The impact of using Different Modes of Transportation ON the Volume of Emissions (A Case Study of Egypt)

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ABSTRACT

The study examined the impact of the freight transport sector between cities in Egypt on CO_2 emissions, and despite ongoing efforts, there was a significant variation in the use of transportation modes, with a predominant reliance on road transport, while railways and IWT remained underutilized.

The importance of the study has returned to evaluating the implications of this variation on CO_2 emissions and emphasized the need to innovate sustainable transport solutions in line with Egypt's Vision 2030. The research questions addressed the role of roads, railways, IWT in CO_2 emissions and the synergistic effects between them, assuming the existence of relationships between modes of transport and CO_2 emissions.

To achieve the study's objectives, quantitative and descriptive analyses were conducted using quarterly data from 2013 to 2023. Transportation modes were the independent variable, while CO_2 emissions were the dependent variable. The statistical methods included simple and multiple regression analyses using the SPSS program to assess the relationships between transportation modes and emissions. Linear mathematical models were also used to predict future emission levels under transportation scenarios aligned with Egypt's transport sector vision 2030.

The analysis results have shown a strong relationship between transportation modes and CO_2 emissions, with road transport alone contributing about 92.3% of CO_2 emissions. The simultaneous use of all transportation modes has proven to be the most effective approach, resulting in an overall impact of 97.1%. When road and IWT are combined, their cumulative impact reaches 96.9%, while road transport combined with rail transport shows an impact of 92.3%. Forecasts indicate that implementing the proposed scenarios could save approximately 292,462,530 tons of CO_2 emissions

The study supported the provision of sectorial incentives for managing IWT and railway activities, in addition to enhancing marketing strategies to encourage customers to benefit from these means. It recommended further future research efforts focusing on supply chain interventions to reduce transport emissions.

Keywords: Freight transport, carbon dioxide emissions, Egypt's Vision 2030, sustainable transport, transportation modes, and emissions reduction

المختلفة على حجم الانبعاثات تأثير استخدام وسائط النقل

(دراسة حالة مصر)

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ملخص البحث

تناولت الدراسة تأثير قطاع نقل البضائع بين المدن في مصر على انبعاثات ثاني أكسيد الكربون فعلى الرغم من الجهود المستمرة، كان هناك تباين كبير في استخدام وسائط النقل ، مع الاعتماد السائد على النقل بالطرق، في حين ظلت السكك الحديدية والنقل المائي الداخلي غير مستغلة بالقدر الكافي.

وترجع اهمية الدراسة إلى تقييم تداعيات هذا التباين على انبعاثات ثاني أكسيد الكربون وشددت على الحاجة إلى ابتكار حلول نقل مستدامة تتوافق مع رؤية مصر 2030. وتناولت أسئلة البحث دور الطرق والسكك الحديدية والنقل المائي الداخلي على انبعاثات ثاني أكسيد الكربون والآثار التآزرية فيما بينها فأفترضت الدراسة وجود علاقات بين وسائط النقل وانبعاثات ثاني أكسيد الكربون.

ولتحقيق هدف الدراسة تم إجراء تحليلات كمية ووصفية باستخدام بيانات ربع سنوية تمتد من عام 2013 إلى عام 2023. فشكلت وسائط النقل المتغير المستقل، في حين كانت انبعاثات ثاني أكسيد الكربون المتغير التابع. شملت الاساليب الإحصائية تحليلات الانحدار البسيطة والمتعددة، وذلك بواسطة برنامجSPSS ، لتقييم العلاقات بين وسائط النقل والانبعاثات كما تم استخدام النماذج الرياضية الخطية للتنبؤ بأحجام الانبعاثات المستقبلية في ظل سيناريوهات النقل بما يتماشى مع رؤية مصر لقطاع النقل2030 .

توصلت نتائج التحليل الى وجود علاقة قوية بين وسائط النقل وانبعاثات ثاني أكسيد الكربون، حيث يساهم النقل بالطرق وحده بحوالي 92.3% من انبعاثات ثاني أكسيد الكربون. وقد ظهر استخدام جميع وسائل النقل بشكل متزامن النهج الأكثر فعالية، مما أدى إلى تحقيق تأثير كلي بنسبة 97.1%. وعندما تم الجمع بين النقل بالطرق والنقل عبر المائي الداخلي، وصل تأثيرهما التراكمي إلى 96.9%، في حين أظهر النقل بالطرق المقترن بالنقل بالسكك الحديدية تأثيرًا بنسبة 92.3%. وتشير التوقعات إلى أن تنفيذ السيناريوهات المقترحة يمكن أن يوفر نحو 292,462,530 طناً من انبعاثات ثاني أكسيد الكربون.

وأيدت الدراسة تقديم حوافز قطاعية لإدارة أنشطة النقل المائي الداخلي وسكك الحديد، إلى جانب تعزيز الاستراتيجيات التسويقية لتشجيع العملاء على الاستفادة من هذه الوسائل واوصت بالمزيد من الجهود البحثية المستقبلية التي تركز على تدخلات سلسلة التوريد للحد من انبعاثات النقل.

الكلمات المفتاحية: نقل البضائع، انبعاثات ثاني أكسيد الكربون، رؤية مصر 2030، النقل المستدام، وسائط النقل، وتقليل الانبعاث.

