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Benefits of Replacement Public Transportation Fleet With Electrical Buses in An Urban Area in Egypt

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Benefits of Replacement Public Transportation Fleet With Electrical Buses in An Urban Area in Egypt

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KEYWORDS

Electric bus
Social benefits
Air pollution

***Abstract* — This study aims to calculate the financial and economic benefits of the application of electric buses in an urban area in Egypt. This is done by estimating the benefits and disbenefits of using this system in Benha, Egypt. In Egypt, there is no clear method to determine the benefits and disbenefits of using electric buses. Therefore, a logical way is used to determine the benefits and disbenefits of this application and to set some policies. This is achieved through the application of the sequential method (4-step model), which consists of four stages as follows: trip generation, trip distribution, model split, and traffic assignment. The questionnaires were designed to determine the factors that affect the choice of electric buses. The data was analyzed and calibrated into a model which predicts the volume of demand for electric buses, the importance of each variable was studied, and the advantages and disadvantages of implementing the electric bus system in Egypt were studied. The questionnaire provided three suggestions for using electric buses. The logistic regression was used to find the best-proposed suggestion for using electric buses if it was the first suggestion or to choose another suggestion according to the following independent variables (travel time) and the following categorical variables (address, gender, age, education, vehicle ownership, income, and trip purpose). The three models were obtained and estimated to obtain the utility function of each suggestion. From the analysis, the best suggestion is the first, as the total number of trips using electric buses is larger than the other two suggestions. By comparing the air pollution with and without electric buses, it is clear that the use of electric buses will reduce air pollution by 69 %. The benefits of electric bus application in Benha, Egypt were estimated by evaluating the money value of air pollution and the value of time. The value of time was calculated by knowing the average travel time with and without electric buses, the average salary from the questionnaire, and the total working hour. Finally, the total reduction of the value of time was estimated and found to be 8.3 *10^5 LE.**

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I.INTRODUCTION

EGYPT is the most polluted country in Africa and the Middle East. Transportation is considered one of the most important sources of pollution in Egypt. Egypt tends to use environmentally friendly and energy-efficient means of transportation to reduce transportation problems such as pollution and congestion, the most famous of which is electric buses [2]. The problem is that there are not enough studies to determine the feasibility of applying this type of transportation in urban areas in Egypt, and therefore this research aims to define a logical way to determine the benefits and disbenefits of this application and setting of some policies. This research is applied to the city of Benha as an example of an urban area in Egypt. The research was applied to this area by calibrating a logic model to estimate the demand for this mode and analyzing the benefits of electrical bus application in an urban area. (Reinhart, 2010) discussed that "the electric bus is categorized as an environmentally friendly and energy-saving transportation system; locally emission-free by the electric drive, low noise, gentle but also powerful, it is easy to merge into existing networks and it gives a higher quality of life in the city". (Kristi, 2020) found that "the electric buses provide an interesting set of benefits to the organizations getting them. The electric buses are very productive and have lower working costs than diesel buses". (Olli & Joni, 2015) analyzed the financial possibility of electric buses in a mid-sized city and said that the electricity is a much cheaper fuel than diesel. He found that the main component of an electric vehicle is the battery. A battery stores electrical energy in the chemical bonds. (Moataz, Ryan, Mark, & Pavlos, 2016) provided a detailed review of different performance features for three categories of electric buses: hybrid, fuel cell, and battery. It showed that hybrid buses will not provide an important reduction in GHG (greenhouse gas) and would be suitable only for short-term goals as a starting point for full-electric transportation. Battery and fuel cell buses are able of satisfying the current operational requirements, however, primary investment remains a major barrier. (Antti, 2018) proved that "the battery-electric buses are energy efficient and emission-free, but their lifecycle costs can be much higher compared to diesel or hybrid buses due to the expensive technology". (Larisa, 2018) found that in arrange to supply reliable and safe working of electric buses, it is needed to develop not only a network of charging stations but to update the existing maintenance system, and found that the most objective of developing electric transport can be related to the progress of high-capacity batteries and charging stations.

Factors that affect an individual's choice of traffic mode

(El Esawey & Ghareib, 2009) studied three groups of variables that would determine an individual's mode choice utility: Level of Service (LOS) variables are system characteristics given by transport modes, including (time components and cost), Socioeconomic (SE) variables: represent the trip maker's characteristics that may impact his/her choice, including (gender, age, and income) and attitudinal variables: (comfort and convenience, reliability and regularity, protection and security and availability). He considered only the first two groups of variables in his research due to a lack of necessary information for the third group. (Huzayyin & Youssef, 2013) mainly analyzed travel time and cost variables. He mentioned other factors in his analysis (gender, age, income, occupation, trip purpose, and the relative level of service offered by the available transport modes on the choice set of the traveler for a particular trip). (Dimitrios, Constantinos, & Yannis, 2017) found that factors that have affected the decisions of people to shift to and from public transportation are:(age, occupation, gender, quality of service, service production /transfer quality, ticket service, and environmental consciousness). (Ander, Oihane, Ainhoa, & Cruz, 2018) found that factors that affect an Individual's Choice are:(time, cost, comfort, and environmentally friendly awareness). Four main categories represent the physical and factual features of a trip: (duration, price, length, and environmental impact). There are other variables that are directly linked to the traveler's background, as these four variables do not cover some other features recorded in the literature. These background variables (profile:(citizen age, citizen gender, socio-economic profile, cultural profile, family size, and trip type), ownership: (car ownership, motorcycle ownership, and bicycle ownership), and climatology: (environment climatology)). (Dmitry & Vaira, 2010) analyzed factors that influence the passengers' choices, which include:(travel-specific factors (departure time), factors that describe the passengers (age, income), and factors that describe the behavior of travelers (time of arrival to a station before departure). (Zhang, Guan, Qin, & Xue, 2013) mentioned in his survey: personal information including gender, age, occupation, car purchase plan, monthly household income, and bus travel behavior, including weekly trip times of used traffic mode, payment mode, bus travel time, and bus satisfaction degree.

