Economic and Financial Evaluation of E-Buses in Colombia

Study Extract

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn

Friedrich-Ebert-Allee 36+40
53113 Bonn, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15
E info@giz.de
I www.giz.de

Authors:
LAT GLOBAL S.A.S

Revision and adjustments:

Andrés Felipe Martínez,
Corinna Winter

Colombia, 2019

Content

Exchange rate

Foreign Currency	Local Currency	Date
1 USD	3.187 COP	Forecast Analysts 2019 - File updated on the website of Colombia's Banco de la República on August 6, 2019
1 EUR	3.872 COP	06/08/2019

Abbreviations

AR4	Fourth Assessment Report (Greenhouse Gas Protocol)
CapEx	Capital Expenditures
C/E	Cost effectiveness
CH_4	Methane
dB	Decibels
DIAN	Directorate of National Taxes
DNP	National Planning Department (Departamento Nacional de Planeación)
BEB	Battery Electric Buses – Night or intermediate charging
OC	Opportunity charging E-Bus at the end of route or ultra-fast
gal	Gallon
GHG	Greenhouse gases
NGV	Natural Gas Vehicle
GWP	Global warming potential (GWP) values relative to CO_2
IPC	Consumer price index
IPK	Passenger Index per Kilometre
PPI	Producer price index
Kg	Kilogram
km	Kilometre
kWh	kilowatts per hour
LHV	Lower Heating Value - Net Calorific Value
m	Meters
MBTU	Mega British Thermal Unit

MJ	Megajoule
mill	Million
MT	Ministry of Transport
m^3	Cubic meters
N/A	Not applicable
N_2O	Nitrous Oxide
OpEx	Operative Expenditures
SETP	Sistema Estratégico de Transporte Público
SITM	Sistema Integrado de Transporte Masivo
SITP	Sistema Integrado de Transporte Público
UTS	Urban Transport Systems
TJ	Terajoule
TCO	Total Cost of Ownership
Ton	Tons
UMUS	Unidad de Movilidad Urbana Sostenible (Unit for Sustainable Urban Transport within MT)
NPV	Net Present Value
WACC	Weighted Average Cost of Capital

1 Introduction

Transport is the highest energy-consuming sector in 40% of all countries worldwide and causes about a quarter of energy-related CO2 emissions. To limit global warming to two degrees, an extensive transformation and decarbonisation of transport is necessary. The TRANSfer project's objective is to increase the efforts of developing countries and emerging economies for climate-friendly transport. The project acts as a mitigation action preparation facility and thus, specifically supports the implementation of the Nationally Determined Contributions (NDC) of the Paris Agreement. The project supports several countries (including Peru, Colombia, the Philippines, Thailand, Indonesia) in developing greenhouse gas mitigation measures in transport. The TRANSfer project is implemented by GIZ and funded by the International Climate Initiative (IKI) of the German Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

This consultancy is developed within TRANSfer's country component in Colombia which aims at preparing a National E-Bus Promotion Programme (E-Bus). In Colombia the transport sector is responsible for 12% of the country's overall greenhouse gas emissions and the sharply increasing motorisation rate is further aggravating this tendency. Buses play an important role in Colombia's transport landscape. However, given the increasing urban population densities and the deteriorating air quality (23% of Bogota's local air pollution comes from buses, especially from older buses), the bus systems' various typologies and routes - from small feeder buses to bi-articulated high frequency corridor buses - together imply an untapped potential for providing access to clean urban mobility. Bus fleet electrification and its concomitant improvement in quality (e.g. surrounding corridor air quality, newer buses, etc.) has the potential to bring back passengers to public transportation. The need to generate schemes promoting the use of electric vehicles is also acknowledged by the Colombian Government trough Law 1964 from 11th July 2019.

The objective of this study is to (i) to conduct a financial exercise that estimates the impact (expenses) of several bus technologies (diesel, electric, natural gas vehicles), in a real transport operation; (ii) to conduct an economic analysis that helps to identify the scheme of project that best contributes to the countries welfare; and (iii) to propose a financing mechanism that allows the mobilization of resources (public and/or private) in an efficient way, in order to implement a fleet electrification program at the service of public transport.

2 Methodology and general assumptions

The economic and financial study conducted within the "E-Bus" Programme, has been developed with the objective of supporting the program of technological promotion that aims to generate financial incentives allowing the introduction of vehicles into the Colombian market that reduce greenhouse gas emissions and reduce air pollution for the citizens of those territories that adhere to the process of replacement or substitution.

Returning to the fundamental objectives of the study, the financial exercise has the goal of analysing the main components involved in the price baskets associated with different types of buses in Colombia.

Therefore, the starting point is the characterization of Urban Transport Systems (UTS) in Colombia. Thus, three types of projects were identified, which differ to a greater or lesser extent according to their scope, operational scheme, business structure of the operating companies, infrastructure, etc. There are Integrated Mass Transport Systems (SITM for its Spanish acronym, in cities with more than 600.000 inhabitants), Integrated Public Transport Systems (SITP for its Spanish acronym, in Bogota), and Strategic Public Transport Systems (SETP for its Spanish acronym, in cities with 250.000-600.000 inhabitants).

The financial modelling spectrum was defined as follows:

- 4 vehicle typologies
- 4 types of corridors (Trunk, Pre-trunk, Feeder and SETP)
- 8 types of technologies
- 14 cities or “cases” with operational data documented

The approach ends with the dimensioning of resources that should be mobilized, based on the assumptions of the financial exercise, either to leverage the vehicle's CapEx, or via interest rate reductions (bank credit or leasing structure), to motivate the introduction of electric technologies in the country.

