Journal of Al-Azhar University Engineering Sector

Vol. 18, No. 66, January 2023, 74 - 82

TOWARD SUSTAINABLE TRANSPORTATION IN DEVELOPING AREAS

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Received: 5 June 2022 Accepted: 17 Dec. 2022

ABSTRACT

Sustainable transportation aims to make best integration of social, economic and environmental conditions for the transportation system. Carbon dioxide (CO_2) is the most dangerous and harmful emissions on human life. Developing areas in Egypt like Zagazig city suffers from continuous traffic congestion that product a huge emission daily. This study tries to achieve three main objectives. The first objective is daily CO_2 emission estimation of urban transportation in Zagazig city. While determination number of trees required to overcome the daily emissions in Zagazig city are the second objective. Finally, the third objective aims to investigate four hypothetical scenarios to reduce CO_2 emission of urban transportation and improve quality of life in Zagazig city. The study methodology started with determining numbers of generated trips for different motorized transportation modes using Zagazig city transportation database. Fuel consumption factor and CO_2 emission factor for different transportation modes were determined based on previous studies. A Visum model was conducted to determine average trips lengths for different travel modes depending on origin-destination matrix for each travel mode in the study area. Analyzing the study results, Daily CO_2 emission for urban area of Zagazig city was 159.12 ton per day from different transportation modes. The contribution of private cars, taxi, and microbus in daily CO_2 emission were 49.04, 26.39, and 83.69 ton per day. The study concluded to encourage passengers in Zagazig city to use non-motorized and public transportation modes in daily trips leads to considered decreasing CO_2 emission and produce sustainable transportation.

نحو نقل مستدام بالمناطق النامية

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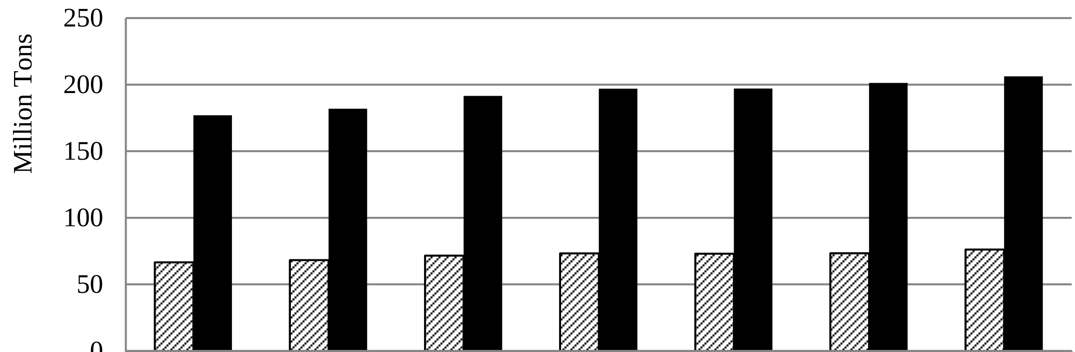
الملخص
يهدف النقل المستدام إلى تحقيق افضل تكامل بين الظروف الاجتماعية والاقتصادية والبيئية لنظام النقل. ثاني أكسيد الكربون (CO_2) هو أخطر الانبعاثات وأكثرها ضررًا على حياة الإنسان. تعاني المناطق النامية في مصر مثل مدينة الزقازيق من ازدحام مروري مستمر ينتج عنه انبعاثات ضخمة يوميًا. تحاول هذه الدراسة تحقيق ثلاثة أهداف رئيسية. الهدف الأول هو التقدير اليومي لانبعاثات ثاني أكسيد الكربون الناتجة عن النقل الحضري في مدينة الزقازيق. كما تهدف الى تحديد عدد الأشجار المطلوبة للتغلب على الانبعاثات اليومية في مدينة الزقازيق. اما الهدف الثالث للدراسة يهدف إلى التحقيق في أربعة سيناريوهات افتراضية للحد من انبعاثات ثاني أكسيد الكربون من النقل الحضري وتحسين نوعية الحياة في مدينة الزقازيق. بدأت منهجية الدراسة بتحديد عدد الرحلات المتولدة لمختلف وسائل النقل باستخدام قاعدة بيانات النقل لمدينة الزقازيق. تم تحديد معامل استهلاك الوقود ومعامل انبعاث ثاني أكسيد الكربون لوسائل النقل المختلفة بناءً على نتائج وتوصيات الدراسات سابقة. تم عمل نموذج Visum لتحديد متوسط أطوال الرحلات لوسائل النقل المختلفة اعتمادًا على مصفوفة المصدر والهدف لكل نمط رحلات في منطقة الدراسة. بتحليل نتائج الدراسة، يقدر حجم انبعاثات ثاني أكسيد الكربون اليومية من وسائل النقل المختلفة للمنطقة الحضرية بمدينة الزقازيق بحوالى 159.12 طن. وتنتج كمية انبعاثات ثاني أكسيد الكربون اليومية بمدينة الزقازيق من السيارات الخاصة والتاكسى والميكروباص والتى تقدر 49.04 و 26.39 و 83.69 طن بالترتيب. وتشير الدراسة إلى أن تشجيع الركاب في مدينة الزقازيق على استخدام وسائل النقل غير الآلية ووسائل النقل العام في الرحلات اليومية يؤدي إلى تقليل انبعاثات ثاني أكسيد الكربون بالمدينة وإنتاج انظمة نقل مستدامه.

