Management Studies, May-June 2025, Vol. 13, No. 3, 97-104
doi: 10.17265/2328-2185/2025.03.001

A Preliminary Study of Greenhouse Gas Emissions From Transportation in Tainan City Using Google Environmental Insights Explorer (EIE)

Chen Yen-Chieh, Sie Cheng-Syue, Chung Ta Huan
Chia Nan University of Pharmacy and Science, Tainan, Taiwan

In recent years, with the increasing attention to issues related to carbon emissions, such as carbon tariffs and government netzero carbon emission policies, carbon emissions have become an important indicator that is being prioritized by governments worldwide. The Google Environmental Insights Explorer (EIE) tool has been developed to facilitate the collection and integration of data in this context. This study focuses on Tainan City and utilizes EIE to analyze greenhouse gas emissions from transportation. By using EIE, the study obtains data on greenhouse gas emissions from transportation activities in Tainan City. EIE utilizes data collected by Google and simulation functions to estimate data based on actual measurements of transportation activities. This tool saves time and resources by eliminating the need for on-site investigations while providing data that closely represent the real emissions from transportation activities in urban areas. Transportation vehicles contribute to greenhouse gas emissions in two ways: through direct combustion of fossil fuels and through the consumption of electricity in electric vehicles (EVs). The level of greenhouse gas emissions in a city's transportation industry depends on factors such as transportation modes, fuel types, fleet age and energy efficiency, total distance traveled, and annual mileage. EIE estimates the greenhouse gas emissions from Tainan City's transportation industry in 2022 to be 3,320,000 metric tons, including emissions from buses, motorcycles, cars, walking, railways, bicycles, and other modes of transportation.

Keywords: Google Environmental Insights Explorer, transportation industry, greenhouse gas emissions

Introduction

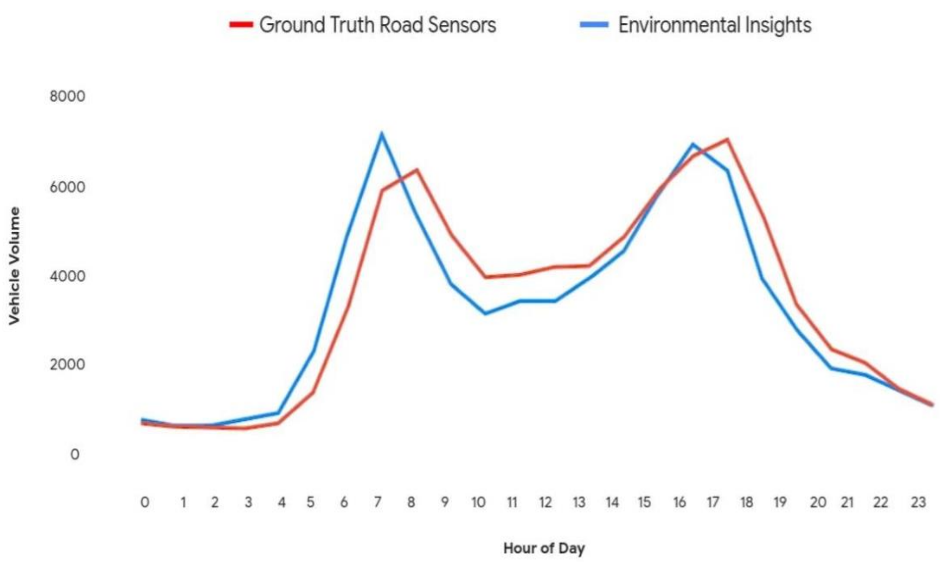
With the increasing severity of global climate change, greenhouse gas emissions have become a focal point of global concern. The transportation sector is one of the main sources of greenhouse gas emissions (EU Commission, 2023; Ahmed, 2023; Wu, Tsou, & Li, 2023). Therefore, studying the impact of transportation on greenhouse gas emissions is crucial for formulating carbon reduction and sustainable development strategies. As an important transportation hub in southern Taiwan (Ko & Cheng, 2021), Tainan City's contribution to

