Problem Faced by Classical Electrical Vehicles and Solution in Kathmandu

Sonam Gyaljen Tamang, Ram Chandra Pageni, Saddam Husain Dhobi

Abstract
The main objective of this research work is to identify the problem faced by classical electrical vehicles in Kathmandu. In this paper we identify some important problem related to classical electric vehicles like batteries, geographical structure of route through which EVs run, maximum number of passengers carry and so on. To solve such problem EVs are developed into different types such as Hybrid Electric Vehicles (HEVs), Plugin Hybrid Electric Vehicle (PHEV), replacing low storage-capacity batteries with high capacity and so on. Here, we define EVs as electric vehicles which run by consuming fuel store in batteries i.e. use electrical energy to travel distances instead of non-renewable energies like diesel, petrol, coal and so on. After identifying the problems, we suggest the possible solution listed below that may concentrate SAFA tempo organizations and owners to change the classical or traditional way to modern way in Kathmandu.

Keywords
Electrical Energy, EVs, HEVs, PEVs, SAFA Tempo, Storage-Capacity etc.

I. Introduction
EVs of three Wheelers are known as SAFA which refers clean in Nepal was first lunch in Kathmandu. Currently, approximately 700 SAFA tempos serves 150,000 passengers with 17 different routes in Kathmandu Valley on a daily basis. Some of EVs industry in Nepal are: Nepal Electric Vehicles Industries (NEVI), Electric Vehicle Company (NECO), Green Electric Vehicle (GREV), Green Valley and Bagmati Electrical. As numbers of diesel vehicles increase in the streets of Kathmandu is the major cause of air pollution. The use of zero emission air pollutant vehicles can be one of the solutions to solve such problem. The zero-emission air pollutant vehicle, electric vehicle or SAFA tempo in context of Kathmandu.

Some Advantages of SAFA tempo are listed below:
- Zero emission air pollutant.
- Low noise level
- Suitable for Narrow streets.
- Promotes the use of clean energy (hydro-electricity).
- Local industry promotion.
- Attract tourists.
- Revenue source for government from the sale of electricity.
- Utilization of renewable energy of country i.e. fuel is not imported.

Electric Vehicles (EVs) has become one technology that dominate the sustainable transport research for its zero emission and green technology. EVs later development was not only using batteries, but also using other power sources as the Hybrid Electric Vehicle (HEV), HEV continues its feature by equipping itself with a grid connection inlet and become Plugin Hybrid Electric Vehicle (PHEV) which excels previous Battery Electric Vehicle (BEV). Grid connectivity between PHEV and the distribution grid recall the need of charging infrastructure to be deployed in the EVs working range. Therefore, charging infrastructure research start emerging rapidly as EVs start promising as the future transportation mode. Electric vehicle charging station basically stated in two common ways: slow charging point and fast charging point which is based on modes of its electrical characteristics, charging period, and charging activity method [1].

II. Literature Review
EVs were first demonstrated in 1828 with the first production electric car introduced in 1884. The invention of the internal combustion engine muffler in 1897 and electric engine starter in 1911. Early EVs applications used the rechargeable Lead-Acid battery developed in 1859 by Gaston Planté and latter in 1899. Waldemar Jungner introduced the nickel-cadmium battery that made significant improvements in storage capacity but had some drawbacks including a voltage suppression issue that occurs as the battery aged, known as a memory effect. Research continued through the beginning and latter in 1985 that the first Lithium-Ion (Li-ion) batteries were created whose aims are to run more than 125 million EVs will be on the road by 2030 worldwide. At the heart of these advanced vehicles is the Lithium-Ion (Li-ion) battery which provides the required energy storage [2]. A report taken in July 2018 show there were over 55,000 Electric Vehicles (EVs) in Sweden. Worldwide, about 3 million and is expected to increase to between 125 million and 220 million by 2030. Volvo Cars will no longer launch vehicles that are driven solely by internal combustion engines, transforming their portfolio into one based on hybrids and plug-in EVs and also buses and other heavier vehicles are also becoming increasingly electrified.

Global Resources Institute built a demonstration fleet of eight SAFA Tempos and operated them as a transportation company for six months. The vehicles carried over 200,000 passengers and travelled over 175,000 km. during the demonstration period reported in Home Power Magazine, published in 2000.
only then recycle the batteries, might lead to big sustainability improvements [3].

