industry. At the same time, in recent years, consumers have gradually developed the green consumption concept. The F&B industry should adopt the measures of green management and consumption. However, few scholars propose the performance evaluation and improvement methods of the green service of coffee chain stores. Therefore, this study focuses on the coffee shops to propose the evaluation and enhancement approach of the carbon-footprints-based environmentally sustainable service competitiveness to reduce environmental impacts and to boost the green market competitiveness.

To sum up, unlike previous relevant studies (Hwang, 2007; Hsu, 2011; Geum and Park, 2011; Yi, 2011; Filimonau et al., 2011), this study uses the service blueprint to represent the entire service process, while dividing the services into the front-stage operations and back-stage operations. In order to effectively estimate the CF, this paper divides the service facilities into direct facilities and supporting facilities. This study also applies DEA to develop the evaluation and improvement approach of environmentally sustainable service performance for coffee shops. The proposed CF-based performance evaluation and decision making process can significantly improve the environmentally sustainable service competitiveness for coffee shops.

Figure 1 Architecture of the evaluation and enhancement approach of the CF-based environmentally sustainable service competitiveness (see online version for colours)

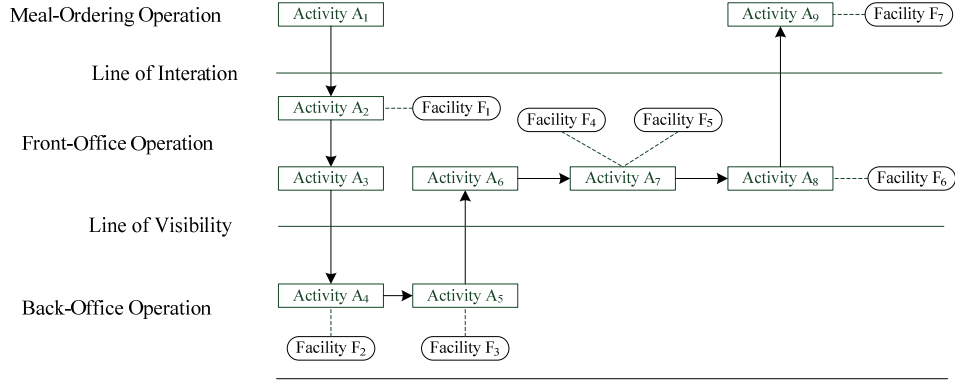
3 Evaluation and enhancement approach of the CF-based environmentally sustainable service competitiveness for coffee shops

This paper presents an evaluation and enhancement approach of the CF-based environmentally sustainable service competitiveness. Figure 1 shows the architecture of the proposed approach which can be divided into three parts, i.e., the CF estimation of

service operations, the holistic performance evaluation of environmentally sustainable service operation for coffee shops, and environmentally sustainable service evaluation and enhancement for service areas of coffee shops. Firstly, this research utilises a service blueprint to describe the service delivery operations, including the meal-ordering operation, the front-office operation and the back-office operation then to identify all activities of each operation. Next, we analyse the facility requirement of each activity. In this paper, the facilities can be divided into the direct facilities and the supporting facilities. The direct facilities are immediately linked to the product-service delivery process and only when customers place orders, these facilities are activated. On the other hand, the supporting facilities indicate that these facilities don't be activated by customers' orders and cannot directly involve the product-service delivery activities, for example, light bulbs and refrigerators. In order to estimate the electric power consumption, this paper investigates the working time of each direct facility based on meal orders. With regard to the supporting facilities, we use the working time of each supporting facility per day to predict the electric power consumption. Using the above information, the levels of the GHG emissions for each facility can be acquired. The second part uses the data of the GHG emissions to calculate the CF of each facility caused by electronic power consumption and then the CFs of the service areas for a coffee shop can be obtained. This paper subsequently uses the holistic evaluation model of environmentally sustainable service operation to evaluate the environmentally sustainable service performance of each coffee shop. For the non-benchmark environmentally sustainable service coffee shops, this research executes the detail analysis to identify the non-benchmark environmentally sustainable service areas, including the meal-ordering and cooking area and the dining area. Moreover, this paper provides the coffee shop managers with substantial suggestions, i.e., the decreasing amount of the CF of each facility in the non-benchmark environmentally sustainable meal-ordering and cooking areas and the dining areas so as to enhance the environmentally sustainable service competitiveness of the coffee shops.

