THE CONTRIBUTION OF METROS TO REDUCING CO2 EMISSIONS FROM A CITY'S TRANSPORT SECTOR

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ABSTRACT: To better understand the impact of a city's metro transport system on CO2 emissions, it is crucial to carry out a comprehensive analysis, knowing the real dimension of the contribution of metro systems to the entire transport system's CO2 emissions. It is necessary to consider the gains that the operation of the metro can bring by reducing the use of other more polluting means of transport, especially road transport, such as cars, vans, motorcycles, and buses. This work aims to present a methodology for estimating CO2 emissions that considers both the emission produced by a metro system and the emission avoided due to the operation of this system, presenting the results of the applications of this proposed methodology.

KEYWORDS: Reducing CO2 emissions; passenger transportation; transport sector; metros.

A CONTRIBUIÇÃO DOS METRÔS PARA A REDUÇÃO DAS EMISSÕES DE CO2 DO SETOR DE TRANSPORTES DE UMA CIDADE

RESUMO: Para melhor compreender o impacto do sistema de transporte metroviário de uma cidade nas emissões de CO2, é crucial realizar uma análise abrangente, conhecendo a real dimensão da contribuição dos sistemas de metro para as emissões de CO2 de todo o sistema de transportes. É preciso considerar os ganhos que a operação do metrô pode trazer ao reduzir a utilização de outros meios de transporte mais poluentes, principalmente o rodoviário, como automóveis, vans, motocicletas e ônibus. Este trabalho tem como objetivo apresentar uma metodologia de estimativa de emissões de CO2 que considera tanto a emissão produzida por um sistema metroviário quanto a emissão evitada devido à operação deste sistema, apresentando os resultados das aplicações desta metodologia proposta.

PALAVRAS-CHAVE: Redução das emissões de CO2; transporte de passageiros; setor de transportes; metros.

INTRODUCTION

It is estimated that by 2050 the energy used in transport systems will double, which would further increase greenhouse gas emissions - GHG if actions to mitigate these emissions are not implemented [1]. These efforts aim to reduce the increase in these emissions, especially carbon dioxide - CO2, which is the main greenhouse gas emitted in the operations of transport systems. Awareness about the need to take actions to reduce emissions in the transport sector is growing, encouraging several cities to establish plans in this regard, such as: a) New York, with the objective of reducing 30% by 2030, compared to 2005 [2]; b) London, with the objective of reducing emissions by 60% by 2025, based on 1999 [3]; c) Rio de Janeiro, which approved legislation that established 30% reduction objectives between 2010 and 2030 [4].

The objective of this work is to analyze the impact on CO2 emissions from a city's transport system due to the operation of the metro system, in terms of CO2 emissions produced and avoided, presenting the results of applications of the proposed methodology in some cities in the world.

CO2 EMISSIONS PRODUCED BY METRO SYSTEMS

The CO2 emissions produced by metros are all those that occur as a result of the operation of this mode of transport. This is an inventory of GHG emissions, prepared in accordance with the standards of the IPCC - Intergovernmental Panel on Climate Change and ISO 14,064 - Greenhouse gases. According to these standards, in scope 1 direct emissions are calculated, such as those from generators, equipment, maintenance vehicles, auxiliaries, or system members. Scope 2 includes indirect emissions, through the use of electricity. Scope 3, an optional item, covers other indirect emissions, such as employee travel, waste treatment, etc. [5].

The value of CO2 emissions produced by a metro system due to the use of electrical energy varies greatly between metros around the world, depending on the energy matrix used by the energy-generating system in each location. Brazil is favored by predominantly using hydroelectric sources, with emissions usually considered negligible, representing more than 80% of Brazilian electrical energy generation [6]. In most countries in Europe, Asia, and Oceania there is a predominance of thermal sources, with a mix of coal, oil, and gas [7], which are more aggressive in terms of emissions. To allow the comparison of real emissions from transport systems, it is more appropriate to use the emission measure per passenger-km, which will indicate the level of efficiency of the system in relation to CO2 emissions.

CO2 EMISSIONS AVOIDED BY METRO SYSTEMS

Without the operation of a metro system, the city would have a much greater circulation of other more polluting means of transport, mainly road transport, such as cars, vans, buses, and motorcycles, and would possibly result in greater carbon emissions. The logic of this approach is to consider that the implementation of the metro system changes the traffic profile in a city, as passengers choosing to travel by metro will consequently reduce the use of other more polluting means of transport. Fewer vehicles in road traffic means lower CO2 emissions, due to the absence of these vehicles and also the better performance of the vehicles that travel, due to less traffic congestion.

The determination of avoided emissions consists of estimating the CO2 emissions produced in other means of transport when absorbing the entire daily demand of the metro system. To do this, data must be obtained on which means of transport each user would use if the metro system did not exist, estimating the amount of CO2 emitted when using this mode of transport. Knowledge of avoided emissions is essential for a better understanding of the impact caused by the metro on road traffic.

