Original Research Article

Effectiveness of Reducing Greenhouse Gases (CO_2, CH_4, and N_2O) in Motorized Vehicle to Train Modes

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Abstract

Greenhouse gases, which contribute to the greenhouse effect, are present in the atmosphere, with the increasing number of vehicles directly impacting the emission of greenhouse gases such as CO2, CH4, and N2O. Transportation activities significantly influence the concentration of greenhouse gases in the air. This study seeks to assess the potential reduction in greenhouse gas emissions (CO2, CH4, and N2O) by transitioning from motorized vehicles to mass rail transportation and to forecast the resulting reduction in greenhouse gas emissions for the upcoming year. The study involved modelling train travel to estimate the greenhouse gas emissions associated with local train routes. Surveys were distributed to potential local train passengers in Operational Area VIII Surabaya, specifically at Gubeng Station. Surabaya, the second-largest city in Indonesia, serves as a metropolitan centre for government, trade, industry, business, education, and tourism. The 2030 projection estimated the CO2e value at 19,633,418 tonnes, reflecting a mere 12.65% increase from the baseline year. Greenhouse gas emissions modelling relied on manual data processing using the basic Tier-1 formula. The modelled greenhouse gas emissions for four local train routes in Daop VIII Surabaya displayed significant emissions, with the CO2e amounting to 297,183 kg for the Commuter Train, 852.15 kg for the Penataran Train, 936,964 kg for the KRD, and 827,561 kg for the Dhoho Railway.

Key Words: Greenhouse Gases (GHG); CO2; CH4; N2O; vehicle activity; shifting

1. Introduction

Greenhouse gases (GHGs) are gaseous compounds in the Earth's atmosphere that trap heat, contributing to the greenhouse effect. This effect is the leading cause of global warming and climate change (Kweku et al., 2018). Essential greenhouse gases include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and fluorinated gases. These gases originate from various sources, including fossil fuel combustion, industrial processes, agriculture, and waste management. The increased concentration of GHGs in the atmosphere has led to significant environmental impacts, such as rising global temperatures, melting polar ice caps, sea-level rise, and more frequent extreme weather events (IPCC, 2014). Greenhouse gases (GHGs) are atmospheric gases that trap heat, contributing to the greenhouse effect, leading to global warming and climate change. The primary GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases. These gases originate from various sources, including fossil fuel combustion, industrial processes, agriculture, and waste management. The increasing presence of greenhouse gases in our atmosphere is causing significant environmental changes, such as higher global temperatures, melting polar ice, rising sea levels, and increasing extreme weather events (IPCC, 2014).

In Indonesia, GHG emissions are particularly pressing due to the country's unique environmental and socio-economic context. Indonesia is one of the world's largest emitters of CO_2, primarily due to deforestation, peatland degradation, and extensive use of fossil fuels. The destruction of forests and peatlands, which act as significant carbon sinks, releases vast amounts of stored carbon into the atmosphere. Additionally, Indonesia's rapid economic development and urbanization contribute to increasing energy consumption and GHG emissions (BAPPENAS, 2015). To mitigate the impact of GHGs, Indonesia has implemented various strategies, including shifting to more sustainable practices and technologies. One effective method is moving from high-emission energy sources, such as coal and oil, to renewable energy sources like solar, wind, and hydropower. This transition reduces GHG emissions and promotes energy security and sustainable development (Gürsan & de Gooyert, 2021). Furthermore, adopting energy-efficient technologies and practices in industries, transportation, and residential sectors is crucial in lowering emissions. For instance, promoting public transportation, enhancing fuel efficiency standards, and supporting electric vehicles are critical measures in the transportation sector (Indonesia, 2017).

In conclusion, addressing GHG emissions is vital for mitigating climate change and its associated impacts. Indonesia's efforts to reduce emissions through shifting to sustainable energy sources and enhancing energy efficiency demonstrate a commitment to environmental sustainability. Continuous monitoring, policy support, and international cooperation are essential to significantly reduce GHG emissions and build a resilient, low-carbon future (Andrieu & Saint Pierre, 2012). Greenhouse gases (GHGs) are crucial contributors to global warming and climate change. The transportation sector represents a significant source of greenhouse gas (GHG) emissions, attributable to the release of various GHGs, which include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These emissions originate from motor vehicles, diesel engines, and rail transport, which heavily depend on fossil fuels (EPA, 2020). Types of GHG Emitted by Transportation can be defined by type of the motor machine; Motor vehicles, such as cars and trucks, primarily emit CO_2 due to fuel combustion. In addition, they release smaller amounts of CH_4 and N_2O from fuel evaporation and other combustion processes. Diesel engines, commonly used in trucks and buses, are notable for emitting higher levels of N_2O and particulate matter alongside CO_2. While rail transport is more efficient in terms of emissions per ton-mile than road transport, it still contributes to greenhouse gas emissions predominantly through diesel locomotives (ICCT, 2015).