A report of 1990 show number of vehicles on Nepal’s roads has risen by 14% annually, driven by urbanization and rising incomes. The majority of this transport is private, with the overall share of public transport vehicles registered falling from 11% in 1990, to just 3% in 2015. In 1995, annual greenhouse gas emissions from the sector totaled 716 kilotons. This had risen to 3,170 kilotons by 2013. The three electric bus models are proposed as viable for this route, namely BYD’s K9 and K7 buses, and Ashok Leyland Circuit bus. In terms of greenhouse gas emissions reduction potential, if all buses within the projected 58-vehicle fleet of 2018 were to switch to electric, a reduction of 2,537 tons of CO\textsubscript{2} per year would be possible. Nepal has targeted to increase its hydropower capacity to 10,000 MW by 2025. Gradually, as supply in the country increases, import from India will decrease. There are some 714 electric three-wheelers (SAFA temps) on the streets of Kathmandu, offering public transport services [4]. Nepal has not taken any kind of energy security measures to protect its people from energy crisis. Petroleum imports in Nepal have almost quadrupled in physical terms in two decades from 550,000 kl in 1995 to 1.8 million kl in 2015 but in monetary terms jumped to NRP 125 billion in 2015 from NRP 20 billion in 2004, more than six times in a decade. An integrated approach is very essential as energy forms can be transformed and interchanged from one form to another and it has been shown from various energy analyses, Nepal harnessed sufficient and reliable electricity from hydropower resources, almost 50% of petroleum imports could be curtailed and an outflow of NRP 50 billion could be saved annually [5].

Kathmandu valley includes 3 cities; Kathmandu, Lalitpur and Bhaktapur with a population of 2.5 million with an annual growth rate of 4.63%. Government of Nepal is supporting the promotion of electric vehicles, Public transport E tuk-tuks (SAFA Tempo) in Kathmandu, besides a few electric cars and buses, an E tuk-tuk model named ‘SAFA Tempo’, with a seating capacity of 6-8 people, is running in the valley. More than 600 of them run the valley, each travels 100-120 km per day with 2 sets of lead-acid batteries. On average 127,000 people use the SAFA Tempo daily. About 17,500 kg of CO\textsubscript{2} will be reduced per day if a passenger uses SAFA Tempo instead of a fossil-fuel run bus or minibus; microbuses reduction potential is about 22,700 kg of CO\textsubscript{2} per day. E tuk-tuks are powered by battery that takes energy from sustainable renewable energy sources, and can be found with various designs and functions. E tuk-tuks used for public transportation have six to eight seats in Nepal [6].

In 1975, Nepal witnessed the use of electricity for transportation, the country has had good success with electric Rickshaws, with regions like Bharatpur sub-metropolis having over 300 e-Rickshaws54. Mahindra e20, imported from India, has found few buyers given the lower 11 operating costs. In the 2016/17 budget, the government passed the first major progressive EV tax reforms with reduction of custom duty to 10% for private, and 1% for public electric vehicles. A study done by the Electric Vehicles Association of Nepal (EVAN), currently, 300 electric cars and 2,000 electric scooters are running in the country and a capacity of 350 electric three wheelers and 200 buses in primary and secondary routes of Kathmandu valley is feasible. Further, the country plans to increase the share of electric vehicles up to 20% by 2020. These currently ply on 17 different routes in Kathmandu. SAFA autos have twelve deep cycle batteries of 12V each, and can carry up to 12 people at a time. China is the global leader in this market with 343,500 units in 2016. China is home to more than 99% of all electric bus stock in the world. China has a target of deploying 5 million New Electric Vehicles (NEVs) by 2020. By the end of 2014, the Central Government had already spent approximately 33.4 billion Yuan on NEV subsidies [7]. The alternative scenarios are 100% replacement of vehicles catering to mass transit in the concerned routes, 50% replacement, 25% replacement, stopping future growth of other vehicles catering to mass-transit in the concerned routes and 25% replacement in the first year, and combination scenarios. The results estimate that the passenger travel demand will increase by three folds from the year 2003 to the year 2025. The fuel consumption will increase by 2.4 times compared to the year 2003. It estimates the total Greenhouse Gas (GHG) emission as 8.5 thousand tons in year 2003 which will increase by more than 3 times in the year 2025. It estimates that 174.3 thousand t CO\textsubscript{2}e can be avoided in combination scenario. In Nepal, Energy consumption in the transport sector has increased from 1.8% to 3.27% during the period from 1984/1985 to 1997/1998. Diesel fuel and road transport dominated the total energy consumption in the transport sector i.e. 15,500 thousand GJ with diesel fuel having 75% share. A study in 1999 estimated an overall CO\textsubscript{2} emission of Nepal from transport sector to be about 957,900t. The personal vehicles have been found consuming 8–10 times more fuel, run 35 times the mileage and produce 30–50 times air pollution in comparison to the bus transport in developing countries. Electric trolley buses in a stretch of 13 km were introduced in the Kathmandu Valley in Nepal during 1974/1975 and were running smoothly until year 2001. It was stopped due to financial crisis. Taking a case of the public transport in the Ring Road of Kathmandu Valley, the study has developed the energy and emission scenarios with the introduction of the trolley buses for the period 2003–2025. Population of the Kathmandu Valley is 1,645,091 with population density of 1836.93/km2 as per the census of 2001. The census registered 3.87% average annual population growth. The population will reach about 4.1 million in 2025 year at this growth rate, which is more than 2.5 times more than that of 2001 [8]. Nepal’s hydropower potential has been estimated to be 83,000 MW purely on a technical basis i.e., based on average river flow (WECS, 2006a). The present exploitation of hydropower in Nepal is only a little over 1% of the economically feasible potential of 42,000 MW. According to the 10-year hydropower development plan of Nepal, the installed hydropower capacity would be increased to around 10,000 MW by 2020. Based on the sales data of Nepal Oil Corporation (NOC), the total gasoline import in the Valley in 2005 was 32 million liters. The Valley constitutes around 56% of modern industries and 57% of small cottage industries present in the CDR [9].