Chen Yen-Chieh, Ph.D., associate professor, Department of Environment Resources Management, Chia Nan University of Pharmacy and Science, Tainan, Taiwan.
Sie Cheng-Syue, Junior, Department of Environment Resources Management, Chia Nan University of Pharmacy and Science, Tainan, Taiwan.
Chung Ta Huan, assistant professor, Department of Tourism Management, Chia Nan University of Pharmacy and Science, Tainan, Taiwan.
Correspondence concerning this article should be addressed to Chung Ta Huan, 60, Sec. 1, Erren Rd., Rende Dist., Tainan City 717301, Taiwan (R.O.C.).

greenhouse gas emissions from transportation cannot be overlooked. Understanding the situation of greenhouse gas emissions from Tainan's transportation sector is significant for developing effective emission reduction policies and measures. This study will use the Google Environmental Insights Explorer (EIE) to conduct a preliminary analysis of greenhouse gas emissions from transportation in Tainan City, providing scientific insights for related decision-making.

Literature Review

The application of the Google Environmental Insights Explorer (EIE) has generated considerable discussion in environmental science research. This tool, based on the Google Earth engine, combines data from multiple sources—such as geolocation records, building outlines, and aerial imagery (Google, 2018)—alongside machine learning techniques to offer detailed information and analyses on various environmental issues worldwide (Chen, 2022). EIE's data can be displayed using two different standards: one that follows the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories (GPC), Section 7.3.1, which accounts for only 50% of cross-boundary trips in total emissions, and another that includes complete trip data (Google, 2018).



Boulder transportation study results showing sample size: 76,560 vehicles, four intersections, three-day period.

Figure 1. Comparison of actual road sensor results and EIE estimates in Boulder, Colorado (Van Groenou, 2019).

Regarding data accuracy, the comparison between actual road sensor results and EIE estimates in Boulder, Colorado (Figure 1) serves as an illustration. Figure 1 shows that the correlation between EIE's estimated traffic volume and the actual traffic volume ranges from 0.91 to nearly 0.99, indicating a high level of accuracy. This suggests that reliable data can be obtained without the need for time-consuming on-site investigations (Van Groenou, 2019).

However, research on greenhouse gas emissions in Tainan's transportation sector lacks preliminary studies using EIE. Therefore, this study aims to fill this research gap by conducting an initial exploration of greenhouse gas emissions from transportation in Tainan City with the EIE tool. The goal is to provide valuable insights for assessing and improving Tainan's transportation system to reduce emissions.

By synthesizing previous research and analyzing the advantages and applications of the EIE tool, this study aims to offer a preliminary research framework for exploring greenhouse gas emissions from transportation in Tainan and other similar cities. The findings will provide scientific support for Tainan's carbon reduction and sustainable development strategies.

Method

This study uses data estimated by EIE for analysis. The EIE estimation process is as follows:

Establishing a Greenhouse Gas Baseline

(1) Define city boundaries and the areas included in the assessment: EIE uses administrative boundaries consistent with Google Maps (Google, 2018).

(2) Collect data on activities within these boundaries: This includes types of energy or fuel consumed (Google, 2018).

(3) Process the data by calculating emissions based on available information within the defined boundaries.

(4) Apply appropriate conversion factors to estimate greenhouse gas emissions.

For example, electricity consumption or fuel usage is converted into greenhouse gas emissions, calculated using emission factors that reflect greenhouse gases emitted by vehicle activities. The greenhouse gases considered include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) (Google, 2018).

EIE does not assess emissions from the following activities: agriculture, forestry, and other land use; industrial processes and product usage; waste and wastewater treatment within or outside the boundaries; transmission and distribution losses (except in Canada); fugitive emissions; aviation and off-road transportation; trips starting and ending outside city boundaries but crossing them; specific emission factors for institutional, industrial, and agricultural buildings; and indirect emissions related to road, off-road, water, and aviation travel (such as electricity used by electric vehicles) (Google, 2018).

Transportation

(1) Greenhouse Gas Emission Methods

Greenhouse gases are mainly emitted in two ways: directly through fossil fuel combustion and indirectly through electricity consumption by electric vehicles. Emission levels depend on factors such as transportation modes, fuel types, total travel distance, and annual mileage.