Keywords
Sustainable transportation, emissions, Carbon dioxide emission factor, Fuel consumption economics

1- INTRODUCTION
Sustainable transportation was defined as ‘satisfying current transport and mobility needs without compromising the ability of future generations to meet these needs’ [1]. Sustainable transportation is the transportation system that provides three main components social, economic, and environmental [2]. Many transportation planners in devolving countries interest only with the social and economic components of transportation systems. The environmental component of sustainable transportation searches about green transportation systems that minimize fuel consumption and emissions. Developing areas in Egypt city are suffering from continuous traffic congestion. Decision makers are moving towards increasing the area of existing roads at the expense of green areas and trees as the best solution to the traffic congestion problem from their point of view.

Emission is the main cause of global warming and climate changes in the world. Emission control is one of sustainable transportation requirements in urban areas. Carbon dioxide (CO_2) is one of the most dangerous and harmful emissions on human life. CO_2 emission represented 98.43 % of the total emissions of the transit buses in the greater Cairo area [3]. According to World meter record, Egypt rank is twenty-seven in the world for carbon dioxide emissions [4]. Many sectors contribute to CO_2 emissions in Egypt that includes transportation, tourism, agriculture, contraction, industry, electricity, petroleum, and buildings. The mobilization and statistics center in Egypt counts the amount of fuel consumption and CO_2 emission per year. Figure (1) presents the amount of fuel consumption and CO_2 emissions in Egypt from year 2009/2010 to year 2015/2016 [5]. Transportation sector contributes by about 18% of CO_2 emission in Egypt according to the latest statistics of the mobilization and statistics center [5]. Vitor William Batista Martins et al [6] defined sustainable transportation as transportation systems that minimize the CO_2 emission as possible in urban mobility.



Year	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
Energy Consumption	66.561	68.258	71.61	73.23	73.044	73.358	76.13
Co2 Emissions	177.01	181.95	191.56	196.99	197.14	201.34	206.2

Figure (1): Fuel consumption and CO_2 emissions in Egypt from year 2009/2010 to year 2015/2016 [6].

