

COST BENEFIT ANALYSIS OF ELECTRIC BUSES IN NAIROBI, KENYA.



INTRODUCTION

The transportation industry accounts for roughly 13% of the country's overall GHG emissions and is expanding rapidly

Global warming is mainly caused by increased GHG emissions which leads to extreme climate occurrences. Kenya is already experiencing the effects of climate change, since 1960

This increased awareness to climate change and its effects had led us to look for alternative/cleaner technologies such as hybrid, biodiesel, and electric buses.



POLICIES

As part of the efforts to create a sustainable transport system, electrification of the public transport is one of deliverables to help achieve the country's targets in the National Climate Change Action Plan (NCCAP 2018-2022). Some other notable policies include;

- The National Climate Change Response Strategy (2010),
- National Climate Change Action Plan NCCAP (2013-2017), the National Adaptation Plan (2015-2030),
- The Kenya Climate Smart Agriculture Strategy (2017-2026),
- The Climate Risk Management Framework (2017), S
- The National Climate Change Policy (2018), and
- The National Climate Finance Policy (2018), among others
- National Climate Change Action Plan (NCCAP 2018-2022).

Cleaner propulsion technologies that are alternatives to standard fossil fuels look to be an expensive undertaking that will not be viable for the majority of the people at first glance. This assumption has necessitated a comprehensive assessment and comparison of all expenses involved with the life cycle of electric vehicles against internal combustion engine propelled vehicles (fossil fuel).

TRANSPORT AND TRAFFIC DEMAND IN NAIROBI



Nairobi City County has a population of over 4 million people.

The Nairobi Metropolitan Area (NMA) is made up of the 5 neighboring counties i.e. Nairobi, Muranga, Kajiado, Machakos and Kiambu

Over 70% of the population of the NMA use public transportation on a regular basis.

Matatus (PSV) and buses account for a huge 40 percent modal share of Nairobi's public transportation

TRAFFIC DEMAND AND PUBLIC TRANSPORT PROJECTIONS

PublicTransportTrafficVolumes in 2013 and 2030 Projections

S. No.	Corridor	TrafficVolume -2013	ProjectedTraffic volume - 2030
1	Juja Road	290,000	480,000
2	Jogoo Road	275,000	410,000
3	Thika Superhighway	195,000	395,000
4	Ngong Road	185,000	380,000
5	Mombasa Road	165,000	320,000
6	Kenyatta Avenue	110,000	450,000
7	Outer Ring Road	110,000	300,000
8	Langata Road	110,000	280,000
9	Waiyaki Way	100,000	200,000
10	Limuru Road	25,000	75,000



FORMATION OF MRTS CORRIDORS

Due to the increased traffic congestion which was being experienced in the Nairobi Metropolitan Area in the early 2000's, the following policies were formulated by the national government:

2009, the Integrated National Transport Policy (INTP) was approved by the Cabinet.