1. Introduction

There is a growing awareness of the detrimental effects of the transportation industry on global warming and climate change in the modern era. As a result, governments and organizations all over the world have enacted stronger laws to decrease emissions from the transportation industry. The worldwide transportation sector currently accounts for around 24% of global energy emissions, with this figure anticipated to climb to 60% by 2050 (World Bank, 2021). Vehicles that employ fossil fuel combustion, such as cars, trucks, ships, and trains, are important contributors to greenhouse gas emissions (Tamiotti et al., 2009)According to statistics, in the recent period in Egypt, the percentage of emissions, namely carbon dioxide emissions, increased to 6.59% (Kenoma, 2023) Specifically, the transport sector in general occupied a rate of 1.37% in the year 2021 (Egypt in Figures, 2023) and the share of the road transport sector was greater than that.

As a result of the increasing demand for transporting goods between Egyptian cities via road transport, compared to the decreasing use of railway transport and inland water transport and the neglect of the other two means of transport, this worrying trend has led to excessive emissions from the road transport sector (Dong et al., 2022) Egypt is using road transport as a main means. According to (Abdelall,2019), this reliance on road transport has led to greater attention being paid to road transport at the expense of railways and inland water transport. However, railways and inland water transport have been ignored despite their great potential to transport goods efficiently and with a lower environmental impact (أحمد et al., 2019). Excessive interest in road transport has led to an increase in emissions rates resulting from the road transport sector, which negative impact on air quality and puts pressure on the environment (Santos, 2017). These trends strongly contradict Egypt's vision of achieving sustainable development and promoting these trends strongly contradict Egypt's vision for achieving sustainable development and promoting environmental transport, which requires studying the reasons for this shift and providing corrective strategies that enhance the sustainability of the transportation sector in the country. In the case of Egypt, this increase is attributed to several factors, including the inefficiency of the transportation system, river navigation, and inefficient growth in the railway network (Bakr,2018) This not only leads to harmful environmental emissions but also contradicts the global trend of preserving a healthy and sustainable environment, as outlined in Egypt's Vision 2030 for sustainable development. This study aimed to explore and propose solutions to reduce emissions from the transportation sector by focusing on other modes of domestic transport to reduce these emissions. The study will address the characteristics of inland water transport and railway transport, which are often underutilized, with a focus on their ability to transport larger volumes of goods. Some key features of inland water and railway transport include their

ability to handle large, time-insensitive goods, providing cost-effective and fuel-efficient means of transport, and having a low environmental impact. The results and recommendations provide tangible guidance for developing regulatory policies in line with Egypt's Vision 2030 for the transport sector.

2. Research Problem

The problem addressed in this study revolves around the imbalance in the use of different internal freight transport modes between cities in Egypt, specifically the increase in demand and reliance on road transport, while there is a significant decrease in the use of railways and inland water transport. It is noted that the volume of transport on the Egyptian road network continues to increase, according to the study (JICA, 2014), A local study on transportation in Egypt highlighted the significant increase that occurred in road transport since 1979, reaching 88.7% and rising to 98% in 2010, compared to other modes where railway transport represented 6.1% in 1979 and decreased to 0.9%, and inland water transport represented 5.2% and decreased to 0.5%, which warrants further study.

According to the study (أحمد et al., 2019) (Y. Li et al., 2019), relying on road transport results in increased carbon dioxide emissions rates from that sector, posing environmental challenges and conflicting with the global sustainability trend and the specific directions in the Egyptian Sustainable Development Plan for 2030. (حجازي, 2021)

Therefore, it can be clarified that the increasing reliance on road transport has many negative effects on society, leading to increased air pollutant emissions such as carbon dioxide, nitrogen oxides, particulate matter in the atmosphere, and sulfur oxides. Hence, the study aimed to develop a framework for a model that helps address these issues and confront the negatives resulting from the imbalance in demand for transport modes by maximizing the use of alternative modes. (Ministry of Transportation, 2015).

3. Research Questions

1. Is there a significant impact of road transports on the volume of carbon dioxide emissions?
2. Is there a significant impact of railway transports on the volume of carbon dioxide emissions?
3. Is there a significant impact of inland water transports on the volume of carbon dioxide emissions?
4. What is the impact of the integrated modes of internal transport, including road transport, railway transport, and inland water transport, on the dependent variable, which is the volume of carbon dioxide emissions?

4. Objectives of the Research

1. To determine the impact of road transports on the volume of carbon dioxide emissions.
2. To determine the impact of railway transports on the volume of carbon dioxide emissions.
3. To determine the impact of inland water transports on the volume of carbon dioxide emissions.
4. To determine the impact of integrated modes of internal transport, including road transport, railway transport, and inland water transport, on the dependent variable, which is the volume of carbon dioxide emissions.

5. Literature review

Transport contributes significantly to harmful emissions leading to environmental degradation and exacerbating the phenomenon of global warming. Many previous studies have paid increasing attention to analysing patterns of domestic transport in different countries.

This Literature review will show the most relevant studies to the subject of this study, in terms of their coverage of road, rail, and inland waterway freight transport, as well as their estimation of transport sector emissions and impacts. Each study will be addressed individually in terms of author and year, location, population, and sample, independent and dependent variables examined, how these variables were measured, key statistical methods utilized, findings, and recommendations.

Through this comprehensive analysis of the literature, the knowledge gap around the subject of the study will become apparent.

- **Internal Transport Sector**

Internal transportation systems, including road, rail, and inland waterway networks, are essential for economic development and connectivity within the countries. In this section, researchers have studied its historical development, current status.

