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Understanding the Public Mobility to Innovate a Carbon-Neutral Transport System for the Twin Cities in Pakistan

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Abstract
The transportation industry in Pakistan is growing rapidly which in turn has raised the cost of energy imports, usage of petroleum products, air pollution, and traffic congestion. It is perturbing that the worldis too much dependent on fossil fuels to meet its energy requirements. To address any nation's energy, economic, and environmental problems, electrification of road transportation appears to be a game-changer. This study aims to help implement a green transportation system in Islamabad and Rawalpindi. This study compares the financial and environmental costs of using electric, diesel, andsolar buses. It also assesses the viability of using suitable electric vehicles (EVs) for Islamabad and Rawalpindi's public transit systems and considers several technological choices. Electric vehicles (EVs) provide a solution to these problems. Hence, switching from fossil fuel vehicles (FFVs) to EVs is a necessary step in decarbonizing the country's transportation sector and reversing its dire socioeconomic situation. In this study, applied quantitative and qualitative analysis forms the foundation of the primary research design as we examine the energy usage and consumption in Plug-In Electric Vehicles (PEVs) for the current private services in Islamabad and Rawalpindi. This paper evaluates socio-environmental and financial comparisons among FFVs, EVs, and Solar buses. The study's findings indicate that solar buses use only 18% energy compared to electric buses, which use 30%, while diesel buses use 52% for the same seating capacity and distance covered. However, batteries-powered buses are currently more expensive than diesel buses. Although it costs more than diesel buses, using electric and solar buses is beneficial for both humans and the environment.

1. Introduction

According to Jain, V., et al. (2012) a society's economy and special activities are hampered by traffic congestion. The lack of an active non-motorized transportation system is another element that these emerging nations have in common. Yet, the number of private vehicles is growing over time. Becausepoor transportation systems simultaneously cause noise pollution and air pollution, they pose a danger to environmental quality. Natural resources have a crucial role in societal and economic prosperity. (Tan, 2023) Argue that fast industrialization and population growth have necessitated large-scale natural resource exploitation. However, humanity's inefficient exploitation of natural resources has created significant issues. (Lingli Qing., 2023), The major factors are climate change (Shang, 2024) and resource shortage (Zhou et al., 2023). Xu et al. (2023) found that freshwater, forests, and underground resources have been inefficiently used, with malpractice being the primary type of exploitation throughout decades. To achieve environmental balance, it's crucial to prioritize sustainability when exploiting natural resources (Abbas and Khan, 2022). Over half of the world's population lacks access to secure, affordable, and sustainable energy sources. Research shows that improving resource and energy efficiency (EE) is vital for promoting low-carbon solutions, since it reduces operating costs and environmental impact (Bhagaloo et al., 2022). (Kim et al., 2022; Xu et al., 2023) Suggests that improving resource efficiency (RE) can reduce energy consumption, reduce carbon emissions, and raise economic production. As a result of the transportation sector's excessive reliance on petroleum derivatives, which also contributes to environmental change and the unfavorable rise in global temperatures, managing greentransportation is arguably one of the most difficult challenges faced by modern society (Balsalobre-Lorente, Driha et al. 2021).

A common characteristic of nations with good developmentindices includes a developed transportation infrastructure (O'Neill, Coney et al. 2020). Green transportation also has a negligible influence on the environment because it only uses energy thatis either renewable or recycled, as opposed to fossil fuels-based vehicles like electric Bicycle, Auto Electric Sky Trains and Electric Motorcycles. Green transportation promotes a healthy and ideal way of living in addition to being an environment friendly or low-carbon method of transportation. Green transportation system development is advantageous for the efficient use of route resources for ease of over trafficking, the reduction of energyconsumption, and the reduction of over emissions, and finally it will minimize GHGS emissions Jiang, Y., et al. (2017. Climate challenges can be resolved by introducing EVs (Electric Vehicles). EVs don't use fuel; instead, they run on electricity. EVs don't emit harmful contaminants in this way. Hence, replacing FFVs with EVs can significantly reduce the release of toxins, which can aid in enhancing the environment for decomposition. Suburban EV drivers will pay a hefty sticker price for each unit of power purchased from the government. The public authority can coordinate the amount for limited installments and generate a sizable money in this approach.