Electric power must become less dependent on fossil fuels and transportation must become more electric to decrease carbon emissions and mitigate climate change. Carbon dioxide is one of the principal greenhouse gases, which cause global warming and climate change. Specifically, in order to decrease carbon emissions by 80%, electric power must be less dependent on fossil fuels and transportation must be electric. Therefore, world need to shift reliance from gasoline powered vehicles and fossil fuel-based electricity generation to electric vehicles and renewable energy. All-electric vehicles have no tailpipe emissions, which as a result improves air quality and lowers health risks. Electric vehicles also help the nation like Nepal reduce its reliance on foreign fossil fuels [10].
The SAFA tempo involves a composite of several components: a skeleton of the SAFA tempo, K91-4003 6.7” motor, a motor controller (Curtis 1209B), 72 volts of battery power with approximate weight 360kg a lifespan 700 to 800 or (12- Trojan 125 batteries), a body and other miscellaneous parts such as a reverse-forward switch, motor mounting plates, couplings, a carbon brush, and a fuel gauge. Because of the heavy batteries, the vehicle can accommodate an extra load of only 550 kg for 10 passengers plus driver. Maximum speed is 45 km/h and the maximum range on one charge of the batteries is 60 km. The Authority reduced fuel costs for SAFA temps by lowering the electricity price by approximately 40% per unit (from NPR 5.10/unit to 3.10/unit, later it was from NPR 6.90/unit to 4.00/unit) [11].

The EVs industry in Nepal currently consists of 3 major stakeholders: the SAFA Tempo owners, the battery charging stations, and the EVs manufacturers. These stakeholders are represented by three organizations: Clean Locomotive Entrepreneurs’ Association of Nepal, Nepal Electric Vehicle Charging Association and Electric Vehicle Manufacturers’ Association of Nepal. The total number of batteries based three wheelers inside the valley is about 700 with 32 battery charging stations inside Kathmandu valley. The battery used is Trojan T125 made in the USA and is of the deep cycle lead/acid type. A fully charged set of batteries will drive the electric vehicle for a maximum of about 65 kilometers with 11 passengers. The cost to charge the battery once is Rs 165 indicating charge as Rs 2.54 per kilometer. The cost of two sets of battery is NRs 250,000 and one set of batteries takes about 7 to 8 hours to get fully charged depending upon the initial charging current and age of the battery [12].

### III. Working Principle and Components of classical electric vehicle’s:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Particular</th>
<th>Cost (NRP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cassis</td>
<td>150,000</td>
</tr>
<tr>
<td>2</td>
<td>Motor</td>
<td>50,000</td>
</tr>
<tr>
<td>3</td>
<td>Motor controller</td>
<td>40,000</td>
</tr>
<tr>
<td>4</td>
<td>Trojan 125 Batteries</td>
<td>150,000</td>
</tr>
<tr>
<td>6</td>
<td>Registration</td>
<td>10,000</td>
</tr>
<tr>
<td>7</td>
<td>Miscellaneous</td>
<td>70,000 – 80,000</td>
</tr>
<tr>
<td>8</td>
<td>Total Manufacturing Cost</td>
<td>470,000 – 480,000</td>
</tr>
</tbody>
</table>

**Market Price**  
535,000

The components of the EV are imported and assembled here in Nepal. The main body part and the chassis are imported from India whereas the electronics components are imported from US. The chassis of the SAFA can withstand weight of 12 people along with one set of batteries. The gross weight of SAFA tempo is 1000kg. Two sets of batteries are required for the commercial operation of EV. A battery charging and exchange stations is also required along the route. So, it travels relatively short distance and makes 8 to 10 round-trips a day (around 150 Kms) with one-time battery swap at the mid-day.