The approach to this "scalability" (number of vehicles targeted) was built by sector specialists who are involved in the implementation of public transport policy. In this way, based on quantitative and qualitative criteria that guide the possibilities of implementing the program, the objectives were defined, and the goals were calibrated

The projection of the required amount of resources is accompanied by the proposal of an economic implementation tool or instrument that tends to level the playing field between traditional business models and electric buses, which becomes even more relevant in the current non-bankable context of the transport sector in Colombia. Therefore, new proposals or strategies that combine the participation of different actors are necessary, in parallel with the exploitation of alternative sources suggested in the current National Development Plan.

The methodology is resumed in the following figure:

Figure 1. Study Methodology

I. Definition and limitation of scope	▪ Consolidation of operational characteristics of Urban Transport Systems (SITP – SITM, SETP) ▪ Definition of 4 types of corridors: Trunk, Pre-trunk, Feeder and SETP ▪ Selection of vehicles (typologies) associated to the corridors: Trunk (18 and 12 meters), Pre-trunk (12 meters), Feeder (12 and 10 meters), SETP (10 and 7 meters)
II. Collection and classification of data	▪ Definition of technologies to be evaluated: Diesel E-VI, Hybrid, Gas, Electric (Night Charging, Intermediate Charging, Opportunity Charging End of Route and Ultra Fast, Trolley) ▪ Collection of cost information of for each vehicle technology/typology ▪ Comparative analysis based on cost information ▪ Selection of best substitutes and target technology for each operation case and comparative analysis of technologies from the "Total Cost of Ownership (TCO)"
III. Modelling and fin-econ. evaluation	▪ Scenario analysis sensitizing interest rate and cost of vehicles (CapEx) ▪ Scale up by numbers of vehicles according to projected renewal of transport systems ▪ Economic evaluation of scale up scenarios ▪ Context of the transport sector financing in Colombia according to the characteristics of the operators and proposal of a funding instrument.

Source: Own creation

3 Scope of financial evaluation

The financial model was structured based on the costs of the different typologies/technologies in each of the corridors.

3.1 Possible evaluation scenarios

Based on the combinations of the alternatives between technologies, typologies, corridors (4), and cases, the model allows the analysis of around 526 combinations of financial evaluation.

Table 1. Possibilities of financial evaluation

Corridors	Trunk	Pre-trunk	Feeder	SETP
Services	1	1	1	1
Typologies	2	1	2	2
Cases (cities)	9	5	10	13
Technologies	8	8	8	7
TOTAL	144	40	160	182

Source: Own creation

3.2 Cost structure

The calculation of the cost that the acquisition and operation of a bus implies, parts from the construction of price baskets that comprise the following components:

Figure 2. Price basket components

Varaible Costs	Fixed Costs	Capital Costs
• Fuel • Lubricants • Tires • Maintenance • Wages and salaries • Station Services	• Depot Infrastructure • Administration costs • Taxes • Insurance	• Capital Repayment • Profitability

Source: Own creation based on information contained in Resolution No. 4359 of 1998, 2nd article

The financial model then allows for comparison of costs between the different technologies at a disaggregated level (by price basket component), or as a sum of factors, what is understood as total cost of ownership or TCO, based on the following inputs and assumptions

3.3 Technical assumptions

Within the technical inputs, there is operational information on the different cases. The importance of the kilometres to be covered is highlighted, given that this is the basic unit of expression of most of the costs.

Table 2. Operational characteristics of trunk corridors

City	Average length route	Buses operating	Typology	Km/day	Passengers per day	IPK
Barranquilla	10,5	78	18 m	226	42.697	2,42
Cartagena	22,3	54	18 m	110	24.876	3,5
Cali	25,7	146	18 m	215	265.084	8,4
Medellín	12,5	31	18 m	ND	ND	ND
Bucaramanga	ND	20	18 m	345	44.000	6,4
Bogotá	23	1342	18 m	280	2.013.871	3,9
Barranquilla	10,5	10	12 m	140	5.474	3,91
Cali	25,7	39	12 m	201	9.895	1,3
Bogotá	23	261	12 m	201	2.013.871	3,9

Source: Own creation based on information provided by UMUs and DNP. ND=No data.

Table 3. Operational characteristics of pre-trunk corridors

City	Average length route	Buses operating	Typology	Km/day	Passengers per day	IPK
Cartagena	29,4	137	12 m	220	49.753	3,5
Medellín	12,5	47	12 m	149,9	16.468	2,3
Cali	20,5	299	12 m	201	108.897	1,8
Bucaramanga	ND	91	12 m	228	46000	2,2

Source: Own creation based on information provided by UMUs and DNP. ND=No data.

Table 4. Operational characteristics of feeder corridors

City	Average length route	Buses operating	Typology	Km/day	Passengers per day	IPK
Barranquilla	7,98	95	10 m	199	55.021	2,91
Cartagena	10,8	93	10 m	236	53.371	3,54
Medellín	4,4	333	10 m	161,3	126.890	2,36
Cali	8,8	131	10 m	204	37472	1,4
Bucaramanga	ND	88	10 m	160	28.000	1,99
Bogotá	23	696	10m	146	849.671	7,6
Cali	8,8	72	12 m	201	32.469	2,24
Barranquilla	7,98	69	12 m	159	39.963	3,63
Bogotá	23	65	12m	146	849.671	7,6

Source: Own creation based on information provided by UMUs and DNP. ND=No data.

