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The Carbon Impact of International Tourists to an Island Country

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Abstract: Taiwan, located in the East Asia, is an island country with limited natural resources. To increase economic growth and reduce CO_2 emission levels, the Taiwanese government is promoting a sustainable low-carbon tourism industry. This study investigated the CO_2 emission coefficient of tourist activities and identified the CO_2 emissions (CE) patterns of international visitors to Taiwan. The total CO_2 emission per visitor without considering international transportation was estimated using a questionnaire. The total CO_2 emission comprises the CO_2 emission of transportation, the CO_2 emission of accommodation, and the CO_2 emission of tourist activities. The results suggest that more convenient public transportation might help to reduce the total CO_2 emission. Without considering CO_2 emission from international air travel, in contrast to many non-island countries where CO_2 emission of transportation is the main contributor to total CO_2 emission, the CO_2 emission of accommodation was the main contributor to total CO_2 emission in Taiwan. To reduce the CO_2 emission of accommodation, the Taiwanese government should improve the energy-use efficiency of devices in tourist hotels and promote bed-and-breakfast accommodations with low CO_2 emission coefficients. Visitors enjoyed culinary journeys and shopping, both of which are activities that contribute highly to the CO_2 emission of tourist activities because of their high CO_2 emission coefficients.

Keywords: carbon emission; transportation; accommodation; tourist activity; low-carbon tourism; sustainable tourism

1. Introduction

Tourism brings economic benefits, but also consumes resources and contributes to emissions of various greenhouse gases, including CO_2 [1]. Global tourism is becoming increasingly less sustainable [2]. In other words, much greater consideration and dissemination of these issues is required to inform future tourism development and travel decisions [3,4]. Tourism development increases energy demand within various sectors, such as transportation, accommodation, water supply, and the management of tourist attractions [5]. Two methods, namely top-down and bottom-up, have been commonly adopted to estimate the quantity of CO_2 emissions being produced (CE) [6]. The top-down method approximates the percentage of CE from tourism in the entire system, while the bottom-up approach analyzes data from tourists arriving at destinations [7]. Tourism CO_2 emissions have mainly been divided it into three sections: transportation, accommodation, and activities [8]. Lots of researchers have used a bottom-up approach to explore the influences of the three sections on the total CO_2 emission [9]. It has previously been shown that the tourism industry accounts for approximately 3.2% of the world's total amount of energy consumption [10], and tourism directly accounts for approximately 4.4% of CE [11]. Tourism CE can be direct (e.g., use of fossil fuels) or indirect (e.g., electricity consumption) energy use. Forty percent of CE is conservatively attributed to tourist air travel [12]. Consequently, studies have investigated the relationships between tourism development, energy demand, environmental degradation, and CE using the environmental Kuznets curve framework and have proposed policy recommendations and dynamical system models to ensure improvements in environmental protection and economic growth [13–15].

The CE calculation takes into account tourism-related items and the corresponding CE coefficients (CECs) [16]. The CE level was found to have a significant correlation with the energy consumption per unit guestroom in Nigeria [17]. Previous studies have indicated that tourism CE is dominated by tourism transport-induced CE [18], with the CEs from road and air transport being the largest and second largest contributors, respectively, to passenger transport CE since 1998 [19]. However, the monthly CE of tourism-associated transportation differed significantly [20]. An increase in tourism activities also increases the energy demand of transportation and accommodation [5,8]. Previous studies have also reported differences in the tourism characteristics of international and domestic travel, such as choice of destination, travel distance, travel motivation, adventure tourism trend, public policies, and climatic conditions [21–25]. For example, young domestic and international tourists exhibit different patterns of tourism behavior because of differences in physical, cultural, and perceptual components [26]. Overall, different countries generate different tourism CEs because of differences in tourism resources and accommodation and transportation conditions; moreover, domestic and international tourists differ in their tourism behaviors.

Taiwan, located in East Asia, is an island country with limited natural resources. Taiwan largely depends on imported energy [27] and the resulting CEs affect Taiwan's environmental sustainability. Therefore, the Taiwanese government is devoted to actively developing a low-carbon tourism industry, given its abundant tourism resources. However, the limited information available on the CE of international visitors has hindered the government's ability to propose a strategy for developing low-carbon tourism. Hence, the objective of this study was to identify the CE patterns of international visitors and to provide the government adequate data to develop a low-carbon tourism industry by (1) calculating the CEC of tourist activities by analyzing the energy consumption of common tourist activities in Taiwan; (2) investigating the travel journeys of international visitors by administering interview questionnaires; and (3) estimating the CE. Furthermore, this study proposes strategies to implement low-carbon tourism on the basis of the identified patterns.

In the following paragraphs, firstly, the study site and investigation method for carbon emission are summarized, and then the estimation and mathematical model of carbon emission per person is described in detail. Finally, the calculated results, including the total CE of each international tourist ($TolCO_2$), transportation CE of each international tourist (TCO_2), accommodation of each international tourist (RCO_2), and tourist activity (ACO_2), are illustrated. In addition, CE patterns for different visiting periods and purposes are analyzed, and then some tourism policies for international tourists are suggested.

2. Methodology

2.1. Tourism in Taiwan and Interview Questionnaire

Taiwan's topography is narrow at both ends, and the land area is approximately 36,000 km^2 (Figure 1). Taiwan is located in tropical and subtropical zones and experiences four seasons; it has abundant natural tourist attractions, some of which include numerous mountains with peaks rising over 3000 m and nine national parks. Taiwan is also among the world's top 15 hot springs sites. Moreover, Taiwan is known for its unique delicacies, and its night markets are popular tourist attractions. A convenient island railway network offer easy access to various tourists locations;

moreover, the unique mountain railway line, Alishan Forest Railway, is itself a tourist activity. In addition, Taiwan has many large shopping centers, such as the Taipei 101 mall that offer various food, leisure, and entertainment services. Given the abundance of tourist activities, approximately 10.4 million international tourists visited Taiwan in 2015.

