SHORT COMMUNICATION

ENHANCING ENVIRONMENTAL CONSERVATION THROUGH GUIDED TOUR BUSES: INSIGHTS FROM TAIJIANG NATIONAL PARK

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ABSTRACT

High visitor numbers in protected areas can create traffic problems that impact on the environmental protection. In Taijiang National Park, a tour bus project 'Taijiang Fun Tour' was introduced to mitigate various environmental problems caused by private cars. This study evaluates the project's environmental benefits, and those of the various bus routes in the park, in reducing CO_2 emissions. The Mangrove route only achieved a CO_2 reduction in 2023, likely due to post-COVID-19 tourism recovery. In contrast, the Black-faced Spoonbill route consistently showed reductions in CO2 emissions, attributed to higher per trip passenger numbers replacing more private cars, better road conditions, and longer distances between attractions, that enabled higher bus speeds and lower CO_2 emissions per unit time. While it is unsurprising that CO_2 reduction is significantly influenced by passenger numbers and bus speeds, the results of this study could be used by TJNP to enhance the benefits from bus use. Starting in 2024, TJNP will optimise routes and implement additional measures to encourage low-carbon transportation.

Keywords: sustainable tourism, transportation management, alternative transportation options, visitor impact mitigation, CO_2 reduction

INTRODUCTION

Private cars provide flexibility and convenience, allowing visitors to travel at their own pace and access remote areas. However, they also lead to significant traffic congestion, parking issues and increased carbon dioxide emissions (Monz et al., 2016; Newton et al., 2020). These adverse effects are especially problematic in protected areas such as Taijiang National Park (TJNP) in Taiwan, where preserving the environment is essential for maintaining its wetland ecosystem and cultural heritage. Reducing carbon dioxide emissions in national parks can contribute to mitigating climate change impacts and protecting natural and cultural resources (Gonzalez, 2020). In this context, buses, including route buses, shuttle buses and tour buses, offer numerous advantages over private cars. They help reduce traffic congestion, reduce emissions and can be more energy-efficient (Anderson et al., 2015; Ko & Song, 2019). Buses following fixed routes can manage visitor flow and minimise habitat disturbance (Lawson et al., 2011). Additionally, tour buses enhance the visitor experience by providing guided tours, educating visitors about the park's natural and cultural resources (Pettengill et al., 2012).

However, replacing private cars with buses does not resolve all environmental and management issues. Buses can bring large groups of visitors at once, potentially causing ecological and social impacts due to sudden spikes in visitor numbers (Monz et al., 2016). Consequently, route buses that do not control where and when visitors get on and off might not be the best solution for national parks or other protected areas. Shuttle buses can effectively replace private cars by reducing traffic congestion and emissions (Lawson et al., 2011; Pettengill et al., 2012). However, the TJNP headquarters prefers to actively share conservation messages and outcomes during visitor visits, which may not be as easily achieved with simple shuttle buses. To address this, the guided tour bus project 'Taijiang Fun Tour' was launched in 2020, aiming not only to mitigate traffic and emissions but also to augment visitor

education on conservation efforts. This initiative aims to enhance the visitor experience through efficient transportation and educational tours, promoting sustainable tourism and conservation efforts within the park. By highlighting the reduced stress from driving and parking, enhanced sightseeing opportunities, and the availability of knowledgeable tour guides (Collum & Daigle, 2015; Newton et al., 2020), the project can attract more visitors to use the bus service (Ko & Song, 2019). Additionally, well-planned itineraries can save time and effort for visitors interested in exploring the park's mangrove and bird habitats. This study focuses on the project's environmental function, specifically the reduction of carbon dioxide emissions during its operation. This now includes tour bus emissions in TJNP's current carbon accounting but also forms part of the ecosystem services inventory, essential for garnering social support and encouraging public participation in climate change adaptation efforts.