Table 5. Operational characteristics of SETP corridors

City	Average length route	Buses operating	Typology	Km/day	Passengers per day	IPK
Pasto	25,17	297	7 m	222	52.950	0,8
Valledupar	26,41	195	7 m	165	34.284	1,1
Montería	23,37	188	7 m	176,7	76.128	1,9
Sincelejo	8,6	85	7 m	196	15.896	1
Popayán	22,85	254	7 m	211	80.854	1,5
Neiva	27,99	305	7 m	183	74.000	1,3
Santa Marta	22,47	98	7 m	174	24.907	1,46
Pasto	25,17	179	10 m	222	31.912	0,8
Montería	23,37	13	10 m	178,4	5.609	2,42
Popayán	22,85	105	10 m	200	25.423	1,2
Santa Marta	22,47	392	10 m	220	188.853	2,19
Armenia	25	346	10 m	153	93.915	1,78

Source: Own creation based on information provided by UMUs and DNP. ND=No data.

Given the high coefficient of variation between some of the samples, the averages between the data were considered distorted, which generated the need to select a representative case by type of corridor to create the financial flows that are presented in this report. However, the tool has the capacity to evaluate any type of combination related to the databases that were previously presented.

Methodologically, it was decided to weigh the concepts according to their impact on the analysis, thus obtaining the cases that are close to the most typical conditions.

The representative cases by corridor and vehicle type, which support the general results of the financial analysis, are presented below:

Figure 3. Representative cases of corridor and vehicle typology selected for general results

Source: Own creation

Other technical assumptions relate to the percentual difference in tyres and general maintenance costs identified in international literature, vehicle prices, battery prices, electric infrastructure (if applicable), and fuel/energy efficiency by technology and vehicle type.

Table 6. Bus prices in USD

Typology	Diesel	Hybrid	Gas	Source
7M	84.000	102.000	96.000	Daimler
10M	96.000	132.000	120.000	Daimler
12M	192.000	276.000	228.000	Daimler
18M	354.000	420.000	372.000	Daimler

Typology	E-Bus (BEB)	Source
7M	150.000	E-Bus manufacturer
10M	250.000	E-Bus manufacturer
12M	358.000	E-Bus manufacturer
18M	550.000	E-Bus manufacturer

Note: The base prices were given in dollars and correspond to Euro 5 for diesel, hybrid and gas (the model adjusts the prices from Euro 5 to Euro 6, with the assumption of a higher value of 20% suggested by the same source). Electric vehicles are composed of a monobloc + battery (range up to 250 km). For this case no differentiation according to technology was obtained. Values with taxes.

Table 7. Assumption on general maintenance and tyres

Typology	Component	Reference of comparison		
		Electric vs Diesel	Gas vs Diesel	Hybrid vs Diesel
7M	Tyres	-20%	0%	0%
	General maintenance	-35%	-13%	-13%
10M	Tyres	-20%	0%	0%
	General maintenance	-35%	-13%	-13%
12M	Tyres	-20%	0%	0%
	General maintenance	-35%	-14%	-13%
18M	Tyres	-20%	0%	0%
	General maintenance	-35%	-11%	-12%

Source: For ties GIZ expert. For general maintenance the data on the comparison of Hybrid/Diesel come from the International Evaluation of Public Policies for Electromobility in Urban Fleets, (ICCT). Data on maintenance provided by consultants.

In terms of electric infrastructure, the substations were costed with the following references:

Table 8. Assumptions on electric infrastructure

Cost of substations (MW), chargers, battery	Value COP	Value USD
Cost 0,5 MW	2.544.403.434	814.470
Cost 1 MW	2.591.161.215	829.437
Cost 2 MW	2.684.676.779	859.372
Cost Charger	54.570.000	17.000

Source: GIZ expert

Table 9. Other assumptions on electric infrastructure

Component	Observation
Buses per charger	2
Buses per charger UF	1
Power of charger (kW)	200
Power of charger UF (kW)	400

Source: GIZ expert

The infrastructure cost for trolley buses was calculated based on information provided by GIZ for the case of Brazil. Thus, it was obtained as a reference that one kilometre of network (plus substation) in Reales, amounts to 2,640,000 (which would be equivalent to $2,138,479,200

Colombian pesos or 684,532 USD). This information was then compared with the average length of the corridors that were analysed.

Given the lack of information available to characterize e-buses in terms of CapEx, the technical advisor of the GIZ proposed to generate as a differentiating factor size, characteristics, and lifetime of the batteries according to the route to be performed, which affects the price and dynamics of replacement, in the time horizon modelled.

It is estimated that the reference is close to real market prices in the case of BEB night charging. The calculations associated with the other technologies are presented as an indication given the absence of inputs that would allow the results to be compared with a real operation.

The assumptions for the calculation of the CapEx associated to batteries of e-busses are presented below.

