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Comparative Study of Lead Acid and Lithium Ion Battery Used in Safa Tempo in Kathmandu Valley

by

Subash Gautam

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **"Comparative Study of Lead Acid and Lithium Ion Battery Used in Safa Tempo in Kathmandu Valley"** submitted by Subash Gautam in partial fulfillment of the requirements for the degree of Master of Science in Engineering in Energy Systems Planning and Management.

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Supervisor, Dr. Jagan Nath Shrestha
Professor (Visiting), Center for Energy Studies (CES)
Institute of Engineering, Tribhuvan University

____

External Examiner, Er. Bal Sundar Malla
Managing Director
CEMAT Consultants (P) Ltd.

____

Committee Chairperson, Dr. Nawaraj Bhattarai
Head of Department
Department of Mechanical Engineering

Date: 8th January, 2020

ABSTRACT

Safa tempo (clean vehicle) was introduced in Kathmandu valley in 1993 A.D to reduce air pollution of Kathmandu valley. Safa tempos are powered by lead acid and lithium ion batteries. There are 37 charging stations and 17 routes and about 700 safa tempos running every day.

The quality of the conventional lead batteries used as the driving force for Safa tempos in Nepal are found degraded in course of time and their price increased. Because of this situation, answer to the profitability of the safa tempo in operation is needed. In 2017 lithium ion battery was introduced in Nepali market but it has high price, so tempo owners are confused as to choose which type of battery.

The objective of this study is to compare and analyze the performance, income generation, energy consumed by both batteries.

For this study, safa tempo powered by Trojan T-125 (240Ah, 72V (6V*12 no's in series connection)) and Sinopoly LiFePO4 (300Ah, 76.8V (100Ah*3 no's in parallel connection)) are chosen for the same route about 9 km length and one and same charging station is used.

One set lithium ion battery can make 9 loops (81 km) per day while 2 sets of lead acid batteries can make 8 loops (72 km) per day. Energy consumed by safa tempo per loop with lithium ion battery is 2.21 kWh of energy per loop and with lead acid battery is 3.99 kWh of energy. The price of 1set lead acid batteries is 33% of 1set lithium ion battery. It is found that the average gross income generated per day by lithium ion (1set) battery is about 10% more than that of lead acid (2sets) batteries on a single charge. But in comparison with life span of both batteries, lithium ion battery generates 300% more income in comparison to lead acid battery. As per financial analysis, IRR (internal rate of return) for lithium ion and lead acid battery is found to be 42% and 16% respectively.

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ABBREVIATIONS

EVs:	Electric Vehicle.
DC:	Direct Current.
BEV:	Battery Electric Vehicle.
Btu	British thermal unit
CLEAN:	Clean Locomotive Entrepreneurs Association of Nepal
CO_2:	Carbon dioxide.
EDC:	Energy Development Council.
EVAN:	Electric Vehicle Association of Nepal.
EVCO:	Electric Vehicle Compan
EVMAN:	EV Manufacturers Association Nepal.
GHG:	Greenhouse Gas.
IPCC:	Intergovernmental Panel on Climate Change.
LA	Lead Acid
LIBs:	Lithium-ion Batteries.
Li-ion:	Lithium-ion.
LPG:	Liquid Petroleum Gas.
MoPE:	Ministry of Population and Environment.
mt:	Metric tons.
MW:	Mega Watt.
NEVCA:	Nepal Electrical Vehicle Charging Association.
NEVI:	Nepal Electric Vehicle Industry.
NOC:	Nepal Oil Corporation.
OEM:	Original Equipment Manufacturer.
PHEV:	Plug-in Hybrid Electric Vehicles.
USAID:	United States Agency for International Development.
VAT:	Value Added Tax.
WHO:	World Health Organization.
ZEVs:	Zero-Emission Vehicles.

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CHAPTER ONE: INTRODUCTION

1.1 Background

1.1.1 Electric Vehicles in Kathmandu Valley

Electric vehicle (EVs) development in the Kathmandu Valley began in 1993 as a response to the urgency of a severe air pollution situation. Because EVs emit no any air pollution constituent like Carbon dioxide, Methane, Sulphur dioxide or sulphur etc. This zero emissions air pollutant is possible because EVs runs with rechargeable batteries. The EVs technology was introduced in Kathmandu Valley by some experts as electric three-wheeler, which later called Safa Tempo.

In this time safa tempo is powered by lead acid battery in Kathmandu valley because there is no flexible option in this time period i.e. from 1993 A.D to 2017 A.D.

A project supported 10 Safa Tempos to install and operate with Lithium ion batteries and towards the end of the project, there are already 25 Safa Tempos installed with the same Lithium battery technology plying in the streets in Kathmandu. The installation and maintenance of the Safa Tempo is being carried out by the Nepali Partners. Since January 2017, three Safa Tempos are in operation, which are equipped with Lithium batteries, the corresponding Battery Management System (BMS), the chargers and further devices. Since mid January 2018, seven more Safa Tempos were added on the list and now the number has reached to 25. The first ten of these vehicles were partially supported be REPIC. 15 more vehicles were converted without any financial assistance of REPIC. In August 2018, Clean Energy Nepal (CEN) conducted a questionnaire survey among 49 respondents representing owners and drivers of Safa Tempos plying in the streets of Kathmandu.

1.1.1.1 Components of Safa Tempo

Safa tempo involves a composite of several components like a chassis with a steering wheel; a skeleton of the Safa tempo, D.C. motor, Motor controller; Curtis, Batteries and other miscellaneous parts such as a reverse-forward switch, motor mounting plates, couplings, a carbon brush, and a fuel gauge. Figure 1-1 below shows that a completed structure of safa tempo running in Kathmandu valley in different routes.

1.1.1.2 Electric Motor

It is first most popular EMs is the 3-Phase AC and Series Wound DC motors, which are usually inexpensive and easily found. EMs have high torque at a wide range of speeds, with incredibly high efficiencies of up to 90 percent compared to conventional ICEs, which have efficiencies of only around 30 percent.

1.1.1.3 Controller

It is second main component of the EVs is the controller. The controller's job is to deliver electric current from the battery to the motor, which is controlled by the accelerator pedal of the vehicle. Therefore, the further a driver presses the accelerator pedal down, the greater the power delivered to the motor and the greater the kinetic energy the vehicle gains. During idling phases, no electrical current is being processed, which means energy is not being used during idling phases.

1.1.1.4 Battery

It is third main component of EVs is the battery. EVs use rechargeable batteries, occasionally referred to as Power Storage Systems (PSSs), which are different from the ignition or lighting batteries. There are mainly three types of rechargeable batteries currently in use in EVs: lithium-ion batteries, lead-acid batteries, and nickel-metal-hydride batteries. An EV's battery must be periodically recharged from the power grid, which itself is powered by a variety of resources, such as coal, steam, solar, wind, or others, at home or using a street or business recharging point (Faraj, 2014).

1.1.2 Description of Safa Tempo

Safa Tempo can carry up to 11 passengers plus the driver. The life span a set of battery uses in safa tempo is about 700 to 800 cycles; each cycle of a battery covers a state from full charge to 80% discharge. The approximate weight of safa tempo with a batteries set 1000 kg. Safa tempo can accommodate an extra load of only 550 kg for 10 passengers plus driver. The maximum speed of safa tempo is about 45 km/hr and the maximum range on one charge of the batteries is 60 km. In general a safa tempo has two sets of batteries for exchange after discharge of one set.

Table 1-1 Price of Safa Tempo with Lead-Acid Battery

S.No.	Part of Safa Tempo using Lead Acid Battery	Price of different part of Safa tempo (NRP)
1	Chassis	Rs. 150,000
2	Motor	Rs. 50,000
3	Motor controller	Rs. 40,000
4	Trojan T125, 240Ah, 6 V, 12 no's of Batteries in 1 set. (Side A + Side B=1Set).	Rs. 300,000
5	Registration	Rs. 10,000
6	Miscellaneous	Rs. 70,000 – 80,000
7	Total Manufacturing Cost	Approx. Rs. 6,25,000
8	Market Price	Approx. Rs. 6,90,000

(Source: EVAN)

Table 1-2 Total weight of Safa Tempo with Single Set Lead-Acid Battery

S.No.	Part of Safa Tempo using Lead Acid Battery	Weight of different Part of Safa Tempo (Kg)
1	Gross Weight of Safa Tempo	1,000
2	Weight of Single Lead Acid Battery (Trojan T125, 240Ah, 6V, 262mmm x 181mm x 283mm)	30
3	Weight of single set battery used in Safa tempo (Number of Batteries =12)	30 x 12=360
4	Weight of Safa Tempo without one set Lead acid battery powered safa tempo	640

(Source: EVAN)

Table 1-3 Price of Safa Tempo with Lithium-Ion Battery

S.N.	Parts of Safa Tempo using Lithium ion Batteries	Price in different part of safa tempo (NRP)
1	Chassis	Rs. 1,50,000
2	Motor	Rs. 50,000
3	Motor controller	Rs. 40,000
4	Lithium Ion Batteries 300Ah , 76.8 V	Rs. 9,00,000
5	Registration	Rs. 10,000
6	Miscellaneous	Rs. 70,000 – 80,000
7	Total Manufacturing Cost	Approx. Rs. 12,25, 000
8	Market Price	Approx. Rs. 13,00,000

(Source: EVAN)

Table 1-4 Total Weight of Safa Tempo powered by Lithium ion battery.

S.N.	Part of Safa Tempo using Lithium ion Battery	Weight of different Part of Safa Tempo (Kg)
1	Gross Weight of Safa Tempo	863
2	Weight of single set Lithium ion Battery (Sinopoly LiFePO4, 300Ah, 76.8V)	223.3
4	Weight of Safa Tempo without one lithium ion	640

(Source: EVAN)

1.1.2.1 Charging Cost for Safa Tempo

In late 1998, the Nepal Electricity Authority, reduced fuel costs for Safa tempos 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. The cost to charge lead acid battery (one set) once is Rs 165 indicating charge as Rs 2.54 per kilometer (Aryal et al. & Maharjan, 2002).

1.1.2.2 Problem facing by Safa Tempo

- **Non-Replacement of a lead acid batteries cell plates**

This is the major problem of lead-acid batteries because in a single battery, cell is made up of numbers of thin plates, if any of the plate is damage then whole battery is waste or can't used again. This mean the cell plate of battery can't be exchange or replace by other cell or plate.

- **Acid as Liquid in Lead acid Batteries**

Lead acid batteries contain acidic solution which helps to conduct the charge from one place to another of battery cell plates to produce current, which is needed to run the safa tempo. Acidic solution is dangerous and needed more safety to handle carefully.

- **Maintenance**

Lead acid batteries used in safa tempo needed maintenance frequently example to check specific gravity or concentration of acid and water ratio.

- **Limitation of Speed and Load**

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.

- **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. (Tamang et al., 2019)

1.1.2.3 Safa Tempo Status

In 1993 AD seven electric three wheelers, locally known as Safa Tempo were introduced in Nepal, as part of a USAID supported project. The number of Safa Tempos, increased significantly after diesel powered three wheelers was banned in 1999. The Safa tempos are locally produced in Nepal and the number goes to 600 Safa tempos operating in 17 routes within Kathmandu Valley by 2000 AD. Many of these three wheelers are operated by women. Around 100,000 passengers benefit from the service provided by Safa Tempos on a daily basis. The EV industry in Nepal consists of 6 manufactures, 37 charging stations and several hundred vehicle-owners who have invested over Rs. 450 million in this industry. There are 6 manufacturer of safa tempo in Kathmandu valley. NEVI is known largest manufacturer of safa tempo.