The studies [7 and 8] were conducted to estimate the amount of CO_2 emission from transportation modes. These studies were classified CO_2 emission estimation methods to activity-based method and energy-based method. The Activity based method depends on the mode emission rate per kilometer while energy-based method depends on the mode energy consumption and emission rate per liter of fuel consumption. Activity based method calculates CO_2 emission for specific travel mode by multiplying the volume, distance of travel, and emission factor for this mode as shown in Equation (1). Energy based method calculates CO_2 emission for specific travel mode as function of fuel consumption for this mode. The form of energy-based method is presented in Equation (2). The independent variables of different methods were determined by similar techniques for these studies. The numbers of each type of transport modes were counted from the transport and traffic administration authorities' inventories. Average running kilometer distance per day for public transport modes were calculated using traffic operation centers and public transportation lines maps. For private cars, Average running kilometer distance per day for public transport modes were calculated by applying questionnaire for representative sample.

$$CO_2 \text{ emission} = V \times D \times EF_1 \qquad (1)$$

V: Number of each type of transport modes,
D: Average running distance (km) per day by transport mode, and
EF_1: Average CO_2 emission factor per-km by transport mode.

$$CO_2 \text{ emission} = V \times D \times CF \times EF_2 \qquad (2)$$

V: Number of each type of transport modes,
D: Average running distance (km) per day by transport mode,
CF: Average fuel consumption factor per kilometer by transport mode, and
EF_2: Average CO_2 emission factor per-lit of fuel consumption.

Many studies [9, 10, 11, 12, 13 and 14] were conducted to determine the fuel Consumption factor and CO_2 emission factor in different cities around the word. Table (1) summarizes the six studies. It shows the author, year of study, study area, study Country, studied travel modes, fuel type, fuel Consumption factor, and CO_2 emission factor for each study.

Table (1): Summery of CO_2 emissions estimation studies

Author	Study Year	City	Country	Travel Mode	Fuel Type	Fuel Consumption Factor	Co² Emission Factor
Aliakbar Kakouei et al [9]	2011	Tehran	Iran	Bus	Diesel	0.25 (Lit//Km)	2.94 (kg/Lit)
				Taxi	Petrol	0.1 (Lit//Km)	2.45 (kg/Lit)
				Private Car	Petrol	0.1 (Lit//Km)	2.45 (kg/Lit)
				Motorcycle	Petrol	0.1 (Lit//Km)	2.45 (kg/Lit)
Desert Development Center [10]	2017	Cairo	Egypt	Cars	Petrol	-	0.2408 (kg/km)
				Van/Microbus/Light Truck	Diesel	-	0.3696 (kg/km)
				Bus (Coach)	Diesel	-	0.8854 (kg/km)
Dinesh Mohan [11]	2014	Delhi, Visakha patnam, and Rajkot	India	Diesel Cars (all engine sizes)	Diesel	16.1 (km/Lit)	-
				Diesel Cars (<=1,600 cc)	Diesel	16.3 (km/ Lit)	-
				Diesel Cars (>1,600 cc)	Diesel	13.5 (km/ Lit)	-
				Petrol Cars (all engine sizes)	Petrol	14.9 (km/ Lit)	-
				Petrol Motorized two wheelers	Petrol	48.5 (km/ Lit)	-
				Diesel Three-Wheelers	Diesel	29.3 (km/ Lit)	-
Sutthicha Nilrit [12]	2012	Thailand	Thailand	Buses	Diesel	2.4 (km/Lit)	1150.1 (g/km)
				Pick-ups and Vans	Diesel	9.1 (km/Lit)	307.2 (g/km)
				Passenger Cars	Petrol	11.6 (km/Lit)	190.5 (g/km)
				Motorcycles and Tuk-Tuks	Petrol	37 (km/Lit)	40 (g/km)
Ministry for the Environment Manatt Mo Te Taiao [13]	2016	New Zealand	New Zealand	Transport modes	Diesel	-	2.69 (kg/Lit)
					petrol	-	2.45 (kg/Lit)
					Gas	-	1.64 (kg/Lit)
Borut Jereb [14]	2018	Celje	Slovenia	Cars	Petrol	0.0000813 (Lit/m)	-
				Light goods vehicles(< 3.5t)	Diesel	0.0001120 (Lit/m)	-
				Medium goods vehicles (3.5t – 7t)	Diesel	0.0001690 (Lit/m)	-
				Heavy goods vehicles(over 7t)	Diesel	0.0002350 (Lit/m)	-
				Trailer vehicles	Diesel	0.0003500 (Lit/m)	-
				Buses	Diesel	0.0002800 (Lit/m)	-
				Motorcycles	Petrol	0.0000400 (Lit/m)	-