This study adopted the bottom-up approach based on the Revised Guidelines for National Greenhouse Gas Inventories [28] to estimate the CE associated with tourism transport in Taiwan. The total CE level of tourism depends on the travel journey and is the sum of the CE of the associated transportation, accommodation, and tourist activities [29]. In this study, international tourists were administered a questionnaire in common tourist locations, such as popular attractions, airports, and high-speed rail (HSR) stations. Travel dates, main transportation modes and itineraries, departure points and accommodation types were recorded (Tables 1–3). According to a previous classification of tourist activities [30], 14 common activities in Taiwan (p = 14) were included in this study (Table 3). The sites where the tourists engaged in the activities (e.g., Zhiben Hot Spring, Taipei-101, Wushi Harbor, and Feng-Chia Night Market) are indicated in Figure 1. In addition, travel purposes were recorded to explore the pattern of international travel to Taiwan. In total, 187 questionnaires were analyzed, and the CEs of transportation, accommodation, and tourist activities were estimated.

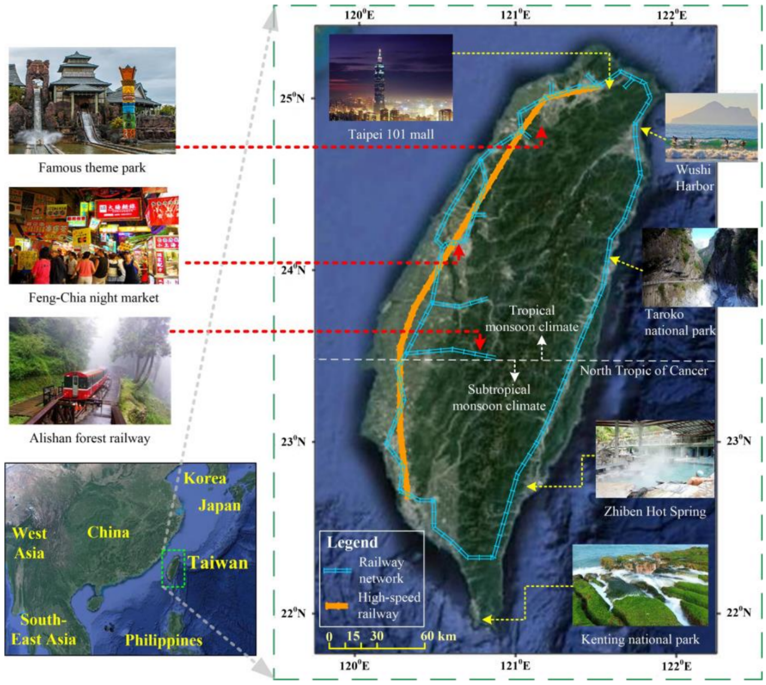


Figure 1. Geographical features of and tourism attractions in Taiwan.

Table 1. Average transportation distance, the probability of international visitors using each transportation mode, and the carbon emission coefficient of each mode.

Transportation Mode	Selected Probability (%) [a]	Distance (km/Person) [a]		Carbon Emission Coefficient (kg CO_2/km) [b]
		Average	Deviation	
Car	29.5	173.9	214.4	0.096
Bus	22.2	404.6	320.7	0.028
High speed rail	20.2	258.3	144.7	0.070
Train	19.4	361.3	274.2	0.034
Minibus	4.4	402.0	376.0	0.052
Mass rapid transit	4.4	31.9	0.0	0.034
Total	100	-	-	-

[a] When an international visitor needs to use a vehicle for transportation; [b] [7].

Table 2. Accommodation type, the probability of international visitors using each accommodation type, and the carbon emission coefficient of each accommodation.

Accommodation Type	Selected Probability (%/Person-Night) [a]	Carbon Emission Coefficient (kg CO_2/Person-Night) [b]
Standard tourist hotel	31.1	19.2
International tourist hotel	24.6	20.15
Friend/relative's house	13.1	3.00
General hotels	16.3	12.47
Bed-and-breakfast	14.3	6.32
Other (such as tent)	0.6	0.0
Total	100	-

[a] When an international visitor needs to have an accommodation; [b] [9].

Table 3. Tourism activities, the probability of international visitors engaging in each activity, and the carbon emission coefficient of each activity.

Activity		Selected Probability (%/Person-Night) [a]	Carbon Emission Coefficient [A_k (kg CO_2/Person)] [b]
Kind	Example		
Hot spring	Going to hot springs	5.0	9.99
Theme park	Theme park tour	1.4	3.46
Watch a show	Aboriginal cultural experience	3.1	2.57
Mechanical air-ground activity	Yacht tourism	0.9	2.42
Industry visit	Visit orchard	4.3	1.85
Nighttime recreation	Nightclub	10.2	1.85
Shopping	Shopping	19.1	1.62
Culinary journey	Taste famous food in night markets	22.5	1.10
Nonmechanical air-ground activity	Surf	2.2	0.85
Park recreation	Picnic	6.0	0.47
Natural leisure activities	Cycling	5.6	0.28
Architecture visit	Visit special buildings	14.1	0.1
Adventure entertainment	Climbing mount	3.3	0.02
Natural attractions activity	Geological landscape	2.3	0.007
Total		100	

[a] When an international visitor want to engage in an activity; [b] [31].