The study (Abd elsamii mahfouz & Idris, 2023) focused on estimating the daily CO2 emissions of urban transportation in Zagazig city, Egypt using activity-based and energy-based methods and recommended sustainable transportation measures to mitigate emissions. The Study (Barros et al., 2023) utilized Q Methodology to assess stakeholder perspectives on inland waterway transport development for Brazilian soybean transportation, finding a consensus that officials lack a voice in investment prioritization. The study (Jurkovič et al., 2023) examined trends in Slovakian inland waterway infrastructure

development, showing deteriorating navigability and untapped potential requiring infrastructure improvements for sustainable commercial shipping. The study (Md. Mahmudul Hassan & Wang Xuefeng, 2022) analyzed the strengths, weaknesses, opportunities and threats of inland water transport (IWT) in Bangladesh, concluding with priorities like maintaining adequate depth and upgrading port infrastructure for sustainable IWT development. The study (Ayadi et al., 2022) reviewed 47 studies using composite indicators to assess transportation sustainability, recommending further research on freight transport and additional sustainability dimensions. The study (Fahmy & Hekal, 2022) compared four approaches for determining safe navigable channel widths along Egypt's Nile River, finding the CCG (2001) and PIANC (2014) approaches optimal for ensuring safety. The study (Solomon et al., 2021) identified constraints facing inland waterway transportation in Ghana and recommended institutionalizing regulation, infrastructure upgrades, integrated planning and public-private coordination to boost the sector. The study (ELSayed & ELGarhy, 2018) highlighted challenges like rising fuel prices significantly impacting Egypt’s road transport industry and government intervention needed to facilitate freight movement. The study (Saidi et al., 2018) confirmed counteraction between transport energy consumption, infrastructure, capital and economic growth in the MENA region. The study (Johnstone et al., 2017) developed a model evaluating modal shift policies in Egypt, projecting partial shifts from road to rail and inland waterways could substantially increase non-road freight with infrastructure investments and fuel pricing changes. The study (Elshahawany et al., 2017) estimated significant economic gains, especially for southern and western Egypt, from a proposed transportation corridor development using an integrated spatial CGE model. The study (Islam & Roberts, 2015) analyzed barriers facing Egypt's inland waterways like navigational issues and lack of coordination, proposing modernized policies, operations and collaborative strategies to realize the sector's potential. The study (Merchan et al., 2015) comprehensively assessed the environmental impact of rail freight intermodality in Belgium using LCA methodology. The study (Wiegmans & Konings, 2015) analysed inland waterway freight competitiveness in Europe based on transport distances and operational scenarios. The study (Nam & Win, 2014) compared costs and transit times of road and inland waterway transport in Myanmar, showing the latter had lower costs but longer times. The study (El-nakib, 2011) identified challenges facing Egypt’s river transport like insufficient infrastructure and competition from road/rail.

- **Emissions from Transport sector's**

The transport sector's emissions, encompassing road, rail, and inland water transport, have garnered global attention due to their significant contribution to environmental pollution and greenhouse gas emissions CO_2. This section explores prior research on emissions from these transport modes. Researchers have investigated historical developments, current trends, and potential mitigation strategies.

The study (Qiao et al., 2024) developed machine learning models to forecast transportation energy use and emissions in the UK, finding road carbon intensity the most important contributor. The study (Huy et al., 2023) assessed on-road and inland waterway emissions in Vietnam over 2010-2019, showing increases and advocating for advanced vehicle technologies and renewable energy to mitigate emissions. The study (Johansson et al., 2023) analyzed freight emissions forecasts in Sweden to 2040, concluding efficiency and biofuels are essential as modal shift has limited emissions benefits by 2040. The global study (Ferrer & Thomé, 2023) reviewed literature on transport carbon mitigation, emphasizing sustainability trade-offs and quick adaptation needs. The study (Lin & Bai, 2023) allocated emissions to production versus consumption using environmentally extended input-output analysis, shedding light on comparative advantage implications. The study (Vasiev et al., 2023) modelled rail versus truck emissions for a building materials shipment in Russia, demonstrating substantially lower rail emissions. The study (Markina et al., 2022) proposed a composite environmental impact indicator for Russia's aging road fleet, advising systemic solutions across the vehicle lifecycle. The study (X. Li et al., 2022) explored predicting transportation CO2 emissions via machine learning, achieving strong accuracy combining socioeconomic factors. The study (Barros et al., 2022) reviewed research on sustainable inland waterway transport, recommending holistic approaches considering social dimensions and stakeholder perspectives. The study (Abbass et al., 2021) modelled emission control scenarios for Cairo, finding inspection/maintenance delivers the greatest reductions while integrated policies can curb growth. The study (Liu et al., 2021) used an LMDI model to analyse China's transportation industry emissions, recommending optimization policies to facilitate decoupling. The study (Chen et al., 2020) found shifting freight from road to rail in China reduces emissions but imposes economic costs exceeding benefits. The study (L. Li & Zhang, 2020) showed dynamic rail pricing with backlog control could substantially cut freight emissions in Chinese cities. The study (Heinold, 2020) reviewed and compared five models for estimating rail freight emissions based on route characteristics. The study (Abdel Wahed Ahmed & Abd El Monem, 2020) provided analysis and recommendations for developing an affordable, eco-friendly transportation system in Greater Cairo. The study (Talbi, 2017)

used a VAR model to examine transport emissions influences in Tunisia, confirming the EKC relationship and supporting efficiency gains.

- **Comments on literature review**

Accordingly, it can be concluded that most studies focused on the extent of the impact of transport modes on carbon dioxide emissions, specifically the strength of the impact of road transport on it, Most studies also relied on statistical methods, namely the multiple regression coefficient and the correlation coefficient, such as the study of (Heinold,2020), (X. Li et al., 2022), and (Markina et al., 2022).