An avoided emission model was presented by APTA [8], through the concepts of:

a. **"mode shift" factor:** without the operation of a metro system, the city would have a much greater circulation of other means of transport that are more polluting than road transport, such as cars, vans, buses, and motorcycles. This would, in general, produce greater CO2 emissions.

b. **"congestion relief" factor:** road traffic, with more vehicles in circulation, would experience a higher level of congestion, which would cause greater fuel burning, further increasing emissions.

c. **"land use" factor:** the operation of the metro contributes to increasing the population density in its surroundings, favoring walking, cycling, and avoiding large journeys by car.

The sum of the emissions avoided by each of the factors determines the total avoided emissions. The difference between the total avoided emission and the produced one will give the net avoided emission.

The determination of avoided emissions by the "mode shift" factor is the most common and consists of estimating the CO2 emissions produced in other means of transport in absorbing the entire daily demand of the metro system. To do this, data must be obtained on which means of transport each user would use if the metro system did not exist, estimating the amount of CO2 emitted when using this transport.

THE CONTRIBUTION OF METROS IN REDUCING EMISSIONS

The methodology proposed in this paper considers the following elements:

a. **Debit:** the emission produced by the metro, which is the result of the GHG emissions inventory.

b. **Credit:** the emission avoided by the operation of the metro, where thousands of passengers would have to make their journeys on foot or by bicycle or use other means of transport that are more polluting than road transport, such as private cars, taxis, buses, vans, motorcycles and others.

It can be concluded, based on the debit-credit difference, whether the metro has positive or negative net emissions. If the net emission is positive, it means that, due to the operation of this metro, there is a greater emission of CO2 in the city's transport system, which would be possible to occur in cities where the energy matrix is basically made up of thermal sources, which would produce high debit values, and/or that there is not a large demand in the system, which would produce low credit values. If the net emission is negative, that is, if the credit is greater than the debit, it means that the metro operation contributes to lower CO2 emissions from the city's transport system.

The emissions produced and avoided, from selected metro systems, were obtained from published reports, as shown in Table 1.

	São Paulo	Rio de Janeiro	Lisbon	Porto	New York
Emissions produced	43.603	7.945	56.906	17.600	2.100.000
Avoided emissions	820.930	41.039	130.275	56.403	17.000.000
Result = Net emissions avoided	777.327	33.094	73.369	38.803	14.900.000
(%) Emissions avoided/produced	1.883%	516%	229%	320%	809%
SOURCES	[10]	[11]	[12]	[13]	[14]

Table 1 - Results of avoided net emissions, in tCO_2e, from the São Paulo, Rio de Janeiro, Lisbon, Porto and New York public transport system.

The results obtained indicate that in all the metros analyzed the avoided emissions were much greater than those produced, and the differences between the avoided emission/produced emission ratio can be explained by the differences in scope and methodology adopted and, in the case of Lisbon and Porto, due to its local energy matrix, as Portugal imports 90% of the primary energy it uses, where a large part of this energy is of fossil origin [9], while in Brazil there is less use of thermal sources, with just around 10% of all electricity generation in the country [6]. In New York, the values include the public transport system (metros, trains, and buses), using the 3 factors, in comparison with the use of cars. In the rest, the values refer only to metros, using the "mode shift" factor.

The structure of the energy matrix used by each metro is essential to determine the final result of avoided net emissions, as it will directly affect the emissions produced. Passenger demand for metro systems is also another relevant factor for the result, as it is necessary that the occupancy rate of the system is not low, so that the avoided emissions have relevant values, and are greater than the emissions produced.

CONCLUSIONS

When determining the impact of CO2 emissions from a city's transport system, one must take into account the fact that the operation of a metro system can avoid the emissions that would be produced if its passengers did not have access to the metro and had to travel their trips by other means of transport that are more polluting than road transport. The proposed methodology consists of calculating the emissions produced (debit) and avoided (credit) and, through their difference, evaluating the real impact of the metro in terms of CO2 emissions throughout a city's transport system.

The structure of the energy matrix used by each metro is essential to determine the final result of applying this methodology, as it will directly affect the emissions produced. The demand for metro passengers is also another relevant factor for the result of applying this methodology, as it is necessary that the occupancy rate of the system is not low, so that the avoided emissions have relevant values, and are greater than the emissions produced.

The application of the methodology to published data from the Metros selected in this article shows that all of them had negative net emissions, that is, their operations had a favorable impact, in the years analyzed, on the emissions produced by the city's transit system. Therefore, it can be seen that, in general, the option of using the metro transport system is the one that has the best performance in relation to CO2 emissions into the atmosphere.

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