2.2. Estimation of Carbon Emission per Person

Based on the bottom-up approach of CE estimation, the $TolCO_2$, (kg CO_2/person) is the sum of the TCO_2 (kg CO_2/person), RCO, (kg CO_2/person), and ACO_2 (kg CO_2/person), as expressed in Equations (1)–(4). Furthermore, the annual CE of international visitors ($ACEIV$) was estimated using Equation (5).

$$TolCO_2 = TCO_2 + RCO_2 + ACO_2 \tag{1}$$

$$TCO_2 = \sum_{i=1}^{m} M_i \cdot D_{ii} \tag{2}$$

$$RCO_2 = \sum_{j=1}^{n} R_j \cdot S_j \tag{3}$$

$$ACO_2 = \sum_{k=1}^{p} A_k \cdot T_k \tag{4}$$

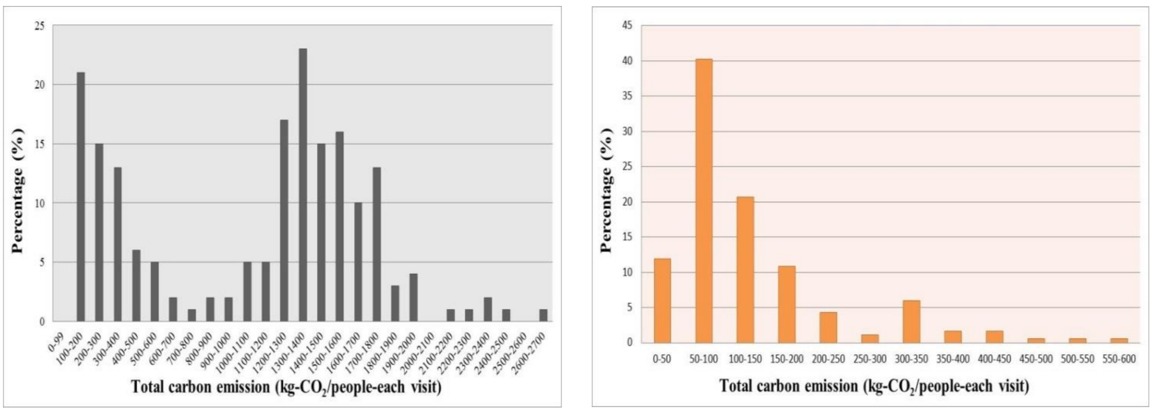
$$ACEIV = \sum_{i=1}^{q} N_l \cdot E_l \tag{5}$$

The CECs of the six transportation modes (m = 6) and five types of accommodation (n = 5) are listed in Tables 1 and 2, respectively. Here, M_i is the average CEC of the ith transportation mode (kg CO_2/km), D_i is the average distance travelled by an international visitor using the ith transportation mode (km), R_j is the average CEC of the jth accommodation type (kg CO_2/person-night). International tourist hotels offer highly energy-consuming facilities and services, such as swimming pools and spas and hence, have higher CEC values. S_j is the number of nights an international visitor stayed in jth hotel (night). A_k is the average CEC of the kth tourist activity and is defined as CE per activity (kg CO_2), and T_k is the number of visitors engaging in the kth tourist activity. R_j and S_j have been described in and were adopted from previous studies [7,9]. N_l is the number of international visitors from lth continent, and S_l is the average CE of international visitors from lth continent. The estimated CECs of the 14 investigated tourist activities are listed in Table 3 [31]. The energy of each tourist activity per annum and the annual number of people engaging in a particular activity were determined from questionnaire responses; subsequently, the average CEC for activities was estimated [31].

3. Results and Discussion

3.1. Total Carbon Emission with and without Considering International Transportation

The estimated $TolCO_2$ patterns identified from the CECs and the questionnaire responses are shown in Figure 2. Air transport generates the largest CE [9], as it is nearly unavoidable during international travel. Assigning jurisdictions for cross-border CEs are difficult [32]. Therefore, in this study, $TolCO_2$ is reported with (Figure 2A) and without (Figure 2B) considering international transportation. When international transportation was included, $TolCO_2$ ranged from 126.0 to 2077 kg CO_2/person (Figure 2A) and was greater than that without international transportation (Figure 2B). No $TolCO_2$ was less than 100 kg CO_2/person, indicating that the lowest $TolCO_2$ from international transportation was larger than 100 kg CO_2/person. The visitor with the lowest $TolCO_2$ was from Hong Kong and stayed in Taiwan for two days (Figure 2A), whereas the visitor with the largest $TolCO_2$ was from Canada and stayed in Taiwan for 20 days. $TolCO_2$ of 100–600 kg CO_2/person was attributed to international travel with a flight time of less than 3 h; such visitors were mainly from neighboring countries, such as China and Japan. By contrast, longer international flights had larger contributions to $TolCO_2$ (1200–1800 kg CO_2/person); such visitors were mainly from Europe and the Americas.



(**A**) (**B**)

Figure 2. Bimodal distribution of international visitor carbon emission (**A**) with and (**B**) without considering international transportation.