- **Research gap**

Previous studies have focused on achieving sustainable transportation with minimal environmental impact, with an emphasis on choosing modes of transportation that emit less carbon dioxide emissions. The study addressed the issue of the unfair distribution of goods between Egyptian cities, the dominance of land transport over freight movement, and the neglect of internal water transport and railway transport. Solutions were sought to enhance the efficiency of internal waterway and railway transport systems for consideration by the competent authorities. In addition, the study aimed to create a low-emission transportation system in line with Egypt's vision for sustainable development from 2023 to 2030. The time frame chosen for the study was from 2023 to 2030 to align with Egypt's vision for sustainable development. This specific period provided an appropriate time frame for implementing and evaluating the proposed solutions, ensuring their continuity in the future.

- **Derivation of study Hypotheses**

Based on the literature review presented, the study hypotheses are derived through four hypotheses. The first hypothesis there is a significant impact between Roads transport on the volume of emissions carbon dioxide. The second hypothesis there is a significant impact between Railways transport on the volume of emissions carbon dioxide. The third hypothesis there is a significant impact between Inland water transports on the volume of emissions carbon dioxide. The fourth hypothesis there is a significant impact between integrated modes of internal transport, including road transport, railway transport, and inland water transport, on the dependent variable, which is the volume of carbon dioxide emissions.

6. Research Model

In this study, the dependent variable to be CO2 emissions volume, representing the outcomes aim to comprehend and analyse. As for the independent variables, they are the factors we believe influence the levels of emissions. In this study focus on various modes of internal transportation, specifically road transport, railway transport, and inland water transport. These modes serve as the independent variables that want to analyse for their impact on carbon dioxide emissions levels.

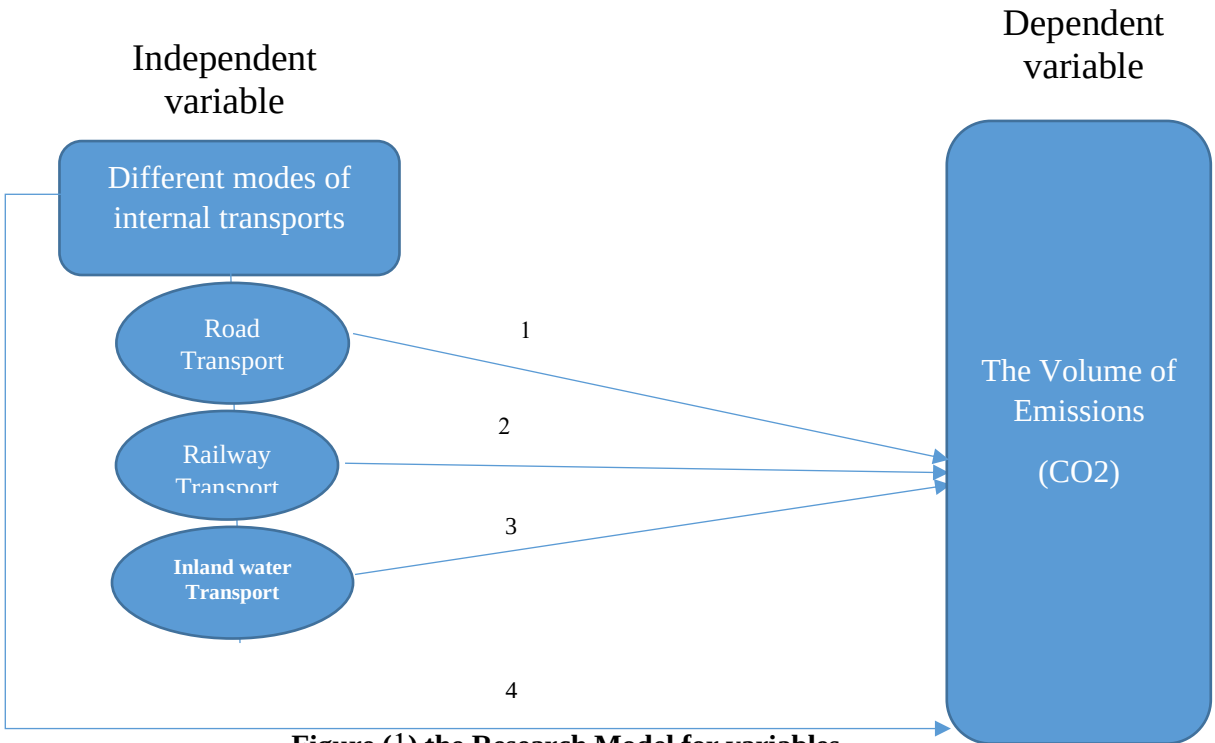

Figure (1) the Research Model for variables
Source: By Researcher

Based on the previous figure

The statistical analysis and methods that were used to answer the hypotheses are as follows:

H_1: There is a significant impact between Road transports **x1** on the volume of emissions carbon dioxide **Y.**

H_2: There is a significant impact between Railway transports **x2** on the volume of emissions carbon dioxide **Y**.

H_3: There is a significant impact between Inland water transports **x3** on the volume of emissions carbon dioxide **Y**.