Table 1-5 Safa Tempo Manufacturer in Nepal

S.N.	Manufacturer Name.	Number of Safa Tempo Sold.
1	NEVI	300
2	EVCO	282
3	Green Electric Vehicle Pvt. Ltd	80
4	Green Valley Electric Vehicle	63
5	Bagmati Electric Vehicle Company	14
6	Eco visionary Pvt. Ltd	18
	Grand total	757

(Source: EVAN, 2018)

1.2 Problem Statements

1.2.1 Pollution and Greenhouse Gases

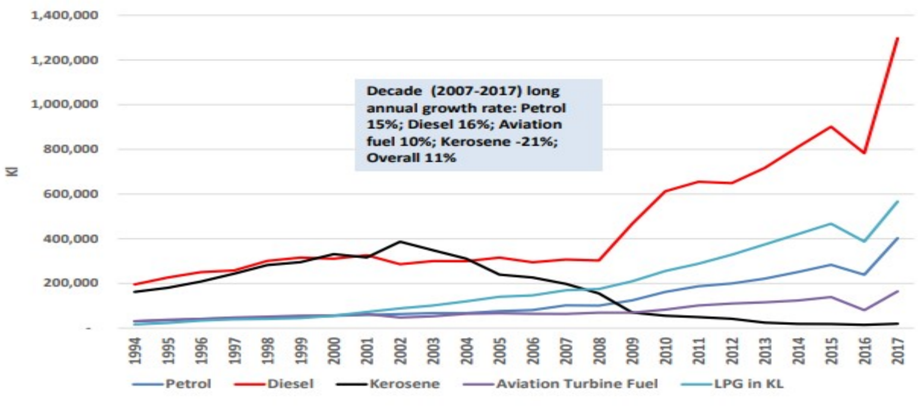
The negative effects of climate change are becoming increasingly obvious. The IPCC has reported that in some 100 physical and 450 biological processes, scientists and researchers have addressed climate induced changes. Over the years, global climate changes have become more extreme and severe, with increases in floods, storms, and heat waves. A major contributor to global warming is fossil-fuel-powered vehicles. EVs could reduce the impacts of global warming and thereby provide a transportation system that is friendlier to the environment. (IPCC, 2003; Anderson & Bausch, 2006)

The major contributor to rising air pollution, according to the 2017 Air Quality Management Action Plan for Kathmandu Valley, is vehicle exhaust, along with smoke from brick kilns and dust from construction. Motor vehicles are responsible for 30 percent of particulate matter (PM10) in the air while the construction sector accounts for 53 percent, as per 2018 data. As per the global Environmental Performance Index released in January 2018, Nepal ranked the worst for air quality among 180 countries. The report also showed Nepal's overall performance as 'poor' in terms of the environmental index.

According to World Energy Council show that approx. 17% of the greenhouse gas emissions released into the environment are produced by road transport. (Ilieva , 2016).

1.2.2 Amount of Oil Consume in Kathmandu Valley

Petroleum imports in Nepal have almost quadrupled in physical terms in two decades from 550,000 kL in 1995 A.D to 1.8 million kL in 2015 A.D but in monetary terms jumped to NR 125 billion in 2015 A.D from NPR 20 billion in 2004 A.D, more than six times in a decade. (EDC, 2015)



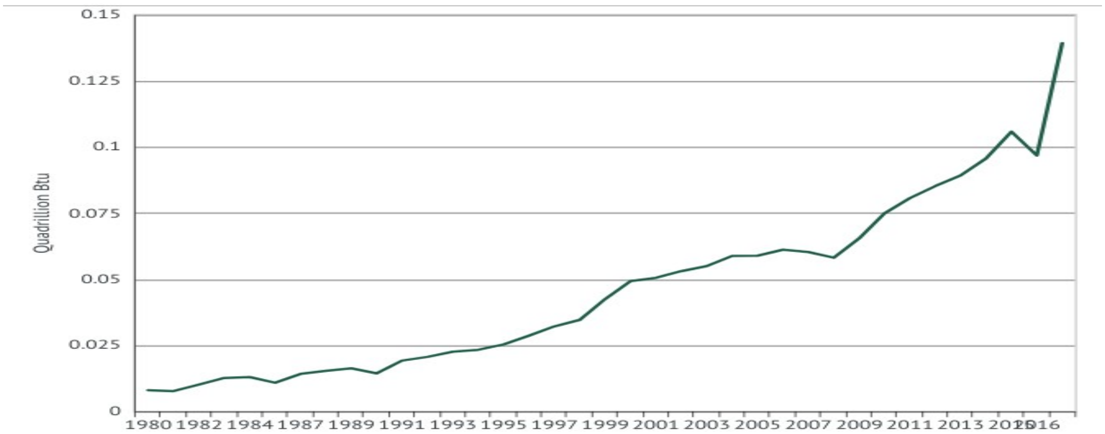
(Source: Nakarmi, 2018)

Figure 1-1 Amount of oil consumed in Kathmandu valley

1.2.3 Greenhouse and Energy Crisis in Kathmandu Valley

Fuel consumptions and green house gas emission due to the possible intervention of the electric run trolley buses in the existing public transport system in a particular road up to the year 2025 B.S. in Kathmandu Valley. 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. It estimates the total GHG emission as 8.5 thousand tons in year 2003 A.D which will increase by more than 3 times in year 2025 A.D. A study in 1999 estimated an overall CO_2 emission of Nepal from transport sector to be about 957,900 ton. Studies in emission and energy consumption due to transport show an alarming picture of the Kathmandu Valley in year 2020. (Pradhan et al., 2006).

In 2005, fossil fuels accounted for about 53% of the total energy consumption in the Kathmandu Valley, whereas the share of biomass and electricity were 38% and 9%, respectively. According to the electricity sales data, around 28% of electricity produced in Nepal in the year 2005, is consumed in the Kathmandu Valley alone (Shrestha & Bhandari, 2010).



(Source: Nakarmi, 2018)

Figure 1-2: Primary Energy Consumption in Nepal

From figure 1-2, in 2016, primary energy consumption for Nepal was 0.14 quadrillion btu Primary energy consumption of Nepal increased from 0.03 quadrillion btu in 1997 to 0.14 quadrillion btu in 2016 growing at an average annual rate of 8.11%.

Gasoline accounted for 64% of total energy demand followed by diesel (31.7%), LPG (4.2%) and electricity (0.4%) in 2000. The study have suggested that the modal structures of travel demand have changed little in the year 2000 compared to 1988 in the Kathmandu Valley with bus and minibus contributing about 40%, light duty vehicles that include car, jeep, minivans contributing about 30% and rest 30% (Dhakal, 2003).

Table 1-6 Amount of CO2 Emission by Public Vehicles

Vehicle type	Average mileage of Vehicles (km/lit)	Average no. of seats	Daily emissions of CO2 by respective public vehicles (kg/day)
Bus	4.55	33.4	17586.83
Mini Bus	6.24	24	17846.35
Micro Bus	7.34	16	22757.74

(Source: Bhatt, 2013)

So, this study aims to compare the performance of safa tempo powered by lead acid battery and li-ion battery in Kathmandu valley, RNAC to Maharajgunj Route. The analysis will consists of charging and discharging, operation life cycle, income generation, distance covers in predefined route etc by safa tempos in both case.

Under this study, safa tempo powered by Lead acid battery with following specification is considered:

- Model: Trojan T125
- Capacity: 240Ah@72V DC
- No of individual battery: 12 nos, 6V each
- Route and Tempo no: 3578, RNAC to Maharajgunj

Similarly, safa tempo with following specification of li-ion battery is considered:

- Model: Sinopoly LiFePO4
- Capacity: 300Ah@76.8 DC
- No of individual battery: Single pack consisting of 100Ah, 3 nos in parallel

- Route and Tempo no: 3582, RNAC to MaharajGunj

Government Policies

Government policies are in general favorable towards EVs. Expansion of the trolley bus system has been mentioned in all the Five -Year plans since the 6th Plan. The National Transport Policy, 2058 has also mentioned that environment-friendly electric vehicles will be promoted. The government does not charge any VAT and only one percent custom duty for import of Safa Tempo's chassis, engine, motor, battery, and battery charger. The MoPE, with the assistance of DANIDA is implementing a project to support the EV sector. The project has established a Clean Vehicle Fund to support research, development and promotion of EVs. In the past, MoPE with the support of DANIDA also provided some soft loan (up to 70%) to establish two battery-charging stations in Lalitpur and to procure 48 EVs for private owners**.** (Bhushan, 2019)

EV Policy in Nepal in 2014/15 target of 20% EVs by 2020 and Nationally Determined Contribution (NDC) report to increase EV by 20% by 2020 compared to that of 2010. In province 3, target 100% EV by 2028 and reduced Custom Duty & VAT for EVs.

1.3 Research Objective

The main objective of this study is to compare and analyze the performance of safa tempos powered by Lead acid battery and Lithium ion battery in Kathmandu Valley.

The specific objectives of this study are as follows:

- To find the charging and discharging nature of lithium ion battery and Lead Acid battery
- To compare distance covered by safa tempo with lithium ion battery and lead acid battery per full charge
- To compare the energy used of both batteries per loop
- To compare the income generation using Lead Acid and Lithium ion batteries
- To calculate and compare financial aspects of both batteries.

1.4 Scope of the work

The study is mainly focused to owner of safa tempo, who is investing money on safa tempo. The scopes of the study have been limited to:

- Comparing of the charging and discharging time of batteries for same loop, owner can take good decision to use it.
- Help to estimate the distance cover by lithium ion batteries and lead acid batteries.
- Help safa tempo owner to choose the batteries i.e. make clear to replace the batteries either lithium ion by lead acid or lead acid by lithium ion safa tempo.

1.5 Limitations

In order to avoid the complexity and vagueness of the study, several assumptions were made, which eventually limited the scope of the study. Some major limitations of the study are as enlisted below:

- While taking the data for comparison, Safa tempo with lead acid battery and Lithium ion battery are only consider this study.
- The loop of the safa tempo for lithium ion and lead acid battery is same which give more accuracy in discharging time of both batteries by avoiding the alternative or different loop in this study.
- Number of passenger per loop from initial to final station is fixed for 11 passengers and in between loop station pick up and drop are not in considered.

CHAPTER TWO: LITERATURE REVIEW

2.1 History o f Electric Vehicle

EVs applications used the rechargeable Lead-Acid battery developed in 1859 A.D by Gaston Planté. In 1899 A.D, Waldemar Jungner introduced the nickel-cadmium battery that made significant improvements in storage capacity but had some drawbacks. Later by 1985 A.D Lithium ion batteries are use in EVs. A Projections estimate that worldwide, more than 125 million EVs will be on the road by 2030 A.D. (Miao et al., 2019).

In July 2018, there were over 55,000 EVs in Sweden. Worldwide, the number exceeds 3 million and is expected to increase to between 125 million and 220 million by 2030 A.D. By 2025 A.D, 250,000 metric tons of EV LIBs are expected to have reached end-of-life which end-of-life means that the batteries are no longer considered useful in a vehicle, but they still retain 70–80% capacity (Olsson et al., 2018).

Most electric cars available in 2014 A.D have ranges, from a fully charged battery, of about 60 kilometers to 160 kilometers depending on various factors such as weather conditions, traffic congestion, and road types (Chung & Kwon, 2014).