Numerous methods for reducing greenhouse gas (GHG) emissions, including modal shifting. Transitioning to more sustainable and low-emission alternatives is essential for addressing emissions from these sources (Bakker et al., 2019). This strategy, referred to as "modal shifting," entails moving from high-emission transportation modes to more environmentally friendly options. For example, promoting public transportation, increasing the use of electric vehicles (EVs), and enhancing infrastructure for cycling and walking can significantly reduce GHG emissions from the transportation sector (IEA, 2019). The anticipated benefits of implementing such changes are substantial. On an individual level, transitioning to electric vehicles or using public transportation can effectively reduce personal carbon footprints and lead to savings in fuel and maintenance costs (Le & Nguyen-Phung, 2024). On a broader scale, governments investing in sustainable transportation infrastructure can significantly decrease national greenhouse gas emissions, enhance air quality, and improve public health. Moreover, these measures can contribute to energy security by reducing dependence on fossil fuels and promoting using renewable energy sources (UNFCCC, 2015). The benefits of shifting on different scales, including individual and government. The benefit of the individual scale is reducing carbon footprints. Individuals can significantly reduce their carbon emissions by adopting electric vehicles or public transportation. Cost Saving: Electric cars generally have lower operating and maintenance costs than internal combustion engines. Health Benefits: Reduced air pollution from fewer combustion engines can lead to better respiratory health and lower incidences of related diseases (EEA, 2016).

The benefit of government scale is that emission reduction in large-scale infrastructure projects, such as expanding electric public transit systems, can lead to substantial GHG reductions (Carroll, Caulfield, & Ahern, 2019). Economic benefits can include investments in green infrastructure to create jobs and stimulate economic growth. Energy security may be Reduced reliance on imported fossil fuels, and increasing the use of domestic renewable energy sources can enhance national energy security (Bank, 2017).

Shifting towards sustainable transportation methods presents a viable and effective strategy for reducing GHG emissions. The combined efforts of individuals and governments can lead to significant environmental, economic, and health benefits, fostering a sustainable future for future generations (Björk, Vierth, & Cullinane, 2023). The increasing concern regarding greenhouse gas (GHG) emissions has prompted extensive research into methods to mitigate these emissions, particularly within the transportation sector. One promising approach is the transition from individual vehicle use to public transportation. This modal shift aims to reduce the number of vehicles on the road, lowering GHG emissions and enhancing air quality (Kwan & Hashim, 2016). Several studies have evaluated the effectiveness of this strategy, shedding light on certain limitations and areas for improvement (Banister, 2008). Research on Modal Shifting; A study by Bailey, Mokhtarian, and Little (2008) examined the potential GHG reductions achievable through increased public transportation use in urban areas. The researchers focused on data from major U.S. cities and employed a simulation model to estimate emissions reductions under different scenarios of public transit adoption. They found that significant reductions in CO_2 emissions could be achieved if a substantial proportion of the population switched from private vehicles to public transit. The study also underscored the importance of integrating public transportation with other sustainable modes, such as cycling and walking, to maximize environmental benefits (Bailey, Mokhtarian, & Little, 2008).

Conversely, Wang, Li, and Zhang (2016) conducted a comprehensive study in Beijing, China, evaluating the impacts of modal shift policies on GHG emissions. The research utilized empirical data and modelling techniques to assess the effectiveness of various policies promoting public transportation. Their findings supported the potential for substantial emissions reductions but also identified significant barriers, such as the existing infrastructure's inadequacy to handle increased public transit usage and the need for behavioural changes among the population (Wang, Li, & Zhang, 2016).

Comparative Analysis of Studies; Bailey et al. (2008) provided a broad analysis covering multiple urban areas, offering a general perspective on the benefits of modal shifting. The study included public transportation modes like buses, trams, and subways. The automation in their methodology involved using simulation models to predict outcomes based on different adoption scenarios. However, one of the critical limitations identified was the assumption that public transportation systems would have the capacity to handle increased demand without significant infrastructure upgrades, which might only sometimes be the case (Doll & Balaban, 2013).

In contrast, Wang et al. (2016) offered a more localized analysis with a focus on Beijing. This study employed a detailed empirical approach, examining real-world data to validate their models. The automation in their research was evident through advanced data analytics and modelling tools to simulate the impact of policy changes. A notable limitation in this study was addressing behavioural barriers and public acceptance, which are critical for the success of modal shift policies but need to be fully accounted for in the models. Discussion of Research Gaps; Both studies underscore the potential of modal shifting to reduce GHG emissions but highlight crucial areas needing further research. Bailey et al. (2008) point out the necessity for infrastructure investments to support increased public transportation use. Similarly, Wang et al. (2016) emphasize the need for comprehensive policies that address both infrastructure and behavioural aspects to achieve effective modal shifts. Future research should integrate these elements, ensuring that public transportation systems can accommodate increased demand and align with public preferences and behaviours.

While shifting from individual vehicle use to public transportation presents a viable strategy for reducing GHG emissions, it requires a multifaceted approach. Addressing infrastructure and behavioral barriers is essential for realizing this method's full potential. Continued research and investment in sustainable transportation infrastructure and policies are critical to reducing emissions (Kazancoglu, Ozbiltekin-Pala, & Ozkan-Ozen, 2021). A 15-day research study was conducted to analyze the potential reduction of greenhouse gas (GHG) emissions by studying the number of train users who transitioned from private to public transportation. The study considered the different types of train propulsion, including diesel, electric, and coal engines, each of which emits different GHG compounds. The research focused on a city area with a service coverage of approximately 720 km.

2. Methods

2.1 Case Study Site

This research area was carried out in Operation Area VIII Surabaya which serves the people of Surabaya City and areas around Surabaya City for short and long-distance train travel. The trains operating in Operation Area VIII Surabaya are diesel-engine trains that use diesel fuel. The following is a table listing local trains operating in Operation Area VIII Surabaya from 2011 to 2015. Table 1 is a table that explains the names of trains operating at Gubeng station, the routes taken along with the length of the route, and the total number of passengers using train services from 2011 to 2015.