H_4: There is a significant impact between (integrated modes of internal transport) **X**, included: Road transport x1, Railway transport x2, and Inland

water transport x3, on dependent variable the volume of emissions carbon dioxide). **Y**

7. Methodology

This study relied on quantitative and descriptive analysis methods to analyse the relationship between independent variables represented by the volume of goods transported between cities and internal transportation modes in Egypt, including road, inland water transport, and rail transportation. Quarterly data on the volume of goods transported from the period 2013 to 2023 were collected, and the emissions volume, which is the dependent variable, was calculated for each quarter using the EcoTransIT World model website. The study used statistical analysis through the SPSS program to measure the simple regression coefficient to find the effect of the independent variable on the dependent variable and measure the multiple regression coefficient to find the extent of the direct impact between the combined independent variables and the dependent variable. The study also tested which of the three independent factors had the most impact on the dependent variable. The study used linear mathematical models and equations to extract solutions for the emissions problem and predict the future volume of shipments. This was done to apply two scenarios that align with Egypt's vision for the transportation sector in 2030. The first scenario is to reduce emissions by converting 25% of the total volume of goods transported to rail transportation, and the second scenario is to convert 10% of the road transport volume to inland water transport.

- **Study sample and population**

The study population was represented by the various modes of internal transportation, specifically road transportation, railway transportation, and inland water transportation.

The study sample relied This study relied on quarterly data on the volume of strategic goods transported between cities in Egypt with a total of 44 observations during the period 2013-2023, referring to the available data from various government entities such as the Ministry of Transport with its various departments, the Central Agency for Public Mobilization and Statistics, and the Ministry of Trade, Industry, Energy, Petroleum, and Mineral Wealth. In addition, data was collected on the emissions of carbon dioxide and greenhouse gases from the freight transport sector from several sources, including the Ministry of Environment and the Central Agency for Public Mobilization and Statistics. These emissions are calculated on a specialized website for calculating emissions from each mode of freight transport per unit of transport (ton-kilometer).

- **Data Collection Methods**

This study relied on data collected from annual reports published in a several of government agencies, namely the Ministry of Transport, the Central Agency for Public Mobilization and Statistics, the Ministry of Petroleum and Mineral Resources, and the World Bank. The data represents the volume of goods transported by internal means of transport, namely road transport, inland water transport and railway transport, during the period from 2013 to 2023. The volume of emissions will be calculated using a website.

https://www.ecotransit.org/calculation.en.html.

It is a site that calculates emissions according to the volume of transportation transported over a certain distance travelled, and the distance that the analysis will entail will be from Alexandria to Aswan.

- **Secondary data method:** The study relied on journals and references available in international databases, the Egyptian Knowledge Bank, and searching for articles on Google to establish the theoretical framework of the study in line with its overall objective.
- **Primary data method:** As for the practical aspect, the necessary information and data for statistical analysis were obtained from several sources from various government entities such as the Ministry of Transport with its various departments, the Central Agency for Public Mobilization and Statistics, and the Ministry of Trade, Industry, Energy, Petroleum, and Mineral Wealth. In addition, data was collected on the emissions of carbon dioxide and greenhouse gases from the freight transport sector from several sources, including the Ministry of Environment and the Central Agency for Public Mobilization and Statistics. These emissions are calculated on a specialized website for calculating emissions from each mode of freight transport per unit of transport.

- **The Procedures Used in the Study**

This study relied on quantitative and descriptive analysis methods to analyse the relationship between independent variables represented by the volume of goods transported between cities and internal transportation modes in Egypt, including land, inland waterway, and rail transportation. Quarterly data on the volume of goods transported from the period 2013 to 2023 were collected, and the emissions volume, which is the dependent variable, was calculated for each quarter using the EcoTransIT World model website. The study used statistical analysis through the SPSS program to measure the simple regression coefficient to find the effect of the independent variable on the dependent variable and measure the multiple regression coefficient to find the extent of the direct impact between the combined independent variables and the dependent variable. The

study also tested which of the three independent factors had the most impact on the dependent variable. The study used linear mathematical models and equations to extract solutions for the emissions problem and predict the future volume of shipments. This was done to apply two scenarios that align with Egypt's vision for the transportation sector in 2030. The first scenario is to reduce emissions by converting 25% of the total volume of goods transported to rail transportation, and the second scenario is to convert 10% of the road transport volume to inland waterway transportation. The research aimed to provide invaluable recommendations that can help formulate effective policies to enhance the domestic transportation system in Egypt, with the goal of ensuring fair distribution of transportation volume across Egyptian cities. The following table shows the data collected.

- **Statistical Methods used**

It was ensured for completeness and validity for the statistical analysis the Statistical Package for Social Sciences (SPSS) ver. (21) is used for data analysis for the statistical analysis and methods that used to answer the questions and hypotheses, of the study the following had been presented:

- Descriptive Statistics:
- Normality Test:
- Pearson Correlation Coefficient:
- Simple Linear Regression:
- Multiple Linear Regression:
- Linear Regression

8. Results

Table (1) the effect of (integrated modes of internal transport) X on (The volume of emissions carbon dioxide Y by using simple and multiple Regression

Independent variables	β	t. test		F. test		r	R^2
		Value	Sig.	Value	Sig.		
Constant	480.969	.2793	0.01**	501.395	0.01**	0.961	92.3%
x1- road transport	0.195	6.234	0.01**				
Constant	4494.38	7.020	0.01**	0.07	3.379	0.273	7.4%
x2- rail way transport	.273	1.838	0.07				
Constant	2146.01	25.337	0.01**	239.998	0.01**	0.923	85.1%
x3- Inland water transport	.923	15.492	0.01**				
Constant	606.549	1.997	0.05*	245.371	0.01**	0.961	92.3%
x1- road transport	0.968	21.284	0.01**				
X2- railway transport	0.023	0.504	0.61				
Constant	325.28	2.172	0.03*	648.924	0.01**	0.985	96.9%
x1- road transport	0.629	12.586	0.01**				
X3- Inland water transport	0.395	7.905	0.01**				
Constant	84.815(1)	0.412	0.683	452.234	0.01**	0.986	97.1%
x1- road transport	0.637(2)	12.952	0.01**				
X2- railway transport	0.047(3)	1.665	0.10				
X3- Inland water transport	0.404(4)	8.203	0.01**				