Trees are environmental important item and it is playing a main role in global climate change through sequestration of CO_2 emissions [15]. Many studies were conducted to estimate the trees absorption rate of CO_2 emission. P.J. Jithila and P.K. Prasadan [16] conducted study to determine the carbon sequestration by trees in India. The study estimated carbon sequestration of 610 trees from 45 different species. The annual carbon sequestered by studied trees was 138.367 ton/year. The carbon sequestration rate per one tree was 0.227 ton/year that equivalent 0.62 kg/day.

This study tries to achieve three main objectives. The first objective is daily CO_2 emission estimation of urban transportation in Zagazig city. While determination number of trees required to overcome the daily emissions in Zagazig city are the second objective. Finally, the third objective aims to investigate four hypothetical scenarios to reduce CO_2 emission of urban transportation and improve quality of life in Zagazig city.

2- THE STUDY METHODOLOGY

The study program consists of three stages that include preliminary, data collection, and data analysis stage. The study problem and objectives are defined in preliminary stage. Then the past studies in the field of this study are reviewed. This stage ends with selecting Zagazig city as study case. Zagazig city is the capital of Alsharkia government, Egypt. It is the largest city in East Delta. It lies at latitude 30°34'36.76''N and longitude 31°30'14.74''E. The study area is the urban area only of Zagazig city. It can represent by circle with radius about three kilometers. Figure (2) shows satellite image for Zagazig city. The study area population was about seven hundred capita in 2018.

In data collection stage the required data to complete this study are collected. The travel modes in the study area are private cars, taxi, and microbus. Zagazig city have not public transportation modes like buses, rails, and metro. The Origin-Destination (O-D) matrix for each travel modes were extracted using Zagazig city transportation database [15]. The occupancy of each travel modes is determined using JICA study [16]. The Study area road network is modeled using Visum Software. Figure (3) shows Visum model for the study area. The trip distance matrixes are extracted from Visum model. The average trip length for different modes is calculated using O-D matrix and distance matrix for each travel mode. Fuel consumption factor and CO_2 emission factor are taken from previous studies in developed areas.

Data analysis stage starts with estimating daily CO_2 emission in Zagazig city using activity-based method. Energy based method is also used to verify the estimated amount of CO_2 emission. Four hypothetical scenarios are discussed to control CO_2 emission in Zagazig city. The first scenario aims to determine the reduction in CO_2 emission when replacing microbus (shared taxi) by public buses. While the second scenario targets estimating the reduction in CO_2 emission when converting private cars trips to non-motorized trips. The reduction in CO_2 emission at converting private cars trips to public transport trips is investigated in the third scenario. Finally, the fourth scenario studies the impact converting petrol engines cars to gas engines cars on Co2 emission.

Figure (2): Satellite image for Zagazig city

Figure (3): Road network model for study area on Visum software

3- COLLECTED DATA

Table (2) presents the collected data for transportation system in Zagazig city. It illustrates that the existing transportation modes are private cars, taxi, and microbus (shared taxi). The study area motorized trips in were 677361-person trip at year 2018. The small cars (Private Car and taxi) trips were about 27% of total motorized trips. Microbus trips were about 73% of total motorized trips. Microbus represents the public transportation in Zagazig city but it similar small cars in its operation. The private cars, taxi, and microbus occupancy were 1.9, 2.5, and 8 person per vehicles respectively. CO_2 Emissions factor was 0.2408 kilogram of CO_2 per kilometer for private cars and taxies, but it was 0.3696 kilogram of CO_2 per kilometer for microbuses [10]. The Fuel consumption factor was 0.1 kilogram of petrol per kilometer for small cars while it was 0.11 kilogram of diesel per kilometer for microbuses. The average trip distances were calculated for private cars, taxi, and microbus using O-D matrix of each mode and its trip distance matrix. It was 3.77, 4.42, and 3.66 kilometer for private cars, taxi, and microbus respectively.