European transportation is 96% dependent on oil, and the vast majority of the oil is imported. Cars are responsible for 12% of Europe´s GHG emissions and the number is increasing. In November 2013 A.D, the EU member-states agreed that in 2021, all manufacturers are obliged to ensure that their new car-fleet will not emit more than 95 grams of CO_2 per kilometer (g/km). EU has a 2015 CO_2 limit of 130 g/km, which almost every car manufacturer will reach. The future goal is 60% reduction of GHG emissions from transport by 2050 as of 1990 level. (Ohlsson, 2014)

Some data show, since 1990s, the number of vehicles on Nepal's roads has risen by 14 % annually in city area. As road transport is now the predominant form of transport in the country, accounting for some 80% of all trips. Due to private uses of vehicle public transport vehicles registered falling from 11% in 1990, to just 3% in 2015 which led to a corresponding increase in greenhouse gas emissions from the transport sector. In 1995, annual greenhouse gas emissions from the sector totaled 716 kilotons and goes to 3,170 kilotons by 2013. Approximately 24,000 vehicles were registered in Kathmandu Valley in 2000. This number had raised to over 67,000 vehicles by 2016 a threefold increase. Vehicles registered in the Kathmandu Valley now comprise some 66% of total registered vehicles in Nepal. The total registered vehicles in the Valley, more than 90% are for personal use In 1990s, there were around 4000 buses in Nepal and will rise up to more than 35,000 by 2015. (GGGI, 2018)

Table 2-1 Emission Factors by Vehicle Type

Vehicle Type	CO_2[a] (kg/GJ)	CO[b] (g/km)	NO_x[c] (g/km)	HC[d] (g/km)	PM_{10}[e] (g/km)
Bus	79.7	4.9	6.8	0.87	1.075
Minibus	79.7	4.9	6.8	0.87	1.075
LDV	-	-	-	-	-
Gasoline car	70.54	3.16	0.21	0.19	0.06
Diesel car	54.82	3.16	0.26	0.14	0.18
Jeep/Van	75.66	3.16	0.28	0.32	0.48
Motorbike	34.71	2.4	0.19	0.52	0.06
HDV	82.61	4.9	9.3	0.87	1.24
Hybrid Car	58.85	0.18	0.019	0.013	0.01

(Source: Bajracharya, & I., Bhattarai, N., 2016)

2.2 Some of Electric Vehicle Used in Kathmandu Valley

The three electric bus models are proposed as viable for this route, namely BYD's K9 and K7 buses, and the 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 CO2 per year would be possible. This is based on a weighted average fuel economy of 2.8 liters per bus, over a total annual distance of 2.5 million kilometers there are some 714 electric three-wheelers (safa tempos) on the streets of Kathmandu, offering public transport services. In addition, a growing range of electric car manufacturers, including Kia, Mahindra and BYD are importing electric cars for private consumption. Total estimates for the number of electric cars in Nepal vary, but tend to range between 300

- 500 units at July 2017. Currently, around 300 Mahindra Reva and 4 BYD E6 have been sold in the market. Time of day rates has been determined for electric vehicles, specifically Trolley Buses and other vehicles. The off-peak rates jumped by 5% in 2012 and increased from NPR 3.1 per unit in 2012 to NPR 3.7 per unit in 2016 (GGGI, 2018).

2.3 Future and past of Electric Vehicle in Nepal in 2017-2020.

The number of EVs in the country, including private two- and four-wheelers and public vehicles, reached 21,000 in 2017, according to the Electric Vehicle Association of Nepal (EVAN). In 2018, that number crossed 45,000. Today, around 10 percent of vehicles sold in the country are EVs. Nepal aims to increase the share of the EVs to 20 percent from 2010 levels by 2020. It also states that Nepal will decrease its dependency on fossils in the transport sector by 50 percent by promoting energy-efficient and electric vehicles. Electric Vehicles (EVs) started to take their place in the market in 2010, with the introduction of electric motorbikes.

2.4 Benefit of Introducing Safa Tempo in Kathmandu

Technically, an EV is defined as one that utilizes electricity as its power source and that can be charged through an electrical outlet at one's place of residence or business. The main reasons for considering EVs as alternatives to fossil-fuel based vehicles constitute both economical and environmental factors. EVs are considered to be a perfect example of what is known as ZEVs (Faraj, 2013).

2.5 Challenges to Sustainable Transport System

The major challenges and constraints related to transport system in Kathmandu that are responsible to make it unsustainable are listed below. (ER: EST: FA, 2014)

2.5.1 Inappropriate Taxation policies for Electric Vehicles (EVs)

The share of renewable energy is very negligible in transport system. Kathmandu is only the city in the world to have biggest number of electrified public transport, SAFA Tempos. But the number of SAFA tempos has not increased significantly since 10 years as compared to other fossil fuel run vehicles.

2.5.2 Heavy Dependence of Transport Sector on Fossil Fuels

Nepal does not have oil reserves so have to rely on oil exporting countries for fuel supply, which has positioned Nepal in difficult position in the context of energy security. We have experienced acute price hiking of the oil products in the recent days. Economists have predicted this will continue in the future as well. This means our economy is vulnerable to price hike as usage of fossil fuel is increasing in Nepal. At the moment, Nepal government is subsidizing price of fossil fuel in the name of poor people. But this subsidy is enjoyed by well-off urban people only who can afford to ride or own vehicles.

2.5.3 Increase in the Number of Private Vehicles

The number of vehicles, in particular private vehicles, is shooting out in alarming rate. The poor transport planning is responsible for traffic congestion, air pollution and over use of fossil fuel. The numbers of vehicles especially the two wheelers are increasing due to the lack of appropriate measures to tackle this unprecedented rise in the ownership of private vehicles.

2.5.4 Inefficient Public Transport System

Around 56.5% of Kathmandu uses one or other mode of public transport on a daily basis. However, Public Transport is not encouraged and maintained as an appropriate mode of travel. Public Transport Operators are not correctly assigned to routes; the plying of inappropriate vehicles on many routes; vehicles competing on the same routes and many routes terminate in the center causing congestion and increasing the ineffectiveness. The public transport system just fails to attract the commuters. The commuters have no option but to choose private system of transport.

2.6.5 Non-Integration of Land Use Planning With Transport Planning

Land use planning and urban development planning have significant roles to play in above mentioned areas. One example is construction of outer ring road in the valley. The government is implementing this project thinking that construction of more roads around the existing ring road may solve the problem of congestion. But we are promoting urban sprawl in the valley. There is already a trend of moving people out of core areas of city. The result is that many residential areas is growing in surrounding semi urban areas. This would demand heavy investment to provide necessary services including transport. In addition to this, we are creating more travel demand. According to experts, Kathmandu is still less dense city.

2.6 Battery Used in EVs

2.6.1 Lithium Iron Phosphate (LiFePO4)

$LiFePO_4$ batteries are one of the most advanced types of batteries suitable for EVs and moreover BYD batteries used in safa tempo. It has good chemical and thermal stability and the energy density per unit weight is rather high (110 Wh/kg). In addition, It can be recharged more than 2,000 times and the self discharge of one cell is less than 1% per month. The LiFePO4 technology has also disadvantages as nominal voltage for one cell is 3.3 V, loses usable capacity both in cold and hot environments, cells were kept at the ambient lab temperature of 24-27 ºC and Subsequent to 2,000 cycles. Lithium Iron Phosphate ($LiFePO_4$) also Power other device and engine for long life. (Lehtinen, 2010, Pharadorn et al., 2014)

2.6.2 Lead Acid Battery used in EVs

The Lead acid batteries can be divided into two distinct categories: flooded and sealed/valve regulated (SLA or VRLA). VRLA batteries are divided into two categories: Gel and Absorbed Glass Mat (AGM). The different names reflect different methods of containing the electrolyte. In Gel batteries, a thickening agent is added to turn the electrolyte from liquid to gel. In AGM cells, a glass matrix is used to contain the liquid electrolyte. As cycle life is influenced by depth of discharge, the figure shows multiple DOD percentages for the lead acid. It can be seen that the AGM pack must be limited to a 30% depth of discharge to get comparable life to a lithium-ion that is at 75% depth of discharge. This means that the AGM battery must be 2.5 times larger in capacity than the lithium-ion to get comparable life. In hot climates where the average temperature is 92°F, the disparity between lithium-ion and lead acid is further exacerbated. The cycle life for lead acid (flooded and VRLA) drops to 50% of its moderate climate rating while lithium-ion will remain stable until temperatures routinely exceed 120°F (Albright et al., 2012)

For every year 100 tons of batteries consumed in Nepal, approximately 5 tons of lead is released in the environment during the collection and recycling process. Although there is limited battery manufacturing capability in Nepal, they estimate that another 0.15 tons of lead are released in the battery manufacturing stage as well. Hence, the amount of lead discharged from lead-acid batteries is approximately 5.15% of the total amount consumed (Bhatta, 2004).

The battery used is Trojan T125 made in USA and is of the deep cycle lead acid type. One set of twelve 6 V batteries are connected in series and placed beneath the passengers' seats which provides a total of 72 volts. A fully charged set of batteries will drive the electric vehicle for a maximum of about 65 kilometers with 11 passengers. Each three-wheeler EV has 2 sets of batteries.

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 Rs 250,000. 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 (Aryal et al., 2013)

2.7 Comparison of Lithium Ion and Lead Acid Battery

The six lead-acid cells used here are VRLA (valve-regulated lead-acid) batteries rated 6 V and 4.5 Ah. The five LCO cells and six LCO-NMC cells are both rated with a nominal voltage of 3.7 V and a capacity of all batteries initially undergo three characterization cycles consisting of a CC&CV (constant current & constant voltage) charge at a C/3 rate, 5 min rest, and constant C/3 discharge followed by another 5 min rest. Voltage ranges used are those specified by the manufacturer: 5.1 V to 7.45 V for the VRLA cells; 3.0 V to 4.2 V for the LCO and LCO-NMC cells; and 2.0 to 3.65 V for the LFP cells. A 12 V LFP pack can be purchased for $0.90/Wh, and 12 V lead-acid packs of the same size for $0.23/Wh (Krieger et al., 2013).

When the life cycle (number of charge/discharge cycles) is considered, Li-ion batteries beat lead-acid by a factor greater than 2 for all DOD. VRLA batteries typically operate for 2 to 5 years. Lifetime varies significantly with SOC of the battery, at 50% SOC and 25^{o}C Li-ion can operate for 20-25 years, while at 100% SOC it drops to 12- 16 years. In charging, lead-acid batteries are slower (around 0.25 C) whereas Li-ion batteries can be charged at a much higher rate (0.25-4C). Lead-acid batteries can safely be charged in ambient temperatures as low as -20^{o}C, provided the charge rate is kept at or below 0.3C. Li-ion batteries, on the other hand, cannot be safely charged below 0^{o}C. Lead-acid batteries, with chemistry more stable than lithium, do not require such a protection circuit.

A Li-ion pack cost between $400 to $700 per kWh, depending upon the manufacture and capacity per cell, which is expected to reduce further with technology advancements and projects a life cycle ranging between 2000 and 4000 charge-discharge cycles. A VRLA battery pack costs around $150 to $200 per kWh, similarly depending on the manufacturer and individual cell capacity and capable of having a life cycle range between 500 to 3000 charge/discharges (Keshan et al., 2015)

2.7.1 Power level

The power level of the charging source, expressed in kW, is defined by both the voltage (V) and the current (A) of the power supply and determines how quickly a battery can be charged. The power level of chargers ranges rather widely – from 3.3 kW (slow) to 50 kW and higher (fast3). Lower power levels are typical of residential chargers and take several hours to fully charge a battery. Chargers of 3.3 kW and 7 kW can charge the battery of a Nissan LEAF in about 8 or 4 hours respectively. For consumers wishing to use higher power levels for charging at home, upgrades of the connection with the local grid are often required. At the other end of the power level range, fast chargers of 43 and 50 kW are available, with Tesla rolling out Superchargers of 120 kW.