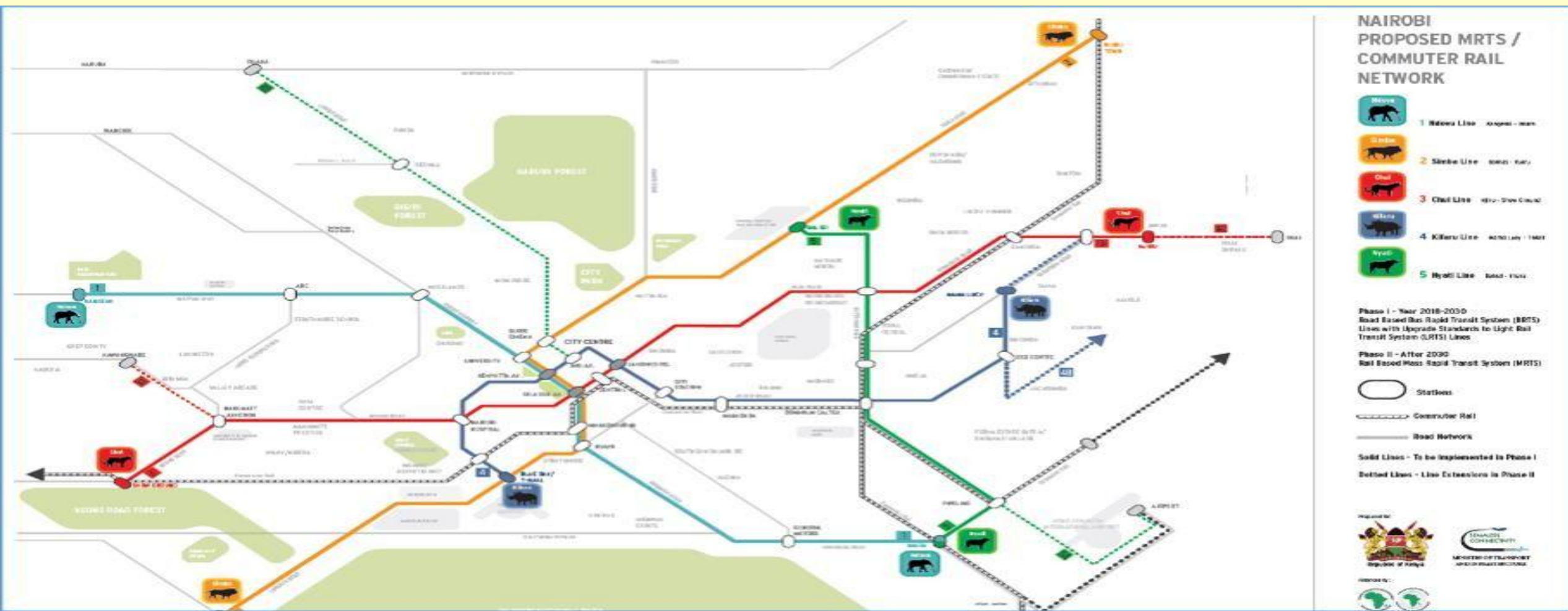
2012, the INTP was adopted by parliament as Sessional Paper No. 2 with the recommendations to; develop a Mass Rapid Transit System I and establish a Nairobi Metropolitan Area Transport Authority (NaMATA).

2019, Declaration of transport Corridors consisting of 5 BRT networks and 7 Commuter Rail networks which was done through Legal Notice No. 16 on the 26th of February.

2011, MRTS network on 9 corridors converging at the City Centre

2014, Harmonization Study which was carried out by Gauff Ingenieure-5 BRT lines and 7 commuter rail

MRTS CORRIDORS FOR NMA



PROPULSION VEHICLE TECHNOLOGY IN NMA

According to a 2019 estimate by the Japan International Cooperation Agency (JICA), the Nairobi Metropolitan Area contains over half a million cars

Survey conducted by the Energy and Petroleum Regulating Authority, less than 350 of these vehicles are electric vehicles (EVs)

DIESEL BUSES

- The majority of the vehicles in the Public transport sector have diesel engines.
- Diesel engines (internal-combustion engines) are those in which diesel fuel injected into the cylinder- combusts and expands, actuating a piston when air is compressed to a sufficiently high temperature.
- It transforms the chemical energy in the fuel into mechanical energy that can be utilized to propel freight vehicles.
- The main disadvantage of diesel engines is the pollution they emit into the atmosphere
- Because many of the vehicles and matatus use older diesel engine technology, the greatest air pollutant is Particulate Matter (PM) 2.5



BATTERY ELECTRIC BUSES

Electric vehicles are not new innovations; the first one was constructed about 1800 by Robert Anderson, a Scottish inventor

The electric bus employs rechargeable battery packs to power the electric motors that propel the vehicle instead of using an internal combustion engine (ICE) .

Charging methods include Plug-in, on-route (opportunistic), slow charging, quick charging, pantograph, and wireless charging

Electric vehicles are pollution-free, quieter, and more efficient than conventional automobiles.

The batteries generally last 6 to 12 years before they start to lose performance to the point where they need to be replaced

The batteries can also be recycled to collect raw materials, lowering their environmental impact even further.