Mode choice models

(Minal & Ch. Ravi, 2014) investigated the aggregate models try to show the average behavior of a group of travelers instead of a single individual, but disaggregate models showed the behavior of individuals and responses as a function of the alternative available characteristics and sociodemographic properties of each individual. The disaggregate approach is more efficient than the aggregate approach. He also discussed that there are three different types of models depending on the functional form namely: Logit model, Probit Model, and General Extreme Value Model. (Chen & Li, 2017) found that "Discrete choice models are a perfect method of research on individual choice behavior. Discrete choice models are used in public transport and show individual choice behavior as the result of preferences that an individual makes with the assumption that the consumer chooses the most preferred option. (L.Watson & Richard, 1975) proved that disaggregate models are able to predict diverse travel situations and compared with the aggregate models which are currently used in urban transportation planning, and it is shown that disaggregate models which are based on small data predict better than aggregate models because of needing no more information about the predicted population. (Richard, David, & Richard, 1982) made an initial difference between aggregate and disaggregate modeling utilizations. Aggregate approaches mainly focused on the mode choices made by average individuals for trips between zones. The defects of the aggregate approach have been found as follows : (The models do not describe the behavior of the individual. Because of these problems, many researchers have begun to develop "disaggregate" models. (Elharoun, Shahdah, & M. El-Badawy, 2018) examined that “the mode choice models can be classified into three main models, namely: logit models, probit models, and general extreme value models ". In this research study, the logit model was suitable for its simple mathematical framework. It can be classified into two main categories: binary and multinomial logit models.

Logit Model

(Minal & Ch. Ravi, 2014): The Logit model can model the complicated travel behaviors of any population with simple mathematical techniques, and this proves to be the most widely used tool for mode choice modeling. The logit models can be categorized into three types depending on whether the data or coefficients are chooser specific or choice-specific (multinomial logit, conditional logit model, and mixed logit model). (Elharoun, Shahdah, & M. El-Badawy, 2018) examined that “Logit models can be classified into two main categories: (1)binary and (2) multinomial logit models. Binary choice models can be used if the individual has only two alternatives to select from, while the multinomial logit models can be used in the case of more than two alternatives. Multinomial Logit (MNL) model structure is probably the most widely used form of behavioral discrete choice analysis. (Tomáš, Katarína, & Mária, 2015) found that, unlike the probit model, the Logit model has two actual advantages instead of their mutual similarity. The equation of the logit function is very simple while the normal cumulative distribution function contains unquantified integral and Interpretability.

Utility Theory for Discrete Choice Model

(Elharoun, Shahdah, & M. El-Badawy, 2018) found that the discrete choice logit model is usually obtained from the random utility theory. It assumes that individuals choose transport modes that maximize their utility. The utility recognized by each individual for every transportation mode is considered a random variable and can be presented as follows:

$$U_{ij} = V_{ij} + \varepsilon_{ij}, \quad j \in A_i \qquad (1)$$

Uij: the utility of mode i for individual j;
Vij: a function of measured mode-specific and socioeconomic variables Xijk;
εij: an unknown random component that represents unobserved attributes and/or observational errors.

Data collection

(El Esawey & Ghareib, 2009) collected the data through the Home Interview Survey (HIS), the Revealed Preference Survey (RPS), and the Stated Preference Survey (SPS). The HIS was the largest home interview survey, and the aim of the HIS was to know the characteristics of households, people, and trips within the study area. The HIS survey was done with a random selection of households within the study area. Whereas the RPS, the objective of the RPS was to collect the important information needed to develop the disaggregate mode choice models and it was conducted to the choice-based sampling method. The SPS is aimed at discussing individuals’ choices when facing some new transit policies in the future. The interviewed households which were selected were done as the same random sampling steps used in the HIS. But, the SPS was conducted separately from the HIS. The individuals will not act in a hypothetical situation in a way that is like how they would act in the real world so the SPS data were not used in the current analysis but using RPS. (Zhang, Guan, Qin, & Xue, 2013) investigated that “revealed preference data (RP data) cannot describe the nonexisting traffic mode, unlike, hypothetical situation stated preference data (SP data) can design future traffic scene and analysis the traffic demand under different conditions. So, the revealed preference choice may be in contradiction with the stated preference choice. The method of revealed preference (RP) survey and stated preference (SP) survey was used to analyze the user's behavior in his paper.