Table 10. Reference cost for batteries

Costs	Value COP/Kw	Value USD/Kw
Average battery cost	1.115.450	350

Source: GIZ expert

Table 11. Other technical assumptions – size and lifetime of batteries

Component	Observation
Battery autonomy	250, 200, 100 km (según la exigencia del recorrido)
Number of charging cycles	2500

Source: GIZ expert

Table 12. Distance associated to route length of electric busses

Technology	Distance
Night charging BEB	Daily journey
Intermediate Charging BEB	Journey/2
Opportunity Charging - End of Route	Route distance
Opportunity Charging - Ultra Fast	Daily journey
Trolley	Journey between stations
Hybrid	Daily journey

Source: GIZ expert

Table 13. Performance curve (% of charge) of the battery, by use cycle

Cycle/ % charge	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
Factor -4,4% every 500 cycles	100	96	91	87	84	80	77	73	70	67	64

Source: GIZ expert

Performance of the fuels/energetics differentiated by typology and technology

Table 14. Performance by technology and vehicle typology

Technology	Vehicle Typology	Unit	Performance energetic per km	Performance fuel por Km	Source
Diesel	7M	gl	16,60	0,06	Consultant
	10M	gl	13,50	0,07	
	12M	gl	6,30	0,16	
	18M	gl	4,20	0,24	
Gas (NGV)	7M	m3	3,64	0,28	Consultant
	10M	m3	3,13	0,32	
	12M	m3	1,41	0,71	
	18M	m3	0,91	1,10	
Hybrid	7M	25% Diesel - 75% Electric	12,8	0,1	Consultant / GIZ expert
	10M	25% Diesel - 75% Electric	10,4	0,1	
	12M	25% Diesel - 75% Electric	4,9	0,2	
	18M	25% Diesel - 75% Electric	3,3	0,3	
Trolley	7M	kWh	0,99	1,01	GIZ expert
	10M	kWh	0,99	1,01	
	12M	kWh	0,87	1,14	
	18M	kWh	0,62	1,62	

Technology	Vehicle Typology	Unit	Performance energetic per km	Performance fuel por Km	Source
BEB	7M	kWh	1,52	0,66	GIZ expert
	10M	kWh	0,9	1,1	
	12M	kWh	0,8	1,3	
	18M	kWh	0,6	1,8	
Opportunity Charging	7M	kWh	1,52	0,66	GIZ expert
	10M	kWh	0,9	1,1	
	12M	kWh	0,8	1,3	
	18M	kWh	0,6	1,8	

3.4 Economic and financial assumptions

The analysis is based on a period of 15 years[1], which required to recognise the variation in the price baskets over time. It should be noted that it is assumed that not all inputs increase with the same dynamics or trend. Some, by their nature, are more associated with the behaviour of the consumer price index (CPI), some with the producer price index (PPI), and others with the increase in the minimum wage, which is correlated to the CPI and with productivity at the country level. The different components of the price basket were adjusted using the following indices:

Table 15. Adjustment factors for price basket

Component	Adjustment factor
Fuel	ID (inflation of diesel), IG (inflation of gas), IE (inflation of energy)
Tyres	PPI
Maintenance	PPI
Service station	CPI
Drivers	Minimum wage
Administration	Minimum wage
Vehicle taxes	(% over CapEx)
Insurance	CPI
Capital Repayment	Investor's Cost of Capital (Ke)
Battery replacement	CPI

Source: Own creation

[1] Estimated life span of the vehicles based on information provided by the electric bus supplier consulted. It is considered that this is the maximum horizon for traditional use technologies.

The reference values from which the projections of energetic prices (energy, gas, diesel) are derived are listed in the following table:

Table 16. Reference price 2019, energetics

Energetic	Unit	Tariff (COP)	Source
Energy	Khw	432	XM
Gas	M3	1.533	National Average Jan/19 Min Valledupar (838) Max Ibagué (2020) Naturgas 2019
Diesel	Gallon	9.068	ACPM Bogotá / March 2019. MME

With respect to interest rates, it is worth noting that the assumed bank interest rates for the year are proposed as an indication if the source of payment is the fare or passenger income from transport projects, given that at present the commercial banks do not consider the traditional transport operator as a credit subject.

The rates that served as input for the exercise are presented in the following table. These correspond to real market rates for different profiles, published by the Superintendence of Finance.

Table 17. Interest rates

Interest rate	Unit	Ref.	Source
Interest rate consolidated operator	%	7,69%	Average rate for preferential commercial credit of credit institutions. Superintendence of Finance (May 2019)
Interest rate affiliated operator	%	10,48%	Average rate for preferential commercial credit of credit institutions. Superintendence of Finance (May 2019)
Interest rate individual operator	%	17,01%	Average rate for preferential commercial credit of credit institutions. Superintendence of Finance (May 2019)

To estimate the Net Present Value of the TCO per kilometre over a 15-year horizon, the Weighted Average Capital Cost - WACC was used, which is defined as follows:

$$WACC_{nominal}=\frac{E}{D+E}*k_e^{COP}+\frac{D}{D+E}*k_d^{COP}*(1-t_x)$$

Where:

E: Total Equity, which corresponds to the total resources contributed by the investor with his own capital. This value is obtained from the Financial Model and varies according to each of the modelled scenarios.

D: Total Debt, this variable refers to the total resources required to meet investment objectives. Within the model, the assumption is made that the debt can only be requested during the Investment stage. Like equity, this value is obtained from the financial model and varies according to each of the proposed scenarios.

In this sense the factor $\frac{E}{D+E}$ corresponds to the proportion of the equity over the total of the possible sources of financing. This proportion must be consistent with the requirements of the financial sector, where lenders require that the project executor fund the project with their own resources in proportions close to 20% and 40% of the projects. This is so that incentives are generated to continue with the project and that in case of default the lender does not assume all the losses.

k_e^{COP}: refers to the cost of equity denominated in pesos. To calculate this cost, it is necessary to use the capital asset pricing model (CAPM), since the cost of equity is not known with certainty.

Multiplying the factors $\frac{E}{D+E} * k_e^{COP}$ the weighted cost of equity is obtained.