Source: From statistical analysis using SPSS. ** Significant level 0.01

1. The first hypothesis states that road transportation increases the impact on carbon dioxide emissions by 92.3%. This means that road transport has a strong statistical impact on emissions. The t-test result (22.392) indicates a

statistically significant relationship ($p < 0.01$). The F test indicates the fit of the model (501.395, $p < 0.01$) and the hypothesis was accepted by clarifying that there is a statistically significant link between road transport and carbon dioxide emissions and supports the interpretation of more than 92% of the changes in carbon dioxide emissions based on the statistical tests conducted in Analysis. A 0.961 unit increase in road transport is associated with a 1 unit increase in emissions, likely due to increased reliance on roads which increases energy use and emissions.

2. The second hypothesis states that there is a low but statistically significant relationship between rail transport (X_2) and CO_2 emissions (Y). The correlation coefficient (r) = 0.273 ($p < 0.10$), which is 7.4%. This means that rail transport has a weak statistical impact on emissions. The t-test result (1.838) indicates a statistically significant relationship ($P < 0.01$). The F test indicates a model fit of 3.379 ($p < 0.10$), indicating that the model is valid. The hypothesis was accepted by clarifying that there is a weak relationship.
3. Stated for the third hypothesis, there is a strong and statistically significant relationship between inland water transport and carbon dioxide emissions ($r = 0.923$ at $p < 0.01$). The statistical hypothesis that assessed the association was accepted, and the study found that inland water transport accounted for approximately 85.1% of the total changes in carbon dioxide emissions, demonstrating a large and statistically significant effect. A T-test of 3.164 and a significance level of less than one percent, as well as an F-test of regression model fit, confirmed the goodness of the model ($P < 0.01$). The analysis shows that inland water transport significantly reduces carbon emissions. This enhances dependence on it.
4. In the fourth hypothesis, the study found that there is a strong, statistically significant correlation between the variable volume of goods movement transported by road and railway transport with the variable carbon dioxide emissions rates, with a correlation coefficient of 0.961. The results of the coefficient of determination indicated an effect of 92.3% for this independent variable on the dependent variable. The F-test also confirmed the significance of the regression model at the 0.01 level. However, when compared with the results for road and rail transport together, which had an impact rate of 92.3%, it turns out that rail transport contributes a slight increase in the overall impact of 0.3%.

The study concluded that there is a strong statistical relationship between the movement of goods transported by land and inland water transport and carbon dioxide emissions rates, with the correlation coefficient reaching 0.985 and the coefficient of determination (R2) 97%, with the significance of the regression model tested with a large F value (648.924) at a significance level of 0.01.

The results were studied, which proved that the movement of goods transported by road and inland water transport affects carbon dioxide emissions rates by 97%, while the results of road transport only show a

rate of 92%, and it is clear that the first result is the best. These results indicate that relying on mixed transport between road transport and inland water transport can be more effective in reducing CO2 emissions than relying on road transport only. So, it is better to use hybrid transportation strategies to achieve maximum impact in reducing emissions to improve sustainability in the transportation sector.

The study found a strong, statistical relationship between the movement of goods transported by land, rail, and inland water transport, and carbon dioxide emissions rates, with the correlation coefficient reaching 0.986, and the coefficient of determination (R2) 97.1%. The significance test of the regression model also showed a large F value (452.234) at a significance level of 0.01, which confirms the importance of the model. It was confirmed that there is a statistical relationship between the total means of internal transport integrated with the three means of transport (roads, railways, inland waters), and the volume of carbon dioxide emissions from goods transported on the three means of transport, which highlights the importance of analysing mixed means of transport for understanding and planning to reduce emissions. CO2

Based on these results, it appears that transport by all three modes together shows the highest impact on CO_2 emissions rates at 97.1%. It is followed by road transport with inland water transport combined at 96.9%, while road transport only and road transport with rail transport show a low impact of 92%. From this analysis, the study concluded that all three modes of transportation together are the best option for reducing CO_2 emissions.

- **Scenarios expected if the model mentioned in Egypt's Vision 2030 is applied**

First scenario

The impact of the application of the model on the total volume of CO2 emissions is examined in this part.

With reference to the vision of the Egyptian Ministry of Transport for 2030, the target is to transfer about 25 million tons of cargo transported by road to the railways and raise the cargo transport capacity according to (Egypt Railways Public transportation system, 2023). This is why the research makes an estimate of the volume of movables in Egypt in 2030 based on the data available by applying the linear regression equation.