METHODOLOGY

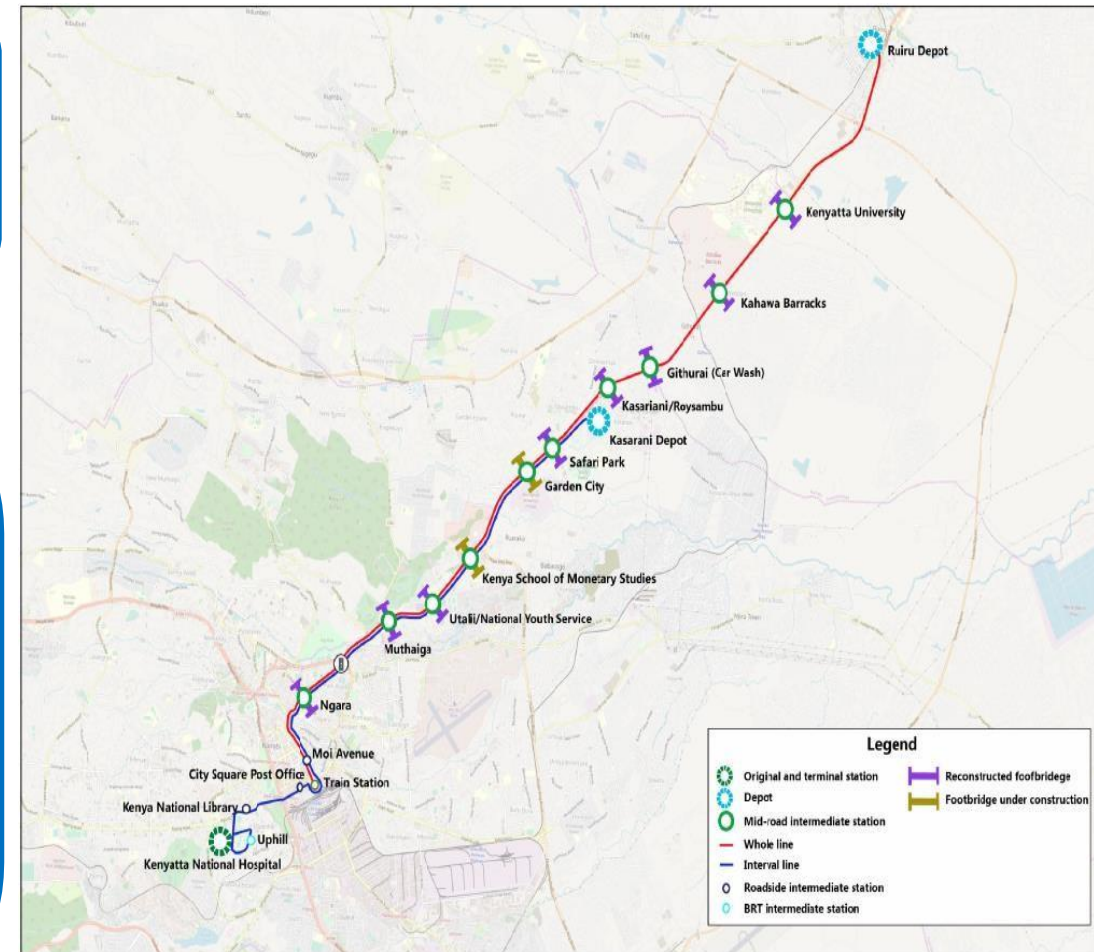
For the study we have considered the following costs for the total lifecycle costs;

- i. Initial Purchase cost. - Cost of Buying the buses
- ii. Fuel and Energy costs. - Cost incurred to fuel or charge the diesel and electric buses respectively.
- iii. Maintenance cost - Cost of keeping the buses in good condition so that they can operate efficiently
- iv. Overheads and management costs - Costs incurred for maintaining staff, monthly bills, taxes and levies
- v. Disposal Costs - When the vehicle has reached the end of its useful life or at its economic service life.
- vi. Environmental costs- Costs associated with polluting the environment

METHODOLOGY

The calculated costs were added up to obtain the Net Present Value (NPV) of each bus that has been selected

For our case study, we selected the BRT Line 2 route which runs from Ruiru on Thika Superhighway through the CBD to the Central Railways (CRS) BRT station and then terminates at Kenyatta National Hospital terminal (KNH). The whole line is a length of 27km and will have 10 intermediate stations on Thika Superhighway. The service life of the buses is assumed to be 12 years.



METHODOLOGY

Purchase Costs

- The base price of a 12m diesel bus was estimated at KES 44 million .
- The electric bus selected was costed at a base price of KES 75 million.
- We considered two scenarios, namely:
 - a) The Operator bears all the costs including the fleet purchase.
 - b) Where the Operator only bears the cost of day-to-day operations and staff salaries. The fleet purchase cost is to be borne by the government.