3.1 CF estimation of service operations

This research applies the service blueprint to illustrate the service delivery process. The Figure 2 shows the conceptual framework of the service blueprint. The horizontal axis delineates the chronological order of product-service delivery activities. In addition, this paper utilises the dashed line to express the required direct facilities of each activity. The vertical axis describes the different operations, i.e., the meal-ordering operation, the front office operation and the back office operation. The line of interaction and the line of visibility respectively separate the interaction among the three operations. In order to estimate the electric power consumption of each direct facility, this paper investigates the working times of the direct facilities for the product-service delivery activities. With regard to the support facilities, this research adopts the actual working time per one day to estimate the electronic power consumption of each supporting facility. After obtaining the power consumption of all facilities, we can employ the data given by the electronic power company to calculate the amounts of the GHG emissions, including CO₂, N₂O and SF₆.

Figure 2 The conceptual framework of the service blueprint (see online version for colours)

3.2 Holistic performance evaluation of environmentally sustainable service operation for coffee shops

Owing to the different global warming effects of the GHGs, this research uses the global-warming potential (GWP) values to convert each GHG into comparable CO₂ equivalent (CO₂-e) so as to obtain the CFs emitted by each facility. The GWP values of N₂O and SF₆ are 298 and 22800 respectively. In order to evaluate the performance of environmentally sustainable service operation, this paper applies an input-oriented BCC-DEA approach (Banker et al., 1984) to develop the holistic evaluation model of environmentally sustainable service operation for coffee shops as shown in equations (1)–(8). The input variables of the holistic evaluation model of environmentally sustainable service operation are the quantities of CO₂-e emitted by the meal-ordering and cooking area and the dining area of these coffee shops. The output variables are the sales quantities of the products.

Equation (1) is employed to obtain the holistic performance value of the environmentally sustainable service operation for a coffee shop. If h_t is less than 1, it expresses that the coffee shop t is a non-benchmark environmentally sustainable service coffee shop. Because equation (1) is a minimum objective function, equations (2) and (3) can find the minimum θ_t to understand the feasibility of reducing the CO₂-e emissions for the meal-ordering and cooking area and the dining area without reducing the sales quantities of the products [as shown in equation (4)]. Equation (5) explains that the sum of the weights of decision-making units (i.e., coffee shops) must be equal to 1. To obtain the total quantities of CO₂-e emitted by the two areas of the coffee shop n , equations (6) and (7) are respectively utilised to calculate the total quantities of CO₂-e emitted by the meal-ordering and cooking area and the dining area of the coffee shop. All variables in this model must be more than or equal to zero and θ_t is less than or equal to 1 as shown in equation (8).

$$\text{Min } h_t = \theta_t - \varepsilon \left(stm_t + std_t + \sum_{c=1}^C so_{t,c} \right) \quad (1)$$

$$s.t. \sum_{n=1}^N \lambda_n tme_n - \theta_t tme_t + stm_t = 0 \quad (2)$$

$$\sum_{n=1}^N \lambda_n tde_n - \theta_t tde_t + std_t = 0 \quad (3)$$

$$\sum_{n=1}^N \lambda_n (io_{n,c} + to_{n,c}) - (io_{t,c} + to_{t,c}) - so_{t,c} = 0 \quad \forall c \quad (4)$$

$$\sum_{r=1}^R \lambda_n = 1 \quad (5)$$

$$tme_n = \left(\sum_{a=1}^A \sum_{f=1}^F \sum_{k=1}^3 mde_k^{n,a,f} wp_k \right) + \left(\sum_{g=1}^G \sum_{k=1}^3 mse_k^{n,g} wp_k \right) \quad (6)$$