To explore which factors contributed the most to the $TolCO_2$ of international visitors to Taiwan, we excluded the CE of international transportation from the $TolCO_2$ analysis. The $TolCO_2$ without CE of international transportation ranged from 7.9 to 591.1 kg CO_2/person (Figure 2B). In this case, the visitor with the lowest $TolCO_2$ (7.9 kg-CO_2/person) was from Singapore and engaged in camping, which has a low RCO_2 and ACO_2. The highest $TolCO_2$ (591.1 kg CO_2/person) was generated by a visitor who stayed in Taiwan for 60 days and engaged in numerous tourist activities. The $TolCO_2$ often ranged from 50–100 kgCO_2/person for a visit. As expected, visitors who stayed in Taiwan for longer periods of time (14–45 days) engaged in several tourist activities and generated larger $TolCO_2$ (250–600 kg CO_2/person). Figure 3A shows the contributions of TCO_2, RCO_2, and ACO_2 to $TolCO_2$. Because Taiwan has relatively few hinterland areas and short transportation distances, TCO_2 contributed only 13.4% to $TolCO_2$; this is in contrast to non-island countries, such as China, where TCO_2 is the main contributor [33,34]. RCO_2 contributed 71.6% to $TolCO_2$, and each visitor generated an average of 92.5 kg CO_2 through accommodation activities. These results suggest that devoting resources to the reduction of RCO_2 can considerably increase $TolCO_2$ reduction. Such results were consistent with the idea that a reduction of CE from tourism should not only improve energy changes on the supply side, but also promote tourists to make environmentally protective decisions in regard to their choice of accommodation [34].

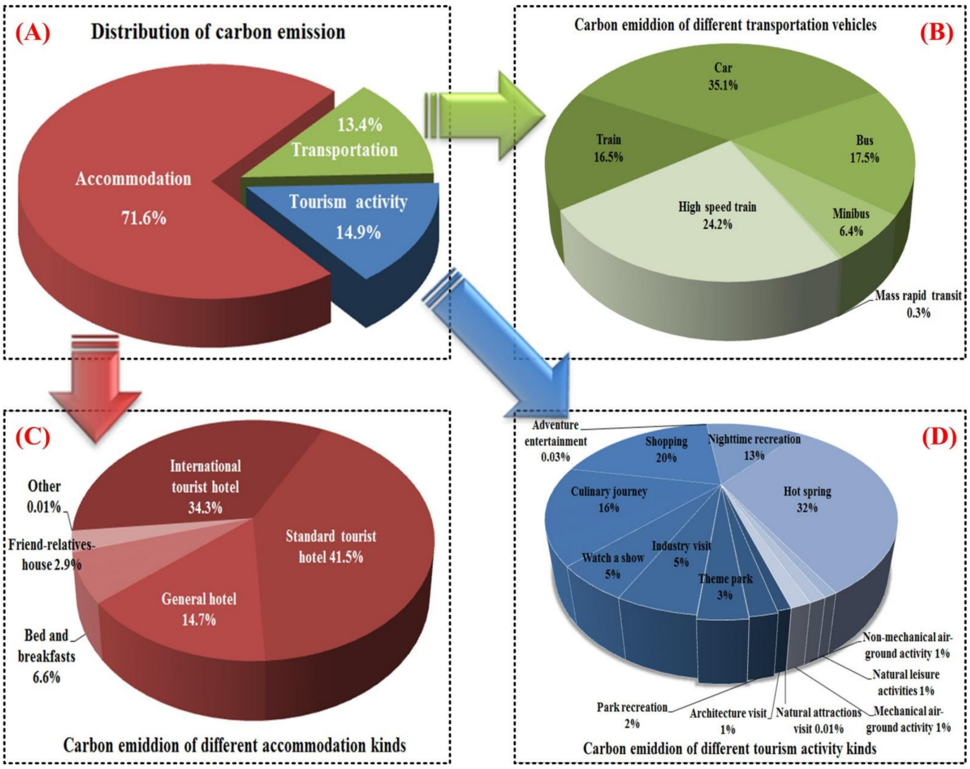


Figure 3. (**A**) Carbon emission (CE) without considering international flights and contributions to CE stratified by (**B**) transportation modes; (**C**) accommodation types; and (**D**) tourist activities.

3.2. Transportation Carbon Emission of International Visitors

Table 1 shows the average transportation distance and the probability of an international visitor using each type of transportation mode. Travel by car, which had the highest CEC in this study, also had the highest probability (approximately 30%) of being selected as the transportation mode, and was used to travel, on average, 173.9 km. This suggests that a more convenient public transportation network could help to reduce TCO_2. However, convenience may influence the choice of transportation mode, which may ultimately hinder the use of public transportation [35,36]. Train, bus, minibus, and HSR had an approximately 20% probability of use as the transportation mode. The HSR was used for longer transportation distances than cars, indicating that HSR was the primary choice for long-distance travel. The use of trains for longer transportation distances indicated that the comprehensive island railway network in Taiwan helps to promote low-carbon tourism, because trains have low CEC values. Mass rapid transit (MRT) was the least used transportation mode, despite it having the lowest CEC.

This may be because of the limited availability of MRT (in the two metropolises of Taipei City and Kaohsiung City only). Some MRT networks under construction, such as that in Taichung, may help to promote low-carbon tourism in the future.

Next, we calculated the ratio of TCO_2 emitted by the different transportation modes (Figure 3B). As expected, cars had the largest contribution to TCO_2 (35.1%) because of their larger CEC and their high probability of use. This further supports the need for a comprehensive and convenient public transport system to replace or reduce the use of cars. While promoting public transport as an alternative mode, the government should consider tourist motivations, social marketing strategies, and tourist behaviors [37]. The HSR was the second largest contributor to TCO_2 (24.2%) because of its large CEC and long travel distances. However, reducing the contribution of HSR to TCO_2 might not be possible because of the high rate of utilization of HSR and its unique function of high-speed travel within Taiwan. Transportation by train or bus both contributed only 17% to TCO_2 despite their long travel distances. Because MRT was the mode least likely to be used and given its low CEC and short travel distances, the CE from MRT had the lowest contribution (0.3%) to TCO_2.