MATERIALS AND METHODS

Site description

Taijiang National Park (TJNP), located on the southwestern coast of Taiwan (Figure 1), spans 40,731.31 hectares, including 5,090.21 hectares of land and 35,641.10 hectares of marine area (TJNP Headquarters, 2017). This park preserves a unique wetland ecosystem, featuring Chigu Lagoon, fishponds, mangrove forests, salt marshes and mudflats. Historically, the region's early ports and waterways facilitated international trade, remnants of which still exist. Coastal communities traditionally engaged in fishing and sea salt harvesting, an important part of the region's heritage. TJNP supports vital ecosystems, including habitats for the endangered Black-faced Spoonbill (*Platalea minor*). Conservation efforts have garnered significant attention, and the park promotes public involvement through tours and environmental education activities. Despite a network of meandering roads, the park lacks comprehensive public transportation, leading visitors to rely on private vehicles, causing traffic congestion and parking issues during peak times. Effective management strategies are needed to mitigate these impacts.

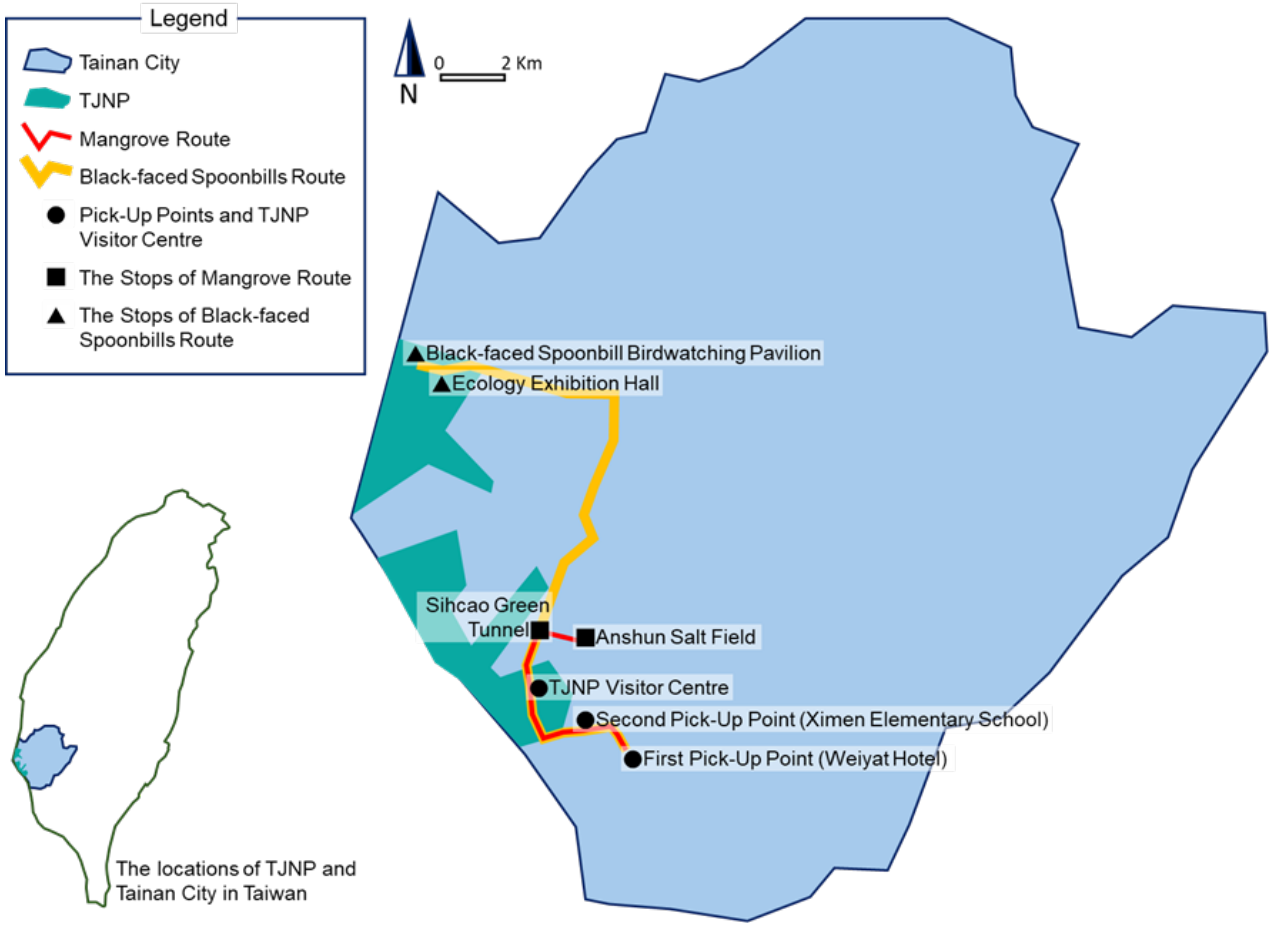


Figure 1. Location of TJNP and Taijiang Fun Tour routes

Taijiang Fun Tour Visitors at Anshun Salt Field © Taijiang National Park

Taijiang Fun Tour project

To mitigate the impact of private cars, TJNP launched the Taijiang Fun Tour bus project. The service features the Black-faced Spoonbill route in autumn and winter, and the Mangrove route in spring and summer (Figure 1). Dedicated tour guides enhance the visitor experience. Buses operate on selected weekends, with two departures daily from a hotel near TJNP, offering four-hour tours. Initially planned to start in early 2020, the service adapted to COVID-19 by starting the Mangrove route in May 2020, reducing capacity to 20 passengers per bus, with assigned seating, enhanced sanitation and contingency plans. Despite restrictions, demand was high and feedback