Table (2) forecast the volume of cargo traffic to 2030

Years	2024	2025	2026	2027	2028	2029	2030
Volumes of goods transported (million ton .	118223	121652	125895	129272	131803	133876	138665

Source: By Researcher

From the previous table, it is clear that the total volume of cargo traffic will increase steadily to about 138,665 million tons * km 2030. Thus, in applying Egypt's Transport Sector Vision 2030, which aims to convert some 25 million tons of road transport by rail, savings in emissions and specifically CO2 emissions can be calculated according to the mathematical

To calculate the abundance of CO2 emissions using the model prepared for study as follows:

$$\mathbf{Y} = 84.815_{(1)} + 0.637_{(2)}\ \mathbf{x1} + 0.047_{(3)}\ \mathbf{x2} + 0.404_{(4)}\ \mathbf{x3}$$

Savings in CO2 emissions resulting from the conversion of 25 million tons for rail transport instead of road transport = 84.815+0.637× (-25000000) + 0.047× (25000000) = **14749915.19 tons.**

Second Scenario

refers to Egypt's Vision 2030, the study find that in addition to the desire to transfer 25 million tons of rail transport, there is a target to convert 10% of the total volume of movement on road transport for river transport (Korkor, Hamed,2017) and to know the expected volume of cargo traffic on road transport until 2030, an expectation has been made The result was as shown in the following table, using that formula to predict the

Table (3) Expected volume of movement on road transport until 2030

Years	2024	2025	2026	2027	2028	2029	2030
Volumes of goods transported by roads (million ton	98641	102066	105491	108916	112340	115765	119190

Source: By Researcher

$$\mathbf{Y} = 84.815_{(1)} + 0.637_{(2)}\ \mathbf{x1} + 0.047_{(3)}\ \mathbf{x2} + 0.404_{(4)}\ \mathbf{x3}$$

The Ministry of Transport's Vision 2030 has been implemented and 10% of the volume of road transport has been attracted to inland water transport. This volume is estimated at approximately 119,190 thousand tons*km. To calculate the savings in the volume of carbon dioxide emissions using the model prepared in the study, it is as follows:

The amount of savings in carbon dioxide emissions resulting from transferring 11,919 thousand tons to inland water transport instead of road transport

= 84.815+0.637× (-1191900000) + 0.404 (1191900000) =**277712615.2 tons**

The saving in the volume of carbon dioxide emissions amounts to about 14749915.19 + 277712615.2 = 292,462,530 tons.

The results for 2 scenarios showed that achieving Egypt's 2030 vision for transportation, by converting a portion of road transport to rail and internal water transport, will significantly reduce carbon dioxide emissions. The prepared model was used in the study, and the savings in carbon dioxide emissions as a result of the conversion were estimated at approximately 292,462,530 tons, and it included saving about 147,499,150 tons of carbon dioxide emissions from converting road transport to rail transport, and about 277,712,615.2 tons of carbon dioxide emissions from converting road transport. To inland water transport. This conversion has resulted in potential environmental benefits for improving the transportation system and supporting efforts to achieve sustainable development in Egypt.

9. Discussion of Results

The review of literature on transport emissions research covered studies across various countries examining factors like carbon mitigation policies, modal shift strategies, machine learning modelling approaches, country comparisons based on economic and emissions indicators, and analysis of rail versus road emissions. However, it did not specifically quantify the relative emissions impact of road, rail and inland waterway transport.

The new findings provide statistical evidence on the comparative CO2 emissions impact of road, rail and inland waterway freight transport based on goods transport volumes. Key conclusions are:

- Road transport alone has a 92.3% impact on CO2 emissions, confirming it is a major contributor.
- Rail transport has a weak 7.4% link to emissions.
- Inland water transport significantly reduces emissions, accounting for an 85.1% influence.
- Combined road and rail freight transport have a 92.3% impact on emissions, only slightly more than road transport alone.
- Integrated road and inland waterway transport have a higher 96.9% association with CO2 emissions.
- Use of all three transport modes collectively has the maximum 97.1% effect on curbing CO2 emissions from freight.

Therefore, the new statistical analysis provides strong evidence that inland water transport combined with road, and optimally also rail transport has greater emission reduction potential, supporting the recommendation that hybrid transportation strategies can be highly effective for mitigating transport's carbon footprint. This reinforces some initial suggestions on examining multimodal emission scenarios and comparative advantage implications in the previous literature review.

The quantification of the relative emissions impact for road, rail and inland water transport provides valuable information for transport planning and investment decisions aimed at achieving sustainability goals. The multi-modal transport strategy aligns well with the emphasis on holistic, integrated approaches considering social dimensions and stakeholder perspectives highlighted in the literature.

10.Summary and Concluding Remarks

The study aimed to propose a model for intercity freight transport in Egypt, as well as to calculate the total volume of carbon dioxide emissions according to Egypt's Vision 2030, to find alternative transportation methods beyond sole reliance on roads. This was to mitigate pollution resulting from freight transport. The study examined the total volume and distribution of goods transported between cities via the three internal transportation modes studied (road, rail, inland water transport) from 2013 to 2023, along with carbon dioxide emissions. Additionally, it forecasted freight traffic volumes until 2030 to develop scenarios for estimating emission reductions if Egypt's 2030 transportation vision of shifting a portion of road transport to rail and inland water transport were implemented.

The study was divided into six chapters. The first chapter provided the study's framework, including problem statement, significance, objectives, variables, and model, assumptions, community, and study plan. The second chapter reviewed previous studies on various transportation and emission topics, emphasizing challenges and opportunities in developing sustainable transportation modes across sectors such as roads, inland waterways, and railways. It highlighted the importance of promoting sustainable transport modes to reduce carbon dioxide emissions and improve environmental and economic sustainability. Recommendations were made to enhance sustainability and reduce emissions, contributing to the development of sustainable transportation policies at the local and international levels.

The third chapter explained definitions and concepts of internal freight transportation modes and discussed key obstacles facing rail and inland water freight transportation. It covered various types of goods transported between cities, their evolution, and their distribution among the three internal transport modes, alongside presenting carbon dioxide emission volumes resulting from the use of these modes within the study area.