3.3. Accommodation Carbon Emission of an International Visitor

International visitors were most likely (31.1%) to stay in a standard tourist hotel and were next most likely (24.6%) to stay in an international tourist hotel (Table 2). However, these two types of accommodation have high CECs due to their energy-intensive facilities and thus higher RCO_2 values (41.5% and 34.3%, respectively; Figure 3C). Bed-and-breakfast (B&B) establishments were used by 14.3% of international visitors and a further 13.1% stayed with a friend or a relative; both of these types of accommodation had low CEC values (6.6% and 2.9% RCO_2, respectively; Figure 3C). Some international visitors stayed in other types of accommodation, such as tents (0.6%). These findings suggest that the government should consider devoting resources to improve the energy-use efficiency of devices in tourist hotels and endorsing the use of alternative accommodations with lower RCO_2, such as by featuring or recommending B&Bs, to promote low-carbon tourism industry in Taiwan.

3.4. Tourist Activity Carbon Emission of an International Visitor

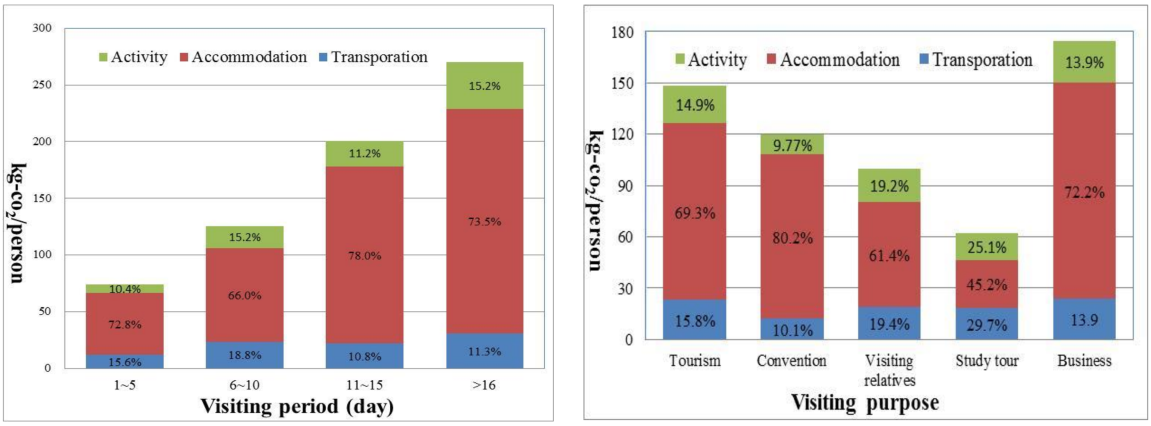
Table 3 shows the probability of an international visitor engaging in the 14 most common tourist activities and the CECs of these activities. International visitors were most likely (22.5%) to engage in a culinary journey, followed by shopping (19.1%), visiting famous architectural sites (14.1%), and nighttime recreation (10.2%). Because Taiwan lacks international large-scale amusement parks, such as Disneyland, international visitors were least likely (0.9%) to engage in non-mechanical air–ground activities. Moreover, the questionnaire responses revealed that international visitors engaged in tourist activities 1.3 times per day, on average; however, this varied widely (ranged from 0.05–4.71 times/day), possibly because of differences in travel purpose. For example, an international visitor who visited Taiwan for business only engaged in tourist activities approximately 0.4 times per day, but visitors whose primary travel purposes were tourism and convention engaged in tourist activities approximately 1.5 and 1.1 times per day, respectively. The latter result indicates that Taiwan's rich tourism resources drive international visitors to engage in tourist activities, even when the primary purpose of their stay is not tourism.

The highest CEC of tourist activities was generated by hot springs (on average, 9.99 kg CO_2/person), followed by theme parks (on average, 3.46 kg CO_2/person). Activities related to natural attractions, such as visiting a geological landscape, had the lowest CEC (0.007 kg CO_2/person), whereas tourist activities classified as man-made, such as watching a show, mechanical air–ground activity, industry visits, nighttime recreation, and shopping, had higher CECs. Approximately 80% of international visitors who engaged in nighttime recreation (such as visiting a nightclub) were from non-Asian countries and generated up to 1.85 kg CO_2/person. There was an approximately 1000-fold difference in CEC between the largest and smallest CEC-generating tourist activities. Of all of the tourist activities, engaging in hot spring activities had the largest contribution to ACO_2

(Figure 3D), despite this activity having only a 5% probability of being engaged in. In other words, if the Taiwanese government promotes hot spring activities to tourists, this will increase the volume of CE. The Taiwanese government should therefore propose strategies to reduce the CEC of hot springs, because hot springs are often promoted as the main tourist activity to partake in during winter. International visitors who engaged in culinary journeys and shopping had the second largest contribution to ACO_2 because of their high CEC combined with the high probability of these activities being engaged in. One effective method for promoting alternative tourist activities is to issue pamphlets that provide information about tourist activities and destinations in hotel receptions [22].