$$tde_n = \left(\sum_{g=1}^G \sum_{k=1}^3 dse_k^{n,g} wp_k \right) \quad (7)$$

$$stm_t, std_t, so_{t,c}, \lambda_n \geq 0; 0 \leq \theta_t \leq 1 \quad (8)$$

where

- h_t is the performance value of the environmentally sustainable service operation for the coffee shop t
- θ_t is the rough performance value of the environmentally sustainable service operation for the coffee shop t
- tme_n is the total quantity of CO₂-e emitted by the meal-ordering and cooking area of the coffee shop n
- tde_n is the total quantity of CO₂-e emitted by the dining area of the coffee shop n
- wp_k is the global warming potential of the GHG k
- stm_t is the slack variable of the CO₂-e emitted by the meal-ordering and cooking area of the coffee shop t
- std_t is the slack variable of the CO₂-e emitted by the dining area of the coffee shop t
- $to_{n,c}$ is the take-out quantity of the product c in the coffee shop n
- $io_{n,c}$ is the dine-in quantity of the product c in the coffee shop n
- $so_{t,c}$ is the slack variable for the quantity of the product c for the shop t
- λ_n is the weight of the coffee shop n
- $mde_k^{n,a,f}$ is the quantity of the GHG k emitted by the direct facility f for the activity a of the meal-ordering and cooking area of the coffee shop n

- $mse_k^{n,g}$ is the quantity of the GHG k emitted by the supporting facility g of the meal-ordering and cooking area of the coffee shop n
- $dse_k^{n,g}$ is the quantity of the GHG k emitted by the supporting facility g of the dining area for the coffee shop n
- Δtme_t is the decreasing amounts of CO₂-e for the meal-ordering and cooking area of the coffee shop t
- Δtde_t is the decreasing amounts of CO₂-e for the dining area of the coffee shop t .

3.3 *Environmentally sustainable performance evaluation and enhancement for service areas of coffee shops*

To discern the reasons of the poor environmentally sustainable performance for non-benchmark coffee shops and provide these coffee shop managers with the authentic and tangible improvement suggestions to enhance the performance of environmentally sustainable service operation, this paper divides a coffee shop into the two service areas, i.e., the meal-ordering and cooking area as well as the dining area. Next, this paper develops the environmentally sustainable performance evaluation models of the meal-ordering and cooking areas and the dining areas respectively as shown equations (9)–(14) and (15)–(19) to assess their performance and find the non-benchmark environmentally sustainable service areas.

The input variables of the environmentally sustainable performance evaluation model of the meal-ordering and cooking area are the quantities of CO₂-e produced by the direct facilities and the supporting facilities at the meal-ordering and cooking areas. At the same time, the output variables of this model are the take-out and dine-in order quantities of the products. Equation (9) calculates the environmentally sustainable service performance value of the meal-ordering and cooking area for the coffee shop t . Because the environmentally sustainable performance evaluation model of the meal-ordering and cooking area is an input-oriented model, equations (10) and (11) calculates the shortening percentage of the quantities of the CO₂-e emitted by the direct facilities and the supporting facilities of the meal-ordering and cooking area of the coffee shop t comparing with the benchmark DMUs. At the same time, the take-out and dine-in order quantities are unchanged as shown in equation (12). Equation (13) displays the sum of the weights of the meal-ordering and cooking areas for the coffee shops must be equal to 1. All variables of DEA must be more than or equal to zero. In addition, α_t is less than or equal to 1 as shown in equation (14).