2.7.2 Battery size

Different EV models have different power level thresholds and current types that they can accommodate, and this capacity is determined by battery size (expressed in kWh). EVs with small batteries such as many PHEV models are often able to charge at a maximum of 3.7 kW; these models include the Mitsubishi Outlander, Volvo V60 Plug-in Hybrid, Opel Ampere, Toyota Prius Plug-in Hybrid version (all 3.7 kW). Full BEVs are completely dependent on their battery for their driving range and usually have larger batteries that can handle higher power levels for charging. Examples include the Nissan LEAF (24 kWh battery size, able to charge at 7 kW AC or 50 kW DC), the Renault Zoe (22 kWh battery size, able to charge at AC charging stations, up to 43 kW), and the Tesla Model S (60 kWh or 85 kWh battery, able to charge at 10 or 22 kW AC, or at 120 kW DC using Tesla's Supercharger stations. (ARF, 2014)

Table 2-2 Lead Acid and lithium ion battery details:

Components	**Lead Acid Battery**	**Lithium-Ion Battery**
Nominal Cell Voltage	2.0V	3.2V
Voltage operating range	1.8-2.1V	3.0-4.1V
Wh/Kg	35-40	140-150

Wh/liter	70	400
Size of 1KWh battery	14liter	2.5litre
Weight of 1KWh battery	25 kg	6.7kg
Temperature ranges working	-40 to 25^{0}C	-25 to 60^{0}C
Constant charging rate in term of C	0.07C rate	C rate(10×faster)
Recharging time duration	10×capacity	1×capacity
Cycle: At 10%discharging At 50% discharging At 95% discharging	 1750 500 250	 4000+ 1000 500
Service In-travel	6 months	12 months
Replacement time frame	2 year	5-7 year

(Source: Ultralife Corporation, 2019).

The figure below shows important information of recycling. Recycling of lead-acid battery is higher than that of other products.

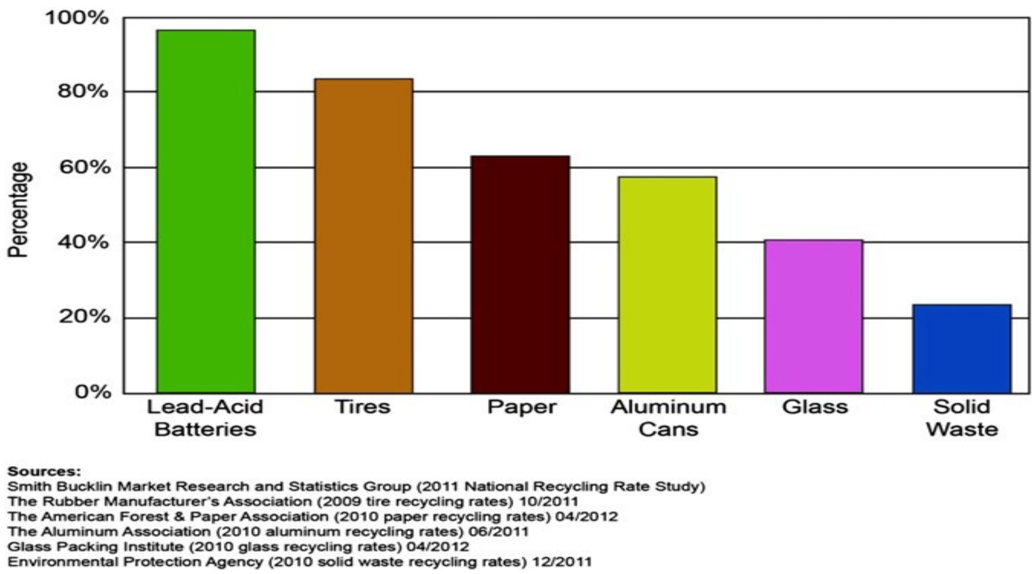
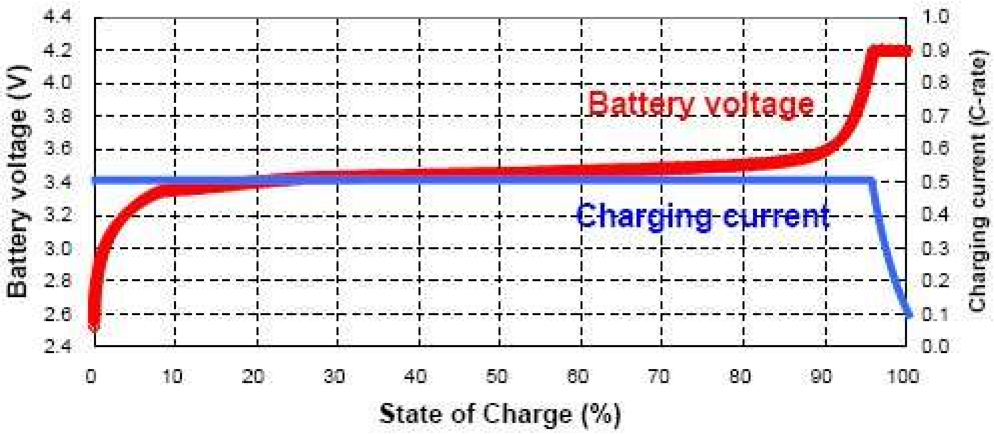


Figure 2-1: Recycling of Materials

2.8 Nature of charging of Lithium ion battery

On comparison after taking the graph should be like figure 3-3, from this figure 3-3, it is clear that charging current is constant up to 90% - 95% and then drop sharply from 0.5A to 0.1A. Moreover the voltage goes to increase from 0% to 10% and when reach 3.4V it is slightly constant up to 90% and then increase sharply from 90% - 95% and then remain constant. Similar type of graph should be accepted for Sinopoly LiFePO4 battery during one full charging.

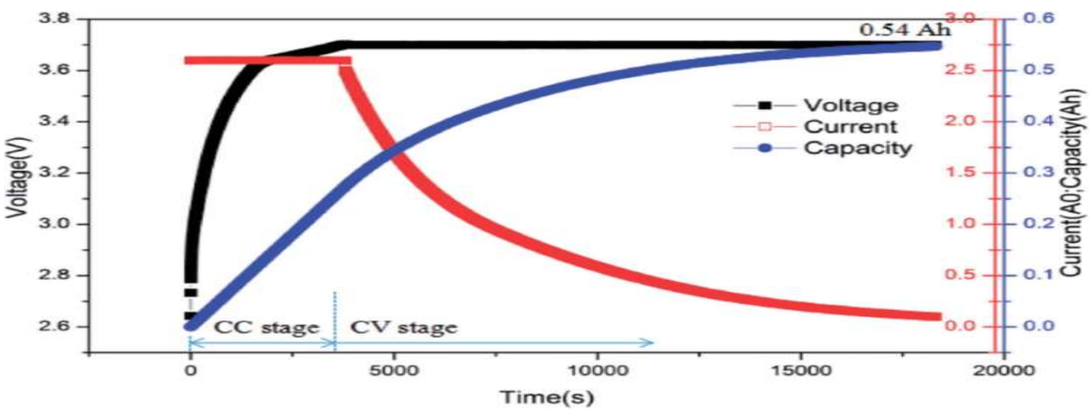


(Source: Battery Council International, 2019)

Figure 2-2: Charging Graph for Lithium Ion

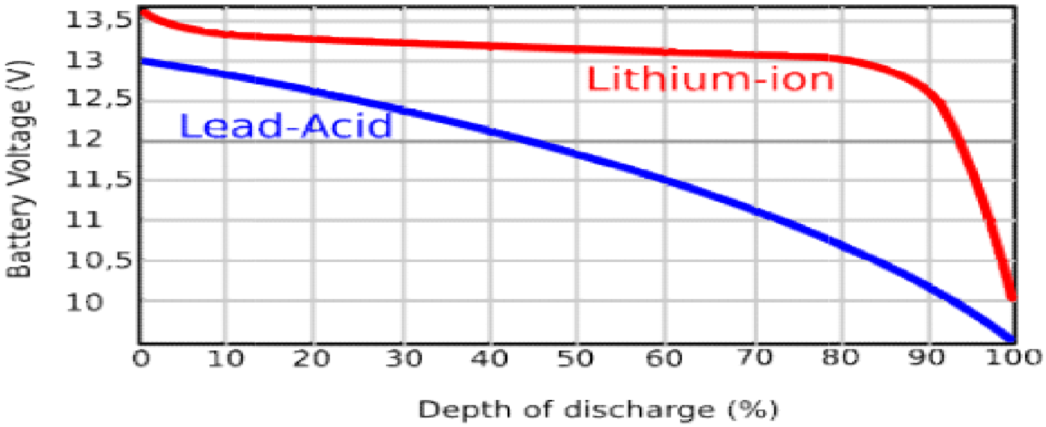
2.9 Nature of Charging of Lead Acid Battery

The figure below show that voltage of cell increase sharply during the initial step of charging and then goes increase slowly and become constant when voltage is above than 3.6V. While the charging current is constant at initial for few hr and then decrease slowly to 0Ah in one full charging cycle and similarly the charging state goes to increase with time and reach to 100% as show in figure 2-3.



(Source: Battery Council International, 2019)

Figure 2-3: Charging Graph for Lead Acid Battery



(Source: Battery Council International, 2019)

Figure 2-4: Discharging Nature of Lead Acid Battery and Lithium Ion Battery

The above figure shows that the voltage drop of lead acid battery is high as compare to lithium ion battery with respect to depth of discharge.

CHAPTER THREE: METHODOLOGY

This research was carried out as per flowchart given below in Figure 3-1.