Analogous to equity, the fraction $\frac{D}{D+E}$ represents the proportion of the debt, over the total sources of capital of the project. In this sense and under the assumption that the investor can only be funded with debt and equity, by adding the ratios $\frac{E}{D+E} + \frac{D}{D+E}$ the total resources needed to make the required investments are obtained.

k_d^{COP}: corresponds to the cost of debt denominated in Colombian pesos (COP). The cost of the debt is obtained through rates in the financial market, where they provide possible rates for the execution of projects with similar terms and comparable risk levels. For the purposes of the financial simulations, the rates are differentiated into three types of credit subjects.

As previously mentioned, in order to calculate k_e^{COP} it is necessary to rely on other models, in this case the capital asset pricing model - CAPM, was used, in which defines:

$$k_e^{USD} = R_f + \beta_u * (R_m - R_f) + PRP$$

Where:

R_f: corresponds to the risk-free rate, which is taken as a reference from the Country Risk Premium rate reported by Damodaran (2019).

R_m: Corresponds to market risk and takes as reference the Equity Risk Premium rate reported by Damodaran (2019)

β_u: is unlevered This variable reflects the correlation of the sector's historical returns with the market's historical returns. In this case, we used the basis of Betas calculated by Damodaran (2019) in place at the time of the calculation, for the Transport sector. Additionally, since the beta is unleveraged, it must be adjusted according to the Debt/Equity ratio of the project, using the following expression:

$$B_l = \beta_u * (1 + \frac{D}{E} * (1 - t_x))$$

Finally, the expression PRP reflects the country risk premium. This variable adjusts the cost of capital for investing in assets in countries where default risk is perceived to exist. In this sense, the EMBI+ index for Colombia is taken as a proxy. This index is estimated based on a dynamic factor analysis model, which explores the common trends of the volatilities of the returns of bonds, shares and currencies of developed economies. It is found that in most critical episodes the index rises, reflecting an increase in investor perceived risk. In addition, it is found that many of the strong deteriorations in country risk (as measured by increases in the EMBI+) are associated with increases in this index. The explanation is that the perception of risk affects the investment decisions of institutional investors in emerging market bonds and in risky assets in general.

Since the cost of equity is denominated in dollars k_e^{USD}, it must be converted to Colombian pesos, for which an adjustment by devaluing the US dollar and Colombian peso under Fischer's parity theory is made.

Finally, by calculating all of the variables, the value of the WACC is obtained, representing the value of the appropriate rate for discounting the flows and thus expressing them in present value so that they are comparable.

The Rolling WACC intends to reflect in the factors that are affected through the debt-equity composition, the evolution of the percentages according to the reality of the debt payment (capital amortization). For the purposes of calculating the TCO, an initial capital structure of 70% debt / 30% equity has been used as an assumption.

Table 18. Discount rates

Variable	Reference	Source
Bu	0,87	http://pages.stern.nyu.edu/~adamodar/
Rf	2,64%	http://pages.stern.nyu.edu/~adamodar/
Rm	8,60%	http://pages.stern.nyu.edu/~adamodar/
Embi Colombia	1,97%	Embi Colombia - http://www.ambito.com/economia/mercados/riesgo-pais/info/?id=4

Thus, the projected cash flows, i.e. the components of the basket of costs indexed to the indexes or adjustment factors as appropriate, are discounted at the WACC rate which varies from year to year in accordance with the debt-equity ratio. This process allows us to obtain the Net Present Value of the total costs of ownership, which includes both the initial investments and the costs of operation, maintenance and replacement of assets that are presented over the 15 years of evaluation.

4 General results

In general terms, diesel busses have the most competitive vehicle prices, followed by gas busses. Within the electric vehicles, the most expensive are night charging BEB due to the characteristics and/or costs of their batteries. Trolley busses, requiring a specialized infrastructure, not available in Colombia, are vehicles with little cost competitiveness, compared to other technologies. Electric busses that imply higher infrastructure costs are ultra-fast opportunity charging and trolley busses; as they have minimum requirements related to the length of the corridor and the established stops, regardless of the number of vehicles in the type of route.