The fourth chapter outlined the study's methodology, including sample selection and study population. Quantitative and descriptive analysis methods were employed to analyse the relationship between independent variables volume of goods transported between cities via internal transportation modes and carbon dioxide emissions. Data on quarterly freight volumes from 2013 to 2023, totalling 44 observations, were collected. Additionally, carbon emission volumes for each quarter were calculated using the EcoTransIT World model. Statistical analysis using SPSS software was conducted to measure the simple regression coefficient to determine the impact of the independent variable on the dependent variable. Multiple regression coefficients were calculated to assess the direct effect of all independent variables combined on the dependent variable.

The fifth chapter presented the statistical analysis results. The first hypothesis indicated a significant effect of road transport on carbon dioxide emissions, accounting for 92.3% of the increase. The second hypothesis suggested a statistically significant but weak relationship between rail transport and carbon dioxide emissions 7.4%. The third hypothesis demonstrated a strong, statistically significant relationship between inland water transport and carbon dioxide emissions, accounting for approximately 85.1% of the total changes. The fourth hypothesis indicated a strong relationship between road and rail transport with carbon dioxide emissions, with road transport having a slightly higher impact. It also underscored the combined effect of the three transport modes, showing the highest impact on carbon dioxide emissions reduction.

The study concluded by revealing that transitioning from road to rail and inland water transport, aligned with Egypt's 2030 vision, led to a significant decrease in carbon dioxide emissions. Using the developed model, the study estimated savings of approximately 292,462,530 tons of carbon dioxide emissions, including significant reductions from road to rail and inland water transport conversions. This shift yielded substantial environmental benefits, aligning with Egypt's sustainable development goals from 2023 to 2030.

Based on the results of the four hypotheses, the sixth and final chapter explains the Findings, recommendations and future studies as follows

11.Findings and Recommendations

Findings of the study	Study recommendations	The agency responsible for implementation	Timeline
• Transferrin some quantity of goods to the means of railways and inland water transport, these two means that enjoy competitive advantages in transport from the means of transport by	• Encouraging the private sector in managing river and rail transport activities. • Improving marketing conditions by working to attract customers to use inland water transport and railways.	• The Ministry of Investment in cooperation with the Ministry of Transport. • Chambers of Commerce. • The Ministry	• Long term plan. • Short term plan. • Continuously

trucks or by road, the most important of which are some raw movables such as iron, coal, clay, phosphates, in addition to the transfers of wheat imports from ports to grain silos (Upper Egypt) although the means of railways and river transport are the appropriate means with movables for long distances.	• Encouraging the transition to inland water transport and rail transport by providing soft financing programs to support inland water transport, financing the manufacture of new river units and the purchase of tractors and railway goods wagons. • Work on implementing Egypt's vision for the transport sector 2030 with regard to transferring part of the movables that are transported on the road network to railways and inland water transport.	of Investment in cooperation with the Ministry of Transport. • Ministry of Transport.	• Long term plan.

• The conversion of a large proportion of railway transport customers is due to several main reasons, such as giving priority to passenger trains compared to freight trains in terms of route schedules, speeds, locomotive allocation, as well as wasting much of the time allocated to preparing and setting up the cargo train and the poor infrastructure of cargo stations.	• Work on the allocation of locomotives dedicated to goods and the rearrangement and modernization of railway goods stations. • Making schedules with fixed dates for transporting goods to gain the confidence of shippers. • Development of collection, distribution and disinfection centers for railway cars.	• The Ministry of Transport represented by the Egyptian Railways Authority. • The Ministry of Transport represented by the Egyptian Railways Authority. • The Ministry of Transport represented by the Egyptian Railways Authority.	• Long term plan. • Short term plan. • Short term plan.

12.Limitation of Study

The study was temporally constrained between 2013 and 2030, aligning with Egypt's Development Plan 2030, and spatially focused on internal transportation modes within Egypt road, inland water transport, and rail transport and their impact on emissions, particularly carbon dioxide (CO_2) emissions. Challenges in data accessibility, such as restricted access and data transparency issues, hindered comprehensive data collection and analysis.

13.Directions for Future Research studies

Within the scope of this study, the point of future studies represents a vital aspect that opens the door for researchers to further investigate and expand our understanding of the relationship between transportation modes and carbon dioxide (CO_2) emissions. These future points may include:

1. Deepening Understanding: Researchers can delve deeper into their understanding of the finer details of how domestic transportation modes, such as road transport, railway transport, and inland water transport, specifically impact CO_2 emissions.
2. Studying Additional Factors: The research can be extended by studying other factors that may influence transportation emissions, such as vehicle technology, congestion levels, and usage patterns.
3. International Comparisons: Researchers can study variations and differences in domestic transportation emissions between different countries and analyse the contributing factors to these variations.
4. Solutions and Measures: Future studies can further complement the research by providing recommendations and measures aimed at improving the sustainability of domestic transportation and reducing emissions.
5. Economic Impacts: Researchers can investigate the economic impacts of enhancing domestic transportation modes and analyse how to direct investments to promote both environmental and economic sustainability.
6. Mode-Specific Carbon Emissions Analysis: Conduct in-depth studies focusing on the carbon emissions associated with each mode of freight transportation individually. Compare the emissions profiles of road, rail, and inland waterway transportation for different types of cargo.
7. Intermodal Freight Transport and Emissions: Explore the environmental benefits of intermodal freight transportation, which involves the seamless integration of multiple transportation modes (e.g., combining road, rail, and waterways) to reduce emissions and enhance efficiency.
8. Alternative Energy Sources: Investigate the feasibility and impact of using alternative energy sources, such as electrification, hydrogen fuel cells, or biofuels, in each mode of transportation to reduce CO2 emissions.

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