Owing to the dining area provides service with the dine-in customers, the output variables of the environmentally sustainable performance evaluation model of the dining area are the dine-in order quantities of the products. In addition, the facilities of dining areas belong to supporting facilities. Supporting facilities are not activated by customers' orders such as air conditioners and light bulbs. The working time of a supporting facility is based on the practical condition. For example, the working time of a refrigerator is 24 hours one day; the working time of the light bulbs is business hours. Hence, the input variables of the environmentally sustainable performance evaluation model of the dining area are the quantities of CO₂-e produced during the working times of the supporting facilities. To evaluate the environmentally sustainable service performance of a dining

area, Equation 15 is utilised to calculate the environmentally sustainable service performance value of the dining area for the coffee shop t . The performance value must satisfy $0 \leq d_t \leq 1$. By using the minimum objective function, i.e., equation (15), equation (16) can find the minimum β_t to analyse the feasibility of reducing the CO₂-e emissions for the dining area without reducing the dine-in quantities of the products [as shown in equation (17)]. Similarly, the sum of the weights of the dining areas for the coffee shops is equal to one. All variables are more than or equal to zero.

$$\text{Min } m_t = \alpha_t - \varepsilon \left(\sum_{f=1}^F \text{smd}_f^t + \sum_{g=1}^G \text{smi}_g^t + \sum_{c=1}^C \text{so}_{t,c} \right) \quad (9)$$

$$\text{s.t. } \sum_{n=1}^N \mu_n \left(\sum_{a=1}^A \sum_{k=1}^3 \text{mde}_k^{n,a,f} \text{wp}_k \right) - \alpha_t \left(\sum_{a=1}^A \sum_{k=1}^3 \text{mde}_k^{t,a,f} \text{wp}_k \right) + \text{smd}_f^t = 0, \quad \forall f \quad (10)$$

$$\sum_{n=1}^N \mu_n \left(\sum_{k=1}^3 \text{mse}_k^{n,g} \text{wp}_k \right) - \alpha_t \left(\sum_{k=1}^3 \text{mse}_k^{t,g} \text{wp}_k \right) + \text{smi}_g^t = 0, \quad \forall g \quad (11)$$

$$\sum_{n=1}^N \mu_n (io_{n,c} + to_{n,c}) - (io_{t,c} + to_{t,c}) - \text{so}_{t,c} = 0 \quad \forall c \quad (12)$$

$$\sum_{n=1}^n \mu_n = 1 \quad (13)$$

$$\text{smd}_f^t, \text{smi}_g^t, \text{so}_{t,c}, \mu_n \geq 0; 0 \leq \alpha_t \leq 1 \quad (14)$$

where

- m_t is the environmentally sustainable service performance value of the meal-ordering and cooking area for the coffee shop t
- α_t is the rough environmentally sustainable service performance value of the meal-ordering and cooking area for the coffee shop t
- μ_n is the weight of the meal-ordering and cooking area for the coffee shop n
- smd_f^t is the slack variable of the CO₂-e emitted by the direct facility f of the meal-ordering and cooking area of the coffee shop t
- smi_g^t is the slack variable of the CO₂-e emitted by the supporting facility g of the meal-ordering and cooking area of the coffee shop t .

$$\text{Min } d_t = \beta_t - \varepsilon \left(\sum_{g=1}^G \text{sds}_g^t + \sum_{c=1}^C \text{sio}_{t,c} \right) \quad (15)$$

$$\text{s.t. } \sum_{n=1}^N \nu_n \left(\sum_{k=1}^3 \text{dse}_k^{n,g} \text{wp}_k \right) - \beta_t \left(\sum_{k=1}^3 \text{dse}_k^{t,g} \text{wp}_k \right) + \text{sds}_g^t = 0, \quad \forall g \quad (16)$$

$$\sum_{n=1}^N v_n (io_{n,c}) - (io_{t,c}) - sio_{t,c} = 0 \quad \forall c \quad (17)$$

$$\sum_{n=1}^N v_n = 1 \quad (18)$$

$$sds_i^k, sio_{t,c}, \lambda_r \geq 0; 0 \leq \beta_t \leq 1 \quad (19)$$

where

d_t is the environmentally sustainable service performance value of the dining area for the coffee shop t

β_t is the rough environmentally sustainable service performance value of the dining area for the coffee shop t

v_n is the weight of the dining area for the coffee shop n

sds_g^t is the slack variable of the CO₂-e emitted by the supporting facility g of the dining area for the coffee shop t .