Pakistan is one of the most vulnerable countries to climate change because it is primarily fueled by pollution. Due to significant greenhouse gas (GHG) emissions, it is ranked as the third worst country in the world in the Global Air Quality Index Report 2022. The recent data from the Pakistan Bureau of Statistics (PBS) show that recorded oil imports for the Julyto October period of 2020–21 were $3.15 billion, demonstrating that the usage of fossil fuels is harmfulto both the environment and the economy. By drastically reducing gasoline imports, EVs will mitigate the growing import/export imbalance. The integration of EVs into the transportation system may create a completely new industry in Pakistan, opening a variety of economic opportunities and strengthening the nation's economy (Todoruț, Cordoș et al. 2020).

Pakistan's ineffective and costly public transportation infrastructure has led to the development in the private transportation industry. Also, as its working class expands, private automobile demand has been steadily rising (Rasool, Zaidi et al. 2019). Many issues with Pakistan's transportation system have various impacts on the country's energy and environmental issues.

For places like Islamabad and Rawalpindi, where urban expansion and development have led to increased population and land use, the risk of environmental degradation and climate change is a question of time given the high speed of technological innovation, industrial development and urban growth. These cities are growing rapidly and as they do, so do their needs for decent housing, decent educational facilities and decent transportation.

This study examines the lack of a transportation system in Islamabad and Rawalpindi, which are cities.

With at least minimal green and sustainable transportation policies in place. Furthermore, this study will gather information and compare the cost of an electric vehicle for the same project to an FFV that is now in use in Islamabad/Rawalpindi. The study presents the financial, social,and environmental costs of both FFV and EV. The alternative (EV) should also be able to provide all thespecific operational and functional needs, such as charging stations, mileage, storage, and consumption.

1. To analyze the mobility trends in Rawalpindi and Islamabad and propose mass transit routesfor the twin cities.
2. To estimate the investment that would be required to establish an EV-based mass transit systemfor the twin cities and compare it with the financial, economic, and environmental costs of the samesystem when operated on fossil fuels.

2. Literature Review

(Julio A. Sanguesa, 2021) Reviews the advances of EVs regarding battery technology trends, and charging methods, as well as new research challenges and open opportunities. (Bashir et al, 2022) Identified many solutions for the government to reallocate the energy mix and align energy demand targets with climate ambitions for Pakistan's green future. Interestingly, the United States used the benefit-cost investigation in the Harbors Act of 1899 (Hyard 2012). Benefit-cost analysis has consistently developed into a crucial tool for analyzingand assessing the financial viability of projects, particularly those that involve public funds. (Muhammad Imran Khan, et al., 2024) The investigation uses product-specific standards from the Global Footprint Network to estimate the ecological footprint of Pakistan's production operations. Although these cars are undoubtedly more energy-efficient than typical cars, vehicle development aims to create entirely electric cars. (Li, Khajepour et al. 2019). Due to its many advantages, including zero outflows, electric vehicles are now available for public transportation in a rising number of urban areas throughout the world. (Enang and Bannister 2017) uses indicators to estimate the improvement made byItalian cities in the smart movement area, thus recognizing how these cities have loomed the new strategies executed by the European Union, and how they have been executed the European deviations. Public motorways and common highways total 13,000 and 93,000 km each, with other areas, common areas, and city roads filling in the remaining distances (Asghar, Rehman et al. 2021). Due to the development of the ambitious China Pakistan Economic Corridor (CPEC), which is currentlybuilding 3070 km of new road and railway routes, this transportation system is expanding. Althoughthe shipping lane will be improved, the current roadway network will be overloaded. In comparison to the previous fiscal year, the population increased from 208.57 to 212.48 million people in 2020–21, and the share of the street transport area increased as well (Rasool, Zaidi et al. 2019). According to statistics, there are 16 vehicles on average per 1000 people, a number that is certain to rise as Pakistan pushes for rapid urbanization. According to the 2018 review, almost 17 million vehicles were enrolled; by 2025, this number is projected to rise by 30 million. As of 2018, the transportation sector was using nearly 302,000 barrels of oil per day; by 2025, that number is projected to rise (Asim, Usman et al. 2022). A hybrid electric vehicle was also recommended by a Pakistani study based on its consumption andcarbon emissions. It was determined that HEVs can operate with emissions decreased by a factor of25–30% annually and can save up to 40% on gasoline. In that approach, Pakistan can readily anticipate putting EVs into use by 2030, as the current administration has intended (Khan, Ali et al.2020). Since the use of EVs has not yet reached its full potential, numerous studies have attempted to concentrate on a particular EV that may be advantageous for a certain nation. (Maham Fatima, et al., 2022) BRTs are sustainable alternatives for large cities that can be employed in place of the traditional bus system, providing an energy-efficient