METHODOLOGY

DIESEL AND ENERGY PRICE

- Month Selected- April/May 2022-Kshs. 125.5
- The cost of diesel without the subsidy paid by the national government - Kshs. 165.74.
- Electricity cost per kWh -Kshs. 21 as per the current tariff rate calculated from stimatracker.com.

METHODOLOGY

Maintenance Cost

- Set at Ksh. 63.6 per Km for the diesel buses
- For the BEB's, they are assumed to be 50% of the diesel buses. The cost chosen was Kshs.31.8 per Km.
- The maintenance costs are assumed to increase at a rate of 20% p.a.
- The discount rate used for the analysis is 12% p.a as per the estimates done for the BRT Line 2 project.

ANALYSIS

Assumptions made -3 Costs were considered for calculating Life Cycle Cost namely:

- i. Purchase Cost
 - ii. Fuel/Energy Cost
 - iii. Maintenance Costs.
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- Fuel consumption rate for diesel buses - 42 Litres per 100Km.
 - Energy consumed by the BEBs - 126kw per 100km
 - Annual Vehicle Kilometres travelled - 60,000 Km per year per bus

ANALYSIS

- Litres consumed by diesel bus for a one-year period will be 25,200 litres.
- The Energy consumed by a BEB in one year's time is 75,600 kWh
- Costs for fuel was obtained by multiplying unit cost of diesel by litres consumed.
- Energy Price was calculated by multiplying unit cost of electricity by units consumed in one year.
- Maintenance costs were calculated by multiplying distance travelled yearly by the unit rate of maintenance per Km.
- The value of cost was adjusted using the above formula to get present worth. The results were then tabulated.

PW= Present Worth, AW= Annual worth, A= Annuity, i = discounting rate, N = useful year.

The formula for conversion from Annual worth to Present Worth, $P = A * \frac{(1+i)^N - 1}{i * (1+i)^N}$

The formula for conversion from Annual Gradient to Present Worth $P = \frac{A}{i - g} * \left[1 - \left\{ \frac{1+g}{1+i} \right\}^N \right]$

RESULTS AND DISCUSSIONS

INDIVIDUAL LCC COSTS WITH PURCHASE OF BUS					
S. No.	Item	Diesel Bus Cost	Diesel Bus w/o Fuel Subsidy	Electric Bus with BR	Electric Bus without BR
1	Bus Purchase Price	44,000,000	44,000,000	75,000,000	75,000,000
2	Fuel and Energy	19,590,327.93	25,871,720.72	10,147,945.96	10,147,945.96
3	Maintenance for 12 years	61,463,401.47	61,463,401.47	30,731,700.73	30,731,700.73
4	Battery Replacement			7,784,385	
	Total	125,053,729	131,335,122	123,664,032	115,879,647

RESULTS

INDIVIDUAL LCC COSTS WITHOUT PURCHASE OF BUS					
S. No.	Item	Diesel Bus Cost	Diesel Bus w Fuel Subsidy	Electric Bus with BR	Electric Bus without BR
1	Fuel and Energy	19,590,327.93	25,871,720.72	10,147,945.96	10,147,945.96
2	Maintenance for 12 years	61,463,401.47	61,463,401.47	30,731,700.73	30,731,700.73
3	Battery Replacement			7,784,385	
	Total	81,053,729	87,335,122	48,664,032	40,879,647

RESULTS AND DISCUSSIONS

LCC Yearly Costs with Purchase of 100 Bus Fleet					
S. No.	Item	Diesel Bus Cost	Diesel Bus w/o Fuel Subsidy	Electric Bus with BR	Electric Bus without BR
1	Bus Purchase Price	366,666,667	366,666,667	625,000,000	625,000,000
2	Fuel and Energy	163,252,733	215,597,673	84,566,216	84,566,216
3	Maintenance for 12 years	512,195,012	512,195,012	256,097,506	256,097,506
4	Battery Replacement	0	0	64,869,875	0
5	Total	1,042,114,412	1,094,459,352	1,030,533,597	965,663,722
6	Staff Costs	333,000,000	333,000,000	333,000,000	333,000,000
7	Total with Staff costs	1,375,114,412	1,427,459,352	1,363,533,597	1,298,663,722
8	Fare 'A'	1,510,000,000	1,510,000,000	1,510,000,000	1,510,000,000
9	Fare 'B'	3,464,250,000	3,464,250,000	3,464,250,000	3,464,250,000
10	Profit/Loss Fare 'A'	134,885,588	82,540,648	146,466,403	211,336,278
11	Profit/Loss Fare 'B'	2,089,135,588	2,036,790,648	2,100,716,403	2,165,586,278