was positive. From 2023, operations stabilised, and passenger limits were lifted. The Mangrove route proceeds to Anshun Salt Field, followed by a boat trip through Sihcao Green Tunnel, and ends at the TJNP Visitor Centre. The Black-faced Spoonbill route goes to the Birdwatching Pavilion, the Ecology Exhibition Hall, and ends at the Visitor Centre. In 2023, the Ecology Exhibition Hall was under renovation, extending the stay at the birdwatching pavilion. Actual operation conditions were adjusted according to weather and the availability of attractions and this study's analysis is based on normal operational conditions.

Data collection and analysis

Data collection included recording the number of trips, visitor numbers, and the estimated reduction in car trips and CO_2 emissions from the tour bus operation. The study analysed data from the Mangrove and Black-faced Spoonbill routes over different years. For details on the data collection methods and specific calculations, see Supplementary Online Material 1 to 3. Distances were calculated using Google Maps to determine routes for both the bus and private cars. Travel times for the bus were based on typical operating conditions, while times for private cars were derived from Google Maps (2024). Average speed was calculated by dividing travel distance by travel time, influenced by road conditions, traffic and parking access. CO_2 emissions during idling were calculated using reasonable waiting times for boarding and alighting. Emissions reductions were based on the average number of passengers per bus and the corresponding decrease in private car use. The 2019 Traffic Construction Project Economic Benefit Evaluation Manual (2021 updated version) by the Institute of Transportation, Ministry of Transportation and Communications, Taiwan (2021), was used as a reference. This manual provides tables for CO_2 emissions calculated by distance (g/km) and time (g/s). The time-based calculation method was adopted to account for emissions during idling.