To assist coffee shop managers to probe the detail causes of poor environmentally sustainable service, this research discovers the hot spots of improving the CFs by profoundly analysing the feasibility of reducing the carbon emission for each facility of the non-benchmark environmentally sustainable service areas at the coffee shops. For the non-benchmark meal-ordering and cooking area, this research utilises equations (20) and (21) to get the maximum reduced amounts of CFs for the direct facilities and the supporting facilities. With regarding to the non-benchmark dining areas, this paper applies equation (22) to acquire the maximum decreased quantities of the CFs for the supporting facilities. Through above information, the coffee shop managers can comprehend which facilities need to be replaced to improve the carbon emissions. At the same time, equations (9)–(14) and (15)–(19) can be used to obtain the benchmark environmentally sustainable service areas for the meal-ordering and cooking areas and the dining areas. Therefore, the electric power consumption of these low-carbon facilities for the benchmark environmentally service areas can be gained. The precious and valuable information can help coffee shop managers propose constructive improvement planning for enhancing the environmentally sustainable service competitiveness.

$$\Delta mde_t = (1 - \alpha_t) \left(\sum_{a=1}^A \sum_{k=1}^3 mde_k^{t,a,f} wp_k \right) + smd_f^t \quad \forall f \quad (20)$$

$$\Delta mse_t = (1 - \alpha_t) \left(\sum_{k=1}^3 mse_k^{t,g} wp_k \right) + sms_g^t \quad \forall g \quad (21)$$

Δmde_t is the decreasing amounts of CO₂-e for the direct facility f of the meal-ordering and cooking area for the coffee shop t

Δmse_t is the decreasing amounts of CO₂-e for the supporting facility g of the meal-ordering and cooking area for the coffee shop t .

$$\Delta dse_t = (1 - \beta_t) \left(\sum_{k=1}^3 dse_k^{t,g} wp_k \right) + sds_g^t \quad \forall g \quad (22)$$

Δdse_t is the decreasing amounts of CO₂-e for the supporting facility g of the dining area for the coffee shop t .

4 Case study

This study selects 15 coffee shops in Taiwan as an example to explain and demonstrate the significant effectiveness of the proposed approach. In this research, the LINGO 13.0 software is employed to solve the proposed mathematical programming models. Before assessing the performance of environmentally sustainable service operation for coffee shops, the related meetings of collecting case data were held. Firstly, this research interviewed the coffee shop managers to understand the service delivery process and the working times of the required direct facilities of each activity in the delivery process. The second meeting collected the working times and quantities of the supporting facilities at the meal-ordering and cooking area and the dining area. Besides, the electrical power consumption of each facility per unit time was gathered. The third meeting asked the coffee shop managers the take-out and dine-in quantities of the products in the coffee shops. Through using the above data, this research can calculate the carbon emission of each facility to analyse the performance of environmentally sustainable service operation for coffee shops and further point out the reasons of the poor environmentally sustainable service performance for the non-benchmark coffee shops.

Because these coffee shops belong to the same coffee shop chain, these coffee shops have a same service operation procedure. At the same time, there is no back-office operation in the coffee shop chain. In addition, this research focuses on the main products at these coffee shops, i.e., coffee beverages. Figure 3 shows the service blueprint of these coffee shops. Firstly, the customers enter a coffee shop and then order coffee beverages by using the point of sale (POS) system. Although these coffee shops provide various types of coffee beverages, they can be categorised into the two main classifications, i.e., Americanos and espressos. With regard to espressos, a series of the diverse coffee beverages are made by adding different materials to espressos. This kind of coffee beverages uses the espresso machines. Based on the automatic levels, there are three kinds of the espresso machines, i.e., automatic espresso machines, semi-automatic espresso machines and manual espresso machines. Because only automatic espresso machines include the grinding function, semi-automatic espresso machines and manual espresso machines need to use the coffee grinders before making coffee. Based on the common compared standard, the electric power consumption of coffee grinders need to be added to electric power consumption of semi-automatic espresso machines and manual espresso machines, respectively. At the same time, each coffee shop only has one type of espresso machines. Moreover, Americanos are made by using the Americano machines. These coffee shops only have one type of Americanos. After receiving the coffee beverages, some customers drink coffee in the coffee shops and others take out coffee. Hence, customer orders contain the dine-in orders and the take-out orders. The dine-in customers use the supporting facilities at the dining area of a coffee shop. Because these coffee shops are established at the different times, the electric power