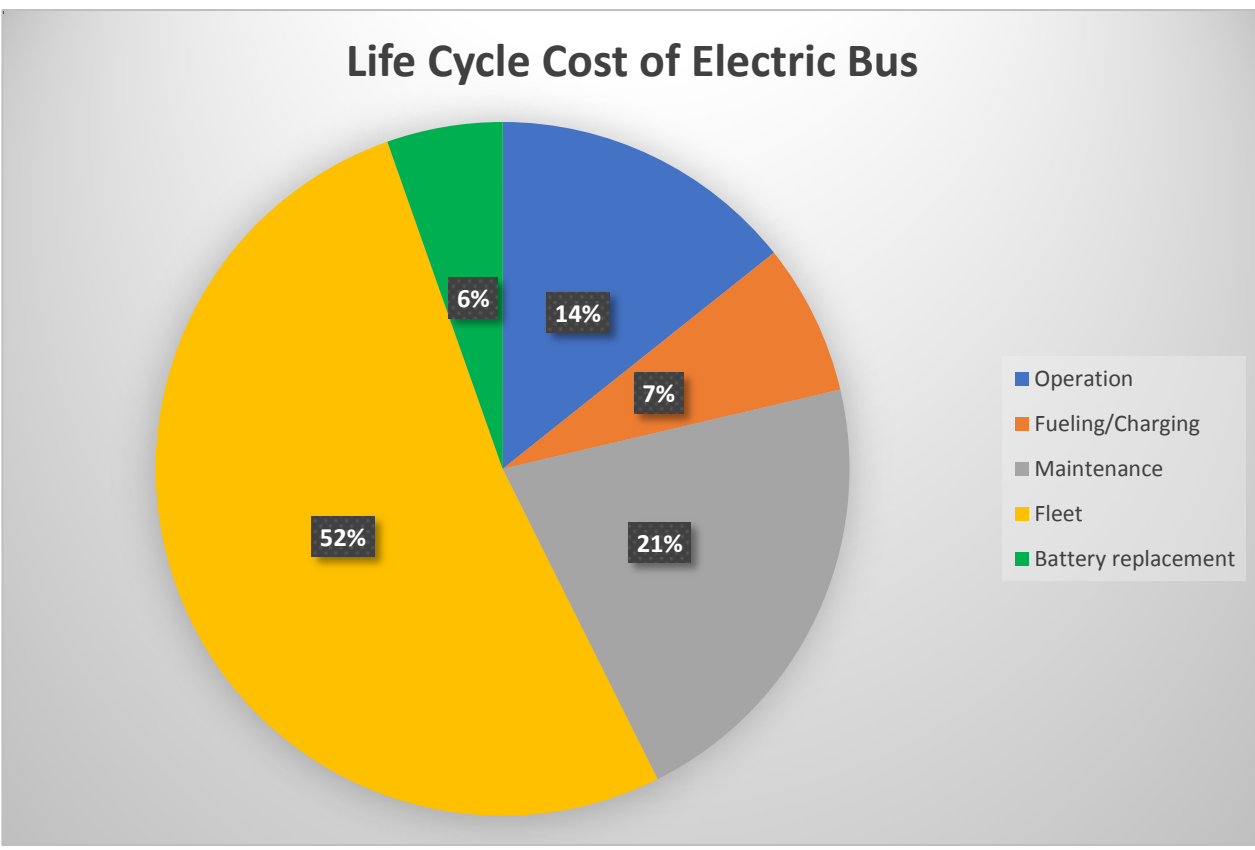