Table 1. Information on trains operating at Gubeng Station in 2011 - 2015

Train Name	**Dhoho Railway**	**Bojonegoro Diesel Train (KRD)**	**Commuter Railway**	**Tumapel Railway**	**Penataran Train**
Route	Surabaya – Blitar / Blitar – Surabaya	Surabaya – Bojonegoro / Bojonegoro – Surabaya	Surabaya – Sidoarjo / Sidoarjo – Surabaya	Surabaya – Malang / Malang – Surabaya	Surabaya – Malang / Malang – Surabaya
Route Length	**149 Km**	**109,28 Km**	**30,175 Km**	**91,8 Km**	**91,8 Km**
Year	Total passenger				
2011	3,006,432	606,199	624,159	192,857	9,115
2012	3,130,598	610,068	616,097	194,096	9,116
2013	3,055,251	598,563	613,316	211,302	9,049
2014	3,079,376	619,438	596,744	190,919	9,199
2015	3,185,382	620,675	637,451	206,641	9,251

2.2 Questionnaire Survey

This research uses a questionnaire method aimed at prospective local train passengers in Operation Area VIII Surabaya who are shifting implementers, passengers who transfer vehicle use from motorized vehicles to trains with a fixed frequency. The survey was conducted five days from 06.30 am to 6.00 pm; most train passengers were people outside Surabaya who traveled to Surabaya for education or work. The following is a table of survey results conducted on prospective passengers at Gubeng Station.

Table 2. Recapitulation of passengers by gender

Gender	**Amount**	**Percentage (%)**
Man	184	68
Woman	87	32
Total	271	100

Percentage of the number of people shifting passengers based on gender. A total of 271 questionnaires were distributed to prospective passengers; 184 respondents were male, and the remaining

87 respondents were female. The percentage of male respondents is 68% and females 32%, so the interest in shifting male passengers is greater than that of female passengers.

Table 3. Recapitulation of passengers by age

Age	Amount	Percentage (%)
<21	51	18.8
21-30	41	15.1
31-40	35	13
41-50	84	31
51-60	41	15.1
>60	19	7
Total	271	100

The results of the passenger shifting questionnaire based on age showed that the highest percentage was generated from passengers aged 41-50 years at 31%, with a total of 84 respondents. Meanwhile, the smallest percentage of passengers was over 60 years old, with a percentage of 7% and 19 respondents.

Tabel 4. Recapitulation of passengers by type of work

Work	Amount	Percentage (%)
Student/Students	73	26
Businessman	27	10
Government employees	13	5
Private employees	75	11
TNI/Polri	28	28
Retired	22	8
Etc	33	12
Total	271	100

Percentage results of the number of shifting passengers based on their work. The number of respondents who work as private sector employees is the most significant percentage, namely 28%, with 75 respondents. The number of respondents with student work types is similar to the number of private sector employee respondents, namely 73 people with a percentage of 26%. The smallest percentage was respondents with civil servant work, namely 5% of the total respondents, 13 people.

From all the questionnaires obtained, the results show that work, gender, and age influence interest in shifting activities. A questionnaire conducted at Gubeng Station in Surabaya shows that interest in shifting motorized vehicles is greater among male prospective passengers. Regarding age demographics, interest in vehicle shifting predominantly emanates from individuals within the 41-50 age bracket. Regarding occupational profiles, the predominant interest in vehicle shifting is evident among individuals employed in the private sector.

Table 5. Recapitulation of passengers shifting from vehicle into train

Vehicle Before Switching	Dhoho Railway		Bojonegoro Diesel Train (KRD).		Commuter Railway		Tumapel Railway		Penataran Train	
	Shifting	%	Shifting	%	Shifting	%	Shifting	%	Shifting	%
Bus	8	50	16	40	31	38.75	20	24.701	27	50
Car	3	18.75	8	20	17	21.25	35	43.209	8	14.8148
Motorcycle	5	31.25	16	40	32	40	26	32.09	19	35.185
Amount	16	100	40	100	80	100	81	100	54	100

The percentage results of the number of shifting passengers to motorized vehicles used, and the percentage results of the types of vehicles used by prospective train passengers are varied. For the Dhoho Railway, the highest percentage is for using buses, namely 50% as a means of transportation, while the lowest is for using cars at 18.75%. For the Bojonegoro Diesel Train (KRD), the highest percentage uses buses and motorbikes, namely 40%, and the remaining 20% The rest are motorbike users. For Commuter Trains, the highest percentage is motorbike use at 40%, while the lowest is car use at 21.25%. For the Tumapel Railway, the highest percentage was car use at 43.209%, while the lowest was bus use at 24.701%. For the Penataran Train, the highest percentage was by bus at 50%, while the lowest was car use at 14.8148%. Of course, not all correspondents shift. The survey results show that the percentage of shifting actors for KA Dhoho, KRD, KA Komuter, KA Tumapel, and KA Penataran is 56.3%, 72.5%, 42.045%, 80.89%, and 42.59%, respectively.

Interviews with train passengers were conducted to determine the reasons for using trains as a means of transportation. The positive answers from shifting operators were due to avoiding traffic jams and saving travel time. Meanwhile, the negative answer from those who shifted was that purchasing tickets for local trains still could not be accessed online, and comfort was one of the factors considered by prospective train passengers, predominantly female prospective passengers.