and ecologically friendly alternative to public transportation.
Numerous research on the environmental advantages of EV (Electric Vehicles) adoption have shown an important association between these advantages and the energy sources used to produce both the batteries andelectronic components that go into manufacturing vehicles as well as the energy needed for runningthose vehicles (Hoekstra 2019), Jurkovič, M., et al. (2020) and Khan, F., et al. (2022).
In the context of this, some writers have suggested evaluating the environmental feasibility of EV adoption while avoiding overestimating or underestimating emission parameters (Hawkins, Singh etal. 2013, Hoekstra 2019, Pipitone, Caltabellotta et al. 2021) by considering both the energy consumption during the production process and the energy utilized by vehicles on the road. When the effects of ICEVs and BEVs on GHG emissions were calculated over the course of their respectivelife cycles, it was discovered that a BEV released 109.6 g/km of CO2eq during production and use, which is 41.4% less than an ICEV. (Costa, Barbosa et al. 2021) estimated a BEV and an ICEV that had similar components, employinga similar approach. These authors examined the GHG emissions produced during the production of both vehicles and discovered that the ICEVs emit more GHGs than the BEVs, attributing this findingto the larger number of components that must be produced for an ICEV as opposed to a BEV; however, this environmental benefit depends on the energy mix.
Consistent with this, (Siragusa, Tumino, et al. 2022) used the LCA to estimate the GHG emissions, considering the complete life cycle of a vehicle (raw material and component acquisition and processing, maintenance, and disposal). According to these authors, switching to EVs can reduce greenhouse gas emissions by 17 to 54% depending on how many miles are driven Vehicle emissions make a significant amount of air pollution along with industrial emissions. The number of vehicles on the road and the number of miles traveled have both had a dangerous effect on Pakistan's air quality. The country's extensive road system contributes to a high demand for petroleum products, which accounts for 47.2% of all petroleum products produced and imported; additionally, the fleet's approximately 50% of older vehicles results in incomplete combustion, whichincreases the amount of hazardous emissions into the atmosphere (Khwaja 2005).
An average vehicle in Pakistan releases 25 times more CO2 and 3.5 times more Sulphur dioxide than vehicles in the United States (Barber 2008). In the capital, Islamabad, the intensity of CO2, NO SO2, and PM2.5 have exceeded the levels set by Pakistan National Environmental Quality Standards (NEQS) (Bilal, Mhawish et al. 2021).
When analyzing the economic viability of adopting BEVs to ICEVs, some studies have indicated that the purchase price is the most important aspect, with high cost being one of the key obstacles delaying the adoption of EVs (Gomez Vilchez, Smyth et al. 2019). By examining consistency and ageing traits and speculating on potential uses, (Jiang, Jiang et al. 2017) suggested a new screening technique to evaluate the ageing status of battery packs and the cost-effectiveness of employing used EV batteries.
Additionally, other studies (Pagliaro and Meneguzzo, Cusenza, Guarino et al. 2019) suggested utilizing used batteries in energy storage systems (ESSs). This economical method would greatly minimize the amount of trash that is harmful to both human health and the environment, which will also reduce the cost of EVs.
This study uses the transport sector of Pakistan as a case study and proposes an economic calculationof different scenarios for sustainable transportation in the region. This study used the Long-range Energy Alternative Planning (LEAP) framework to estimate the social and environmental costs of three scenarios, Efficient Combustion Scenario (ECS), Business as Usual Scenario (BAUS), and Hybrid Vehicle Scenario (HVS). The result shows that by 2040, the ECS and HVS will decrease carbon dioxide emissions by 303.7 and 213.3 million metric tons correspondingly linked to

BAUS. These savings in stints of social cost will be US$ 10.1 billion in HVS and US$ 7.2 billion in ECS asrelated to BAUS. By the year 2040, oil demand in the transportation system will also be possible tocontain at the 2026 level. It is anticipated that this research will help in determining the optimum course of action for raising the percentage of green fuels in Pakistan's transport sector (Shahid, Ullah,et al. 2022).

EVs will ultimately be more advantageous due to an increase in battery useful life and low maintenance costs. (Siragusa, Tumino et al. 2022) compared electric vans with ICEVs for last-mile deliveries in line with this.