II. METHODOLOGY AND ANALYSIS

The logistic regression is used in this research and the main objective of regression analysis is to obtain the estimated model that represents the relationship between variables for use in statistical forecasting. To estimate logistic regression coefficients, the maximum likelihood method is used. The data in this research were collected using a questionnaire. The questions in the questionnaire are information about personal characteristics, trip characteristics, and proposed mode characteristics : (Electrical Buses). Table (1) shows the questions used in the questionnaire :

TABLE 1
THE QUESTIONNAIRE

	The Questions	The Choices
Person characteristics	Person address	-In Benha -out of Benha
	Gender	-Male -Female
	Age	-Less than 18 -18-40 -More than 40
	Educational Level	-Uneducated -Presecondary education -Technical education -Secondary education -Academic education

(continued on the next page)

(TABLE 1: continued)

	The questions	The Choices
Person characteristics	Income	-<2000 -From 2000 to 5000 -From 5000 to 10000 ->1000 -Other
	Car ownership	-One car -More than one car -Do not have a Car
Trip Characteristics	Trip origin	"Short answer"
	Trip destination	"Short answer"
	Trip Purpose	-Work purpose -Education purpose -Entertainment purpose - Shopping purpose -Social purpose -The other purpose
	Travel Time(min)	"Short answer"
	Travel cost(LE)	"Short answer"
	Used Mode	-Private car -Taxi -Van -Microbus -Train -Other means
Proposed Mode Characteristics:(Electrical Buses)	If there is an alternative mean of transportation, do you prefer to change to this mean if it is	-Walking Time is (15 min), Bus frequency is (15 min), Cost (3 LE), and Travel Time shorter by up to (10 %). -Walking Time is (10 min), Bus frequency is (10 min), Ticket Cost (5 LE), and Travel Time shorter by up to (20 %). -Walking Time is (5 min), Bus frequency is (5 min), Ticket Cost (7 LE), and Travel Time shorter by up to (30 %).

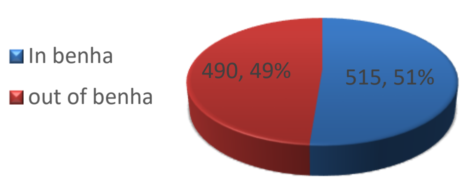
– The random sample size used in this work was 1005 samples.

– The distribution of samples according to the variables**:**

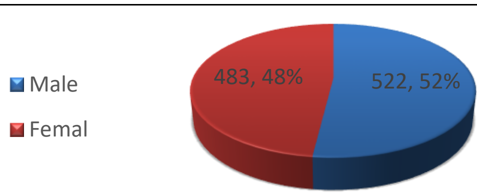
The data, obtained from the questionnaire, was described by calculating the frequency and the corresponding percentage, as shown in table (2) : (The source: depending on the results of statistical analysis of the data).

TABLE 2
THE NUMBER AND THE PERCENTAGE OF THE DISTRIBUTION OF SAMPLES

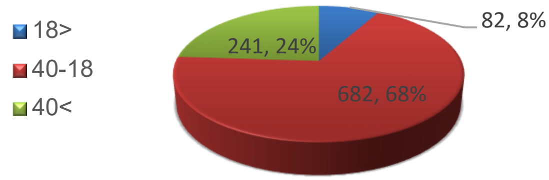
Address



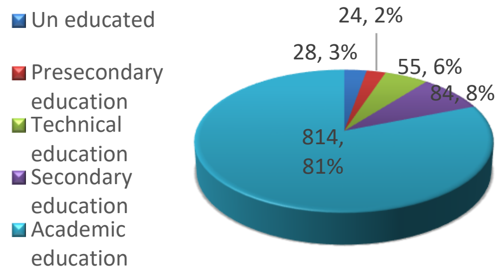
Gender



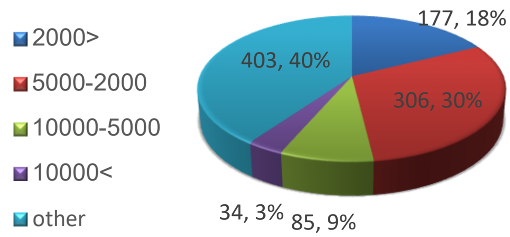
Age



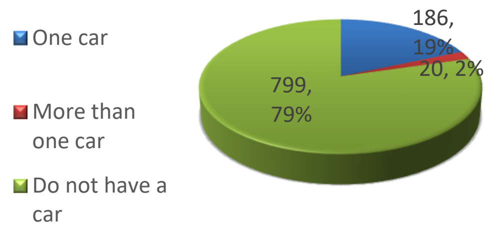
Education



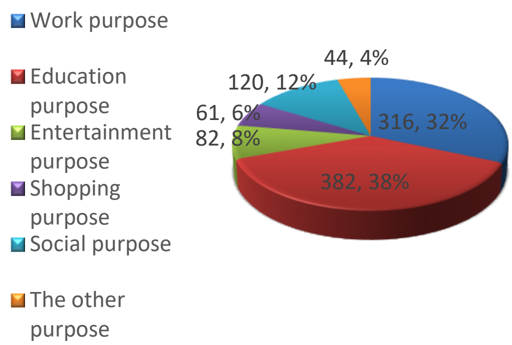
Income



Car ownership



Trip purpose



Analysis of logistic regression

The logistic regression is used to find the best-proposed suggestion for using electric buses if it is the first suggestion or to choose another suggestion as shown in the questionnaire according to the following independent variables (travel time), and the following categorical variables (address, gender, age, education, vehicle ownership, income, and trip purpose).