Based on the questionnaire survey results of prospective passengers who switched from motorized vehicles to trains at Gubeng Station in Surabaya, it can be concluded that several factors, such as gender, age differences, and type of work, influence interest in switching vehicles. Especially in the 20-50-year age range, where individuals are in their productive years as students or workers who require punctuality. The majority of interest in vehicle shifting occurs among male passengers aged 41-50 years with the type of work as private employees. The transition from motor vehicle use to trains by society will impact air quality. The greater the number of switches that occur, the fewer motorized vehicles will operate on the road, reducing gas emissions released into the air (Beşer, Tütüncü, Beşer, & Magazzino, 2024).

2.3 Contribution of Transportation to Greenhouse Gas Emission

The transport sector is a significant contributor to global greenhouse gas (GHG) emissions, thereby substantially impacting climate change. This sector is the primary source of GHG emissions within the United States, representing approximately 29% of the total emissions in 2021. Road transport, including cars and trucks, dominates this sector, contributing three-quarters of transportation emissions, according to the US Environmental Protection Agency (EPA) (Chapman, 2007). Globally, the transportation sector accounts for about 20% to 24% of carbon dioxide emissions, with road transport being the major contributor. Aviation and maritime transportation also contribute to GHG emissions, although to a lesser extent than road transport, according to Transport Geography and the United Nations Environment Programme (UNEP) (Blok et al., 2011). The decarbonization of the transportation sector poses significant challenges due to the technical limitations of current alternatives to fossil fuels. For example, hydrogen and battery technology have limited energy density, making it difficult to power large vehicles like trucks, ships, and planes. Developing and implementing new technologies that can offer high energy density is essential to reduce GHG emissions effectively in the transportation sector, according to Our World in Data.

Efforts to decrease GHG emissions from transportation include improving fuel efficiency, increasing the use of renewable fuels, and implementing stricter emissions standards for vehicles (Bleviss, 2021). The United States Environmental Protection Agency (US EPA) has implemented standards to reduce billions of metric tons of greenhouse gas (GHG) emissions by enhancing vehicle efficiency and diminishing reliance on oil (Eom, Schipper, & Thompson, 2012). The US EPA has established standards that are expected to reduce billions of metric tons of GHG emissions by improving vehicle efficiency and reducing dependence on oil. The EPA's standards for greenhouse gas emissions from passenger cars and trucks, for example, are expected to cut over six billion metric tons of GHG emissions through 2025. Furthermore, global initiatives like the Renewable Fuel Standard program aim to expand the use of renewable fuels, which can help to mitigate the environmental impact of the transportation sector, according to the US EPA (Bracmort, 2018).

Moreover, shifting the transportation sector towards more sustainable practices is essential to reduce GHG emissions and address other environmental and health impacts associated with transportation, such as air pollution, which is a significant cause of premature deaths worldwide, according to UNEP. There are many ways to achieve this, including implementing low-carbon transportation policies, promoting public transportation, and incentivizing the use of electric vehicles (Mun Ng, Wah Yuen, Chuen Onn, & Ibtishamiah Ibrahim, 2024). In summary, the transportation sector is a critical area that requires action to address climate change. Technological advancements and regulatory policies offer opportunities for reducing GHG emissions in this sector. However, a comprehensive approach involving both technological advancements and policy implementations is essential to achieve substantial reductions in GHG emissions.

2.4 The Effect of Shifting Motor Vehicle Modes to Trains

When individuals switch from motorized vehicles to trains, the number of vehicles operating on the road will decrease. So this affects the number of vehicles that cause gas emissions from burning fossil materials or diesel, such as carbon dioxide (CO_2), nitrogen oxide (NO_x), methane (CH_4), and (N_2O) Nitrous Oxide, logically the use of vehicles in transporting passengers in large numbers in one destination compared to individual motorized vehicles (Yap, Correia, & Van Arem, 2016). With shifting, the use of trains will transport more people with a lower number of emissions released per passenger compared to the use of individual private vehicles (Islam, Ricci, & Nelldal, 2016). Many rail systems use more efficient energy sources, such as electricity or diesel, than the internal combustion engines used in typical motorbikes. This can reduce direct emissions associated with transportation. Compared to transportation networks, rail infrastructure often uses land more efficiently. As a result, the amount of land needed for roads can be reduced, thereby reducing the negative impact on the environment due to the growth of transportation infrastructure. Increased demand for rail transportation could encourage the development of more environmentally friendly rail technology, such as using alternative fuels or more effective rail lines (Chester, Horvath, & Madanat, 2010).