3.5. Carbon Emission Patterns for Different Visiting Periods and Purposes

The findings of this study show that the majority of international visitors (40.6%) stayed in Taiwan for 6–10 days; on average, international visitors stayed in Taiwan for 9 days for short-term trips (<60 days). Visitors to Taiwan for 1–5 days (38.0%) were mostly from East and Southeast Asia. The $TolCO_2$ pattern for the different visiting periods and purposes is illustrated in Figure 4. The $TolCO_2$ increased with visiting time (Figure 4A), but TCO_2 did not markedly increase, mainly because of the non-tourist nature of such trips and because such visitors engaged in few activities. In contrast, visitors who stayed for shorter periods (<10 days) engaged in many tourist activities and spent more time traveling, thus generating a higher rate of TCO_2. Such intensive tourist activities would possibly lead to lower tourism quality and higher $TolCO_2$; thus, if the Taiwanese government recommends appropriate itineraries based on visiting periods, the tourism quality and $TolCO_2$ could potentially be improved.



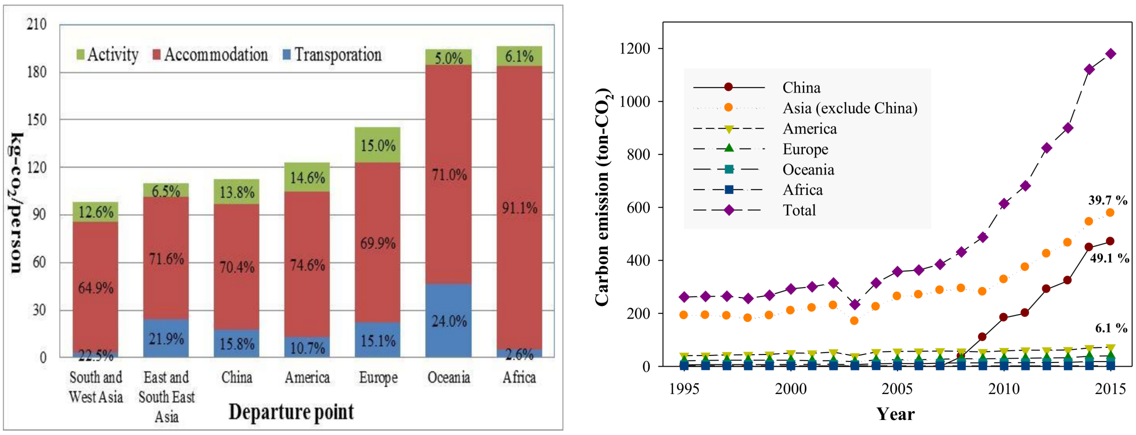
(**A**) (**B**)

Figure 4. Average carbon emission generated by visitors for different visiting (**A**) periods and (**B**) purposes.

RCO_2 contributed more than 70% to $TolCO_2$, except when the visiting period was 6–10 days. This is due to a higher probability of such visitors staying in their friends' or relatives' house and engaging in more activities with higher TCO_2 values. Most visitors travelled to Taiwan for tourism (50.5%), convention (26.9%), visiting relatives (12.6%), study (5.5%), and business (4.4%). Figure 4B shows the average $TolCO_2$ for different visit purposes; visitors who travelled for business had the largest $TolCO_2$ values (174.2 kg CO_2/person), mainly because these visitors often stayed in international tourist hotels, which have the highest accommodation CEC. In contrast, visitors who travelled for study often stayed with their friends or relatives, which has a low accommodation CEC and thus generates the lowest RCO_2 and $TolCO_2$ (62.2 kg CO_2/person). Similarly, visitors who travelled to visit relatives usually stayed in their relatives' house, resulting in low RCO_2 and $TolCO_2$ values. Visitors who travelled for tourism and convention had similar RCO_2 but different TCO_2 and ACO_2, mainly because these visitors engaged in many tourist activities.

3.6. Carbon Emission Patterns for Visitors' Departure Points, and Annual Carbon Emission of International Visitors

Visitors who participated in this study were from Europe (39.2%), China (22.2%), the Americas (18.5%), East and Southeast Asia (12.7%), South and West Asia (2.6%), Oceania (2.6%), and Africa (2.1%). Figure 5A shows the average $TolCO_2$ generated by the visitors with different departure points; visitors from Africa and Oceania generated the highest $TolCO_2$ values. Furthermore, visitors from Africa often stayed in international tourist hotels, possibly because of language barriers. However, they generated low TCO_2 and ACO_2 because they visited Taiwan for business and engaged in few tourist activities. In comparison, because visitors from Oceania visited Taiwan for a longer period (on average, 11.4 days) and had a higher probability of using a car as their transportation mode than other visitors, they generated the highest TCO_2. Visitors from Europe generated a high TCO_2 because of their longer visiting period and engagement in several tourist activities. Overall, these results suggest that the government should vigorously advocate low-carbon accommodation for visitors from Oceania, Africa, and Europe; for example, promoting B&Bs to these visitors and improving the communication skills of the owners of these establishments to promote low-carbon tourism for international visitors. In addition, visitors from East and Southeast Asia and China who visit Taiwan for shorter periods (approximately 6.8 days) would generate similar $TolCO_2$ values. Visitors from South and West Asia also visited Taiwan for shorter periods (approximately 7.0 days) and often stayed in a single city for conventions; thus, they had shorter transportation distances and the lowest TCO_2 values, despite their preference to travel by car. In other words, the Taiwanese government should promote the policy of attracting tourists from South and West Asia. This policy would reduce the tourism carbon footprint of international tourists but also obtain economic benefit.



(**A**) (**B**)

Figure 5. (**A**) Average carbon emission generated by visitors from different departure points and (**B**) the estimated annual carbon emission generated by international visitors to Taiwan during 1995–2015.