A. Analysis of logistic regression (first suggestion):

The following items are used in the interpretation of the analysis:

1. Omnibus Tests :

This test uses a chi-square test to know the effect of the independent variables combined on the dependent variable.

We note the following from the table (A1) in the appendix:

- The level of significance of chi-square is less than 0.01, so the model is morally and statistically significant and the independent variables combined to affect the dependent variable.

2. The explanation of the logistic regression coefficients:

The values of the independent variable coefficients are based on the wald test and the researchers also used the exponential function beta exp (b) coefficient, i.e. weighting ratio, to explain the weighting ratio. It is easier to explain the β coefficient than the logarithmic unit.

We note from the table (A2) in the appendix the following:

- The level of significance for the variables (travel time, address, and education) is less than 0.05, so they have a significant effect.
- The level of significance for the variables (gender, age, income, and the trip purpose) is greater than 0.05, so they do not have a significant effect.
- The level of significance for the variable (car ownership) is 0.05, so it has a significant effect.

The estimation model is as follows:

$$\textbf{Log (p/1-p)} = (-0.003)\, x_1 + (0.275)\, x_2 + (0.236)\, x_3 + (-0.166)\, x_4 \quad (2)$$

As :

Log (p/1-p): the logistic regression equation for predicting the dependent variable (choosing the first suggestion or another suggestion)

X_1: Travel Time variable (min)
X_2: Person address variable
X_3: Educational Level variable
X_4: Car ownership variable

B. Analysis of logistic regression (second suggestion):

The following are the results of this analysis:

1. Omnibus Tests:

This test uses a chi-square test to know the effect of the independent variables combined on the dependent variable.

We note from the table (A3) in the appendix the following:

- The level of significance of chi-square is less than 0.01, so the model is significant and statistically significant and the independent variables combined to affect the dependent variable.

2. The explanation of the logistic regression coefficients:

The values of the independent variable coefficients are based on the wald test and the researchers also used the exponential function beta exp (b) coefficient, i.e. weighting ratio, to explain the weighting ratio. It is easier to explain the β coefficient than the logarithmic unit.

We note from the table (A4) in the appendix the following:

- The level of significance for the variables (travel time, address, age, income, and the trip purpose) is less than 0.05, so they have a significant effect.
- The level of significance for the variables (gender, education, and car ownership) is greater than 0.05, so they do not have a significant effect.

The estimation model is as follows:

$$\textbf{Log (p/1-p)} = (-0.002)\, x_1 + (0.323)\, x_2 + (-0.210)\, x_5 + (-0.086)\, x_6 + (-0.096)\, x_7 \quad (3)$$

As :

Log (p/1-p): the logistic regression equation for predicting the dependent variable (choosing the first suggestion or another suggestion)

X_1: Travel time variable (min) X_2: Person address variable
X_5: Age variable X_6: Income variable
X_7: Trip purpose variable

C. Analysis of logistic regression (third suggestion):

The following are the results of this analysis:

1. Omnibus Tests:

This test used a chi-square test to know the effect of the independent variables combined on the dependent variable.

We note from the table (A5) in the appendix the following:

-The level of significance of chi-square is less than 0.01, so the model is significant and statistically significant and the independent variables combined to affect the dependent variable.

2.The explanation of the logistic regression coefficients:

The values of the independent variable coefficients are based on the Wald test, and the researchers also used the exponential function beta exp (b) coefficient, i.e. weighting ratio, to explain the weighting ratio. It is easier to explain the β coefficient than the logarithmic unit.

We note from the table (A6) in the appendix the following:

-The level of significance for the variables (travel time, address, and car ownership) is less than 0.05, so they have a significant effect.

-The level of significance for the variables (gender, age, education, income, and the trip purpose) is greater than 0.05, so they do not have a significant effect.

The estimation model is as follows:

$$\textbf{Log (p/1-p)} = (-0.005)\, x_1 + (0.382)\, x_2 + (-0.298)\, x_4 \quad (4)$$

As :

Log (p/1-p): the logistic regression equation for predicting the dependent variable (choosing the first method or another method)

X_1: Travel Time variable (min)

X_2: Person address variable

X_4: Car ownership variable

III. THE RESULTS AND DISCUSSION

The utility functions obtained from the estimation models are used to calculate the percentage of people that will use electric buses, the number of trips by electric buses all-day and during peak hours for the three suggestions, and the number of trips by other means of transportation all-day and during peak hours.