consumption of most supporting facilities in these coffee shops is some differences. The POS systems at these coffee shops, however, are all the same electric power consumption. Therefore, this research does not incorporate the POS systems in the holistic performance evaluation of environmentally sustainable service operation for the coffee shops. Appendix Table 1 shows the electric power consumption of the direct facilities and the supporting facilities per hour.

Figure 3 The service blueprint of the coffee shops (see online version for colours)

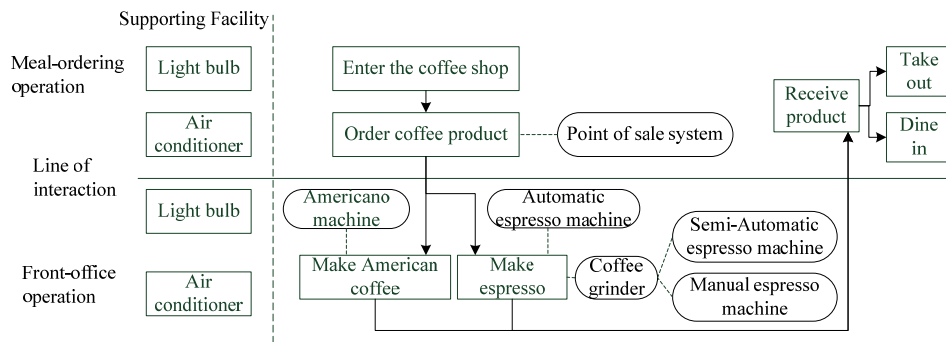


Table 1 CFs of the direct facilities and the supporting facilities (unit: gram)

No.	Meal-ordering and cooking area				Dining area	
	Direct facility		Supporting facility		Supporting facility	
	Espresso machine	Americano machine	Light bulb	Air conditioner	Light bulb	Air conditioner
1	2,755	92	873	3,243	1,642	6,486
2	3,361	68	2,184	6,559	3,397	13,118
3	2,554	68	1,310	5,588	1,423	16,765
4	2,701	73	987	6,559	2,184	19,677
5	2,741	81	445	3,243	768	9,729
6	3,082	108	1,205	3,243	1,965	9,729
7	2,392	77	1,310	5,588	3,931	16,765
8	2,999	92	2,426	5,588	6,066	16,765
9	3,116	85	2,669	3,243	4,853	9,729
10	2,919	97	1,205	5,588	2,515	16,765
11	3,357	85	526	3,243	930	12,972
12	3,396	102	1,310	3,243	2,297	12,972
13	2,770	77	1,423	5,588	3,389	22,354
14	2,835	90	445	5,588	1,132	22,354

Due to the different sizes of one cup of coffee, this study uses the working time of a direct facility for making one millilitre of coffee and the total millilitre of selling the coffee beverages within one month to estimate the total working time of a direct facility. In regard to the supporting facilities, the working times of light bulbs and air conditioners

are the total business hours during a month. By using the above data, we can calculate the total electrical power consumption and the total CF of each facility for each coffee shop as shown in Table 1. Table 2 displays the take-out and the dine-in quantities of each coffee beverage for every coffee shop.