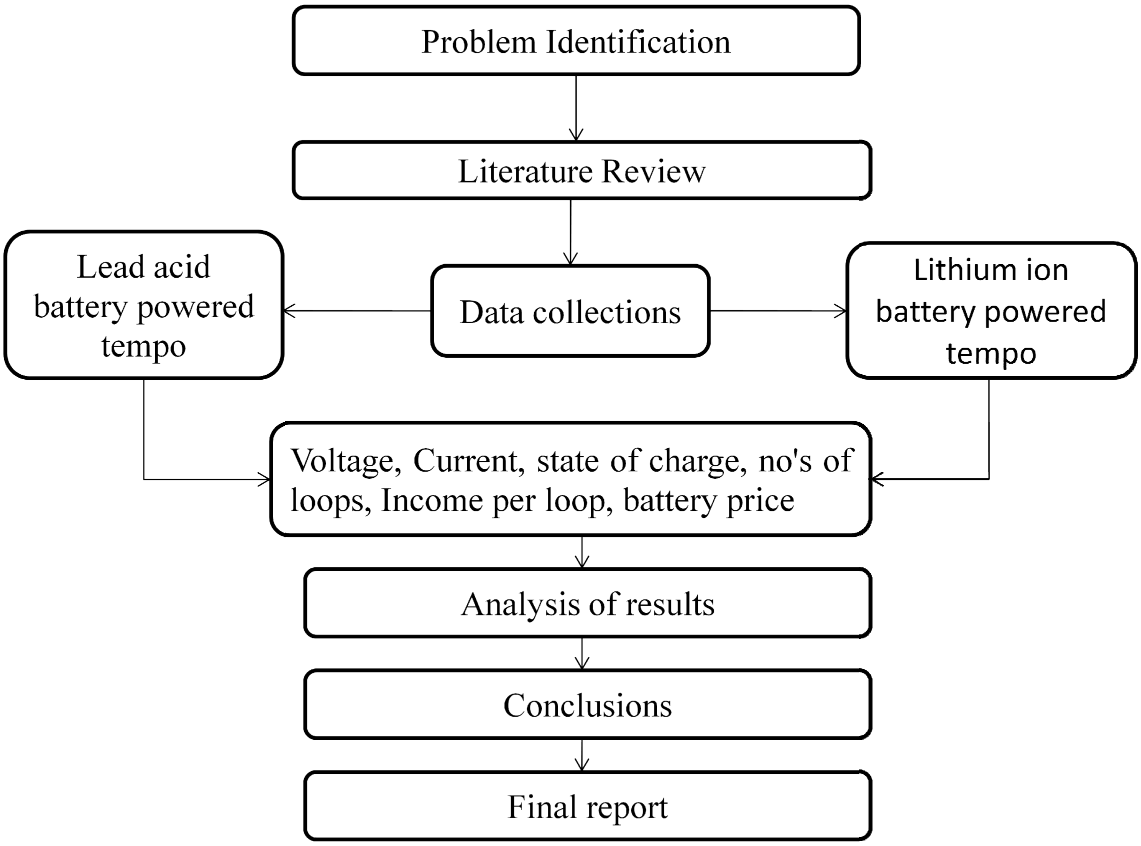


Figure 3-1: Flow chart of methodology adopted

3.1 Problem Identification

The quality of the conventional lead batteries used as the driving force for all Safa Tempos in Nepal became worse and their price increased. They now last barely 12 months (formerly 18 months). This put a question to the profitability of the Safa Tempo in operation. In 2017 lithium ion battery was introduced in Nepali market but it has high price so tempo owners are confused or in dilemma to choose a battery.

3.2 Literature Review

The extensive literature review was conducted with the help of internets, national libraries', and journals available. The literature related history of electric vehicle in worlds as well as in Kathmandu valley, problems faced by safa tempo, green house gas emissions, recycling of materials, comparison of lead acid and lithium ion battery, charging and discharging nature of batteries is review in this section.

3.3 Data Collections

Charging and discharging nature of battery, loops wise income data was collected by measurement of different parameters related to battery. Route details, charging stations details related data was collected from EVAN.

3.3.1 Flow Chart to Collect Loop Wise Income Data

For this, one route and two safa tempo are selected. Safa tempo No. 3582 powered by Sinopoly LiFePO4 (300Ah, 76.8V a Single set Battery) and safa tempo No. 3578 powered by Trojan 125 (240Ah, 72V a single set Battery: 6V x 12batteries) are selected. The selected route is approx. 9Km from RNAC to Maharajgunj to RNAC, The give figure or sketch below figure 3-1 is road map for the report to calculate the income generated by two safa tempo No. 3582 and No. 3578 for a single charge.

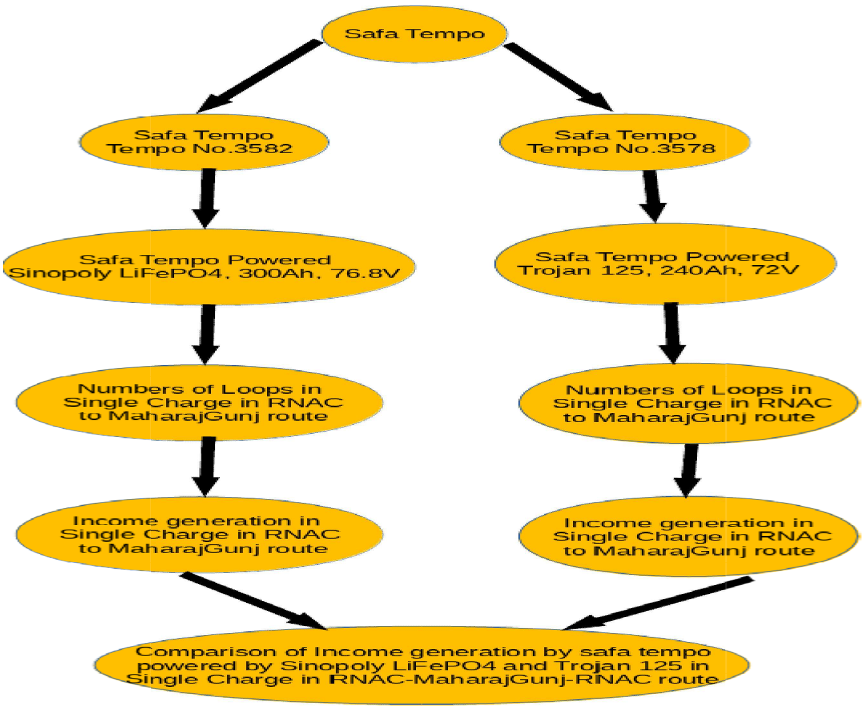


Figure 3-2: Flow Chart to Compare the Income Generation

3.3.2 Flow Chart to Find Out the Nature of Charging

For this, NEVI charging station is selected to find out the charging time, charging voltage and current of both batteries. The sketch or figure 3-2 below is the road map to calculate and compare the charging time of both batteries.

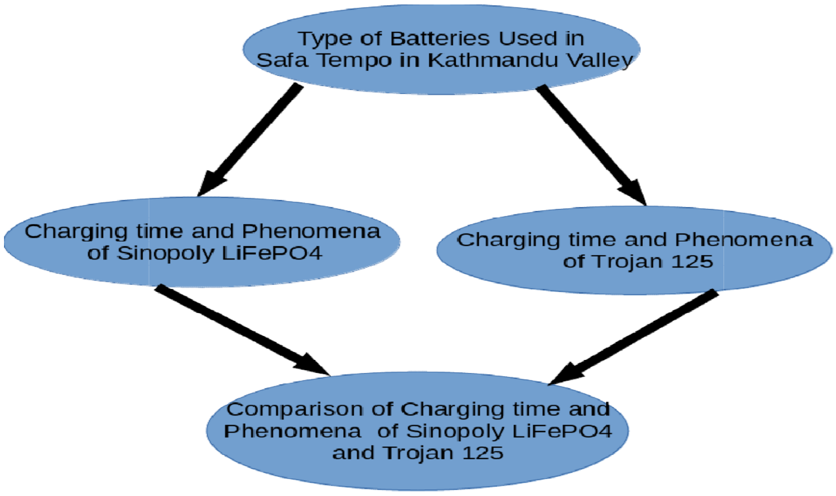


Figure 3-3: Flow Chart to Compare of Charging Nature

3.3.3 Flow Chart to Find Out the Nature of Discharging

For This, State of charge and voltage of battery is measured in every loop. The figure 3-3 below is the road map of calculating the discharging nature of the batteries in every loop.

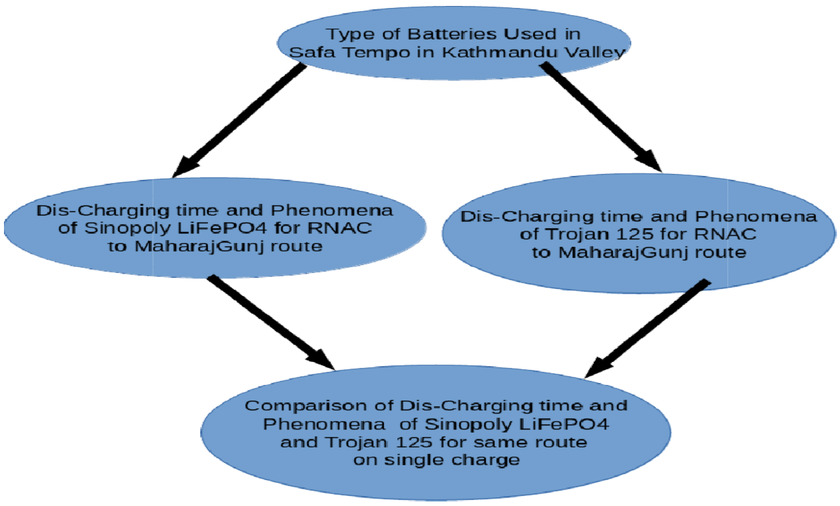


Figure 3-4: Flow Chart to Compare of Discharging Nature

3.4 Analysis of Results

After data was collected, it was put in Microsoft Excel and different graphs and bar charts were drawn for to analyze the output of the collected data. After analysis, findings are compared and the results are indicated.

3.5 Report Writing

At last, after completion of analysis and finding results, the research report is written, submitted and final presentation was done.

CHAPTER FOUR: MEASUREMENT

In this chapter, the calculations and comparisons was done from the data's which are collected (ANNEX-B),in this study, same route for both safa tempo and distance is about 9km (Route: RNAC-Maharajgunj-RNAC) and calculate the distance traveled by safa tempo No.3582 using lithium ion battery of 76.8V, 300Ah (1 set) and another safa tempo No.3578 using lead acid battery Trojan T125, 72V (2 sets) with 240Ah

4.1 Power Calculations

A Trojan T125 Lead acid battery used in safa tempo No.3578 has following specification i.e. one set battery of 72V, 240Ah. Then to calculate the power generated by this battery is calculated as follows

Current (I_A) =240Ah

Voltage (V) =72V

We have, Power (kWh) = (Current x Voltage)/1000

Power= (240 x 72)/1000=17.28kWh

But after charging the voltage increase up to 82.12V then the power reaches to approx. 19.71kWh.

A Sinopoly LiFePO4 lithium ion battery used in safa tempo No.3582 has following specification i.e. one set battery of 76.8V, 300Ah. Then to calculate the power generated by this battery is calculated as follows

Current (I_A) =300Ah

Voltage (V) =76.8V

We have, Power (kWh) = (Current x Voltage)/1000

Power= (300 x 76.8)/1000=23.04kWh

But on charging the voltage increase up to 83.18V then the power reaches to approx. 24.95kWh.

4.2 Distance Traveled per day

On a single charge of lead acid battery, safa tempo no.3578 completed 4 loops. Since one loop is of approx. 9km consideration in this report. Then the total distance traveled by safa tempo No. 3482 traveled (4x9) km=36km in a single charge, On a single charge of lithium ion, battery safa tempo no. 3582 completed 9 loops. Since one loop is of approx. 9km consideration in this report. Then the total distance traveled by safa tempo No.3582 traveled (9x9) km=81km in a single charge.

4.3 Energy Consumed per Loop

From table (ANNEX-B), at one full charge, Sinopoly LIFePO4 has about 24.95 kWh of energy and can traveled 9 loops.

Therefore, On Average 24.95 kWh of 80% energy is consume in 9 loops (Since 20% Sate of charge remains and 80% is used in working hours)

Or, On Average (24.95 x 0.8/9) kWh energy is consumed in 1 loop

Or, On Average (19.96/9) kWh energy is consumed in 1 loop

Or, On Average 2.21kWh energy is consumed in 1 loop

Moreover, 2.21 kWh energy is consumed by safa tempo No.3582 powered by Sinopoly LiFePO4 lithium ion battery in one loop or to cover 9 km distance.

At one full charge, lead acid battery has about 19.71kWh energy and can traveled 4 loops or about 36km in a single charge.