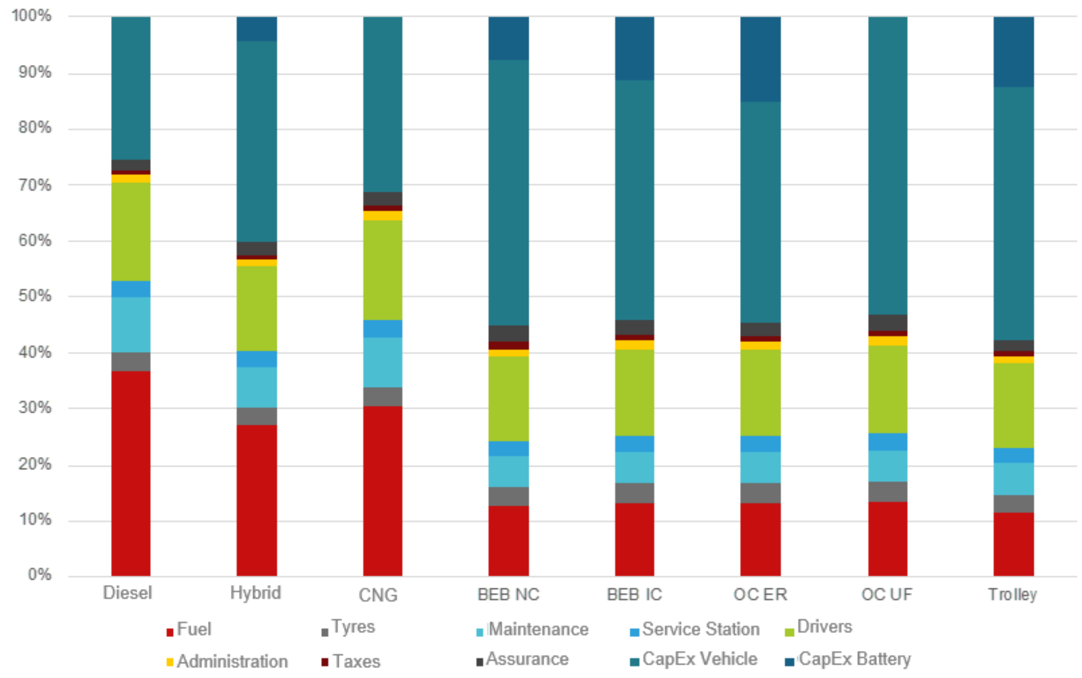
4.1 Price baskets

The projected cash flows depend on the calculations and projections of the price baskets in order to evaluate the differences in TCO between the technology to be introduced and the best substitute or most competitive vehicle in terms of market costs.

For all cases, the most cost-intensive components are CapEx, fuel/energy, drivers[2] and maintenance.

[2] The analysis does not consider differences in drivers' wages given the lack of evidence in this regard in the labour market. However, it is considered that driving experience in electric vehicles can improve energy efficiency. Given that the analysis horizon is 15 years, and that driver training is anticipated in the short term, the impact is considered marginal.

Illustration 1. Comparison of cost components for trunk route 12 m



4.2 Financial results per typology

The financial results indicate that, for all the routes and typologies, except in the case of the trunk corridor with 18 meters buses, the Net Present Value of the Diesel and Natural Gas Vehicle technologies are lower than the electric technologies, even though the maintenance costs are lower for electric buses (see Table7).

The difference between the total costs of the technologies, TCO, between vehicles varies depending on the operation conditions of each typology being the average daily trip distance the most important factor for the price difference, bearing that vehicles with more intense use, present smaller differences.

The difference between the total costs of the technologies, TCO, between vehicles varies depending on the operation conditions of each typology being the average daily trip distance the most important factor for the price difference, bearing that vehicles with more intense use, present smaller differences.

Thus, the difference between diesel and electric vehicles ranges from 44% in the case of 10-meter buses in SETP corridors, to 9% in pre-trunk corridors with 12-meter buses. The financial result also does not take into account the positive externalities of electric buses. There is evidence of greater competitiveness of electric vehicles for the larger types, applying for the 18M case, the postulate that in terms of TCO, the vehicle can be similar, or cheaper than the diesel. The electric vehicles with lower costs are the BEB intermediate charging, and the end-of-road opportunity charging.

Note: The estimates include battery replacements and the associated electrical infrastructure for electric vehicles.

Table 19. Estimated net present value (NPV) of costs per kilometre per component (horizon 15 years).– 18M trunk route

18 m		Diesel	Gas	Hybrid	BEB - NC	BEB - IC	OC - ER	OC - UF	Trolley
	TCO (USD)	1.108.208	1.042.196	1.193.641	1.188.483	1.134.989	1.120.567	1.093.355	1.152.200
	CapEx (USD)	354.000	372.000	512.876	709.485	664.398	654.137	617.017	702.005
	OPEX (USD)	754.208	670.196	680.765	478.998	470.591	466.430	476.338	450.195
	Dif. % TCO to Diesel	0%	-6%	8%	7%	2%	1%	-1%	4%
	TCO (USD / km)	1,10	1,04	1,19	1,18	1,13	1,11	1,09	1,15

Table 20. Estimated net present value (NPV) of costs per kilometre per component (horizon 15 years) – 12M trunk route

12 m		Diesel	Gas	Hybrid	BEB - NC	BEB - IC	OC - ER	OC - UF	Trolley
	TCO (USD)	750.170	725.114	874.464	874.958	842.837	825.832	957.337	1.077.493
	CapEx (USD)	192.000	228.000	359.671	482.840	456.339	442.306	567.069	705.506
	OPEX (USD)	558.170	497.114	514.793	392.118	386.498	383.526	390.268	371.987
	Dif. % TCO to Diesel	0%	-3%	17%	17%	12%	10%	28%	44%
	TCO (USD / km)	0,80	0,77	0,93	0,93	0,90	0,88	1,02	1,15

Table 21. Estimated net present value (NPV) of costs per kilometre per component (horizon 15 years) –12M pre-trunk route

12 m		Diesel	Gas	Hybrid	BEB - NC	BEB - IC	OC - ER	OC - UF	Trolley
	TCO (USD)	752.767	725.361	860.299	864.560	834.591	837.706	821.750	866.659
	CapEx (USD)	192.000	228.000	310.104	409.604	357.104	330.854	435.371	389.762
	OPEX (USD)	560.767	497.361	550.195	454.957	477.487	506.852	386.379	476.897
	Dif. % TCO to Diesel	0%	-4%	14%	15%	11%	11%	9%	15%
	TCO (USD / km)	0,73	0,70	0,84	0,84	0,81	0,81	0,80	0,84

Table 22. Estimated net present value (NPV) of costs per kilometre per component (horizon 15 years) – 12M feeder route

12 m		Diesel	Gas	Hybrid	BEB - NC	BEB - IC	OC - ER	OC - UF	Trolley
	TCO (USD)	642.780	633.700	787.851	814.751	740.671	740.671	769.095	769.701
	CapEx (USD)	192.000	228.000	367.785	484.946	418.328	418.328	440.719	456.200
	OPEX (USD)	450.780	405.700	420.066	329.805	322.343	322.343	328.376	313.501
	Dif. % TCO to Diesel	0%	-1%	23%	27%	15%	15%	20%	20%
	TCO (USD / km)	0,86	0,85	1,06	1,09	0,99	0,99	1,03	1,03