Table 2 Take-out and dine-in quantities of each coffee beverage for every coffee shop (unit: millilitre)

No.	<i>Americanos</i>		<i>Espressos</i>	
	<i>Take-out</i>	<i>Dine-in</i>	<i>Take-out</i>	<i>Dine-in</i>
1	3,850	2,100	14,700	7,950
2	3,850	1,750	14,400	6,150
3	4,200	1,400	15,750	5,250
4	4,900	1,050	18,750	4,650
5	2,100	3,150	8,250	12,450
6	3,150	3,850	12,000	14,700
7	3,150	3,150	12,150	12,150
No.	<i>Americanos</i>		<i>Espressos</i>	
	<i>Take-out</i>	<i>Dine-in</i>	<i>Take-out</i>	<i>Dine-in</i>
8	3,150	2,800	12,450	10,200
9	4,200	2,800	16,200	10,800
10	3,150	3,150	12,000	12,000
11	3,150	3,850	12,450	15,150
12	2,800	3,850	10,200	15,450
13	2,100	4,200	8,400	15,600
14	2,100	5,250	8,700	20,100

This paper employs equations (1)–(8) to obtain the holistic performance values of the environmentally sustainable service operation for these coffee shops as shown in Table 3. Because the coffee shops no. 2, 3, 4, 7, 8, 9, 10, 12 and 13 belong the non-benchmark environmentally sustainable service coffee shops, the coffee shop managers hope to understand the reasons of poor environmentally sustainable service operation. Equations (9)–(14) and (15)–(19) can be therefore used to profoundly analyse the environmentally sustainable service performance of the meal-ordering and cooking areas and the dining areas (as shown in Table 4) to understand which service areas must be improved. From Table 4, we can find that the environmentally sustainable service performance values of the meal-ordering and cooking areas of the coffee shops no. 2, 3, 4, 7, 9 and 12 are equal to 1. Hence, these coffee shop managers can quickly understand that the CFs of the dining area causes the poor holistic performance of environmentally sustainable service operation. Subsequently, to discover the hot spots of improving carbon emissions, equation (22) is utilised to analyse the amount that the CF of each supporting facility at the dining areas should be decreased as shown in Table 5. Using the above analytical results, these coffee shop managers can fully comprehend that the energy consumption of the inefficient air conditioners produces a lot of carbon emissions. Therefore, it is a key point that adopts the energy-saving air conditioners to significantly enhance the holistic

performance values of the environmentally sustainable service operation for these coffee shops. Secondly, the light bulbs at the dining areas of the coffee shops no. 2, 4 and 7 use the halogen light bulbs. Therefore, these light bulbs should be replaced with LED (light-emitting diode) light bulbs. Comparing with the benchmark environmentally sustainable coffee shops, the dining areas of the coffee shops no. 3, 9 and 12 should reduce the number of the light bulbs at the dining area to become an LED light bulb per 1.32 square meters.

Table 3 Holistic performance values of the environmentally sustainable service operation for these coffee shops

No.	1	2	3	4	5	6	7
Performance	1	0.556	0.699	0.658	1	1	0.740
No.	8	9	10	11	12	13	14
Performance	0.611	0.852	0.707	1	0.878	0.703	1

Table 4 Environmentally sustainable service performance values of the meal-ordering and cooking area and the dining area of the non-benchmark environmentally sustainable service coffee shops (unit: gram)

No.	Meal-ordering and cooking area	Dining area	No.	Meal-ordering and cooking area	Dining area
2	1.000	0.494	9	1.000	0.807
3	1.000	0.570	10	0.875	0.538
4	1.000	0.452	12	1.000	0.885
7	1.000	0.507	13	0.995	0.576
8	0.848	0.464			

Table 5 Decreased amounts of CO₂-e of each facility for the dining areas of the non-benchmark environmentally sustainable service coffee shops (unit: gram)

No.	Light bulb	Air conditioner	No.	Light bulb	Air conditioner
2	1,718	6,635	9	938	1,876
3	612	7,214	10	1,162	7,747
4	1,197	10,784	12	264	1,490
7	1,937	8,262	13	1,436	9,470
8	3,252	8,985			