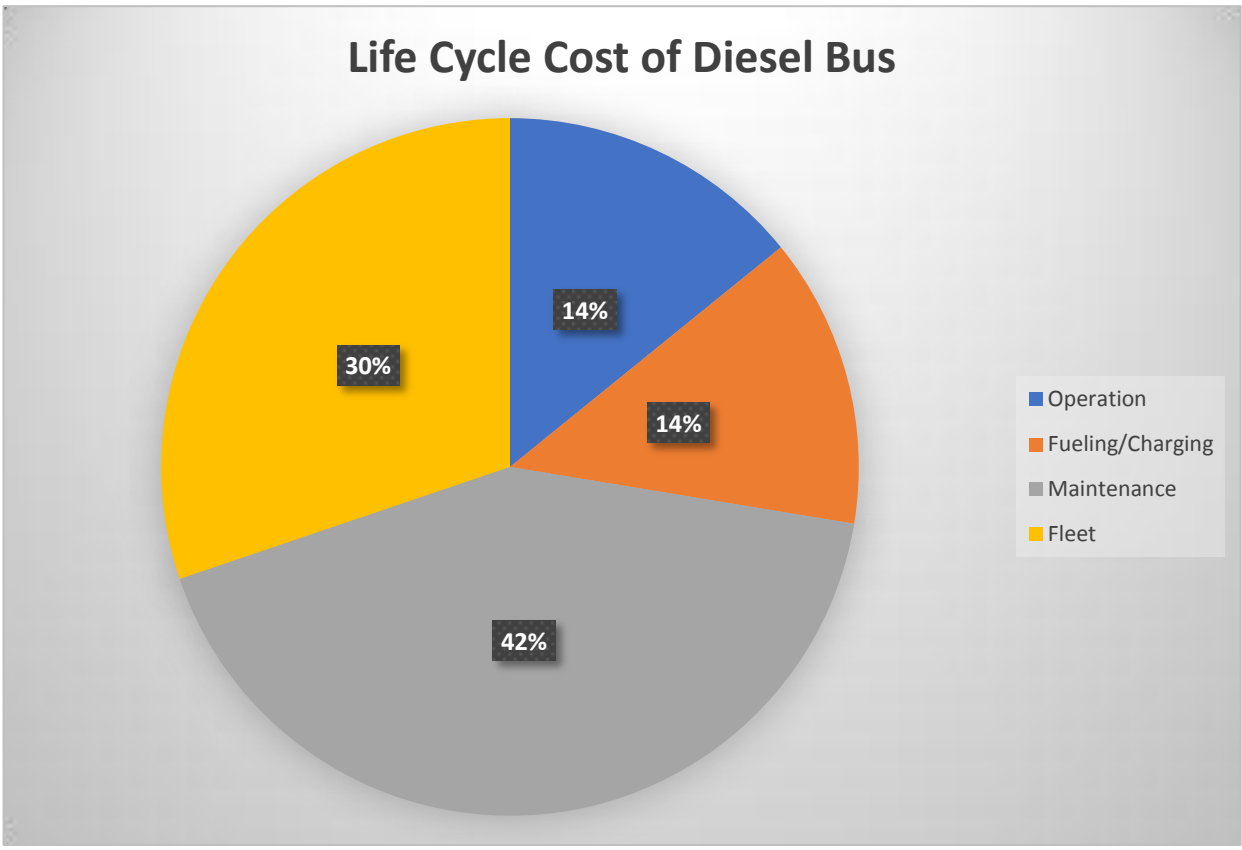
RESULTS AND DISCUSSIONS