Table 1. Summary of Taijiang Fun Tour route operations and CO_2 emission comparisons (2020–2023)

Route	Year	Number of Trips	Number of Passengers	CO_2 Emission Reduction (kg)	Ratio of Bus to Car CO_2 Emissions
Mangrove Route	2020	46	742	-222.25	115.87%
	2021	14	157	-197.57	166.67%
	2022	52	246	-1,370.28	395.07%
	2023	36	1155	910.23	58.25%
Black-faced Spoonbill Route	2020	12	243	222.95	67.76%
	2021	72	1274	814.10	77.55%
	2022	48	607	-146.89	108.50%
	2023	30	671	645.31	63.11%

RESULTS

Route operations and carbon dioxide emissions analysis

The Taijiang Fun Tour's Mangrove and Black-faced Spoonbill routes have specific stops detailed in Supplementary Online Materials. For example, the Mangrove route includes a 10-minute stop at the first pick-up point, followed by a 2.4-km drive to the second pick-up point, then a 6.5-km drive to Anshun Salt Field. Emissions during idling were calculated using the dynamic CO_2 emission coefficient of 2.139 g/s, leading to an idling emission of 3,209 g. The driving emissions for the Mangrove route were calculated using a coefficient of 7.6496 g/s for speeds around 14 km/h, totalling 32,074 g. The combined emissions for the Mangrove route were approximately 35,282 g, compared to 5,663 g for a private car. The Black-faced Spoonbill route, depending on the years, emitted approximately 39,048 g (2020–2022) and 36,804 g (2023), compared to 8,537 g and 7,822 g for a private car.

Comparison between Taijiang Fun Tour and private cars

The overall CO_2 emissions for the bus routes and private cars were compared to determine the effectiveness of the guided bus tours. Table 1 summarises the operations and CO_2 emission comparisons for the Taijiang Fun Tour routes from 2020 to 2023. The Mangrove route, for example, replaced an estimated 247.33 car trips in 2020, resulting in a total CO_2 emission of 1,622.98 kg for the bus compared to 1,400.73 kg for private cars, showing a higher emission for the bus. In 2023, however, the Mangrove route replaced 385 car trips, reducing emissions by 910.23 kg, with the bus emitting only 58.25 per cent of the CO_2 compared to private cars. The Black-faced Spoonbill route generally showed better CO_2reduction, with bus emissions being about 60–70 per cent of those from private cars in 2020, 2021 and 2023, although in 2022, the bus emissions slightly exceeded those of the private cars.

DISCUSSION

The results of this study highlight the varying effectiveness of the Taijiang Fun Tour routes in reducing carbon dioxide emissions. In Table 1, analysis showed that the Mangrove route achieved CO_2 reduction only in 2023, likely due to the post-COVID-19 tourism recovery which increased passenger numbers. On the other hand, the Black-faced Spoonbill route consistently demonstrated better CO2 reduction across multiple years. This improvement is attributed to higher per-trip passenger numbers, which effectively replaced more private cars, as well as the longer distances between attractions and better road conditions allowing for higher bus speeds and lower CO_2 emissions per unit time. The influence of passenger numbers and bus speeds on CO_2 reduction aligns with the evaluation method used in this study, indicating that optimising these factors could further enhance the environmental benefits of the tour bus project.

Firstly, the Taijiang Fun Tour's ability to reduce carbon dioxide emissions depends heavily on careful route planning and the strategic placement of pick-up and drop-off points. Ensuring that a significant portion of the journey occurs on faster segments of the route is crucial. Starting from 2024, moving the starting points of the half-day Mangrove and Black-faced Spoonbill routes to Tainan Railway Station and planning the routes to prioritise travel on less congested, wider roads will help maintain a consistent speed. Although buses will still stop at secondary pick-up points if there are reservations, the overall route will be optimised to ensure faster segments make up a significant portion of the journey. This adjustment is expected to enhance the overall emissions reduction effect. Continuous monitoring and analysis of passenger numbers and trip data will be necessary to evaluate the environmental benefits accurately.