3. Results and Discussion

3.1 Reducing Greenhouse Gases (CO_2) From Motorized Vehicles by Trains

3.1.1 Preliminary Data on Reduction in Greenhouse Gas emissions due to Shifting

Through existing calculations and data provided, results will be obtained from reducing GHG emissions by changing the use of motorized vehicles to trains for each parameter

Table 6. Recapitulation of the Percentage of Transportation Used Along with the Total Number of Shifting Participants

Transportation Type	Percentage (%)
Bus	50%
Car	18.75%
Motorcycle	31.25%
Total passenger	3.185.382
Number of Shifters	1.791.777
Percentage of passengers who shift	56.3%

Table 7. Recapitulation of GHG emission calculations for Each Train Passenger

Train Name	Emission CO_2 (tons)	Equivalent CH_4 emissions (tons)	Equivalent N_2O emissions (tons)	Indication of GHG Emission Reduction (tons)
Dhoho	13,185.173	164.154	198.438	13,547.76
Commuting	380.837	4.681	5.647	391.15
Tumapel	736.072	8.919	10.709	775.70
Penataran	18.206	0.227	0.274	18.71
KRD	2,642,884	32,.557	39.143	2,714.58
Total	16,963,161	210.537	254.210	17,427.91

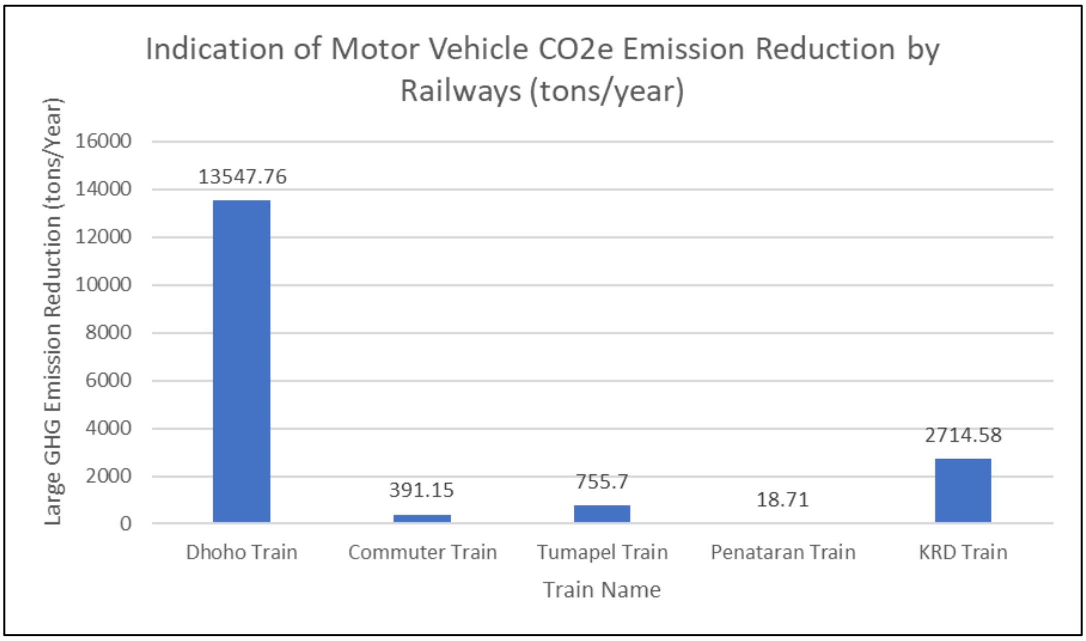

Figure 1. Bar chart indication of motor vehicle co_2e emission reduction by railways

The calculation graph indicating CO2e emission reductions shows the value of GHG emission reductions resulting from train passenger shifting activities. The Dhoho Train on the Surabaya-Blitar route of 149 km has a total of 3,185,382 passengers with a shifting percentage of 56.3%, resulting in a CO2e GHG emission reduction value of 13,547.76 tons/year. The Commuter Train has 637,451 passengers and a passenger shifting percentage of 42.045%. The train with the Surabaya-Sidoarjo route, which is 30.76 km, produces a reduction in GHG CO2e emissions of 391.15 tons/year. The Tumapel Train and the Penataran Train have the same travel route, namely Surabaya to Malang, a distance of 91.8 km. The Tumapel Train has 206,641 passengers, with a percentage of shifting actors of 80.89%.

In contrast, the Penataran Train has fewer passengers, namely only 9,251 people, with a percentage of shifting actors of 42.59%. These two trains' GHG emission reduction value is 755.70 tons/year and 18.71 tons/year respectively. The Diesel Rail Train (KRD) on the Surabaya-Bojonegoro route, with a distance of 109.28 km, has a total of 620,675 passengers with a shifting percentage of 72.5%, resulting in a reduction in GHG CO2e emissions of 2,714.58 tons/year. Upon analyzing the data, it was determined that the passenger shifting activity of the Dhoho Train contributed to a substantial reduction in emissions, with a calculated CO2e of 13,547.76 tons/year. In contrast, the passenger shifting activity on the Penataran Train resulted in a notably smaller emission reduction, with a recorded CO2e of 18.71 tons/year. The Dhoho train has the most significant number of passengers among other trains, namely 3,185,382, with a total of 1,791,777 people shifting. The Dhoho Railway also has the longest travel route, which is 149 km long, so the Dhoho Railway produces the most significant GHG emission reduction value. The most minor reduction in GHG emissions results from passenger shifting activities on the Penataran Train. The number of passengers on the Penataran Railway is 9,251 people, with a total of 3,940 shifting operators, resulting in a reduction in CO_2e emissions of 18.71 tons/year. The Penataran Train, which covers a distance of 91.8 km, exhibits the most marginal reduction in greenhouse gas (GHG) emissions despite travelling 30.76 km further than the Commuter Train. This reduction is influenced by various factors, including the spatial distribution of passengers and the calculations derived from the number of passengers, shifting percentages, distance covered by the trains, and the spatial arrangement of stations if using highways. The remainder of the combustion of fuel oil used by motorized vehicles is the primary source of CO_2 emissions (Carroll et al., 2019). This is proven by the fact that total CO_2 emissions are the most dominant among the other parameters. The CO_2 emission factor, according to IPCC, 1996 is the highest for each type of vehicle, thus influencing the calculation results.