Figure 5B shows the ACEIV and the estimated annual CE generated by international visitors traveling to Taiwan during 1995–2015 (without considering international transportation), derived from our results and data from the Taiwan Tourism Bureau. The annual CE generated by visitors from Asia was analyzed separately for visitors from China and the rest of Asia. The number of international visitors increased 4.6-fold and the annual CE approximately 4.5-fold during 2005–2015. For example, the annual CE in 2015 was 1180.1 ton CO_2/year and was mainly derived from visitors from China (49.1%) and the rest of Asia (39.7%); this was because the number of visitors from China and the rest of

Asia increased significantly despite visitors from these countries having a lower CE per person than those from other continents. The increase of visitors from China is because the China and Taiwanese governments allowed regular China tourists to visit Taiwan in 2008 [38]. In addition, the Taiwanese government actively promoted tourism in Asia after its rapid economic development, which could have resulted in the large increase in the number of visitors from these countries.

4. Conclusions

To develop the tourism industry, in addition to the attracting international tourists, promoting low-carbon tourism was deemed vital by the Taiwanese government. This study identified the CE patterns of international visitors to Taiwan with the objective of providing the Taiwanese government with comprehensive data to determine their approach towards promoting a low-carbon tourism industry. Further, this study evaluated $TolCO_2$ with and without international transportation as well as the contribution of TCO_2, RCO_2, and ACO_2 to $TolCO_2$.

Travel by car, which has the highest CEC among all transportation modes, had the highest probability of use over short distances. Although cars are preferred because of convenience and tourist behavior, the results nevertheless suggest that construction of more convenient public transportation might help to reduce TCO_2. Furthermore, TCO_2 contributed to only 13.4% of $TolCO_2$, probably due to the presence of few hinterland regions and the shorter transportation distances in Taiwan. Visitors who travelled for conventions also engaged in tourist activities, indicating that Taiwan has rich tourism resources from which the tourism industry can be developed and that low TCO_2 would be conducive to promoting low-carbon tourism. ACO_2 was the main contributor to $TolCO_2$ in Taiwan, whereas TCO_2 is the main contributor in many other countries.

Visitors from Africa often stayed in international tourist hotels (possibly because of language barriers), which have the highest accommodation CEC and consequently generate higher $TolCO_2$ than do visitors from other continents. This suggests that the Taiwanese government should devote resources to improve the energy-use efficiency of devices in accommodations and promote unique B&Bs with lower CECs.

International visitors enjoy culinary journeys and shopping, which contributes highly to ACO_2 because of the high CEC values of these activities. Hot spring activity had the highest CEC among all tourist activities and contributed the most to ACO_2, despite few international visitors engaging in it. The government should therefore develop strategies to reduce the CEC of hot spring activity as it is often promoted as the main tourist activity during winter. We believe that our results provide the Taiwanese government a reference for promoting a low-carbon tourism industry. Apart from $TolCO_2$, environmental pollution resulting from tourism development should be considered in the future.

Author Contributions: K.-T.T. established the framework and analysis methodology, performed the statistical analysis, created tables and graphs, and wrote the manuscript. T.-P.L. and Y.-H.L. determined the research rationales and objectives, synthesized the results of the data analysis. C.-H.T. determined the article structure and outline, wrote the manuscript, and acted as the corresponding author. Y.-T.C. performed the field surveys and collected data. All authors critically revised and approved the final manuscript.

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References

1. Gössling, S.; Peeters, P. Assessing tourism's global environmental impact 1900–2050. *J. Sustain. Tour.* **2015**, *23*, 639–659. [CrossRef]
2. Buckley, R. Sustainable tourism: Research and reality. *Ann. Tour. Res.* **2012**, *39*, 528–546. [CrossRef]
3. Sharpley, R. *Tourism Development and the Environment: Beyond Sustainability?* Earthscan: London, UK, 2009.