LCC Yearly Costs without Purchase of 100 Bus Fleet

S. No.	Item	Diesel Bus Cost	Diesel Bus w Fuel Subsidy	Electric Bus with BR	Electric Bus without BR
1	Fuel and Energy	163,252,733	215,597,673	84,566,217	84,566,217
2	Maintenance for 12 years	512,195,013	512,195,012.25	256,097,506	256,097,506
3	Battery Replacement			64,869,875	
4	Total	675,447,745	727,792,685	405,533,597	340,663,722
5	Staff Costs	333,000,000	333,000,000	333,000,000	333,000,000
6	Total with Staff Costs	1,008,447,745	1,060,792,685	738,533,597	673,663,722
7	Fare 'A'	1,510,000,000	1,510,000,000	1,510,000,000	1,510,000,000
8	Fare 'B'	3,464,250,000	3,464,250,000	3,464,250,000	3,464,250,000
9	Profit/Loss Fare 'A'	501,552,255	449,207,315	771,466,403	836,336,278
10	Profit/Loss Fare 'B'	2,455,802,255	2,403,457,315	2,725,716,403	2,790,586,278

RESULTS AND DISCUSSIONS

 LCC Costs in terms of percentages for the diesel and electric Bus



BREAKDOWN OF LCC COSTS

BRT Line 2 Yearly Costs with Purchase of fleet

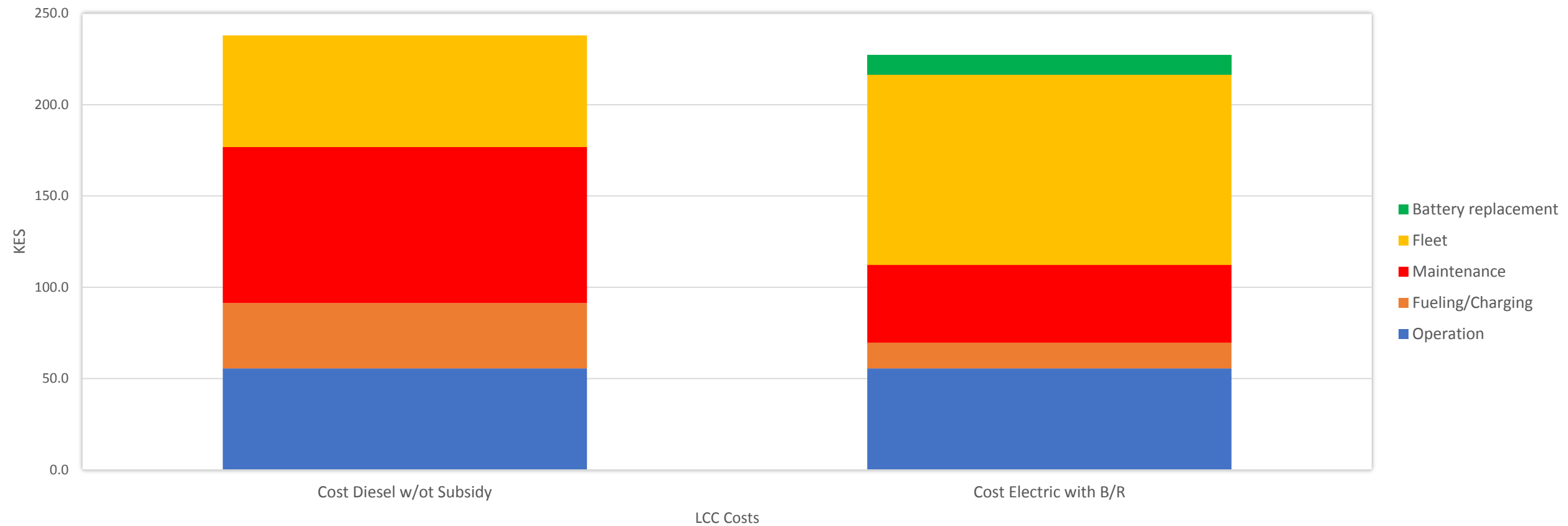
Item	Diesel Bus (KES) Cost per Km
Fleet Purchase Cost	61.1
Fuel Costs	27.2
Maintenance cost	85.4
Annual Personnel costs (Kshs)	55.5
Total	229.2
Fare Revenue per Km (Fare 'A')	251.7
Fare Revenue per Km (Fare 'B')	577.4

BRT Line 2 Yearly Costs with Purchase of fleet

Item	Electric Bus (KES) Cost per Km
Purchase Cost	104.2
Energy Costs	14.1
Cost for battery replacement	10.8
Maintenance cost	42.7
Annual Personnel costs (Kshs)	55.5
Total	227.3
Fare Revenue per Km (Fare 'A')	251.7
Fare Revenue per Km (Fare 'B')	577.4