3.2 Greenhouse Gas Emission Reduction Projections

The data in Table 8 is a projection of train passengers in the operating area; data for 2011 - 2015 was obtained from secondary data, and for 2016 - 2030 data is projection data, which is a data description of the increase in passengers for each type of train fleet operating up to the next 15 years.

Table 8. Calculation results of local train passenger projections in operation area

Year to-	Year	Dhoho Train	Commuter Train	Penataran Train	Tumapel Train	KRD
1	2011	3,006,432	624,159	5,816	192,857	606,199
2	2012	3,130,598	616,097	5,816	194,096	610,068
3	2013	3,055,251	613,316	8,949	211,302	598,563
4	2014	3,079,376	596,744	7,458	190,919	619,438
5	2015	3,185,382	637,451	9,251	206,641	620,675
6	2016	3,183,411	619,723	10,012	206,480	622,485
7	2017	3,214,079	620,446	10,863	208,919	626,317
8	2018	3,244,747	621,169	11,714	211,359	630,150
9	2019	3,275,415	621,892	12,565	213,798	633,982
10	2020	3,306,082	622,615	13,416	216,237	637,814
11	2021	3,336,750	623,338	14,268	218,676	641,646
12	2022	3,367,418	624,061	15,119	221,115	645,478
13	2023	3,398,086	624,784	15,970	223,554	649,311
14	2024	3,428,754	625,508	16,821	225,993	653,143
15	2025	3,459,421	626,231	17,672	228,432	656,975
16	2026	3,490,089	626,954	18,524	230,871	660,807
17	2027	3,520,757	627,677	19,375	233,310	664,639
18	2028	3,551,425	628,400	20,226	235,750	668,472
19	2029	3,582,093	629,123	21,077	238,189	672,304
20	2030	3,612,760	629,846	21,928	240,628	676,136

After obtaining passenger projections in 2030, to search the projected value of GHG emission reduction for that year uses a formula reducing previous GHG emissions by changing the number of shifting actors using the multiplication result of the percentage of shifting perpetrators with the results projections that have been obtained.

Table 9. Projected GHG emission reduction value 2015-2030 Dhoho Railway

Year	Total Passenger	CO_2 (ton/year)	CH_4 (ton/year)	CH_4 Equivalent (ton/year)	NO_2 (ton/year)	NO_2 Equivalent (ton/year)	CO_2e (ton/year)
2015	3,185,382	13,185.173	6.566	164.154	0.666	198.438	13,547.764
2016	3,183,411	13,177.015	6.562	164.052	0.665	198.315	13,539.382
2017	3,214,079	13,303.957	6.625	165.633	0.672	200.226	13,669.816
2018	3,244,747	13,430.900	6.689	167.213	0.678	202.136	13,800.249
2019	3,275,415	13,557.842	6.752	168.794	0.685	204.047	13,930.682
2020	3,306,082	13,684.785	6.815	170.374	0.691	205.957	14,061.116
2021	3,336,750	13,811.727	6.878	171.954	0.698	207.868	14,191.549
2022	3,367,418	13,938.670	6.941	173.535	0.704	209.778	14,321.982
2023	3,398,086	14,065.612	8.848	221.205	0.710	211.688	14,498.505
2024	3,428,754	14,192.555	7.068	176.696	0.717	213.599	14,582.849
2025	3,459,421	14,319.497	7.131	178.276	0.723	215.509	14,713.283
2026	3,490,089	14,446.439	7.194	179.857	0.730	217.420	14,843.716
2027	3,520,757	14,573.382	7.257	181.437	0.736	219.330	14,974.149
2028	3,551,425	14,700.324	7.321	183.017	0.742	221.241	15,104.583
2029	3,582,093	14,827.267	7.384	184.598	0.749	223.151	15,235.016
2030	3,612,760	14,954.209	7.447	186.178	0.755	225.062	15,365.449

Table 9 is an example of a reduced GHG emissions calculation due to shifting the vehicle modes of cars, motorbikes, and motorized vehicles for the parameters CO_2, CH_4, CH_4 equivalent, NO_2, NO_2 equivalent, and CO_2e in units of tons/year.

Table 10. Projection of overall GHG emission reduction value 2015-2030

Year	CO_2e DHOHO (ton)	CO_2e KOMUTER (ton)	CO_2e TUMAPEL (ton)	CO_2e PENATARAN (ton)	CO_2e KRD (ton)	Total (ton)
2015	13,547.764	391.155	755.699	18.707	2,714.584	17,427.908
2016	13,539.382	380.276	755.111	20.245	2,722.501	17,417.515
2017	13,669.816	380.720	764.031	21.966	2,739.261	17,575.794
2018	13,800.249	381.164	772.951	23.687	2,756.022	17,734.073
2019	13,930.682	381.608	781.871	25.409	2,772.782	17,892.352
2020	14,061.116	382.051	790.791	27.130	2,789.543	18,050.631
2021	14,191.549	382.495	799.711	28.851	2,806.303	18,208.909
2022	14,321.982	382.939	808.631	30.572	2,823.064	18,367.188
2023	14,498.505	383.382	817.551	32.294	2,839.824	18,571.556
2024	14,582.849	383.826	826.471	34.015	2,856.585	18,683.746
2025	14,713.283	384.270	835.391	35.736	2,874.058	18,842.737
2026	14,843.716	384.713	844.311	37.457	2,890.106	19,000.303
2027	14,974.149	385.157	853.231	39.189	2,906.866	19,158.592
2028	15,104.583	385.601	862.151	40.900	2,923.627	19,316.861
2029	15,235.016	385.571	871.070	42.621	2,940.387	19,474.666
2030	15,365.449	386.488	879.990	44.342	2,957.148	19,633.418