4. Scott, D.; Peeters, P.; Gössling, S. Can tourism deliver its "aspirational" greenhouse gas emission reduction targets? *J. Sustain. Tour.* **2010**, *18*, 393–408. [CrossRef]
5. Gössling, S. Global environmental consequences of tourism. *Glob. Environ. Chang.* **2002**, *12*, 283–302. [CrossRef]
6. Roibás, L.; Loiseau, E.; Hospido, A. Determination of the carbon footprint of all Galician production and consumption activities: Lessons learnt and guidelines for policymakers. *J. Environ. Manag.* **2017**, *198 Pt 1*, 289–299. [CrossRef] [PubMed]
7. Lin, T.-P. Carbon dioxide emissions from transport in Taiwan's national parks. *Tour. Manag.* **2010**, *31*, 285–290. [CrossRef]
8. Becken, S.; Simmons, D.G.; Frampton, C. Energy use associated with different travel choices. *Tour. Manag.* **2003**, *24*, 267–277. [CrossRef]
9. Tsai, K.-T.; Lin, T.-P.; Hwang, R.-L.; Huang, Y.-J. Carbon dioxide emissions generated by energy consumption of hotels and homestay facilities in Taiwan. *Tour. Manag.* **2014**, *42*, 13–21. [CrossRef]
10. Huang, Z.; Cao, F.; Jin, C.; Yu, Z.; Huang, R. Carbon emission flow from self-driving tours and its spatial relationship with scenic spots—A traffic-related big data method. *J. Clean. Prod.* **2017**, *142*, 946–955. [CrossRef]
11. Peeters, P.; Dubois, G. Tourism travel under climate change mitigation constraints. *J. Transp. Geogr.* **2010**, *18*, 447–457. [CrossRef]
12. Gössling, S. Carbon neutral destinations: A conceptual analysis. *J. Sustain. Tour.* **2009**, *17*, 17–37. [CrossRef]
13. De Vita, G.; Katircioglu, S.; Altinay, L.; Fethi, S.; Mercan, M. Revisiting the environmental Kuznets curve hypothesis in a tourism development context. *Environ. Sci. Pollut. Res.* **2015**, *22*, 16652–16663. [CrossRef] [PubMed]
14. Ozturk, I.; Al-Mulali, U.; Saboori, B. Investigating the environmental Kuznets curve hypothesis: The role of tourism and ecological footprint. *Environ. Sci. Pollut. Res.* **2016**, *23*, 1916–1928. [CrossRef] [PubMed]
15. López-Menéndez, A.J.; Pérez, R.; Moreno, B. Environmental costs and renewable energy: Re-visiting the Environmental Kuznets Curve. *J. Environ. Manag.* **2014**, *145* (Suppl. C), 368–373. [CrossRef] [PubMed]
16. Becken, S.; Patterson, M. Measuring national carbon dioxide emissions from tourism as a key step towards achieving sustainable tourism. *J. Sustain. Tour.* **2006**, *14*, 323–338. [CrossRef]
17. Oluseyi, P.; Babatunde, O.; Babatunde, O. Assessment of energy consumption and carbon footprint from the hotel sector within Lagos, Nigeria. *Energy Build.* **2016**, *118*, 106–113. [CrossRef]
18. Filimonau, V.; Dickinson, J.; Robbins, D. The carbon impact of short-haul tourism: A case study of UK travel to Southern France using life cycle analysis. *J. Clean. Prod.* **2014**, *64*, 628–638. [CrossRef]
19. Loo, B.P.Y.; Li, L. Carbon dioxide emissions from passenger transport in China since 1949: Implications for developing sustainable transport. *Energy Policy* **2012**, *50*, 464–476. [CrossRef]
20. Tang, C.; Zhong, L.; Fan, W.; Cheng, S. Energy consumption and carbon emission for tourism transport in World Heritage Sites: A case of the Wulingyuan area in China. *Nat. Resour. Forum* **2015**, *39*, 134–150. [CrossRef]
21. Hoxter, A.L.; Lester, D. Tourist behavior and personality. *Personal. Individ. Differ.* **1988**, *9*, 177–178. [CrossRef]
22. Ortega, E.; Rodríguez, B. Information at tourism destinations. Importance and cross-cultural differences between international and domestic tourists. *J. Bus. Res.* **2007**, *60*, 146–152. [CrossRef]
23. Jones, T.E.; Yamamoto, K. Segment-based monitoring of domestic and international climbers at Mount Fuji: Targeted risk reduction strategies for existing and emerging visitor segments. *J. Outdoor Recreat. Tour.* **2016**, *13*, 10–17. [CrossRef]
24. Rutty, M.; Scott, D. Comparison of climate preferences for domestic and international beach holidays: A case study of Canadian travelers. *Atmosphere* **2016**, *7*, 30. [CrossRef]
25. Kozak, M. Comparative analysis of tourist motivations by nationality and destinations. *Tour. Manag.* **2002**, *23*, 221–232. [CrossRef]
26. Carr, N. A comparative analysis of the behaviour of domestic and international young tourists. *Tour. Manag.* **2002**, *23*, 321–325. [CrossRef]
27. Yang, M.-D.; Chen, Y.-P.; Lin, Y.-H.; Ho, Y.-F.; Lin, J.-Y. Multiobjective optimization using nondominated sorting genetic algorithm-II for allocation of energy conservation and renewable energy facilities in a campus. *Energy Build.* **2016**, *122*, 120–130. [CrossRef]
28. UNEp, O.; IEA, I. *Revised IPCC Guidelines for National Greenhouse Gas Inventories*; IPCC: Bracknell, UK, 1996.

29. Collier, A. *Principles of Tourism*; Pitman Publishing: London, UK, 1989.
30. Becken, S. *Energy Consumption of Tourist Attractions and Activities in New Zealand: Summary Report of a Survey*; Lincoln University: Lincoln, UK, 2001.
31. Chiu, Y.-T. *Carbon Emissions and Ecological Footprint of Foreign Tourists in Taiwan*; National Formosa University: Yunlin, Taiwan, 2012.
32. Sun, Y.-Y. A framework to account for the tourism carbon footprint at island destinations. *Tour. Manag.* **2014**, *45*, 16–27. [CrossRef]
33. Tang, Z.; Shang, J.; Shi, C.; Liu, Z.; Bi, K. Decoupling indicators of CO_2 emissions from the tourism industry in China: 1990–2012. *Ecol. Indic.* **2014**, *46*, 390–397. [CrossRef]
34. Robaina-Alves, M.; Moutinho, V.; Costa, R. Change in energy-related CO_2 (carbon dioxide) emissions in Portuguese tourism: A decomposition analysis from 2000 to 2008. *J. Clean. Prod.* **2016**, *111*, 520–528. [CrossRef]
35. Lew, A.; McKercher, B. Modeling Tourist Movements: A Local Destination Analysis. *Ann. Tour. Res.* **2006**, *33*, 403–423. [CrossRef]
36. Kelly, J.; Haider, W.; Williams, P.W. A behavioral assessment of tourism transportation options for reducing energy consumption and greenhouse gases. *J. Travel Res.* **2007**, *45*, 297–309. [CrossRef]
37. Le-Klähn, D.-T.; Hall, C.M. Tourist use of public transport at destinations—A review. *Curr. Issues Tour.* **2015**, *18*, 785–803. [CrossRef]
38. Sun, Y.-Y.; Pratt, S. The economic, carbon emission, and water impacts of Chinese visitors to Taiwan: Eco-efficiency and impact evaluation. *J. Travel Res.* **2014**, *53*, 733–746. [CrossRef]