This study specifically emphasized many benefits of using EVs, including 40% lower repair and maintenance costs, 60% lower refueling prices, 35% lower insurance costs, absence of road tolls, and Absence of property tax. In the end, EV and ICEV operating expenditures were 35% and 73% of their total cost of ownership (TCO), respectively. In this situation, it became apparent that using an EV is more cost-effective than using an ICEV after 4.5 Years of ownership. In line with this, (Costa, Barbosa, et al. 2021) mentioned how the economic advantages rely on the end user's mobility profile. The authors assumed that the greater the price differential between the two types of vehicles, the greater the traveled distance required to make the Electrical Vehicle a beneficial solution from an economic perspective, which would then increase in the payback time. This assumption was madespecifically concerning the acquisition cost of electric and combustion vehicles and the costs of power supply (electricity and fuel costs).

With increasing global concern regarding climate change and oil consumption, the adoption of BEVshas now become an important step towards an improved transportation system for modern society (Żelazna, Bojar et al. 2020, Galati, Migliore et al. 2022, Guo, Kelly et al. 2022). The government incentives offered may also make it possible to accomplish the aforementioned goals. (Ebrie and Kim 2022) asserted that tax incentives and direct subsidies for EV purchases have a substantial impact on EV adoption in light of this. (Peiseler and Serrenho 2022) made a similar case for the need for improved governmental incentives.The authors specifically suggested categorizing automobiles according to their emissions and takingemissions into account in both subsidy programs and the system of road taxes. They also recommended looking at end-of-life vehicle directives. In addition to employing policy incentives to reduce the cost difference between EVs and ICEVs, it is essential to take additional policy steps to ease range anxiety by setting up an adequate number of publicly accessible charging stations (Thiel,Tsakalidis, et al. 2020). Furthermore, (White, Carrel et al. 2022) studied the American metropolises of Los Angeles, Dallas/Fort Worth, and Atlanta and discovered that government incentives to increase the availability of charging infrastructure guarantee customers' unrestricted freedom of movement and are essential to the widespread adoption of EVs. (Napoli, Polimeni et al. 2021) emphasized the significance of EV adoption in the logistics industry in this context as it represents the most economical step towards carbon reduction. The UK'ssituation is notable because it was the first to use electric vehicles for delivery services. A law requiring net-zero greenhouse gas emissions by 2050 was approved by the UK parliament.

The literature review amply indicates the importance of electric vehicles as a study topic, both theoretically and practically. The most fascinating and challenging topic, however, may be the choice of electric transportation because of its distinctive features in the context of electric vehicle development. This study used an annual time series dataset spanning from 1990 to 2020 to examine the role of green energy consumption, eco-innovation, and urbanization while expressing the desire for a low-carbon economy and environmental sustainability in the context of Pakistan. The symmetric, asymmetric, and quantile autoregressive distributed lag models were employed to investigate the short-run and long-run correlations among explained and explanatory variables. The study's results indicated that under symmetric, asymmetric, and quantile autoregressive distributed lag models, the labor force, urbanization, consumption

of green energy, ecological innovation, and GDP per capita are all co-integrated for the long-term association.
In addition, efficient eco-innovation and the use of green energy are the best ways to assure environmental sustainability, whereas urbanization, GDP per person, and labor force hurt the low-carbon economy. By focusing on green energy consumption, ecological innovation, and controlled urbanization as well as the integration of environmentally friendly policiesinto economic development policies, the authors of the study finding provide a policy framework for the creation of a comprehensive strategy to promote environmental sustainability in Pakistan (Ullah, Abbas et al. 2023).

3. Methodology

3.1 Research Design

In this study, the primary research design is based on applied quantitative analysis where the researcher inquires about the usage and consumption of energy in Plugin Electric Vehicles (PEVs) for the Mass Transit (BRT) of Islamabad and Rawalpindi, Public Transportation currently operational in the zone as well as any Private services. The author has conducted both financial and socio-environmental feasibility of using electricity insteadof fossil fuel. The financial comparative analysis of using fossil fuel or electricity is done through quantitative analysis. Whereas the socio-environmental between the two will be calculated through qualitative analysis. The author wishes to establish workable policies regarding PEV adaption in the Federal capital Islamabad according to a recent policy proposed by Dr. Naveed Arslan of LUMS University on PEV usage (Ullah 2019). Furthermore, the author will determine the energy consumption patterns of the Electric Buses for the pre-existing Bus Routes of Islamabad and Rawalpindi.