Table 4 shows that the meal-ordering and cooking areas and the dining areas of the coffee shops no. 8, 10 and 13 must be improved to enhance the performance of the environmentally sustainable service operations. This research employs equations (20)–(21) to acquire the decreasing amounts of CO₂-e of each facility at the meal-ordering and cooking areas as shown in Table 6. Tables 5 and 6 show there is much room for improvement in the carbon emissions of the air conditioners at the dining areas and the meal-ordering and cooking areas of the coffee shops no. 8 and 10. Hence, these coffee shop managers should adopt the inverter air conditioners to reduce the carbon emissions. Moreover, the espresso machines at the coffee shops no. 8 and 10 should be changed into the automatic espresso machines to reduce the CFs. In addition, the dining

areas of the coffee shops no. 8, 10 and 13 should use the LED light bulbs to reduce the carbon emissions. At the same time, this research suggests that the meal-ordering and cooking areas of the coffee shops no. 8 and 10 should reduced the density of the light bulbs.

Table 6 Decreasing amounts of CO₂-e of each facility for the meal-ordering and cooking areas of the non-benchmark environmentally sustainable service coffee shops (unit: gram)

No.	<i>Direct facility</i>		<i>Supporting facility</i>	
	<i>Espresso machine</i>	<i>Americano machine</i>	<i>Light bulb</i>	<i>Air conditioner</i>
8	455	14	369	848
10	364	14	150	697
13	13	0	7	26

By using the proposed methodology, the coffee shop managers can get a lot of insights about environmentally sustainable service competitiveness of each coffee shop and find the hot spots of the reducing CFs. Finally, this paper provides the coffee shop managers of the non-benchmark environmentally sustainable service operation with the clear directions and substantial suggestions to significantly boost the environmentally sustainable service competitiveness.

5 Conclusions

Given the rapid blooming growth of the service section in the developing and developed countries, a lot of business activities of the service-sector firms lead to an abundance of electrical consumption. In addition, the main source of CO₂ emissions is electricity use which accounts for 32%. The service-sector companies should take substantial actions to curb or even decrease the electricity consumption. To deal with the crucial challenge, this paper develops the evaluation and enhancement approach of the CFs-based environmentally sustainable service competitiveness for coffee shops. The presented approach uses the service blueprint to clearly describe the service operation process and accurately estimate the electricity consumption and the CFs of the direct facilities and the supporting facilities used in the activities of the service operation process. Moreover, this paper creates the holistic performance evaluation model of environmentally sustainable service operation for coffee shops to find non-benchmark environmentally sustainable service coffee shops. In order to identify the reason of the poor environmentally sustainable service performance, this paper employs the environmentally sustainable performance evaluation models of the meal-ordering and cooking area and the dining area to profoundly analyse the environmentally sustainable performance of the service areas and then calculate the decreasing CO₂-e amount of each facility for achieving the environmentally sustainable service aim. These scientific analytical results can let non-benchmark coffee shop managers know how to enhance the environmentally sustainable service competitiveness through providing the concrete improvement suggestions. Finally, this paper takes the coffee shops in Taiwan as an example to elaborate on and certify the significant efficacy of the proposed approach.

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Appendix**Table 1** Electric power consumption of the direct facilities and supporting facilities (unit: kWh)

No.	<i>Meal-ordering and cooking area</i>				<i>Dining area</i>	
	<i>Direct facility</i>		<i>Supporting facility</i>		<i>Supporting facility</i>	
	<i>Espresso machine</i>	<i>Americano machine</i>	<i>Light bulb</i>	<i>Air conditioner</i>	<i>Light bulb</i>	<i>Air conditioner</i>
1	5,800	1,200	108	401	203	802
2	7,800	950	270	811	420	1,622
3	5,800	950	162	691	176	2,073
4	6,800	950	122	811	270	2,433
5	7,800	1,200	55	401	95	1,203
6	6,800	1,200	149	401	243	1,203
7	5,800	950	162	691	486	2,073
8	7,800	1,200	300	691	750	2,073
9	6,800	950	330	401	600	1,203
10	5,800	1,200	149	691	311	2,073
11	5,800	950	65	401	115	1,604
12	7,800	1,200	162	401	284	1,604
13	6,800	950	176	691	419	2,764
14	5,800	950	55	691	140	2,764