(2) Calculation Method

First, travel distances for main road categories are considered. Based on these trips, the total fuel consumption is calculated, which is then used to derive the total carbon emissions.

Research Findings and Results

We obtained data from Google EIE on Tainan City's transportation-related carbon emissions for the years 2020, 2021, and 2022, as well as data from the Tainan City Government on greenhouse gas emissions within administrative boundaries for 2020 and 2021. A total of five years of data were analyzed.

The analysis includes total emissions and the data for inbound and outbound trips, categorized by those calculated using the GPC standard and those not using the GPC standard (i.e., complete trips). Differences in these data are explained in the literature review.

Table 1

Estimated Carbon Emissions From Transportation in Tainan City, 2020 (Google, 2024)

Year	2020					
Travel boundary	Total					
Mode of transportation	Bus	Motorcycle	Car	Walking	Rail	Bicycle
Metrics	9,368,512	1,013,712,641	520,890,018	95,562,989	17,123,423	38,227,333
Total distance (km)	375,014,918	4,558,043,872	9,521,178,659	59,099,154	1,714,552,199	80,001,516
GPC distance (km)	216,864,201	4,071,996,095	6,435,214,437	58,859,756	857,276,099.5	76,819,629.5
100,000 tons of CO_2 equivalent (GPC)	228,717.8831	382,135.6338	2,209,337.333	0	0	0
GPC 100,000 tons of CO_2 equivalent (complete journey)	132,263.3277	341,386.536	1,493,256.246	0	0	0
Total emissions by transportation (GPC)	1,970,000					
Total emissions by transportation (complete journey)	2,820,000					
Inbound emissions (GPC)	429,000					
Outbound emissions (GPC)	424,000					
Inbound emissions (complete journey)	858,000					
Outbound emissions (complete journey)	848,000					

Emission unit: metri; Trip unit: trips.

Table 2

Estimated Carbon Emissions From Transportation in Tainan City, 2021 (Google, 2024)

Year	2021					
Travel boundary	Total					
Mode of transportation	Bus	Motorcycle	Car	Walking	Rail	Bicycle
Metrics	7,059,590	1,059,021,326	567,611,077	103,406,772	13,427,743	38,194,354
Total distance (km)	269,951,832	4,602,552,849	10,477,409,799	63,361,507	1,084,893,783	81,678,329
GPC distance (km)	157,617,881.5	4,194,999,958	7,133,575,266	63,361,507	542,446,891.5	78,845,315.5
100,000 tons of CO_2 equivalent (GPC)	164,640.9479	385,867.1614	2,431,225.529	0	0	0
GPC 100,000 tons of CO_2 equivalent (complete journey)	96,129.5844	351,698.89	1,655,307.049	0	0	0
Total emissions by transportation (GPC)	2,100,000					
Total emissions by transportation (complete journey)	2,980,000					
Inbound emissions (GPC)	442,000					
Outbound emissions (GPC)	437,000					
Inbound emissions (complete journey)	884,000					
Outbound emissions (complete journey)	873,000					

Table 3

Estimated Carbon Emissions From Transportation in Tainan City, 2022 (Google, 2024)

Year	2022					
Travel boundary	Total					
Mode of transportation	Bus	Motorcycle	Car	Walking	Rail	Bicycle
Metrics	8,492,801	1,056,188,380	609,048,994	107,128,882	13,709,343	39,837,283
Total distance (km)	350,293,313	4,657,654,654	11,720,826,226	73,558,660	894,785,226	89,724,136
GPC distance (km)	202,555,857	4,272,974,583	7,940,825,154	73,558,660	447,392,613	86,459,171
100,000 tons of CO_2 equivalent (GPC)	213,640.4212	3,904,867,666	2,719,753.497	0	0	0
GPC 100,000 tons of CO_2 equivalent (complete journey)	123,536.8104	3,582,360,979	1,842,624.962	0	0	0
Total emissions by transportation (GPC)	2,320,000					
Total emissions by transportation (complete journey)	3,320,000					
Inbound emissions (GPC)	504,000					
Outbound emissions (GPC)	496,000					
Inbound emissions (complete journey)	1,010,000					
Outbound emissions (complete journey)	992,000					