3.2 Data Methodology:

The author, based on the first objective of this study, will adopt the findings of Sustainable Public Transportation Plan proposed by Khizar (2020) where she established Public Bus Transport routesfor Islamabad-Rawalpindi. These routes will be used to total the FFV vs EV (Fossil Fuel Vehicles and Electric Vehicles) consumption patterns. Method employed for the recording these routes is based on Geo Time tracing where an object moves in between t and Δt (where t is the stay still pointof the route and Δt is the change in the length of the route). The researcher employs both primary and secondary data sources. Firstly, the primary data wouldbe collected on the number of pre-existing Bus Routes including the Metro Bus System of Islamabadand Rawalpindi, and secondary data from Khizar (2020) on the routes. The data collected wouldbe of the following factors.

- Road Length and Travel Distance
- Timetable on Bus Usage (Preexisting)
- Bus Stops (Number of stations in a single Bus Route)

Secondly, the second source would be used to collect data on other factors in the equation of energy consumption model of EVs (Burkhart and Aurich 2015).

Equation 1

$$E_{total} = t * P$$

Where,

- P = Power
- T = Time between two set points and to calculate power,

Equation 2

$$P = v * \Sigma F$$

Where,

- V = Velocity of the Bus $\sum F$ = Total Forces acting on or moving the vehicle like acceleration and air resistance and the total force is calculated.

Equation 3

$$\sum F = F\,rail + F\,grade + F\,air + F\,ace$$

Where,

F roll = the force that prevents rolling. It is where the force between the tyres and theroadinteracts, F grade = the force connected to grade. This could be negative if the vehicle is travellingdownward because gravity will then be helping in speed, F air = the resistance of the vehicle against the air, & F ace = the acceleration force acting on the vehicle. Secondary data is be collected on the Terrain (Road Quality and Elevation changes) in the Routes of the Buses, Duration of travel of each Bus (Time between each stops) and the duration of stops (2-minute wait for passengers) (Abousleiman and Rawashdeh 2015).
For equation 1, the author needs to calculate the Time required to travel. The research would use the following equation for that.

Equation 4

$$\text{Time (t)} = \frac{E\,(t + \Delta t) - E(t)}{D\,(t + \Delta t) - D(t)} * \alpha * \beta$$

Where,

E = the elevation over the period (t, Δt)
D = the distance (length of the route) a bus travels in the single time step Δt (One second is used in this study for Δt).
α = the traffic response and increase or decrease in traffic.β
= Go and Stop status of the vehicle (traffic stops).

4. Results and Discussion

4.1 Brief about Calculations

We have to calculate the forces for the individual buses. Equation No 1: $\sum F$ = F rail + F grade + F air + F ace. The F roll essentially represents the rolling resistance force. The force interface betweenthe tyres and the ground is called F grade, and the force is grade related. If the vehicle is moving downward, this could be detrimental because gravity will be assisting in propulsion in this situation.F air is the vehicle's resistance to the air, and F ace is the acceleration force acting on the vehicle. This formula has been used to determine the total of these forces separately for each type of bus.

Table 4.1: Forces for all categories

Forces (N)	For Electric Buses	For Diesel Buses	For Solar Buses
F_{rail}	360	320	63.5
F_{grade}	97,200	86,400	17145
F_{air}	105332.4	105332.4	105332.4
F_{ace}	127.47	125.6	94.08
∑F	**203019.8**	**192177.6**	**122634.9**

In Table 4.2 we have calculated the ∑F that is Total Forces acting on or moving the vehicle like acceleration and air resistance by using the formula for Electric buses, Diesel buses and Solar buses. The total force required to run electric buses is 203019.8 N for diesel buses 192177.6 N and for solar buses 122634.9 N.

Table 4.2: Preexisting Bus Routes of Islamabad and Rawalpindi

Route No.	Distance (km)	Duration (hours)	Routes
1	44.513	0.884	Bhara Kahu to Morga
2	130.716	2.82	G-6 through RWP to I-8
3	24.324	0.5	I-8 to PWD Housing Society
4	44.451	1.063	Islamabad Sectors
5	83.08	1.541	PIEAS to Rawat
6	89.444	1.911	PIEAS to Rawat to Afzal Town
7	17.056	0.332	Pir Sohawa to F-7 Markaz
8	67.885	1.545	QAU to Saddar
9	20.918	0.564	Rawalpindi Medical Line
10	97.661	2.309	Satellite Town to Blue Area

In Table 4.2 we have taken the preexisting routes for Islamabad and Rawalpindi. In column three time is taken in hours but in the coming tables this time is converted into seconds through formula. The data is collected from the following factors.

Road Length and Travel Distance

Timetable on Bus Usage (Preexisting)

Bus Stops (Number of stations in a single Bus Route)

Time, Power, and Energy consumption through given below formulas.