1-In First suggestion :

X_1 = 46 (average travel time), X_2 = 1 (address), X_3 =(1, 2, 3, 4, 5) (uneducated, pre-secondary educated, secondary educated, technical educated, academic educated), X_4 =(1, 2, 3) (one car, more than one car, do not have car)

-Calculated the people's percentage that will use electric buses (P).

$$P=\frac{e^{-0.003x1+0.275x2+0.237x3-0.166x4}}{1+e^{-0.003x1+0.275x2+0.237x3-0.166x4}} \quad (5)$$

-From the questionnaire: the total number of people who chose the first suggestion was 342.

-From the questionnaire: the people's percentage according to car ownership is calculated.

-The total trips in peak hours = 133692 trips/day (From the strategic plan of Benha city).

-The distributed trips in peak hours = The total trips in peak hours (133692)* the people's percentage from the questionnaire.

-The number of trips by electric buses in peak hours = The distributed trips in peak hours * P (the people's percentage that will use electric buses).

TABLE 3
NO OF TRIPS BY ELECTRIC BUSES IN PEAK HOUR

Educational level (X_3)	Car ownership (X_4)		
	1	2	3
The uneducated people	481	-	1864
The presecondary people	-	-	3677
The secondary people	329	-	5182
The technical people	2974	337	7508
The academic people	14920	2707	69847

-The total number of trips by electric buses in peak hours =109826 trips/day.

-The total number of trips by other means in peak hours =133692-109826 =23866 trips/day.

In all-day

-The total trips in all-day = 253440 trips/day (From the strategic plan of Benha city).

-The distributed trips in all-day = The total trips in all-day (253440) * the people’s percentage from the questionnaire.

-The number of trips by electric buses all-day = The distributed trips * P.

TABLE 4
NO OF TRIPS BY ELECTRIC BUSES IN ALL-DAY

Educational level (X_3)	Car ownership (X_4)		
	1	2	3
The uneducated people	913	-	3533
The presecondary people	-	-	12672
The secondary people	38	-	13724
The technical people	1584	23	13139
The academic people	4866	171	124712

-The total number of trips by electric buses all-day =175375 trips/day.

-The total number of trips by other means all-day =253440-175375 =78065 trips/day.

2-Second suggestion :

X_1=46 min (average travel time), X_2 = 1 (address), X_5(age)= (1, 2, 3)(< 18, 18-40, >40), X_6(income) =(1, 2, 3, 4, 5)(< 2000, 2000-5000, 5000-10000, >10000, Other), X_7(the trip purpose)=(1, 2, 3, 4, 5, 6) (for work, for education, for entertainment , for shopping, for social, for the other purpose).

-Calculated the people’s percentage that will use electric buses (P).

$$P=\frac{e^{-0.002x1+0.323x2-0.21\,x5-0.086\,x6-0.096\,x7}}{1+e^{-0.002x1+0.323x2-0.21\,x5-0.086\,x6-0.096\,x7}} \quad (6)$$

-The total number of people who chose the second suggestion was 401.

-From the questionnaire: the people’s percentage according to age & income & the trip purpose is calculated.

-The total trips in peak hours = 133692 trips/day (From the strategic plan of Benha city).

-The distributed trips in peak hours = The total trips in peak hours (133692)* the people’s percentage from the questionnaire.

-The number of trips by electric buses in peak hours = The distributed trips in peak hours * P.

1- For the people that age <18 (X_5 = 1).

TABLE 5
NO OF TRIPS BY ELECTRIC BUSES IN PEAK HOUR

Trip purpose (X_7)	Income (X_6)				
	1	2	3	4	5
1	-	-	-	-	-
2	169	-	-	-	2155
3	139	133	-	-	112
4	-	-	-	-	116
5	-	-	-	-	108
6	-	-	-	-	278

$\sum$ = 3211 trips.

2- For the people that age 18-40 (X_5 = 2).

TABLE 6
NO OF TRIPS BY ELECTRIC BUSES IN PEAK HOUR

Trip purpose (X_7)	Income (X_6)				
	1	2	3	4	5
1	1822	5108	1230	232	219
2	4285	1476	349	-	10457
3	800	1075	301	103	526
4	371	699	-	-	382
5	328	701	96	89	413
6	80	228	69	-	127

∑ = 31564 trips.

3- For the people that age >40 (X_5 = 3).

TABLE 7
NO OF TRIPS BY ELECTRIC BUSES IN PEAK HOUR

Trip purpose (X_7)	Income (X_6)				
	1	2	3	4	5
1	447	3611	1050	383	357
2	-	91	-	-	-
3	91	256	-	-	-
4	96	89	172	-	305
5	176	425	156	143	284
6	-	759	-	179	162

∑ = 9230 trips.

-The total number of trips by electric buses in peak hours =3211+31564+9230=44005 trips/day.
-The total number of trips by other means in peak hours =133692-44005 =89687 trips/day.