Table 23. Estimated net present value (NPV) of costs per kilometre per component (horizon 15 years) –10M feeder route

10m		Diesel	Gas	Hybrid	BEB - NC	BEB - IC	OC - ER	OC - UF	Trolley
	TCO (USD)	433.838	427.951	526.190	669.148	621.100	673.229	611.620	N.A
	CapEx (USD)	96.000	120.000	198.769	357.485	315.989	368.118	301.497	N.A
	OPEX (USD)	337.838	307.951	327.421	311.663	305.111	305.111	310.123	N.A
	Dif. % TCO to Diesel	0%	-1%	21%	54%	43%	55%	41%	N.A
	TCO (USD / km)	0,47	0,46	0,57	0,72	0,67	0,72	0,66	N.A

Table 24. Estimated net present value (NPV) of costs per kilometre per component (horizon 15 years) –10M SETP route

10m		Diesel	Gas	Hybrid	BEB - NC	BEB - IC	OC - ER	OC - UF	Trolley
	TCO (USD)	354.444	358.705	435.936	572.468	509.597	509.597	520.988	N.A
	CapEx (USD)	96.000	120.000	183.843	329.059	271.858	271.858	278.279	N.A
	OPEX (USD)	258.444	238.705	252.093	243.409	237.739	237.739	242.709	N.A
	Dif. % TCO to Diesel	0%	1%	23%	62%	44%	44%	47%	N.A
	TCO (USD / km)	0,50	0,50	0,61	0,80	0,71	0,71	0,73	N.A

Table 25. Estimated net present value (NPV) of costs per kilometre per component (horizon 15 years) –7M SETP route

7m		Diesel	Gas	Hybrid	BEB - NC	BEB – IC	OC – ER	OC – UF	Trolley
	TCO (USD)	366.319	357.582	436.846	469.038	440.128	452.104	419.323	N.A
	CapEx (USD)	84.000	96.000	168.439	231.990	206.088	218.788	182.944	N.A
	OPEX (USD)	282.319	261.582	268.407	237.048	234.040	233.317	236.379	N.A
	Dif. % TCO to Diesel	0%	-2%	19%	28%	20%	23%	14%	N.A
	TCO (USD / km)	0,35	0,34	0,42	0,45	0,42	0,44	0,40	N.A

giz

5 Assessment of the need for financial instruments

Since the financial analysis found that under current market conditions the total cost of ownership of E-Busses is higher than those of conventional technologies, despite the fact that the electric bus market has reduced its costs in recent years and its operation and maintenance costs are lower, it is necessary to assess whether through financial instruments the conditions of the new technologies could be equalized.

The final objective is to achieve, from a financial point of view, that investment between the two technologies is indifferent, so that operators decide in favour of electric technologies. This is of particular importance because fleet renewal processes involve high investments and long time horizons, so the purchase of a traditional technology can generate a technological lock-in for many years.

The following table shows the incremental costs of electric buses versus Natural Gas Vehicles, which is the cheapest option, for different types of vehicles in Colombia.

Table 26. Summary of total cost of ownership for all typologies for Diesel and Battery Electric Buses (horizon 15 years) – Own creation 2019.

SERVICE	TOTAL DISTANCE PER DAY (KM)	TCO GNV (MM_USD)	TCO BEB (MM_USD)	INCREMENTAL COSTS (MM_USD)
SETP 7M	222	0,38	0,48	0,10
SETP 10M	153	0,37	0,57	0,20
FEEDER 10M	199	0,38	0,56	0,17
FEEDER 12M	159	0,55	0,66	0,11
PRETRUNK 12M	120	0,64	0,71	0,07
TRUNK 12M	201	0,59	0,66	0,07
TRUNK 18M	215	0,83	0,87	0,04

Given that for all cases the incremental is positive, through an analysis based on the same method of cost evaluation, the financial support to reduce the reference interest rate $k_{e,}$ necessary to achieve equality of the Net Present Values of both technologies, is assessed.

The viability of an interest rate compensation instrument to match costs between technologies is constrained by the transaction costs that can be incurred in a concessional credit process to be re-disbursed by a second-tier bank.

As long as the NPV analysis shows that the rate needed to match costs between technologies is lower than the minimum rate that can be offered through a rate compensation program, this mechanism would not be sufficient to achieve technological change and it would be necessary to consider options to compensate for the capital investment

In order to make this evaluation for the case of Colombia, an estimate of the minimum cost on which rate subsidy operations could be considered is made, taking into account that:

1. The GCF in its *"Policy on fees for accredited entities and delivery partners" (Green Climate Fund, 2018)* establishes that for operations between USD 50-250 millions, the maximum is 5%.
2. The FINDETER's listing of rediscount rates for operations associated to energy, sustainable infrastructure and environmental impacts are around 5.3% and 7.7%. (FIDETER, 2019)
3. Evaluating BANCOLDEX rediscount rates, specifically those used in credit lines supporting electric mobility, we find rates between 3.36% and 7.4%. (BANCOLDEX, 2019). The 3.36% rate has non-refundable resources from the CTF for compensation of rates.

According to the above data, the average reference rate found possible for a credit operation from GCF funds would be around 6%. All analyses showing a rate below this value would require the assessment of additional capital investments.

5.1 Evaluation of requirements on interest rate to achieve cost parity

To evaluate the impact of a compensated interest rate, the case for the 18M trunk typology is omitted since due to the high levels of operation, the incremental between the total costs between combustion and electric technologies in a 15-year horizon is zero or negative.