### A. The SAFA Tempo Working Mechanism

The potentiometer hooked to accelerator pedal tells the DC Controller how much power it needs to deliver. DC Controller takes power from batteries and supply energy to the DC motor which converts electrical energy to mechanical energy to run the vehicle or SAFA tempo. A sketch diagram below shows simple mechanism of SAFA tempo.

![Fig.2: Source: https://auto.howstuffworks.com/electric-car2.htm](https://auto.howstuffworks.com/electric-car2.htm)

**B. Price of Different part of SAFA Tempo reported from Kalanki Sai Baba Energy Station.**

The EV drivers saves NPR 12,000 to NPR 15,000 per month. They need NPR 8,000 to NPR 10,000 per month for charging and NPR 15,000 per month for depreciation of the batteries.

### C. Working Capacity of Trojan 105 Batteries

In Kalanki Sai Baba Energy Station, Trojan T-105 Battery each of 2V deep-cycle lead acid is used to run SAFA tempo whose lifespan is around 450 cycles with drawing 220amp-hr @ C20. When the batteries are new, SAFA tempo can get a range up to 70kms or more but due to regular uses as the time passes range reduced up to 50kms.

![Fig. 3: Trojan 105 Battery](https://auto.howstuffworks.com/electric-car2.htm)

### D. DC/DC Converter in SAFA Tempo of Trojan 125 Batteries:

Curtis DC/DC converter 1400 is used to convert 72V to 12V and nominal input current of 4.9A to nominal output current of 25A.

![Fig. 4: Curtis DC/DC Converter 1400](https://auto.howstuffworks.com/electric-car2.htm)

### E. Trojan Batteries’ Charge Controller

Conventional charger containing transformer, contractor, relay and controlling circuit with displaying voltage, current and indicator is in use in most of the charging station.
Drivetrain in SAFA Tempo

Drivetrain is an advanced DC K91-4003 72-volt motor, 25 ft-lbs. giving 3000 rpm or 8.5 HP giving 3800 rpm. with peak 22 HP Curtis 1209-72 controller gear reduction through reduction gear and differential. The maximum speed in the city is 40 km/hr. and the average less than 12 km/hr. While, some SAFA tempo has already installed China made brushless motor model DT-175-90-3 (72V, 8000W).

IV. Identification of Problems faced by classical electrical Vehicle:

A. Poor Braking System

SAFA tempo has no regenerative braking installed in it thus, the brakes operated close to design limits. Both larger brakes and regenerative braking would be very desirable, especially if the vehicle were to operate at higher speeds considering the road condition of Kathmandu city and geographical structure.

B. Geographical Structure of Route

Most of the Kathmandu urban roads, within the ring road are highly congested with traffic during the daytime. Similarly, there are ups and downs on the route to their destination which has created damage on drive system and batteries of the SAFA tempo.

C. Cost of Batteries

Saving amount for SAFA tempo driver itself is a hard task because the cost of new battery is major future expenses and for the using battery, as operating expenses, it requires regular maintenance from engineer and technician which needs larger share of the earnings.

D. Lack of Timely Maintenance

The number of engineer and technician involved for the repair and maintenance of SAFA tempo are outnumbered compared to the SAFA tempo running in the capital city. Thus, there is always delay in repair and maintenance of EVs which further deteriorate the life of the battery and EVs.

E. Poor electrical wiring system in EVs and station

Likewise, the EVs used has loosely held wiring system and also some driver run the EVs without the fuse in the circuit. Another problem is that most of the station have 3-phase wiring system but, they have limited protection for the wiring system in the station. Hence, we can say it is definitely a hazardous situation so, the wiring should be strictly taken into account considering its consequences.

F. Lack of Technical Research and Upgrade

SAFA tempo used in the capital city is in the same condition as it was in use since 1900s. There has been some change in color and some use brushless China made motor but other than that there is not much. As we look inside, we can see poor electrical wiring and high-power consumption by light used in it. Furthermore, the upgrade of the vehicle is a major issue as there is lots of initial expenses which is difficult for every owner of the vehicles.

G. Limitation of Speed and Load

The SAFA tempo cross the gross weight of a ton including EVs itself, one set of batteries and passengers (10-12 in numbers). Considering the inappropriate management of traffic, road condition and also poor baking system the speed should be maintained with the route as accident could be the result. Further if the number of passengers is limited to the seat than there is a chance to minimize the cause.