Table 4

Carbon Emissions From Transportation Within Tainan City's Administrative Boundaries, 2020 (Tainan City Government, 2020)

Year	2020
Category	Traffic
Emissions (10,000 tons)	348.21

Table 5

Carbon Emissions From Transportation Within Tainan City's Administrative Boundaries, 2021 (Tainan City Government, 2021)

Year	2021
Category	Traffic
Emissions (10,000 tons)	340.11

Based on the above tables, it is evident that the data from Google EIE (Tables 1 and 2) tend to underestimate emissions compared to the data collected by the Tainan City Government (Tables 4 and 5). This discrepancy is likely due to differences in how boundaries are defined by Google EIE and the government's administrative boundaries, as well as differences in detailed statistical methods.

In 2021, the number of bus and rail trips estimated by EIE was 7,059,590 and 13,427,743 trips (Table 2), respectively. These figures are lower compared to the 2020 data: 9,368,512 bus trips and 17,123,423 rail trips (Table 1), as well as the 2022 data: 8,492,801 bus trips and 13,709,343 rail trips (Table 3). This reduction in 2021 can be attributed to the widespread local outbreak of COVID-19 and the subsequent Level 3 Alert, which discouraged people from using public transportation like buses and rail. This led to EIE estimating significantly lower figures for 2021 compared to 2020 and 2022. Despite the drop in public transportation trips, the total emissions for transportation in 2021 were still higher at 2,100,000 metric tons (GPC) and 2,980,000 metric tons (complete trips) (Table 2), compared to 1,970,000 metric tons (GPC) and 2,820,000 metric tons (complete trips) in 2020 (Table1). This is likely due to an increase in inbound trip emissions in 2021: 442,000 metric tons (GPC) and 884,000 metric tons (complete trips) (Table 2), compared to 429,000 metric tons (GPC) and 858,000 metric tons (complete trips) in 2020 (Table 1).

In addition, the number of trips by private vehicles such as motorcycles (1,059,021,326 trips) and cars (567,611,077 trips) in 2021 increased compared to 2020. This increase could be due to a shift from public transportation to motorcycles and cars during the pandemic. Since rail emissions per million metric tons of CO_2 equivalent were zero, the transition of users from rail to motorcycles or cars likely contributed to the overall rise in emissions.

In 2022, the number of bus and rail trips was 8,492,801 and 13,709,343 trips (Table 3), respectively, which shows a difference from 2020's 9,368,512 bus trips and 17,123,423 rail trips (Table 1). This discrepancy may result from the underestimation of total rail trips in 2021 (13,427,743 trips) (Table2), as EIE's 2022 estimates were likely based on the 2021 data. However, the slight rebound in bus and rail trips in 2022 compared to 2021 suggests that the peak of the pandemic had passed, and people were gradually returning to public transportation as their primary travel mode.

For private vehicles in 2022, the number of trips by motorcycles and cars was 1,056,188,380 and 609,048,994 trips (Table 3), respectively. Compared to 2021's figures (1,059,021,326 trips for motorcycles and 567,611,077 trips for cars, Table 2), motorcycle trips decreased slightly while car trips increased. This shift suggests that some motorcycle users in 2021 switched to cars in 2022, possibly reflecting increased car ownership. This pattern is also reflected in the EIE estimates.

Additionally, the number of car trips in 2021 (567,611,077 trips, Table 2) was higher than in 2020 (520,890,018 trips, Table 1). During the pandemic, while global car sales rebounded in 2021 (as shown in Figure 2), Taiwan's car market experienced a slight decline (Figure 3). The increase in EIE's car trip estimates in 2021 may be influenced by both global and local market trends. If Taiwan's car market had not declined, the number of car trips might have been even higher.