The impact on the interest rate is evaluated with reference to the initial rate for each typology and type of operation. Subsequently, in each case, the spreads that should be reduced for the rates to achieve cost parity were adjusted.

Finally, the spread is subtracted from the initial reference rate to evaluate the rate needed to reach cost parity.

Table 27. Summary of results scenarios - Interest rate subsidy. Figures in millions of USD

Initial reference interest rate	7M	10M	12M
SETP	17,01%	17,01%	
Feeder		10,48%	10,48%
Pretrunk			10,48%
Trunk			7,69%
Spread to achieve parity	**7M**	**10M**	**12M**
SETP	9,4%	12,7%	
Feeder		9,8%	3,6%
Pretrunk			2,3%
Trunk			1,6%
Final interest rate for cost parity	**7M**	**10M**	**12M**
SETP	7,28%	3,85%	
Feeder		0,30%	6,74%
Pretrunk			8,13%
Trunk			6,04%

Source: Own creation

As shown in the results, the interest rates needed to obtain cost parity are between 0.30% E.A, up to 7.28%. The large difference in values is mainly due to the intensity of operation in each case. In most cases interest rates are equal to or higher than 6%, so a financial instrument with a subsidized rate could be applicable.

However, there are typologies and operations with 10m buses, which could not be made competitive only through these instruments, given that the necessary rates are much lower than the reference rate. These cases are important because the small typologies are highly applicable in medium and small cities in Colombia, and in general in Latin America, which need to offer transport service to users in peri-urban areas of difficult geographical access, especially in mountainous topographies with narrow roads.

It is also important to consider, that in the election of the cases of financial analysis the most common situation of operation by typology in Colombia was taken as a reference, therefore smaller cities could need additional subsidies, whenever for the typology of 12 meters were found values of required rate very near to 6%.

Finally, it is important to consider that the cost parity can make the decision indifferent in financial terms, but in addition to the cost difference it is important to consider that in Colombia and especially in Latin America the transport systems operate at high levels of deficit, which makes the decision of technology switch difficult from the outset, especially given the uncertainty associated with the technology risk posed by e-busses for the actors in the sector.

Likewise, it is necessary to consider that although for the effects of this exercise the assumption was made that an electric bus can operate under the same indicators as a bus with conventional combustion technology, due to the restrictions given by the charging times and autonomy, the operators with electric fleets must operate with lower Passenger Kilometre Rates, which forces them to have a fleet supply around 20% higher, as identified in cities like Cali. These conditions also generate the need to support instruments based on special interest rates with capital subsidies and other incentives that lead to the adoption of new technologies by the market.

6 Conclusion

In terms of vehicle cost, diesel busses have the lowest prices, followed by gas buses. However, fuel costs are higher for diesel, which in most cases weight more than the lower value of the vehicle. Therefore, in most cases, gas buses have the lowest Net Present Value for the Total Cost of Ownership, thus being the best financial substitute for diesel technology.

For electric fleets, the CapEx is even more significant in the cost structure, accounting for about 50% of it (including battery replacements), followed by drivers' wages, fuel and maintenance. However, the financial TCO shows that this gap decreases over time, due to the greater competitiveness of price basket components such as energy and maintenance. The analysis shows that the incremental TCO of an electric bus vs. a diesel bus is from 9% to 44% depending on the route and charging technology and evidences the need to look for tools that allow to cushion the impact of CapEx and the risks implied by introducing a technology that has not been tested very much in Colombia, where commercial banks are not willing to finance the urban transport sector, given the constant default of the operators that adduce financial imbalances in their current operations.

The most efficient way to promote electrification is through CapEx compensation. The CapEx subsidy can be given directly to the value of the vehicle or in the financing of the vehicle. The interest rate subsidy faces the limited access that operators currently have to commercial banking and the resulting transaction costs.

The development of a financing instrument should be supported by different funding sources, as well as promoting schemes that generate economies of scale, seeking to acquire high volumes of fleet in competitive conditions (large typologies with high intensity of operation), which also make it possible to purchase smaller capacity typologies, that although more expensive from a financial point of view, are the most used in intermediate cities.

Given that there are many conditions that affect the competitiveness of electric buses, a programme to promote electric buses should go beyond financial support. It is necessary to technically support the construction of the most efficient systems for each city's conditions.

Bibliography

Material	*Reference*
Emission Factors	*Unidad de Planeación Minero Energética (2003)* *https://bdigital.upme.gov.co/bitstream/001/1285/18/17%20Factores%20de%20emision%20de%20combustibles.pdf*
Economic Costs of Respiratory Diseases	Institutito Nacional de Salud – Ministerio de Salud (2018) Carga de Enfermedad Ambiental en Colombia
Sale of diesel gallons in Colombia	*Econometría Consultores – UPME (2014) Determinación de la demanda real de Gasolina Corriente, Gasolina Extra, Diésel Oil y GNV en el territorio nacional*
Economic costs of noise	*RICARDO-AEA Update of the Handbook on External Costs of Transport (2014)*
Cost Economic ton of CO2	DIAN RESOLUCIÓN NÚMERO 000006 DE 2019
Decibels emitted by an electric and a hybrid bus	Janos Turcsany, Electric Bus Noise, Volvo (2016)
International experiences in public policies for electromobility in urban fleets	International Evaluation of Public Policies for Electromobility in Urban Fleets, (ICCT) *https://theicct.org/publications/international-evaluation-public-policies-electromobility-urban-fleets*