BREAKDOWN OF LCC COSTS

Yearly LCC Costs per Km in KES with Fleet Purchase



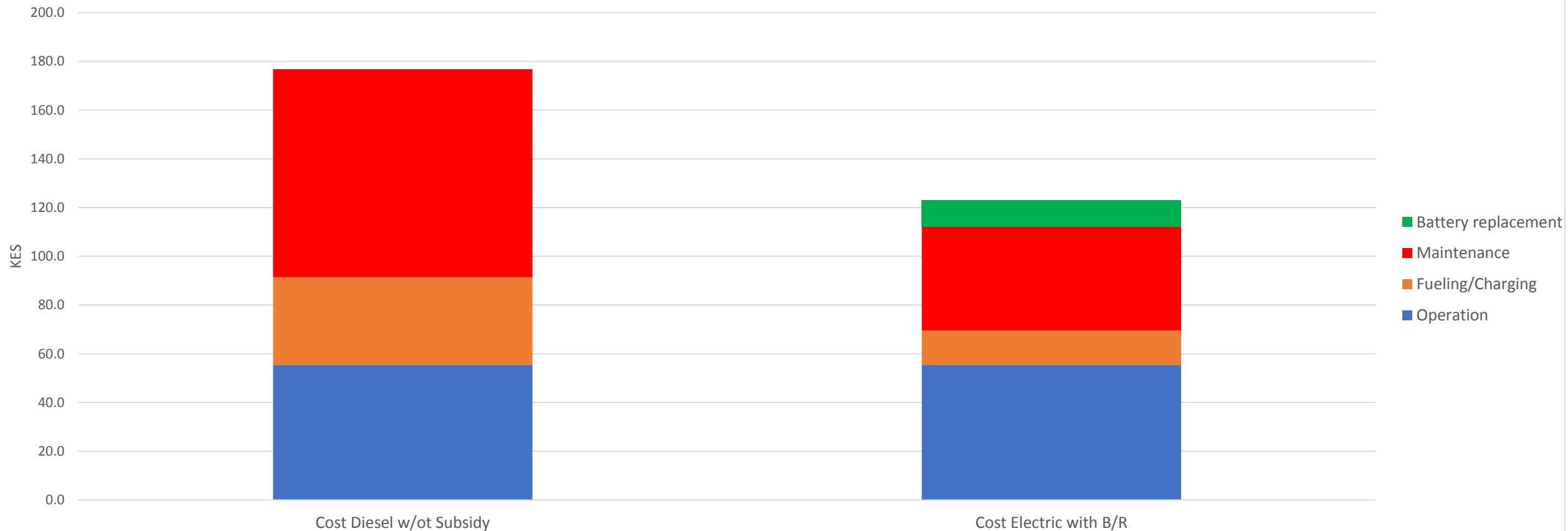
BREAKDOWN OF LCC COSTS

BRT Line 2 Yearly Costs without Purchase of fleet	
Item	Diesel Bus (KES) Cost per Km
Fuel Costs	27.2
Maintenance cost	85.4
Annual Personnel costs (Kshs)	55.5
Total	168.1
Fare Revenue per Km (Fare 'A')	251.7
Fare Revenue per Km (Fare 'B')	577.4

BRT Line 2 Yearly Costs without Purchase of fleet	
Item	Electric Bus (KES) Cost per Km
Energy Costs	14.1
Cost for battery replacement	10.8
Maintenance cost	42.7
Annual Personnel costs (Kshs)	55.5
Total	123.1
Fare Revenue per Km (Fare 'A')	251.7
Fare Revenue per Km (Fare 'B')	577.4

BREAKDOWN OF LCC COSTS

Yearly LCC Costs per Km in KES without Fleet Purchase



CONCLUSIONS

- All scenarios considered, the study clearly shows that in the long run the electric buses are less costly than the diesel ones.
- The current initial purchasing costs of the electric buses are one of the largest barriers of shifting from ICE buses to E- buses. Government policies and incentives will result in reduction of prices of the BEB's over the coming years which will attract more investors and stakeholders to adopt them.
- As the government has developed several policies and standards to adopt EV's in the Kenyan market, a combined effort from the regulatory and implementing agencies will enable an easier operating environment for future investment opportunities in the EV sector.
- There is need for more charging infrastructure to be installed around the country. As it is, the current initial costs of setting up the charging infrastructure are very high. It would be more feasible if private entities were encouraged to take up this initiative as a PPP.
- There is need for KPLC, as the power distributors, to adopt special rates for transport sector aside from the off-peak rates currently charged to EV companies and EV's owners. This will go a long way in fast tracking the adoption of EV's in the Kenyan market.