(1) Time (t) $\frac{E(t+=t)-E(t)}{D(t+\Delta t)-D(t)} * \alpha * \beta$

In this formula E represent the elevation over the time span (t, Δt) while D signify the distance (lengthof the route) a bus travels in the single time step Δt (One second is used in this study for Δt), α showsthe traffic response and increase or decrease in traffic and β represent Go and Stop status of the vehicle (traffic stops). For the assessment of the socio-environmental comparison between FFV and EV, the author wants to adapt an econometrics model of environmental impact of both the types of vehicles.

(2) $P = v \times \sum F$

Where, V is the Velocity of the Bus and ∑F represent the total Forces acting on or moving the vehicle like acceleration and air resistance.

In formula two power is equal to velocity (V) multiply F characterize the total Forces acting on ormoving the vehicle like acceleration and air resistance (∑F). Velocity for electric and solar bus is 2.6 but for diesel bus, is 4.7. Velocity for diesel bus is higher because when a diesel bus running on fuel, 70 percent of its fuel is used, and the remaining 30 percent is going to waste. For fuel efficiency of modern vehicles, they are trying to convert them into half hybrid vehicles so that they can run on 30 percent electricity andenergy loss will be 10 percent. All vehicles that are currently running in Pakistan, 70 percent of theirfuel is being used and the remaining 30 percent is being wasted.

E Total = t x P

In this formula, P shows the Power and T shows the time between two set points.
In table 4.3 Time is the same for all buses. While power (P) and total Energy (E) are different for the Deasil bus, Electric bus, and Solar bus.

Table 4.3: Energy Consumption of Diesel Bus

No. of Routes	Distance Km	Time (T) minutes	Power (P) watt (w)	Energy (E) kilowatt hour
1	44.513	0.884	903234.72	1092914.0
2	130.716	2.82	903234.72	370.3
3	24.324	0.5	903234.72	1806.4

4	44.451	1.063	903234.72	1083.8
5	83.08	1.541	903234.72	5871.0
6	89.444	1.911	903234.72	541.9
7	17.056	0.332	903234.72	2769.7
8	67.885	1.545	903234.72	6322.6
9	20.918	0.564	903234.72	1806.4
10	97.661	2.309	903234.72	451.6

As mentioned in the beginning, distance and time are the same for all kinds of buses but power and energy are different. So, using the formula which is given in the methodology section, we have found out the power and energy for all types of buses.

Table 4.4: Energy Consumption of Electric Bus

No of Route	Distance km	Time (T) minute	Power (P) watt (w)	Energy (E) kilowatt hour
1	44.513	0.884	507549.5	614134.8
2	130.716	2.82	507549.5	208.0
3	24.324	0.5	507549.5	1050.0
4	44.451	1.063	507549.5	609.0
5	83.08	1.541	507549.5	32990.7
6	89.444	1.911	507549.5	304.0
7	17.056	0.332	507549.5	1522.6
8	67.885	1.545	507549.5	3552.8
9	20.918	0.564	507549.5	1015.0
10	97.661	2.309	507549.5	279.1

Table 4.5: Energy Consumption of Solar Bus

No of Route	Distance km	Time (T) minutes	Power (P) watt (w)	Energy (E) kilowatt hour
1	44.513	0.884	306587.2	370970.5
2	130.716	2.82	306587.2	125.7
3	24.324	0.5	306587.2	613.1
4	44.451	1.063	306587.2	369.9
5	83.08	1.541	306587.2	1992.8
6	89.444	1.911	306587.2	183.9
7	17.056	0.332	306587.2	919.7
8	67.885	1.545	306587.2	2146.1
9	20.918	0.564	306587.2	613.1
10	97.661	2.309	306587.2	168.6

In the above tables 4.3, 4.4 and 4.5 total ten routes are taken for Islamabad and Rawalpindi. Time (T) And distance is same because we are doing comparisons among Electric buses, Diesel buses and solar buses so, distance and time is same for all buses. Power and energy are different for Electric buses, Diesel buses and solar buses.

(U)

Table 4.6: Total Energy Consumption of the Buses

Buses Category	**Duration (hours)**	**Average of the bus Energy (E) kilowatt hour**
Diesel Bus	13.4	111393.37
Electric Bus	13.4	65566.6
Solar Bus	13.4	37810.34

In this research we are assuming total ten routes and combining these routes the total distancebecomes 13.4 hour Pakistan's annual import of oil and gas accounts for about 80%. “If all 240,000 buses in Pakistan were changed into electric ones, it would save a lot of fuel, and the dependence on imports will be largely reduced. 40-50% of traffic emissions pollution can be lessened,” said Liu Xueliang, GeneralManager of Asia Pacific Auto Sales Division, BYD.