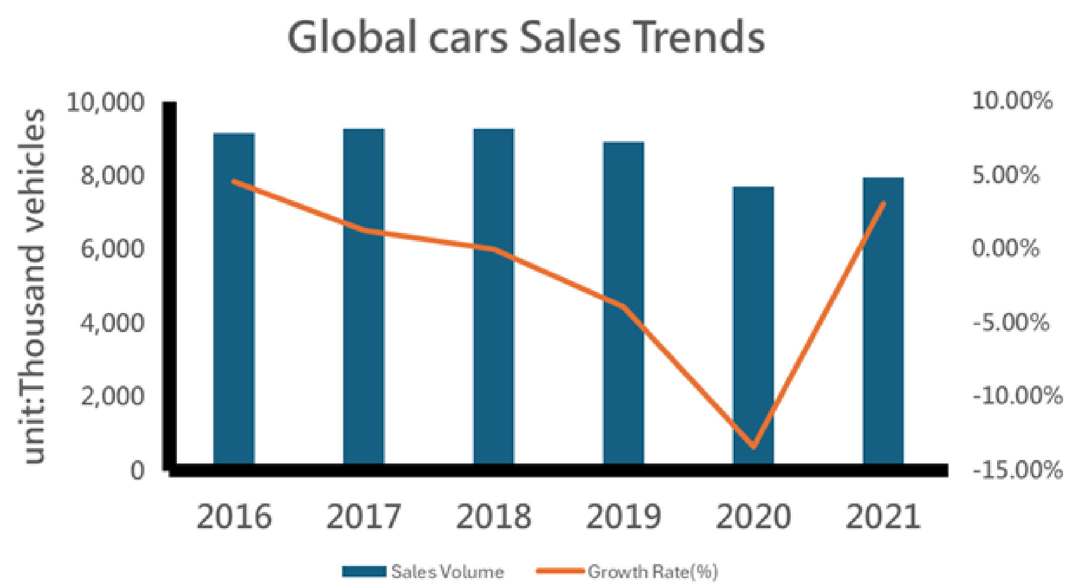


Figure 2. Global cars sales trends (HSU, 2021).

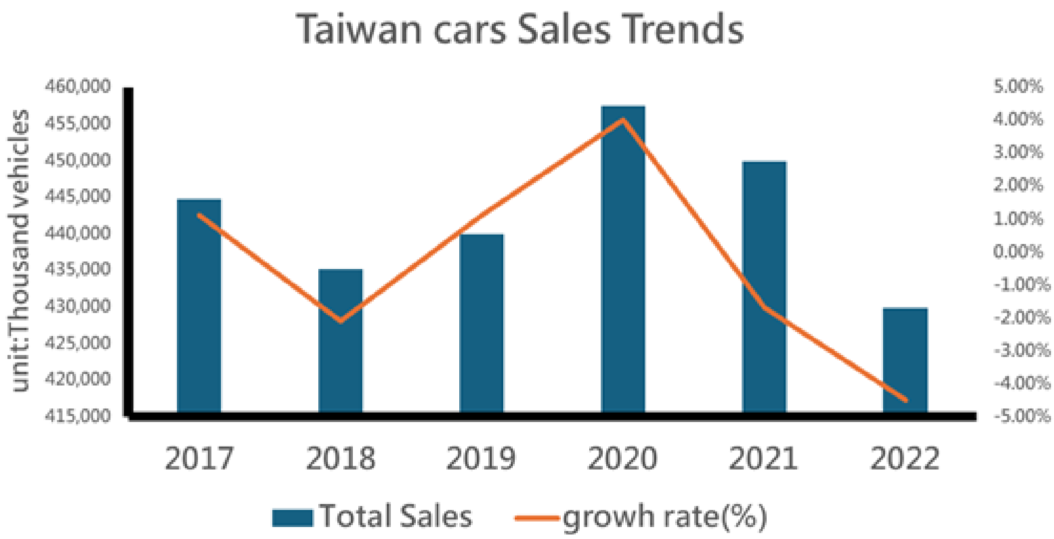


Figure 3. Taiwan cars sales trends (Liao, 2023).

The total emissions from transportation have shown a continuous increase each year. In 2022, the emissions reached their highest values: 2,320,000 metric tons (GPC) and 3,320,000 metric tons (complete trips) (Table 3). However, despite a slight decrease in motorcycle trips in 2022 (1,056,188,380 trips, Table 3) compared to 2021 (1,059,021,326 trips, Table 2), the total travel distance in 2022 was higher at 4,657,654,654 kilometers (Table 3). This increase in total distance contributed to the estimated rise in total transportation emissions for 2022.