Table (2): Collected data for transportation system in Zagazig city

Travel mode	Private Car	Taxi	Microbus
Number of trips (person/day)	102620	80132	494609
Vehicle occupancy (person/vehicle)	1.90	2.50	8.00
Co^2 Emission factor (kg/km)	0.2408	0.2408	0.3696
Fuel consumption factor (Lit//Km)	0.10	0.10	0.11
Average trip distance (km)	3.77	3.42	3.66

4- DATA ANALYSIS AND DISCUSSION

In this section the collected data was used to catch the study objectives. It was disused in the following two subsections.

4.1- Estimation of CO_2 Emission in Zagazig City

Activity based method was used to estimate daily CO_2 emission in Zagazig city. Table (3) presents the vehicles trips and daily CO_2 emission for different travel modes. It illustrates that the number of total daily vehicles in Zagazig city was 147889 vehicles per day. The numbers of private cars, taxi, and microbus were 54011, 32053, and 61826 vehicles per day respectively. The small cars were about 58% of daily vehicles in the study area while microbus contributed by 42%. Table [3] also shows that the amount of daily CO_2 emission was 159.12 ton. The contribution of private cars, taxi, and microbus in daily CO_2 emission were 49.04, 26.39, and 83.69 ton per day. The private cars CO_2 emission was about 31% of daily CO_2 emission while taxi CO_2 emission was about 17%. The amount of daily CO_2 emission was about 52% for microbuses. It is noticed that the percent of small cars was 58% of daily vehicles and it contributed by 48% of daily CO_2 emission in Zagazig city. So, it is very important to investigate the best direction to control CO_2 emission.

The daily CO_2 emission in Zagazig city was also estimated using energy-based method. This step aims to verify the estimated CO_2 emission. The daily fuel consumption of different travel modes reached to 56233 ton per day. The CO_2 emission factor was 2.962 ton of CO_2 emission per ton of fuel consumption [6]. So, the amount of daily CO_2 emission in Zagazig city was 166.56 ton per day. A very slight difference between the amounts of daily CO_2 emission calculated using activity based and energy-based method was noticed. This indicates that the quantities of daily CO_2 emission in Zagazig city calculated using activity base method has high accuracy. To eliminate daily CO_2 emission in Zagazig city, the required number of trees was about 270000.

Table (3): Vehicles trips and daily CO_2 emission for different travel modes

Travel mode	Private Car	Taxi	Microbus	Total
Number of trips (vehicles/day)	54011	32053	61826	147889
Co2 Emission (ton/day)	49.04	26.39	83.69	159.12

4.2- CO_2 Emission Control Policies in Zagazig City

Table (4) shows the amounts of daily CO_2 emission for base situation (Scenario 0) in addition the four suggested scenarios. Figure (4) presents reduction percentages in CO_2 emission for suggested scenarios. The table illustrates that by using bus instead of microbus led to decreasing the CO_2 emission for public modes to 35.46 ton per day and decreasing the daily CO_2 emission to 110.89 ton per day. The reduction in CO_2 emission for Scenario (1) reached to about 30% of daily CO_2 emission. It may be due to the high occupancy of public buses. This indicates that encouragement of passengers to use public transportation produces less CO_2 emission and sustainable transportation.