Financial Analysis

For the introducing of any new project its financial cost matters. The recent price of diesel bus is 150,000US$, electric bus is 235,000 US$ and for the solar bus is 395,000US$. In a comparison among electric buses, diesel buses and solar buses the result shows that electric buses are still more expensive that fossil fueled buses, electric buses can provide cost saving over the long run. Prices fordiesel, electric and solar buses have been acquired from M/s Hino Motors Global, M/s Zhengzhou Yutong China and M/s.

Table 4.7: Total Distance in miles for all routes under consideration

Route No.	Distance (km)	Duration (hours)	Routes	Total Distance Both sides (km)	Distance (Miles)	Charging Station Required
1	44.513	0.884	Bhara Kahu to Morga	89.026	55	2
2	130.716	2.82	G-6 through RWP to I-8	261.432	162	5
3	24.324	0.5	I-8 to PWD Housing Society	48.648	30	1
4	44.451	1.063	Islamabad Sectors	88.902	55	2
5	83.08	1.541	PIEAS to Rawat	166.16	103	3
6	89.444	1.911	PIEAS to Rawat to Afzal	178.888	111	3
7	17.056	0.332	Pir Sohawa to F-7 Markaz	34.112	21	1
8	67.885	1.545	QAU to Saddar	135.77	84	3
9	20.918	0.564	Rawalpindi Medical Line	41.836	26	1
10	97.661	2.309	Satellite Town to Blue Area	195.322	121	4
	620.048	**13.469**		**1240.096**	**768**	**25**

In this research author takes total ten routes of Islamabad city for all buses as mentioned in below table. It is quite evident from the estimations that bus will cover **768 miles** (round trips) as a whole For all these ten routes in **13.5 hours**. Total number of charging station required for all routes are **25** as a whole. As rule of thumb one charging station is required for after each 40 miles, because batteries powered vehicles can cover 40 miles with initial full charge.

Table 4.8 Cost of Charging Station

Cost of Charging Station	
Charger	$20,000
Installation	$1,000
New Connection	$2,500
Misc. @ 10%	$2,350
Total Cost (USD) / Charging Station	$25,850
Total Cost (PKR) / Charging station	723800
No. Charging Station Required	25
Total Cost of all charging stations (billion PKR)	0.18

The installation cost included the labor cost, material cost, and other such parameters; the new connection cost was the cost of the regulator, and in the case of the transformer, there was a minimum cost both for the regulator and transformer. The operational and maintenance cost was taken as the 10% annual cost. The electricity and taxes costs were obtained from the provider, while we had to consider the rupee devaluation for investment and some miscellaneous charges, as this is the new technology, and there will inevitably be some unknown annual charges.

Cost and benefit analysis for all three buses (diesel, electric and solar) has been mentioned in the following table.

Following equations were used in the analysis:

1. Average Cost (Rs) = Average energy consumption (kWh) * Cost of Generation (Rs/kWh)
2. Depreciation cost per route= Duration of all routes * Average Cost
3. Adjusted Cost (PKR) = Average Cost + Depreciation cost per route
4. Net Saving (Billion PKR) = HSD Import bill reduction + Adjustment of Charging Station

For the estimation of savings of EVs, adjusted cost has been determined by including depreciation cost, price of single unit of energy and amount of total energy consumed by each vehicle. During the analysis, considerable savings have been recorded from both electric and solar bus as 41% and 65% respectively. Use of electric bus and solar bus can save up to 220.62 and 353 billion PKRs of Total HSD Import bill. Moreover, Net savings by adding charging station adjustment has been recorded as 220.63 and 353.81 billion PKR for electric and solar bus respectively.

Total import bill for all petroleum products for the year 2022 is $4, 6405, 690, 00, while 42% of this amount ($1,930,087,598) is being consumed for HSD only. Which needs to address on priority basis. Introduction of EVs and solar buses can reduce import bills as reflected in analysis. Electric and solar buses require less fossil fuel power energy as compared to diesel buses, while having same passengers' capacity. Which reflects benefits of these batteries powered vehicles over diesel buses.