In all-day

-The total trips in all-day = 253440 trips/day (From the strategic plan of Benha city).
-The distributed trips in all-day = The total trips in all-day(253440)* the people's percentage from the questionnaire.
-The number of trips by electric buses all-day = The distributed trips all-day * P.

1-For the people that age <18 (X_5 = 1).

TABLE 8
NO OF TRIPS BY ELECTRIC BUSES IN ALL-DAY

Trip purpose (X_7)	Income (X_6)				
	1	2	3	4	5
1	-	-	-	-	-
2	320	-	-	-	4086
3	264	251	-	-	213
4	-	-	-	-	220
5	-	-	-	-	206
6	-	-	-	-	527

∑ = 6087 trips.

2-For the people that age 18-40 (X_5 = 2).

TABLE 9
NO OF TRIPS BY ELECTRIC BUSES IN ALL-DAY

Trip purpose (X_7)	Income (X_6)				
	1	2	3	4	5
1	3455	9682	2332	441	415
2	8123	2799	660	-	19823
3	1516	2037	570	194	998
4	703	1324	-	-	725
5	622	1328	181	168	783
6	151	433	131	-	240

∑ = 59836 trips.

3-For the people that age >40 (X_5 = 3).

TABLE 10
NO OF TRIPS BY ELECTRIC BUSES IN ALL-DAY

Trip purpose (X_7)	Income (X_6)				
	1	2	3	4	5
1	847	6845	1991	726	678
2	-	173	-	-	-
3	173	485	-	-	-
4	182	169	326	-	577
5	333	806	296	271	537
6	-	592	-	139	126

∑ = 16272 trips.

-The total number of trips by electric buses all-day =6087+59836+16272=82196 trips/day.
-The total number of trips by other means all-day =253440-82195=171244 trips/day.

3-Third Suggestion:

X_1= 46 min (average travel time), X_2 =1 (address), X_4 (car ownership) = (1, 2, 3)(one car, more than one car, do not have car).
-Calculated the people's percentage that will use electric buses (P).

$$P=\frac{e^{-0.005x1+0.382x2-0.298x4}}{1+e^{-0.005x1+0.382x2-0.298x4}} \quad (7)$$

-The total number of people who chose the third suggestion was 262.
-From the questionnaire: the people's percentage according to car ownership is calculated.
-The distributed trips in peak hours = The total trips in peak hours (133692)* the people's percentage from the questionnaire table.
-The number of trips by electric buses in peak hours = The distributed trips in peak hours* P.

TABLE 11
NO OF TRIPS BY ELECTRIC BUSES IN PEAK HOUR

Car ownership (X_4)	1	2	3
No of trips by electric buses	12514	669	13850

-The total no of trips by electric buses in peak hours =27033 trips/day.

-The total no of trips by other means in peak hours =133692 - 27033=106659 trips/day.

In all-day

-The total trips in all-day = 253440 trips/day (From the strategic plan of Benha city).

-The distributed trips all-day = The total trips in all-day (253440)* the people's percentage from the questionnaire.

-The number of trips by electric buses all-day = The distributed trips all day * P.

TABLE 12
NO OF TRIPS BY ELECTRIC BUSES IN ALL- DAY

Car ownership (X_4)	**1**	**2**	**3**
No of trips by electric buses	23722	1267	26256

-The total number of trips by electric buses all-day =51245 trips/day.

-The total number of trips by other means all-day =253440-51245=202195 trips/day

From the analysis, the best suggestion is the first, as the total number of trips used by electric buses is larger than the other two suggestions.

3.1. Estimation of the benefits of electric bus application in Benha city

From the strategic plan of Benha city :

For the first suggestion:

-Use average occupation = 4 pc /car.

-The number of car trips = total trips /average occupation =total trips /4.

TABLE 13
NO OF CAR TRIPS/DAY

Without electric bus	With electric bus
All day : No of car trips =63360 car trips/day.	All day : No of car trips = 19516 car trips/day.

❖ *-To calculate air pollution :*

-The number of occupation hours =average travel time * no of car trips.

- Average travel time=0.92 hr.

TABLE 14
NO OF OCCUPATION HOURS

Without electric bus	**With electric bus**
All day : No of occupation hours=2428.8 hr.	In Ally : No of occupation hours=748.11 hr.

-To calculate air pollution for every kilometer for each pollutant:

❖ *To calculate the pollution rate:*

-Use RPM (rotation per minute) = 3500 rpm, G = 0% (Benha roads are almost flat : all grades on it's roads are very small), RH (average ambient humidity in Benha) = 51.5 %, P(average ambient pressure in Benha) =101.32 kpa, T (average temperature) = 25 °c, V (average speed in Benha) =20 km/hr.

-Co_2 pollution rate =79.9 kg/hr, Co pollution rate =7230.99 kg/hr, and Nox pollution rate =0.49 kg/hr [23] .

-Total pollution rates= the number of occupation hours *the pollution rate of each pollutant.