Therefore, On Average 91.716kWh of 80% energy is consumed in 4 loops (Since 20% Sate of charge remain and 80% is used in working hours)

Or, On Average (19.71 x 0.8/4) kWh energy is consumed in 1 loop

Or, On Average (15.76/4) kWh energy is consumed in 1 loop

Or, On Average 3.99kWh energy is consumed in 1 loop

Moreover, 3.99 kWh of energy is consume by safa tempo No.3578 powered by Trojan 125 lead acid battery in one loop or to cover 9km distance.

Since the energy consumption per loops is 3.99 kWh. Therefore energy consumption for 3435 loops is (3.99kWh x 3435) =13705.65 kWh in life span.

This shows that safa tempo powered by 2 sets lead acid batteries consumed 13705.65 kWh in 19 months life span.

The energy consumption per loops is 2.21kWh. Therefore energy consumption for

10850 loops is (2.21kWh x 10850) = 23,978.5kWh in life span.

4.4 Income Comparison

From table (ANNEX-B), per day 8 loops and 9 loops can complete by lead acid and lithium ion battery respectively. From 2 sets of lead acid batteries of 19 months life span can covered 3435 loops and generate gross income Rs.12, 11,000 and 1set of lithium ion batteries of 72 months life span can covered 10850 loops and generate gross income Rs.37,97,500.

4.4 Price Comparison

Price of one set lead acid battery (Trojan T125) which safa tempo (PR_{lead}) = Rs.3, 00,000

Price of one set lithium ion battery (Sinopoly LiFePO4) which safa tempo ($PR_{lithium}$) = Rs.9, 00,000

Now to compare the value,

$PR_{lead}/PR_{lihtium}$ = (Rs. 3,00,000/Rs.9,00,000)=0.333

or, $PR_{lead}/PR_{lihtium}$ =0.33

or, PR_{lead}=0.33 $PR_{lithium}$

This show that price of lead acid battery is 0.33 times of lithium ion battery. This means price of lead acid batteries is 33% of the price of lithium ion batteries.

4.5 Charging Of Lithium Ion Battery

From the table 4-1 (ANNEX-B), help to study the nature of charging Sinopoly LiFePO4 lithium battery. The state of charge of battery remains 20% with 80% DOD after working at that state the voltage of battery is about 75.51V. After charging the battery the state of charging is 100% after 410minutes. This means the lithium ion battery is fully charged in 410 minutes and the maximum charging voltage at this state is 85V. It consumed about 24 kWh of energy during charging.

Moreover from the table 4-1 (ANNEX-B), it is more clear that the charging current remain constant for 20% to 72%, for 270 minutes of charging and then goes decrease from 72% to 100%, for (410-270)minutes=140minutes and become zero.

4.6 Charging of Lead Acid Battery

Data of table (ANNEX-B), help to study the nature of Trojan 125 lead acid battery which power safa tempo No. 3578. The state of charge of battery remains 20% with 80% DOD after working at this state the voltage of a battery is about 72.01V. After charging the battery the state of charging is 100% after 560minutes. This means the lead acid battery is fully charged in 560 minutes and the maximum charging voltage at this state is 99.02V. It consumed about 40 kWh of energy for two sets of batteries.

More over from the table (ANNEX-B), it is more clear that the charging current remain constant for 20% to 26%, for 40 minutes of charging and such process is going on till sate of charging is 100% for 560 minutes and become zero.

CHAPTER FIVE: RESULTS AND DISCUSSIONS

5.1 Gross Income Generated per Day

The graph below shows the cumulative gross income generated by Safa tempo with Lithium ion and Lead Acid battery per day with respect to loops. It is found that the income generated by safa tempo powered by lithium ion battery more than safa tempo powered by lead acid battery because lithium ion battery can make one more loop than lead acid battery.

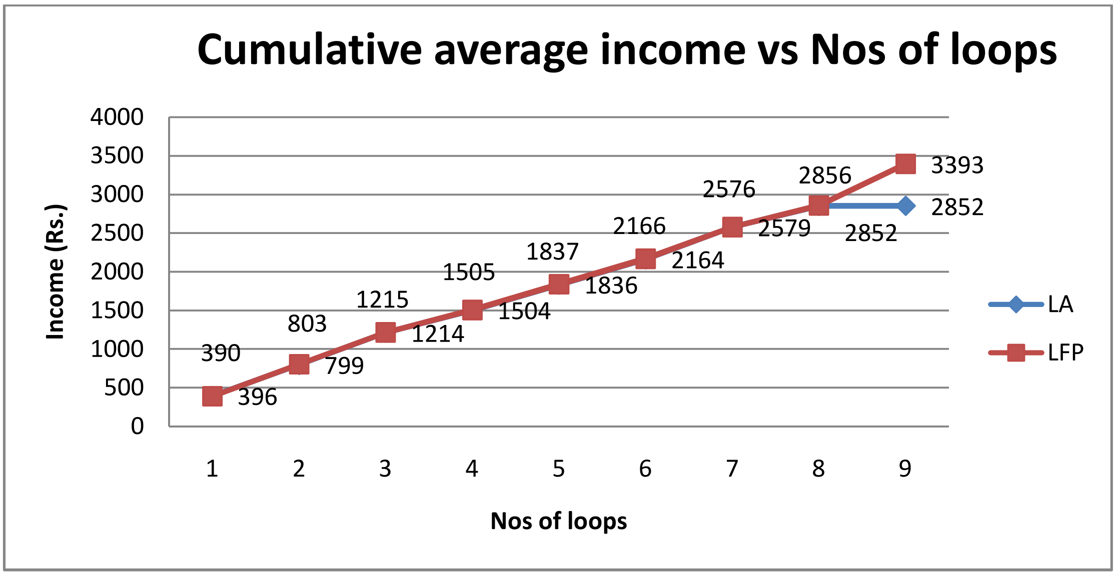


Figure 5-1: Income Generated per Day

Also the difference income generated per day 2sets of lead acid and lithium ion battery about (Rs. 3383-Rs.2852=Rs.531)

5.2 Discharging Nature of Lithium Ion Battery

The graph below shows the nature of state of charge, corresponding voltage and loops of Sinopoly LiFePO4 lithium ion battery. From figure 5-2, it is clear that the voltage is constant for a certain loops with continuous decreasing state of charge, during the working hour as loop increases. After certain loops voltage goes to slightly decrease with continuous decreasing in sate of charge.

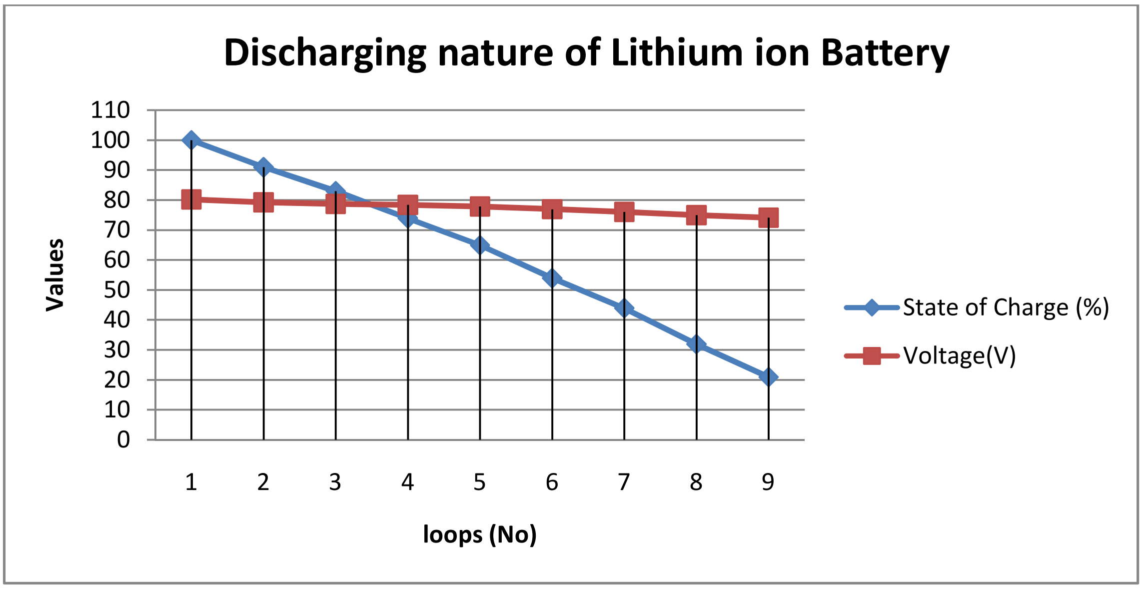


Figure 5-2: Discharging Nature of Lithium Ion Battery

5.3 Discharging Nature of Lead Acid Battery

The graph below shows the nature of state of charge, corresponding voltage and loops of Trojan T125 lead acid battery. From figure 5-3, it is clear that the voltage is continuous decrease with continuous decreasing state of charge, during the working hour as loop increase.

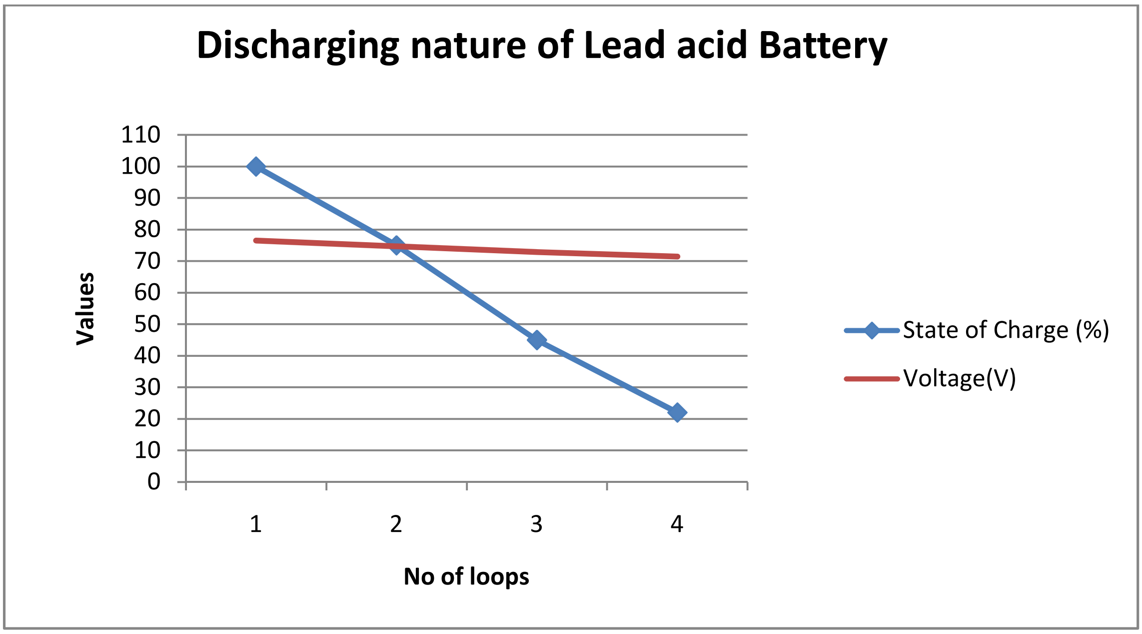


Figure 5-3: Discharging Nature of Lead Acid Battery

5.4 Charging Nature of Lithium Ion Battery

The graph below shows the nature of charging of Sinopoly LiFePO4 battery with time. The nature of state of charging with time is increase while the voltage is going slightly increases and then it is constant and after certain time it increases sharply and become constant at full charge. Also the nature of ampere with time is constant for certain time and then goes to decreases and finally at full charge charging current in zero.