Traditional salt-making tools at Anshun salt field © Taijiang National Park

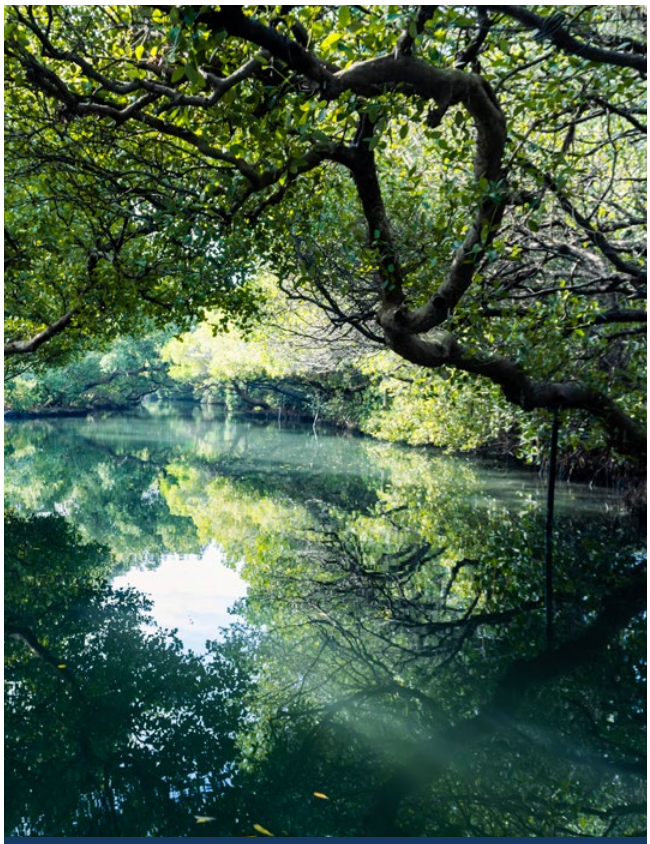
Secondly, visitor satisfaction is a critical component of the project's success. The Taijiang Fun Tour not only aims to reduce emissions but also to promote TJNP's conservation goals. Providing a high-quality visitor experience through well-managed itineraries, professional explanations of attractions, and engaging activities such as birdwatching and sea salt harvesting is essential. These experiences offer educational value and enjoyment that are not attainable through self-driving tours, thus encouraging more visitors to opt for the bus service. By focusing on both environmental benefits and visitor satisfaction, the project can achieve its dual goals more effectively.

Thirdly, the effectiveness of bus services in reducing carbon emissions can be enhanced by integrating additional measures. At TJNP, the 2024 adjustment of pick-up points aims to make it more convenient for visitors arriving by train to directly access the bus service. The nearby availability of public bicycles, shared electric scooters and hotel-provided bicycles allows visitors to seamlessly connect with the Taijiang Fun Tour. Other measures such as replacing fuel-powered buses with electric ones, providing priority bus lanes or giving buses priority over private cars in the park, and improving infrastructure for pedestrians and bicycles are essential strategies. As indicated by the results in Table 1, in certain years the bus routes did not achieve CO_2 reductions, such as in 2020 and 2021 for the Mangrove route. By adopting these additional measures, it is possible to mitigate such inconsistencies and enhance the overall environmental benefits. Protected areas in different regions can adopt similar tailored solutions to offer visitors more comprehensive transportation alternatives.

Moreover, diversifying recreational activities can further enhance sustainable transportation in parks. Increasing the variety of tour bus itineraries, such as integrating bus trips with small boat journeys or offering options for human-powered vessels like kayaks and paddleboards, can enrich the visitor experience and reduce reliance on traditional motorised transport. This holistic approach balances visitor experience with diverse transportation options, catering to different visitor preferences while reinforcing the intrinsic value of protected areas.

CONCLUSION

Future guided tour bus projects in TJNP and other protected areas can enhance their effectiveness by incorporating comprehensive route planning, strategically positioning pick-up and drop-off points, and integrating sustainable transportation options such as electric buses and public bicycle systems. These initiatives not only reduce carbon emissions but also provide broader environmental benefits,



Sihcao Green Tunnel © Taijiang National Park

Bird watching pavilion © Taijiang National Park

such as improving air quality in the park, minimising habitat disturbance and improving visitor flow management. To maximise outcomes, recreational activities aligned with conservation goals should be included, promoting eco-friendly transportation while enriching visitor experiences. Additionally, these projects present opportunities to enhance conservation education and cultural engagement, fostering stronger connections between visitors, local communities and the environment.