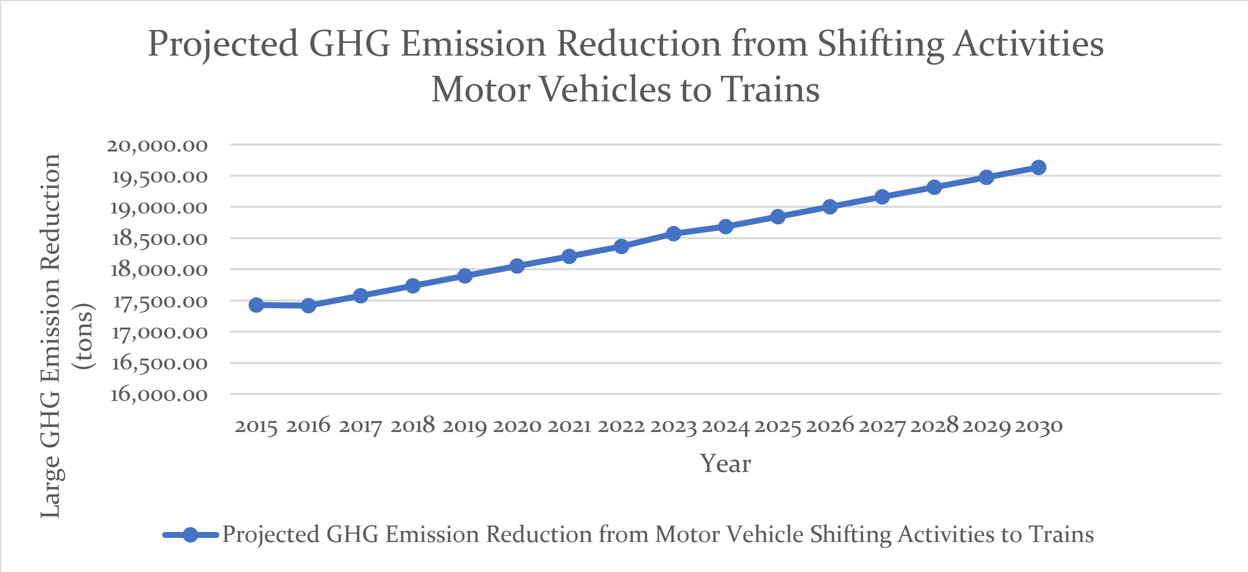

Figure 2. Projected GHG Emission Reduction from Shifting Activities Motor Vehicles to Trains

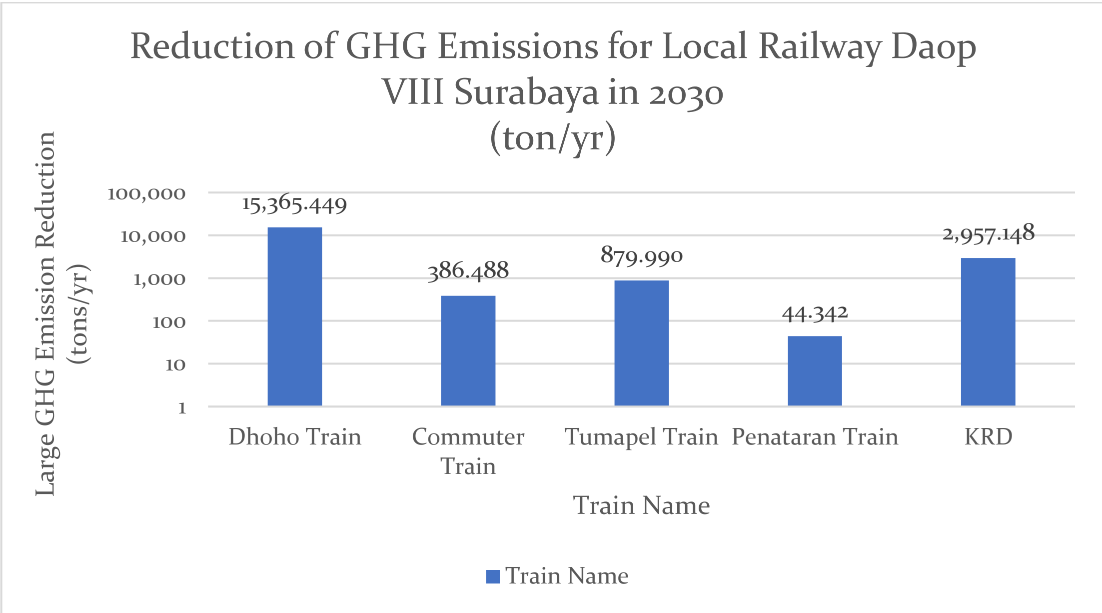

Figure 3.Reduction of GHG Emissions for Local Railway Daop VIII Surabaya in 2030

Our graph displays a significant decrease in emissions in 2016 due to a reduced number of passengers, but we did not let that discourage us. We continued our efforts, and our hard work paid off as we saw a steady increase in passenger numbers, resulting in a remarkable increase in emissions reduction until 2030. Our projections for the Dhoho Train on the Surabaya-Blitar route show that we are on track to reduce 15,365,449 tons of GHG CO_2e emissions annually, with an expected 3,612,760 passengers commuting on the train.