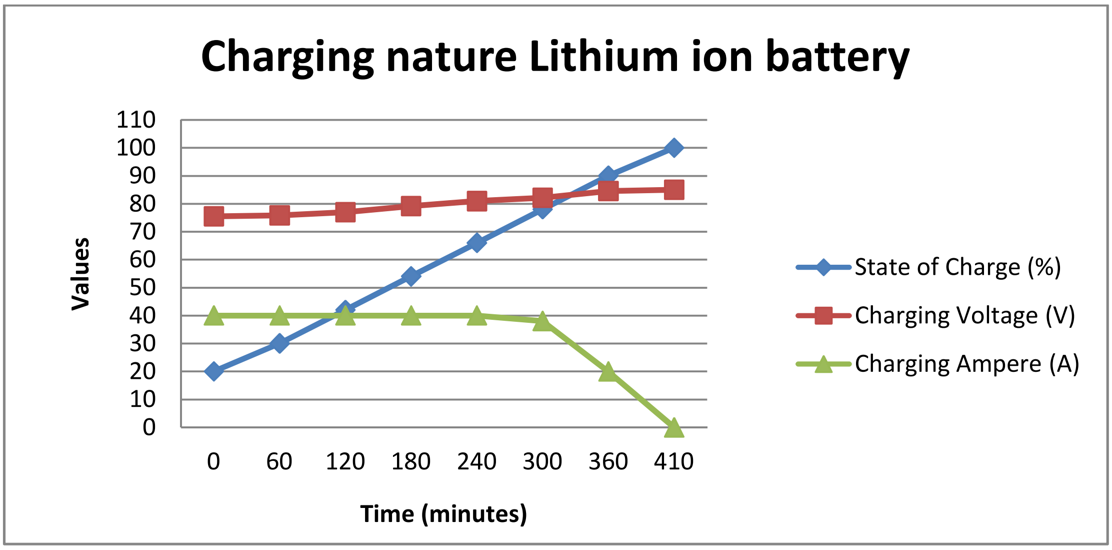


Figure 5-4: Charging Nature of Lithium Ion Battery

5.5 Charging Nature of Lead Acid Battery

The graph below show the nature of charging of Trojan T125 leads acid battery with time. The nature of state of charging with time is increase; similarly the voltage is also going increases with time till battery is fully charged. Also the nature of ampere with time is going to decrease step wise through charging and finally at full charge charging current in zero.

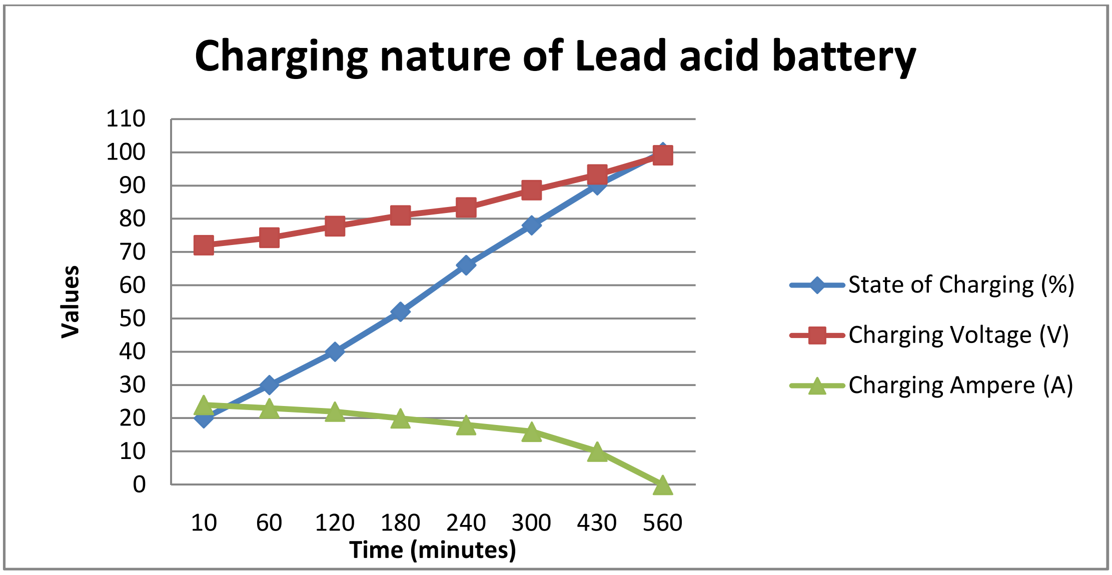


Figure 5-5: Charging Nature of Lead Acid Battery

5.6 Financial Results

The results came from financial analysis (ANNEX C), as per financial analysis, internal rate of return is 42% and 16%, net present value is Rs. 1,117,230.56 and Rs. 393,896 and discounted payback period is 1.49 years and 1.31 years of lithium ion battery and lead acid battery respectively.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- 13.8 kWh of electrical energy is required to fully charge one set of battery in 9 hours and 18.42 kWh of electrical energy is required for lithium ion battery in 8 hours. During the charging, lithium ion battery of nominal voltage 76.8V reaches to 83.18V at 100% state of charge while in case of lead acid nominal voltage 72V reach to 82.12V at 100% state of charge
- One set lithium ion battery can make 9 loops (81 km) per day while 2 sets of lead acid batteries can make 8 loops (72 km) per day. But in comparison with life span of both batteries, lithium ion battery can make 3 times more loops than by lead acid battery.
- Energy consumed by safa tempo per loop with lithium ion battery is 2.21 kWh and 3.99 kWh by lead acid battery.
- It is found that the average gross income generated per day by lithium ion battery is about 10% more than that of lead acid (2sets) battery. But in comparison with life span of both batteries, lithium ion battery can generate 300% more income than by lead acid battery, so in life span 1 set of lithium ion battery can replace 6 sets of lead acid battery.
- As per financial analysis, IRR (internal rate of return) for lithium ion and lead acid battery is found to be 42% and 16% respectively.

6.2 Recommendations

This research just touches the one route and one charging station in Kathmandu valley for the performance comparison of lead acid battery and lithium ion battery because all the routes and charging stations didn’t have both batteries in operation. Followings are the recommendations of this research.

1. Further research is needed to compare the performance the performance of lead acid and lithium ion battery in others routes and others charging stations.
2. Further research is needed how the battery capacity is degraded with the course of time.

3. Further research is suggested to compare performances of charging safa tempos using lead acid and lithium ion battery with the help of stand alone PV power system.

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ANNEXES

ANNEX-A Route Details of Safa Tempo

Path Of Routes (Origin-Transit-Destination)	**No. Of Tempos**	**Max No Of Cycle/Day/Tempo**	**Route Number**	**Min To Maximum Charges/Person (Rs.)**
Lagankhel-Jawalakhel-Kupondole-Baneswor-Koteswor-Satdobato-Lagankhel	100	10	14 A	15-20
Lagankhel-Satdobato- Koteswor-Baneswor-Kupondole-Jawalakhel-Lagankhel	53	10	14 B	15-20
Lagankhel-Sanepa-Kalimati-Dallu	27	8	14	15-20
Gwarkho-Mangalbazzar-Pulchowk-Kupondole-Tripureswor-Ratnapark	20	10	14	15-20
Imadol- Gwarkho-Mangalbazzar-Pulchowk-Kupondole-Tripureswor-Ratnapark	13	6	14	15-23
Mangalbazzar-Pulchowk-Ratnapark-Baluwatar	15	8	14	15-20
Maharajgunj-NAC	55	8	5	15-23
Tinchuli-Chabahil-NAC	123	10	2	15-20
Sankhamul-Jorpati	51	10	2 SHA	15-20
Sinamangal-Ratnapark	35	10	2 GA	15-20
Bagdol-Sanepa-Ratnapark	12	8	14	15-20
Chhauni- Tahachal-Teku-Ratnapark	54	8	20	15-20
Purano Baneswor-Dilli Bajar-NAC	43	10	1 KHA	15-20
Kharibot-NAC	20	10	1 PA	15-20
Katyani Chowk- NAC	13	10	1 MA	15-20

ANNEX-B Charging and Discharging Profile of Batteries

Charging profile of Sinopoly LiFePO4 lithium ion battery

State of Charging (%)	**Charging Voltage (V)**	**Charging Ampere (A)**	**Charging Time (minute)**
20	75.51	40	10
22	75.63	40	20
24	75.72	40	30
26	75.79	40	40
28	75.82	40	50
30	75.88	40	60
32	76.01	40	70
34	76.12	40	80
36	76.34	40	90
38	76.56	40	100
40	76.95	40	110
42	77.01	40	120
44	77.34	40	130
46	77.56	40	140
48	77.89	40	150
50	78.34	40	160
52	79.01	40	170
54	79.13	40	180
56	79.34	40	190
58	79.53	40	200
60	80.12	40	210
62	80.23	40	220
64	80.55	40	230
66	80.95	40	240
68	81.15	40	250
70	81.35	40	260
72	81.53	40	270
74	81.75	40	280
76	81.99	39	290
78	82.11	38	300

80	82.55	35	310
State of Charging (%)	**Charging Voltage (V)**	**Charging Ampere (A)**	**Charging Time (minute)**
82	82.95	30	320
84	83.85	28	330
86	83.11	25	340
88	83.56	23	350
90	84.52	20	360
92	84.52	15	370
94	84.52	13	380
96	85	10	390
98	85	5	400
100	85	0	410

Charging profile of lead acid battery

State of Charging (%)	Charging Voltage (V)	Charging Ampere (A)	Charging Time in minute
20	72.01	24	10
22	72.38	24	20
24	73.65	24	30
26	73.95	24	40
28	74.01	23	50
30	74.24	23	60
32	75.64	23	70
34	75.98	23	80
36	76.51	22	90
38	76.53	22	100
40	77.73	22	120
42	77.79	21	130
44	78.02	21	140
46	78.15	21	150
48	79.55	20	160
50	79.75	20	170
52	80.94	20	180
54	80.16	20	200
56	81.25	19	210
58	81.45	19	215
60	82.74	19	220
62	82.96	18	225
64	83.09	18	230
66	83.34	18	240
68	85.54	17	250
70	85.76	17	260
72	86.94	17	270
74	87.13	16	280
76	87.12	16	290
78	88.55	16	300
80	88.95	15	310
82	89.25	15	340

State of Charging (%)	Charging Voltage (V)	Charging Ampere (A)	Charging Time in minute
84	90.75	14	350
86	91.96	13	380
88	92.03	11	400
90	93.25	10	430
92	94.75	9	480
94	95.78	6	510
96	96.85	5	520
98	97.95	3	540
100	99.02	0	560

Discharging profile of lithium ion battery

State of Charge (%)	Voltage(V)	loops(No)
100	80.25	1
91	79.3	2
83	78.75	3
74	78.42	4
65	77.87	5
54	76.97	6
44	76.04	7
32	75.01	8
21	74.12	9

Discharging profile of lead acid battery

State of Charge (%)	Voltage(V)	loops (No)
100	76.55	1
75	74.67	2
45	72.85	3
22	71.45	4

ANNEX-C Financial Data

Income Generation by Safa Tempo for Both Batteries (Tempo No. 3582 –Li-ion and No. 3578-Lead acid)