Conclusion

The number of bus and rail trips in 2021 was lower compared to 2020 and 2022. This reduction is likely due to the local outbreak of COVID-19 in 2021 and the implementation of Level 3 Alert, which discouraged people from using public transportation. Bus and rail trips in 2020 were higher than in 2022, which may have affected EIE's estimation for 2022 due to the lower figures recorded in 2021. However, the bus and rail trips in 2022 rebounded compared to 2021, possibly because the peak of the pandemic had passed, and people resumed choosing public transportation as a primary mode of travel.

In terms of car and motorcycle trips, 2020 recorded the lowest figures, while 2021 and 2022 showed varying changes. Motorcycle trips were higher in 2021 compared to 2022, while car trips increased in 2022 compared to 2021. This shift may be attributed to some public transportation users switching to motorcycles or cars, as well as some motorcycle users transitioning to car ownership in 2021. The upward trend in global car sales also influenced this pattern.

Total emissions from transportation increased every year, reaching their peak in 2022. This suggests that despite fluctuations in trip numbers, the overall distance traveled and other factors contributed to the steady rise in emissions.

The study finds that EIE data are influenced by events and global trends specific to each year, allowing for insights into the factors affecting emissions. However, when comparing EIE data with the Tainan City Government's data, significant discrepancies were observed, complicating the analysis. If EIE continues to evolve and collaborates with more cities, its accuracy and reliability are expected to improve, enabling comprehensive data analysis to fully leverage this system in the future.

References

Ahmed, J. (2023). Mapped: World's biggest polluting countries as Cop28 gets underway. *The Independent*. Retrieved from https://www.independent.co.uk/climate-change/most-polluting-countries-cop28-b2455704.html

Chen, Y.-C. (2022). Google to launch an environmental sustainability platform in Taiwan, environmental insights explorer. Retrieved from https://taiwan.googleblog.com/2022/11/TWEIE.html

EU Commission. (2023). EDGAR database: EU's emissions keep falling, as post-COVID rebound in world emissions continues, News announcement. Retrieved from https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/edgar-database-eus-emissions-keep-falling-post-covid-rebound-world-emissions-continues-2023-10-19_en

Google. (2018). Environmental insights explorer. Calculation method. Retrieved from https://insights.sustainability.google/methodology?hl=zh-TW

Google. (2024). Environmental insights explorer. Retrieved from https://partnerdash.google.com/apps/environmental-insights/places/ChIJG3R6elFDbjQRNypzVEqiJkg?a=1491746025

Hsu, C.-W. (2021). In 2021, the global car market rebounded, with automobile sales recovering from their lowest point. Retrieved from https://www.artc.org.tw/tw/knowledge/articles/13638

Ko, M.-H., & Cheng, H.-H. (2021). The changes of Tainan urban axis under the modern transformation. *Journal of Architecture, 116*, 81-103.

Liao, C.-H. (2023). Declining demand, electric vehicles grow against the trend, influencing automakers' product strategies. Retrieved from https://www.credit.com.tw/NewCreditOnline/Epaper/IndustrialSubjectContent.aspx?sn=359&unit=559

Tainan City Government. (2021). Urban carbon disclosure: Greenhouse gas emissions within administrative boundaries. Retrieved from http://tainan.carbon.net.tw/P_uncover.aspx

Tainan City Government. (2022). Greenhouse Gas Inventory. Retrieved from https://epb2.tnepb.gov.tw/carbon-zero/mode02.aspx?boss=20240911132004655

Van Groenou, S. (2019). Accelerating city climate action with high resolution geospatial data. Retrieved from https://medium.com/google-earth/accelerating-city-climate-action-with-high-resolution-geospatial-data-f7b489c9e9f6

Wu, Y.-C., Tsou, M.-H., & Li, S.-C. (2023). Post-pandemic global carbon emissions show a two-track trend: The EU suppresses rebound, while global emissions continue to rise. Retrieved from https://e-info.org.tw/node/238132