TABLE 15
THE TOTAL POLLUTION RATES

Without electric bus	**With electric bus**
In all day : For co: Total pollution=17562628.5 Kg. For co2: Total pollution=194061.12 Kg. For Nox: Total pollution=1190.11 Kg.	In all day For co: Total pollution=5409575.9 Kg. For co2: Total pollution=59773.9 Kg For Nox: Total pollution=718.18kg

For the first suggestion :

We note in the first suggestion that no of trips by other means of transportation is less than the other suggestions, so the total pollution is the least

– *By applying the first suggestion :*

The reduction of air pollution =The difference between the air pollution with and without electric buses.

The percentage of Co, Co_2, and Nox pollution have been reduced by 69%.

– *To calculate the money value of air pollution :*

The money value of co = 4.544 LE / ton [24], the money value of Nox = 1.446 LE / ton [24], and the money value of co_2 = 50 $ / ton [25].(Equivalent by Egyption cost =50 LE /ton.)

– *For the first suggestion:*

The money value of air pollution for each pollutant (LE)= the money value of each pollutant (LE / ton)* Total pollution(ton).

TABLE 16
MONEY VALUE OF AIR POLLUTION

Without electric bus	**With electric bus**
The money value of Co =79804.6 LE.	The money value of Co = 24581.1 LE.
The money value of Co_2 =9703.1 LE.	The money value of Co_2= 2988.7 LE.
The money value of Nox =1.72 LE.	The money value of Co = 0.53 LE.

– *To calculate the value of time:*

- The average travel time with and without electric bus=45 and 55min (from the questionnaire).
- Saving time = 9 min.
- Total trips in all day =253440 trips/day (from the strategic plan of Benha city).
- Total saving time= total trips in all day* saving time=38016 hr.
- Average salary = 5666.7 LE (from the questionnaire).
- Total working hours =169.8 hr [9].
- The volume of working time = average salary/total working hours =33.37 LE /hr.

- The percentage of working purposes ≈32% (from the questionnaire).
- The percentage of other purposes ≈68% (from the questionnaire).
- Let the value of other purpose time = 0.5* the value of working time.
- Average value of time= value of working time *0.32+ 0.5 value of working time *0.68= 22.0242L.E.
- Total reduction of value of time= average value of time*total saving =837271.9872 LE.

IV. Conclusions

In the present paper, the financial and economic benefits from the application of electric buses in Benha, Egypt are calculated in a logical way, and the effect of different factors on the demand for electric buses in Egypt is studied. The data in this research were collected using a questionnaire. The questions in the questionnaire are about personal characteristics, trip characteristics, and proposed mode characteristics(Electrical Buses). These samples of the questionnaire were used to calibrate the model. The logistic regression was used to find the best-proposed suggestion if it was the first suggestion or the other suggestion according to the following independent variables (travel time) and the following categorical variables (address, gender, age, education, car ownership, trip purpose, and income). After collecting the questionnaires, they were analyzed and three models were obtained. Comparing the analysis of the three models, showed that the first suggestion is better than the others. The number of trips by other means of transportation in the first suggestion is less than the other suggestions, so the total pollution is the least. The rate of each pollutant of air pollution was calculated with and without the application of electric buses, and the first suggestion will reduce air pollution by 69 %. Finally, the money value of air pollution and the value of time were calculated. The money value of co, co2, and Nox were calculated with and without the application of electric buses. By knowing the average travel time with and without an electric bus, the average salary from the questionnaire, and the total working hours, the value of time was calculated. Then, the total reduction of the value of time was calculated.

Recommendation

- It is better to apply the system of electric buses in large cities like Cairo, Alexandria, ….etc, because of the availability of data and the urgent need for environmentally friendly and energy-efficient means of transportation that will reduce air pollution.
- The travel cost variable should be included in the analysis as it affects the individual choice.
- In future research, it is better to use one suggestion for using electric buses to get one model to calculate the volume of demand for electric buses and compare the electric buses and other means of transport.
- Electric buses must be easy to access, so their accessibility should be taken into consideration in future research.
- The main component of an electric vehicle is the battery, and it has an important effect on the electric bus costs, so the batteries must be studied.
- The binary regression may be better to be used to conduct if the traveller prefers to use electric buses or other means of transportation.

Appendix

Analysis of Logistic Regression (First Suggestion):

1. Omnibus Tests:

TABLE A1
Omnibus Tests of Model Coefficients

Step 1	Chi-square	Df	Sig.
Step	141.093	20	.000
Block	141.093	20	.000
Model	141.093	20	.000

2. The Explanation of the Logistic Regression Coefficients :

TABLE A2
Variables in the Equation

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
Travel time	-0.003	0.001	5.747	1	0.017	0.997
Address	0.275	0.136	4.097	1	0.043	1.317
Gender	-0.041	0.138	0.090	1	0.764	0.960
Age	-0.095	0.112	0.715	1	0.398	0.909
Education	0.236	0.057	17.294	1	0.000	1.266
Income	-0.009	0.042	0.046	1	0.829	0.991
Car ownership	-0.166	0.087	3.649	1	0.05	0.847
Trip purpose	0.017	0.045	0.147	1	0.702	1.018

Analysis of Logistic Regression (Second Suggestion):