Table 4.9: Net saving overview of Electric and Solar Bus in comparison with diesel bus

Sr. #	Description	Diesel Bus	Electric Bus	Solar Bus
1	Duration (Hrs.)	13.4	13.4	13.4
2	Prices (USD)	150,000	235,000	395,000
3	Prices (PKR) (1 USD = 280 PKR)	42,000,000	65,800,000	110,600,000
4	Average Life of Bus (Km)	250,000	250,000	250,000
5	Depreciation	168	263.2	442.4
6	Average Bus Energy Consumption (kWh)	111393.37	65566.6	37810.34
7	Cost of Generation (Rs/ kWh) *	6.2654	6.2654	6.2654
8	Average Cost (PKR)	697924.02	410800.98	236896.90
9	Depreciation per route	2251.2	3526.88	5928.16
10	Adjusted Cost (PKR)	700175.22	414327.86	242825.06
11	Net Saving	-	40.8%	65.3%
12	Import Bill of Diesel (Billion PKR)**	540.42	319.80	187.42
13	Saving of Import Bill (Billion PKR)	-	220.63	353.00
14	Adjustment for charging station	-	0.18	0.18
15	Net Saving (Billion PKR)	-	220.81	353.18

5. Conclusion

Electric vehicles do not contribute to air pollution of ecosystem. Air quality is also being improveddue to use of EVs instead of diesel vehicles. Replacing the traditional diesel buses with EVs will alsoreduce noise pollution in the environment as well. Improved quality of air due to reduced noise and emissions level can improve human's behavior as well. Nickel is obtained after horizontal surface mining, which leads towards extensive environmental degradations like deforestation and scrapping out the top layer of soil. Such degradation of natural resources should remain under consideration during the electrification of transportsystem. EVs usually used lithium-ion batteries. These batteries do have serviceability over 10 to 15 years. These batteries can be recycled. As per new technologies available now a day, we can recover up to 90% of battery components. During recycling process, delicate care should be taken during handling of battery cell electrolyte. Electric motors are almost always far greener than conventional cars if you assume they get their energy from the typical American grid, which often consists of a mix of fossil fuel and renewable energy plants. Because of their batteries, electric cars produce more emissions during production, but their electric motors are still greener than traditional internal combustion engines, which burn fossil fuels. Solar and electric buses are superior to diesel bus while considering overall environmental footprint and impacts. As both solar and electric buses have almost zero emission technology during operation.At present moment or initially, cost-feasibility is positive for diesel bus due to low prices of vehicle in comparison with solar or electric bus and cost-feasibility is negative for electric and solar bus due huge capital expenditure (CAPEX) requirement in the beginning.

In a long run, social feasibility will be positive for electric and solar bus. As human being's attitudes towards environment friendly appliances, equipment and machines are quite optimistic. Behaviors of humans towards energy efficient and environmentally friendly solutions are increasing day by day as shown in upcoming few examples such as, preferring wind or solar energy sources over thermal, replacing old conventional lights with LED. These positive behaviors depict that people will move or prefer electric or solar bus over the diesel bus. Therefore, in the future, social feasibility of diesel bus will be negative. The detailed analysis and study of both fossil fuel and electric vehicles differentiate the use of both vehicles. The electric vehicles are expensive, but their prices are coming down.

Although fossil fuel vehicles are cheap but have a high maintenance cost, more fuel cost and burningof fuel leaves behind the dangerous carbon, Sulfur, and fine particulate matter which are destroying the environment, endangers the human lives, and economy of Pakistan. It is concluded from this paper that using the electric car in Pakistan can be very useful, cost-saving, environment saving, fuel-saving, and lifesaving as well. The increasing population and increasing number of cars on roads are creating serious problems for the nation. As the world is moving towardsrenewable sources of energy so, it is the responsibility of our government to invest in using the new technology resources to save the lives and environment of Pakistan. In the light of the current automotive market, new electric car manufacturing is encouraged and a tax-free import of electric vehicles is allowed.

6. Recommendations

- Driving the EVs from renewable energy sources will significantly enrich system efficiency in general.
- Pakistan must implement a successful and environmentally sustainable fuel substitution strategy during economic downturns. Environmentally friendly manufacturing, transportation, and supply production methods should be used to encourage increased growth and sustainable mobility.
- Rethinking physical infrastructure is required, as is the development of green transportation, as well as public education about the usage of and financial investment in green transportation options through tax breaks, subsidies, and incentives.
- Develop local innovation and capacity-building initiatives that will enable local investors to gain from the inflow of capital and cutting-edge technology. The expansion of local markets will be facilitated by this in turn.

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