H. Competitors of SAFA Tempo

Kathmandu is a busy city and hence, there are lots of public vehicles (oil operated and electric) for the transport service. There are cooking gas operated Tempos, micro bus, Sajha buses, taxis and public buses on different routes and these are the main competitors of SAFA tempo.

V. Possible upgrade or solutions for Classical electrical Vehicle:

A. Replacement of Traditional Batteries

Lead-Acid batteries can be replaced with Li-ion batteries can be the best alternative as it has better efficient in speed, power, capacity, life-cycle.

B. Saving Energy of Batteries

Another solution is related to the power consumption by the light used in the SAFA tempo. Most of the light (head light, backlight and passenger light) used are tungsten made and consume more than 170W and if we replace it with LED (approx. 50W) than the power consumption will decrease by 70%.

C. Replacement of Charge Controller

Conventional Charge controller are in use which shows lack in upgrade in the used system. Hence, for the better operation modern smart battery charger should be taken into account.

D. Battery Management System

The charging station in different parts of the Kathmandu should be encouraged on proper management of battery charging with cooling system and regular maintenance as it can enhance the life of the batteries, which has the major operating expenses.

E. Selection of Route

It should be better for those routes which is less up and down or plain to run the SAFA tempo as it can contribute to save the energy of the batteries and also an increase in the number of loops.
F. Encouragement to Researcher
EVs has become a new challenge in the field of transport and energy saving worldwide. Thus, looking to the need of researcher, association of SAFA tempo, station and EVs owner should welcome the interested researcher and learner for possible upgrade of the SAFA tempo. Moreover, focusing on the upgrade of vehicles can minimize the junk on one hand and increase the value of EVs on the other hand.

G. Results and Discussion
Hence from the above study and interview, we are able to identify some problems which are listed above and able to find a possible solution to these problems. These problems and solutions of the EVs can help different organizations, who run SAFA tempo in Kathmandu in different fields; like energy saving of batteries, life prolonging of the batteries, time and money saving and many more. Hence, this awareness or result can help in the improvement of the classical electrical vehicle or SAFA tempo of Kathmandu.

VI. Acknowledgement
Here, we would like to especially thank to, all the members of “Kalanki Sai Baba Energy Station” and Yasuo Nikahira, Lecturer, Osaka Sangyo University who provided us the valuable informations, space and collaborate with us during this research period. We would like to thank all members of “Innovative Ghar Nepal” for guiding and motivating us in the research field. Similarly, we would like to thank all of our family members who directly and indirectly help us during this research work.

References
[12] S. Aryal et al.,"Feasibility study on installation of photovoltaic powered charging station for smooth operation of electric three wheelers in Kathmandu during load-shedding hours".

Sonam Gyaljen Tamang received his B.E. in Electrical Engineering from Kathmandu Engineering College, Tribhuvan University, Kathmandu, Nepal in 2018. Furthermore, he was a former President of KEC Electrical Club for 2017/18. The club conducts both technical and non-technical workshop for all the interested Engineering Students and publishes SYNERGY magazine annually. Recently, he is working as R&D unit for Innovative Ghar Nepal, where he works on Electrical Behavior analysis, Repairment and design of electric Vehicle wiring and Super-Fast Charging station study. He is interested in automotive designing and Power engineering.

Ram Chandra Pageni received his B.Sc. degree in physics from Prithivi Narayan Campus, Tribhuvan University, Kathmandu, Nepal in 2009 and M.S. degree in Atmospheric physics from Patan Multiple Campus, Tribhuvan University, Lalitpur, Nepal in 2011. He was an assistant professor at Department of Physics, Janakpur Engineering College & Patan Multiple Campus, in 2012 and 2014 respectively. He is an assistant professor of Department of Physics, Patan Multiple Campus, Tribhuvan University. His research interests include computational physics, data science, and optical and electrical properties measurement technique. At present, He is engaged in computational physics and simulation technique in physics application.

Saddam Husain Dhobi received his B.Sc degree in Physics, from Tri-Chandra Multiple Campus, Tribhuvan University, Kathmandu Nepal in 2016 and Master of Science in physics from Tribhuvan University, Kathmandu, Nepal in 2019. He is a senior researcher of “Physics and Chemistry Laboratory” at Innovative Ghar Nepal since 2017. He also works as researcher at BOSC Foundation Pvt. Ltd. since 2017. His interested field are light, energy, superconductor, hydrogen fuel cell, traveling etc. Currently, he is working as senior researcher at Innovative Ghar Nepal.