Future research could explore differences in visitor experiences between guided bus tour users and private car users, helping park authorities prioritise actions and allocate resources for long-term sustainability. While challenges such as funding limitations or infrastructure upgrades may arise, they also provide opportunities for innovation in sustainable transportation. Furthermore, investigating the economic benefits for local communities and businesses, along with reductions in environmental pressures like noise and parking, would strengthen conservation partnerships. The insights from TJNP offer valuable lessons that can be adapted to other protected areas globally, providing a model for achieving environmental, social and economic sustainability.

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SUPPLEMENTARY ONLINE MATERIAL

Supplementary Online Material 1. Taijiang Fun Tour Mangrove route analysis and dynamic CO_2 emission estimation (2020–2023).

Supplementary Online Material 2. Taijiang Fun Tour Black-faced Spoonbill route analysis and dynamic CO_2 emission estimation (2020–2022).

Supplementary Online Material 3. Taijiang Fun Tour Black-faced Spoonbill route analysis and dynamic CO_2 emission estimation (2023).

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RESUMEN

El elevado número de visitantes en las zonas protegidas puede crear problemas de tráfico que repercuten en la protección del medio ambiente. En el Parque Nacional de Taijiang se introdujo el proyecto de autobús turístico «Taijiang Fun Tour» para mitigar diversos problemas ambientales causados por los coches particulares. Este estudio evalúa los beneficios ambientales del proyecto, y los de las distintas rutas de autobús del parque, en la reducción de las emisiones de CO_2. La ruta del Manglar sólo consiguió reducir las emisiones de CO_2 en 2023, probablemente debido a la recuperación del turismo tras el COVID-19. Por el contrario, la ruta de la Espátula Carinegra mostró sistemáticamente reducciones en las emisiones de CO_2, atribuidas a un mayor número de pasajeros por viaje en sustitución de más coches privados, mejores condiciones de las carreteras y distancias más largas entre las atracciones, que permitieron mayores velocidades de los autobuses y menores emisiones de CO_2 por unidad de tiempo. Aunque no es sorprendente que la reducción de CO_2 se vea influida significativamente por el número de pasajeros y la velocidad de los autobuses, los resultados de este estudio podrían ser utilizados por TJNP para mejorar los beneficios del uso del autobús. A partir de 2024, TJNP optimizará las rutas y aplicará medidas adicionales para fomentar el transporte bajo en carbono.

RÉSUMÉ

Le nombre élevé de visiteurs dans les zones protégées peut créer des problèmes de circulation qui ont un impact sur la protection de l'environnement. Dans le parc national de Taijiang, un projet de bus touristique « Taijiang Fun Tour » a été mis en place pour atténuer les divers problèmes environnementaux causés par les voitures particulières. Cette étude évalue les avantages environnementaux du projet et ceux des différentes lignes de bus dans le parc, en termes de réduction des émissions de CO_2. La route de la mangrove n'a atteint une réduction de CO_2 qu'en 2023, probablement en raison de la reprise du tourisme après le projet COVID-19. En revanche, la ligne de la Spatule à face noire a constamment montré des réductions d'émissions de CO_2, attribuées à un plus grand nombre de passagers par voyage remplaçant plus de voitures privées, un meilleur état des routes, et des distances plus longues entre les attractions, qui ont permis des vitesses de bus plus élevées et des émissions de CO_2 plus faibles par unité de temps. S'il n'est pas surprenant que la réduction des émissions de CO_2 soit influencée de manière significative par le nombre de passagers et la vitesse des bus, les résultats de cette étude pourraient être utilisés par TJNP pour améliorer les avantages de l'utilisation des bus. À partir de 2024, TJNP optimisera les itinéraires et mettra en œuvre des mesures supplémentaires pour encourager les transports à faible émission de carbone.