1. Omnibus Tests:

TABLE A3
Omnibus Tests of Model Coefficients

Step 1	Chi-square	Df	Sig.
Step	79.972	20	0.000
Block	79.972	20	0.000
Model	79.972	20	0.000

2. The explanation of the logistic regression coefficients:

TABLE A4
Variables in the Equation

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
Travel time	-0.002	0.001	6.070	1	0.014	0.998
Address	0.323	0.096	11.200	1	0.001	1.381
Gender	-0.040	0.094	0.178	1	0.673	0.961
Age	-0.210	0.075	7.773	1	0.005	0.811
Education	0.058	0.039	2.183	1	0.140	01.059
Income	-0.086	0.030	8.205	1	0.004	0.918
Car ownership	-0.025	0.060	0.166	1	0.683	0.976
Trip purpose	-0.096	0.032	8.936	1	0.003	.909

Analysis of Logistic Regression (Third Suggestion):

1. Omnibus Tests:

TABLE A5
Omnibus Tests of Model Coefficients

Step 1	Chi-square	Df	Sig.
Step	269.504	20	0.000
Block	269.504	20	0.000
Model	269.504	20	0.000

2. The explanation of the logistic regression coefficients:

Table A6
Variables in the Equation

Variables	B	S.E.	Wald	df	Sig.	Exp (B)
Travel time	-0.005	0.001	10.045	1	0.002	0.995
Address	0.382	0.130	8.639	1	0.003	1.465
Gender	-0.059	0.131	0.200	1	0.655	0.943
Age	0.008	0.108	0.006	1	0.937	1.009
Education	0.072	0.055	1.716	1	0.190	1.075
Income	0.031	0.040	0.582	1	0.445	1.031
Car ownership	-0.298	0.082	13.186	1	0.000	0.743
Trip purpose	0.044	0.043	1.041	1	0.308	1.045

AUTHORS CONTRIBUTION

The following is a summary of the author statement, which highlights their contributions to the paper based on their respective roles:

1. *Eman M.Ahmed*: Data collecting and tools, data analysis and interpretation, inquiry, methodology, and article writing. Furthermore, the corresponding author is in charge of ensuring that the descriptions are correct and that all authors agree on them.
2. *Mohamed S. Eisa:* Work conception and design, data interpretation, supervision, and article critical revision.
3. *Ibrahim M. Ramadan:* Work conception and design, data interpretation, supervision, and article critical revision.
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Arabic Title:

فوائد استبدال اسطول النقل الجماعى بالحافلات الكهربية فى منطقة حضرية فى مصر.

Arabic Abstract:

تهدف هذه الدراسة إلى حساب الفوائد المالية والاقتصادية من تطبيق الحافلات الكهربائية في منطقة حضرية في مصر ، والتي يمكن القيام بها من خلال نموذج يمكن من خلاله معرفة الفوائد والعيوب من استخدام هذا النظام في مدينة بنها بمصر. لا توجد طريقة جيدة لتحديد مزايا وعيوب استخدام الحافلات الكهربائية فى مصر ، لذا فإن الهدف من هذا البحث هو تحديد طريقة منطقية لتحديد مزايا وعيوب التطبيق ووضع بعض السياسات. ويتحقق ذلك من خلال تطبيق الطريقة المتسلسلة (نموذج من 4 خطوات) ، والتي تتكون من أربع مراحل على النحو التالي: توليد الرحلة ، وتوزيع الرحلة ، وتقسيم النموذج ، وتخصيص حركة المرور . وتم جمع الاستبيانات لتحديد العوامل التي تؤثر على اختيار وسيلة نقل معينة (الحافلات الكهربائية). تم تحليل البيانات ومعايرتها في نموذج يتم من خلاله التنبؤ بحجم الطلب على الحافلات الكهربائية ودراسة أهمية كل متغير ومزايا وعيوب تطبيق نظام الحافلات الكهربائية في مصر. قدم الاستبيان ثلاثة اقتراحات لاستخدام الحافلات الكهربائية. تم استخدام الانحدار اللوجستي للعثور على أفضل اقتراح مقترح إذا كان هو الاقتراح الأول أو لاختيار اقتراح آخر وفقًا للمتغيرات المستقلة التالية (وقت السفر) والمتغيرات الفئوية التالية (العنوان والجنس والعمر والتعليم وملكية السيارة والدخل والغرض من الرحلة). تم الحصول على النماذج الثلاثة وتقديرها للحصول على دالة المنفعة لكل اقتراح. من نتائج تحليل نجد ان أفضل اقتراح هو الأول ، حيث أن إجمالي عدد الرحلات باستخدام الحافلات الكهربائية فى الاقتراح الاول أكبر من الاقتراحين الآخرين. بمقارنة تلوث الهواء بالحافلات الكهربائية وبدونها ، يتضح أن استخدام الحافلات الكهربائية سيقلل من تلوث الهواء. تم تقدير فوائد تطبيق الحافلة الكهربائية في مدينة بنها بمصر من خلال تقييم القيمة المالية لتلوث الهواء وقيمة الوقت. أخيرًا ، تم تقدير الانخفاض الكلي لقيمة الوقت.