Scenarios (2, 3, and 4) were investigated the impact of CO_2 emission in the study area at converting one percent of small cars trips to non-motorized, microbus, and gas cars. The daily CO_2 emission reached to 156.39 ton at applying Scenario (2). This means that encouragement the non-motorized trips (Walk and bicycle) to attract only one percent of private cars trips leads to 1.72% reduction in daily CO_2 emission. Scenario (3) led to decrease the daily CO_2 emission to 157.54 ton with reduction percentage about one percent. So, it can be concluded that converting one percent of small cars to microbus (public transport) leads to one percent reduction on daily CO_2 emission. Finally, at encouragement one percent of small cars owner to convert their cars to use greenhouse gas instead of petrol (Scenarios 4) the daily CO_2 emission reached to 158.22 ton. Scenarios (4) lead to 0.57% reduction for daily CO_2 emission in Zagazig city.

Table (4): Daily CO_2 emission of different scenarios

Travel mode	Small Cars	Microbus or bus	Total
Scenario (0)	75.43	83.69	159.12
Scenario (1)	75.43	35.46	110.89
Scenario (2)	72.70	83.69	156.39
Scenario (3)	72.70	84.84	157.54
Scenarios (4)	74.53	83.69	158.22

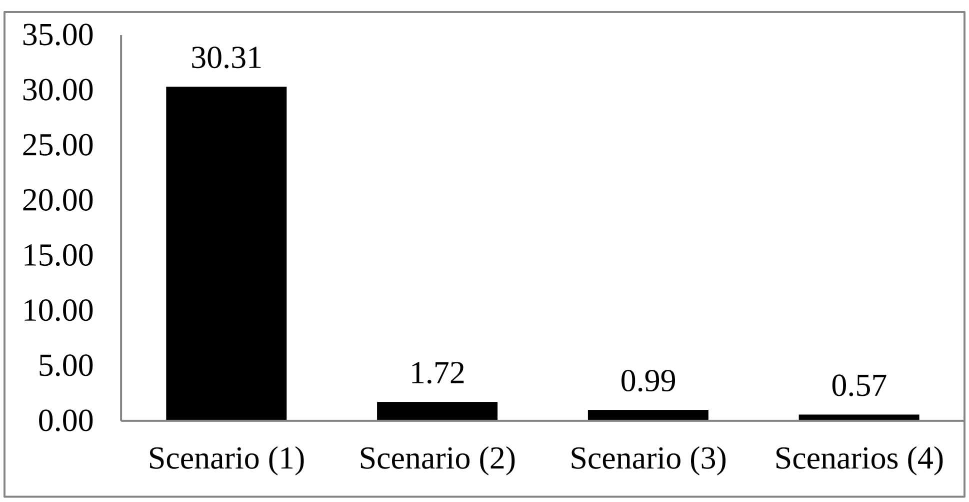


Figure (4): Reductions percentages in CO_2 emission for suggested scenarios.

5- CONCLUSIONS AND RECOMMENDATIONS

The estimated daily vehicles in Zagazig city was 147889 vehicles per day. The private cars, taxi, and microbus contributed by 54011, 32053, and 61826 vehicles per day respectively. Daily CO_2 emission for urban area of Zagazig city was estimated using activity and energy base methods. It was 159.12 ton per day from different transportation modes of Zagazig city. The contribution of private cars, taxi, and microbus in daily CO_2 emission were 49.04, 26.39, and 83.69 ton per day. Daily CO_2 emissions for Scenarios (1, 2, 3, and 4) were 110.89, 156.39, 157.54, and 158.22 ton. To eliminate daily CO_2 emission depending on green areas in Zagazig city, the required number of trees was about 270000. Daily CO_2 emission was decreased by about 30% through applying Scenario (1) policy. Scenario (2, 3, and 4) led to decrease the daily CO_2 emission in study area by 1.72%, 0.99%, and 0.57% respectively. Analyzing the study results concluded that daily CO_2 emissions for travel modes in developing urban area are high due to loss of public and clean transportation. It also concluded that encouragement of passengers to use non-motorized and public transportation modes in daily trips produces less CO_2 emission and sustainable transportation.

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