On the Surabaya-Sidoarjo route, we proudly report a GHG CO_2 emission reduction value of 386,488 tons annually in 2030. This route covers 30.76 km and will have 629,846 train commuters in 2030. We are thrilled to contribute to a more sustainable future and look forward to continuing our efforts towards reducing GHG emissions. I am excited to present the results of our study on GHG emissions reduction through train passenger shifting activities from 2015 to 2030. Our graph displays a significant decrease in emissions in 2016 due to a reduced number of passengers, but we did not let that discourage us. We continued our efforts, and our hard work paid off as we saw a steady increase in passenger numbers, resulting in a remarkable increase in emissions reduction until 2030. Our projections for the Dhoho Train on the Surabaya-Blitar route show that we are on track to reduce 15,365,449 tons of GHG CO2e emissions annually, with an expected 3,612,760 passengers commuting on the train.

On the Surabaya-Sidoarjo route, we proudly report a GHG CO2 emission reduction value of 386,488 tons annually in 2030. This route covers 30.76 km and will have 629,846 train commuters in 2030. We are thrilled to contribute to a more sustainable future and look forward to continuing our efforts towards reducing GHG emissions. The graph displays the results of calculating greenhouse gas (GHG) emissions reduction resulting from train passenger shifting activities between 2015 and 2030. The graph shows a decrease in emissions in 2016 due to fewer passengers. However, the graph also indicates that the number of passengers has continuously increased since then, resulting in an increase in emissions reduction until 2030. The passenger projection calculations for the Dhoho Train for the Surabaya-Blitar route show that in 2030, the number of passengers is expected to be 3,612,760, leading to a GHG CO2e emission reduction value of 15,365,449 tons per year. There will be a total of 629,846 train commuters in 2030.

The Surabaya-Sidoarjo train route covers a distance of 30.76 km. The passenger shifting activities on this route are expected to result in a GHG CO2e emission reduction value of 386,488 tons per year in 2030.

Tumapel Train and Penataran Train with travel routes Surabaya to Malang is 91.8 km. From the results of projection calculations for passengers in 2030 for the Tumapel Railway, the number of passengers is 240,628. The Penataran Train has fewer passengers, namely only 21,928 people. These two trains ' GHG emission reduction values, respectively CO2e, amounted to 879,990 tons/year and 44,342 tons/year. Diesel Rail Train (KRD) traveling the route Surabaya-Bojonegoro with a distance of 109.28 km will have a total of 676,136 passengers in 2030. According to the results of projection calculations that have been carried out, the KRD Train produces a CO2e GHG emission reduction value of 2,957,148 tons/year. So, the total reduction in GHG CO2e emissions on Daop local trains VIII Surabaya amounted to 19,633,418 tons/year. In 2030, the Dhoho Railway achieved the highest emission reduction of 15,365,449 tonnes/year of CO2e from passenger shifting activities, while the Penataran Train only yielded a reduction of 44,342 tons/year of CO2e. The calculation results of Dhoho Train passenger projections produce the most significant number of passengers among other trains, amounting to 3,612,760, with the number of shifting perpetrators amounting to 2,032,178 people. The Dhoho Railway holds the record for the longest route, spanning 149 kilometres. Consequently, it yields the most significant greenhouse gas (GHG) emission reduction values.The most minor GHG emission reduction results are produced from passenger shifting activities on the Penataran Train. The number of passengers resulting from calculations of passenger projections in 2030 was 21,928 people, with the number of shifting actors amounting to 9,340, resulting in a reduction in CO2e emissions of 44,342 tons/year. Even though the distance traveled by the Commuter Train is 30.76 km, it is smaller compared to the Penataran Train, which covers a distance of 91.8 km, results from the slightest reduction in GHG emissions from the Penataran Train influenced by the number of passengers who are quite far apart following equation (1)

$$Efficiency = \frac{19.633.418 - 17,427.908}{19,633.418} \times 100\% = 12,65\% \quad (1)$$

In 2015, the efficiency of shifting activities using data passengers was 12.65% compared to the projected results in 2030. This target was established as part of Indonesia's National Action Plan for Reducing Greenhouse Gas Emissions to reduce greenhouse gas emissions by 29% by 2030. However, railway activities in Operation Area VIII Surabaya have fallen short of the target. The regional government, Department of Transportation, and PT Kereta Api Indonesia must make improvements to railway facilities and simplify ticket purchasing procedures to encourage more people to use trains as a means of transportation (Lanori & Supriyanto, 2023).

4. Conclusion

The research concludes that a shift has resulted in a reduction of greenhouse gas (GHG) emissions in local railway activities in Operation Area VIII, Surabaya, with a total CO2e of 17,427.91 tons per year. It is projected that the reduction in GHG emissions for motor vehicle to train users in 2030 will be 19,633,418 tons per year. This represents a 12.65% increase in GHG emissions in 2030 compared to the research year. The shift in behaviour towards using public transportation instead of private vehicles has contributed to this reduction in GHG emissions. Utilizing more public transportation to reach destinations has multiple benefits, including reducing GHG emissions.

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