No. of Loop by Safa Tempo No. 3578	**Gross income (NPR) generated by Safa Tempo No. 3578**	**No. of Loop by Safa Tempo No. 3582**	**Gross income (NPR) generated by Safa Tempo No.3582**
8	2850	9	3305
8	2925	9	3280
8	2995	9	3450
8	2750	9	3380
8	2980	9	3405
8	2635	9	3490
8	2830	9	3350
7	2520	8	2870
7	2615	8	2925
7	2705	8	2990
7	2575	8	2750
7	2550	8	2985
7	2665	8	2655
7	2420	8	2820
6	2305	7	2515
6	2225	7	2610
6	2085	7	2715
6	2050	7	2555
6	2220	7	2540
6	2155	7	2665
6	2110	7	2430
5	1845	6	2325
5	1805	6	2215
5	1780	6	2095
5	1990	6	2040
5	1900	6	2225
5	1735	6	2150
5	1800	6	2115

No. of Loop by Safa Tempo No. 3578	Gross Income (NPR) Generated By Safa Tempo No. 3578	No. of Loop by Safa Tempo No. 3582	Gross Income (NPR) Generated By Safa Tempo No.3582
4	1400	5	1835
4	1535	5	1800
4	1495	5	1790
4	1435	5	1980
4	1550	5	1910
4	1600	5	1735
4	1515	5	1810
3	1215	4	1425
3	1190	4	1545
3	1250	4	1485
3	1230	4	1415
3	1180	4	1550
3	1205	4	1610
3	1225	4	1505
2	835	3	1205
2	805	3	1195
2	825	3	1245
2	790	3	1230
2	770	3	1170
2	850	3	1235
2	720	3	1225
1	420	2	845
1	410	2	815
1	395	2	820
1	380	2	790
1	415	2	775
1	400	2	845
1	350	2	730
		1	400
		1	410
		1	390
		1	370

Gross Income generated by Safa tempo No. 3578 in life span powered by of lead acid batteries

Months Of Operations	Loops Per Day	Total Days Of Operation	Total Loops	Income Generation Per Loop (NPR)	Total Income Generated With Corresponding Loops (NPR)
Up to 12	8	310	2480	Rs.350	Rs.8,68,000
13	7	27	189	”	Rs.66,150
14	7	27	189	”	Rs.66,150
15	6	26	156	”	Rs.54,600
16	6	26	156	”	Rs.54,600
17	5	25	125	”	Rs.43,750
18	4	25	100	”	Rs.43,750
19	2	20	40	”	Rs.14,000
		Total days = 486	Grand Total=3435loops.		Grand Income by 2set Lead Acid Batteries= Rs.12,11,000

Income generated by Safa tempo No.3582 in life span powered by lithium ion batteries.

Months Of Operations	Loops Per Day	Total Days Of Operation	Total Loops	Income Generation Per Loop (NPR)	Total Income Generated With Corresponding Loops (NPR)
Up to 12	9	310	2790	Rs.350	Rs.9,76,500
12 to 24	9	310	2970	”	Rs.9,76,500
12 to 36	6	310	1860	”	Rs.6,51,000
36 to 48	6	310	1860	”	Rs.6,51,000
48 to 60	3	310	930	”	Rs.3,25,000
60 to 72	2	310	620	”	Rs.2, 17,000
			Grand Total=10850loops.		Grand Total= Rs.37,97,000

Financial Analysis of Li-ion power Safa Tempo

Year	Battery Investment	Electricity	O&M	Driver	Revenue	Energy (kWh/year)	Net Cash Flow	PW of Cash Flow	Cumulative Cash Flow
0	(900,000.00)	0	0	0	0	0	(900,000.00)	(900,000.00)	(900,000.00)
1		(45,711.36)	-1,100.00	(168,000.00)	976500	5713.92	761,688.64	692,444.22	(207,555.78)
2		(45,711.36)	-1,100.00	(168,000.00)	976500	5713.92	761,688.64	629,494.74	421,938.96
3		(45,711.36)	-1,100.00	(168,000.00)	651000	5713.92	436,188.64	327,714.98	749,653.94
4		(45,711.36)	-1,100.00	(168,000.00)	651000	5713.92	436,188.64	297,922.71	1,047,576.65
5		(45,711.36)	-1,100.00	(168,000.00)	325000	5713.92	110,188.64	68,418.48	1,115,995.13
6		(45,711.36)	-1,100.00	(168,000.00)	217000	5713.92	2,188.64	1,235.43	1,117,230.56

IRR	42%
NPV	1,117,230.56
KWh/Loop	3.16
Charging Ratio	18 min/kWh
Discounted Payback(year)	1.49

Assumptions:		
NRs/kWh	8	
Charging/Year	310	
DOD	80%	
Interest Rate	10%	
No of Loops	10,850	In 6 years

Financial Analysis of Lead Acid Powered Safa Tempo									
Year	**Battery Investment**	**Electricity**	**O&M**	**Driver**	**Revenue**	**Energy (kWh/year)**	**Net Cash Flow**	**PW of Cash Flow**	**Cumulative Cash Flow**
0	(600,000.00)			0	0	0	(600,000.00)	(600,000.00)	(600,000.00)
1	0	(68,567.04)	(13,200.00)	(168,000.00)	868,000.00	8,570.88	618,232.96	562,029.96	(37,970.04)
2	0	(38,928.38)	(9,900.00)	(98,000.00)	343,000.00	4,866.05	196,171.62	162,125.30	124,155.27
3	(600,000.00)	(68,567.04)	(13,200.00)	(168,000.00)	868,000.00	8,570.88	18,232.96	13,698.69	137,853.96
4	0	(38,928.38)	(9,900.00)	(98,000.00)	343,000.00	4,866.05	196,171.62	133,987.85	271,841.81
5	(600,000.00)	(68,567.04)	(13,200.00)	(168,000.00)	868,000.00	8,570.88	18,232.96	11,321.23	283,163.05
6	0	(38,928.38)	(9,900.00)	(98,000.00)	343,000.00	4,866.05	196,171.62	110,733.76	393,896.81

IRR	16%	
NPV	393,896.81	
kWh/Loop	3.91	
Charging Ratio	32 min/kWh	
Energy Saving/Loop	0.75	
Life time energy saving	8159.2	kWh using Li-ion
Discounted Payback(year)	1.31	

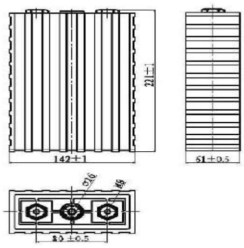
Assumptions:		
NRs/kWh	8	
Charging/Year	310 (first Year)	176 (2nd year)
DOD	80%	
Interest Rate	10%	
No of Loops	10,305	In 6 years

ANNEX-D Technical Specifications of Batteries

Technical Specifications of Sinopoly lifepo4 lithium ion battery used in safa tempo

Model: SP-LFP100AHA

Item		specification	Remark
Product Model		SP-LFP-100AHA	
Nominal Capacity		100Ah	
Nominal Voltage		3.2V	
Weight		3.15Kg±0.1Kg	
Internal Impedance		≤0.7mΩ	AC1kHz
Cycle Life		≥2000Times	80%DOD
Self-discharge rate		≤5%	25℃, 1 month
Dimension	Height	221±1mm	
	Width	142±1mm	
	Thickness	61±0.5mm	
Charge	Standard Current	33A	CC&CV
	Max. Current	200A	2C
	Limited Voltage	3.65V	
	End Current	2A	0.02C
Discharge	Standard Current	33A	
	Max. Current	300A	3C
	End Voltage	2.5V	
Operation Temperature	Charge	0℃~45℃	
	Discharge	-20℃~55℃	
Storage Temperature		-10℃~45℃	
Storage Humidity		25%~85%	RH



For more details, please contact us by sending email to: sales@sinopolybattery.com (ver 1.1)

Technical Specifications of Trojan T-125 Lead Acid Battery

Trojan BATTERY COMPANY

T-125 DATA SHEET

MODEL: T-125 with Bayonet Cap

VOLTAGE: 6

DIMENSIONS: Inches (mm)

BATTERY: Flooded/wet lead-acid battery

COLOR: Maroon (case/cover)

MATERIAL: Polypropylene

WATERING SYSTEM: HydroLink™ Watering System

T2 Technology

PRODUCT SPECIFICATIONS

BCI GROUP SIZE	TYPE	CAPACITY [A] Minutes		CAPACITY [B] Amp-Hours (AH)				ENERGY (kWh)	TERMINAL Type [E]	DIMENSIONS [C] Inches (mm)			WEIGHT lbs. (kg)
		@25 Amps	@75 Amps	5-Hr Rate	10-Hr Rate	20-Hr Rate	100-Hr Rate	100-Hr Rate		Length	Width	Height [D]	
6 VOLT DEEP CYCLE BATTERY - with T2 TECHNOLOGY™													
GC2	**T-125**	488	132	195	221	240	266	**1.60**	1, 2, 3, 4	10.30 (262)	7.11 (181)	11.07 (283)	66 (30)

A. The number of minutes a battery can deliver when discharged at a constant rate at 80°F (27°C) and maintain a voltage above 1.75 V/cell. Capacities are based on peak performance.
B. The amount of amp-hours (AH) a battery can deliver when discharged at a constant rate at 80°F (27°C) and 86°F (30°C) for the 5-Hour rate and maintain a voltage above 1.75 V/cell. Capacities are based on peak performance.
C. Dimensions are based on nominal size. Dimensions may vary depending on type of handle or terminal.
D. Dimensions taken from bottom of the battery to the highest point on the battery. Heights may vary depending on type of terminal.
E. Terminal images are representative only.
Trojan's battery testing procedures adhere to both BCI and IEC test standards.

CHARGING INSTRUCTIONS

CHARGER VOLTAGE SETTINGS (AT 77°F/25°C)

System Voltage	6V	12V	24V	36V	48V
Daily Charge	7.40	14.8	29.6	44.4	59.2
Float	6.60	13.2	26.4	39.6	52.8
Equalize	7.75	15.5	31.0	46.5	62.0

Do not install or charge batteries in a sealed or non-ventilated compartment. Constant under or overcharging will damage the battery and shorten its life as with any battery.

CHARGING TEMPERATURE COMPENSATION

.028 VPC for every 10°F (5.55°C) above or below 77°F (25°C) (add .028 VPC for every 10°F (5.55°C) below 77°F and subtract .028 VPC for every 10°C above 77°F).

OPERATIONAL DATA

Operating Temperature	Self Discharge
-4°F to 113°F (-20°C to +45°C). At temperatures below 32°F (0°C) maintain a state of charge greater than 60%.	5 – 15% per month depending on storage temperature conditions.

TERMINAL CONFIGURATIONS

1 ELPT Embedded Low Profile Terminal

Terminal Height Inches (mm)
1.22 (31)
Torque Values in-lb (Nm)
95 – 105 (11 - 12)
Bolt Size
5/16"

2 EHPT Embedded High Profile Terminal

Terminal Height Inches (mm)
1.50 (38)
Torque Values in-lb (Nm)
95 – 105 (11 - 12)
Bolt Size
5/16"

3 EAPT Embedded Automotive Post Terminal

Terminal Height Inches (mm)
.95 (24)
Torque Values in-lb (Nm)
50 – 70 (5.6 - 7.9)

4 EUT Embedded Universal Terminal

Terminal Height Inches (mm)
1.10 (28)
Torque Values in-lb (Nm)
95 – 105 (11 - 12)
Bolt
5/16"

TRJN_T-125_DS_0315