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Estimating Optimal Number and Locations of Electric Vehicle Charging Station for Two Wheelers on Route Kathmandu-Chitwan, Nepal

by

Dison Maharjan

A THESIS

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DEPATRMENT OF MECHANICAL AND AEROSPACE ENGINEERING

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "Estimating Optimal Number and Locations of Electric Vehicle Charging Station for Two Wheelers on Route Kathmandu-Chitwan, Nepal" submitted by Dison Maharjan (PUL-075-MSREE-020) in partial fulfillment of the requirements for the degree of Master in Renewable Energy Engineering.

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ABSTRACT

Electric Vehicles (EVs) are plagued with some drawbacks that act as the major hindrance for people to accept with open arms. One of the most pivotal factor to consider is range anxiety: majorly due to the limited range of battery, and lack of charging infrastructure. This research intends to address the issue of range anxiety or the feeling of not reaching the destination on an EV through optimal distribution of charging stations in a specified route. So as to achieve the objective a generic algorithm is designed and programmed that pins out optimal number of charging locations on a route based on least range anxiety. The model fabricated is implemented on 132km stretch connecting two major cities of Nepal: Kathmandu and Chitwan. The algorithm calculates the average range anxiety placing two, three and four charging locations of different combinations. The best result for two charging locations was found to be 43km and 89km from Nagdhunga CheckPost, Kathmandu. The range anxiety for the combination was 2.6, means the average arriving SoC was 43%, and ending SoC (State of Charge) level of 11%. Similarly, with charging locations at 33km, 58km, and 87km produce 2.16 range anxiety level and 53.6% ending SoC level. Likewise, average anxiety level of 2 and ending SoC level of 63.5% is obtained with locations at 27km, 52km, 77km, and 102km. Since, not much difference in anxiety level is observed between having 3 and 4 charging locations, the locations are analyzed under different conditions: rate of usage of locations, increasing the initial SoC level range, and charging behavior of recharging up to 80%. The results under these conditions didn't show much advantage of having an extra charging location over 3 locations. The average usage rate of 3 charging locations was 80% whereas the average usage rate of 4 charging locations was only 50%. So, the optimal charging locations along Kathmandu-Chitwan route was found to be 3 locations. With three locations at 33km, 58km, and 87km, every rider shall complete the journey with least range anxiety. Then, it was calculated that charging location at Galchi, Malekhu, and Kurintar would have service time of 36 minutes, 47 minutes, and 40 minutes respectively based on average arriving SoC level. Assuming no queue shall be formed at each location, and with 3 bikes arriving per hour, it is optimal to have 2, 3, and 3 charging stations at locations 1, 2, and 3 accordingly.

Keyword: Range anxiety, Charging Infrastructure, Queuing Model

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LIST OF ABBREVIATIONS

AC	Alternating Current
CAN	Controller Area Network
CHAdeMO	Charge de Move
CS	Charging Station
CSS	Combined Charging System
DC	Direct Current
EV	Electric Vehicle
FCLP	Flow Capturing Location Problem
FRLP	Flow Refueling Location Problem
hp	horsepower
ICE	Internal Combustion Engine
km	Kilometer
km/hr	Kilometer per hour
kph	Kilometer per hour
SoC	State of Charge

CHAPTER ONE: INTRODUCTION

1.1.Background

The continued growth in internal combustion engines powered vehicles worldwide will eventually lead to increased crude oil demand and consumption, and CO_2 emission as well. The increasing global temperature, sea level rise, and local pollution are other consequences that follow. In order to accommodate the need of vehicles without increasing the demand of fossil fuels, vehicles that drive on alternative source of energy is the best solution. One of the pathways to sustainable petroleum displacement is a transition to the high-efficiency powertrain technologies, such as fuel-cell or battery-electric vehicles that could deliver better performance, higher efficiency, and zero tailpipe emissions. (Kromer & Heywood, 2007)

Electric vehicles are the best alternative to conventional fuel driven vehicles. Electric motors can deliver high torque at low revolution speeds which makes for a simpler and lighter powertrain and transmission when compared to internal combustion engine powered vehicles. The conversion of electrical energy to mechanical energy by an electric motor is much more efficient than deriving mechanical energy from fossil fuels in an internal combustion engine. A pure electric powertrain is also able to gain greater efficiency using regenerative braking. This leads to a much larger 'tank-to-wheel' efficiency for an electric vehicle. (Shukla, Pekny, & Venkatasubramanian, 2011). Switching to or getting an EV have other advantages like reduced noise and air pollution, lower maintenance cost, lower ownership cost, and can be charge at home, work, public charging networks.

According to National Action Plan for Electric Mobility, 2018, Nepal has set a target to decrease its dependency on fossil fuel in the transport sector by 50% through mass public transport, while promoting energy efficient and electric vehicles (GGGI, 2018). In context of Nepal, the use of electric vehicles will reduce import of petroleum from India, saving billions from national treasury, and reduce the pollution generated during logistics of these fuel. In fiscal year 2078/79, Nepal imported petroleum worth NRs. 320 billion (myRepublica Newspaper, 2022). Also, a conjunction can be developed where the fleet of new vehicles' load is matched with power from renewable source like sun and wind, and hydropower plants. Unlike in western countries where most of the EV run on electricity produced by coal or petroleum fired power stations, Nepal can run their EV via power produced by clean hydropower plants.

The adoption and use of light duty electric vehicles could reduce oil dependence and potentially reduce greenhouse gas emission. In the present context, Nepal imports all of its transportation fuel demand from India. In fiscal year 2076/77, a little over 500,000 kilo liters of petrol imported equaling 4000 crore Nepali rupees. (NOC, 2021). The encouragement and promotion of two-wheeler EVs in Nepal can save considerable amount on oil import. Also, Nepal meets most of its electricity demand through power generated from renewable and sustainable hydropower plants which makes the overall operation of EVs in Nepal sustainable and environment friendly.

1.2.Problem Statement

Consumer acceptance, technological advances, and policy measures are among the important factors for electric vehicle market success. Among them consumer acceptance and adoption is a major hindrance. The fear that the vehicle has insufficient range to reach the destination, referred to as range anxiety has been shown to be a significant obstacle to market acceptance of electric vehicles (EV). Range anxiety not only discourages consumer acceptance but also restrains the social benefits of EV. A 2020 study on barriers against electric vehicle use in Nepal ranked Infrastructure barrier as the most prominent factor, and within that lack of charging stations accounted for 60% (Adhikari, Ghimire, Kim, Aryal, & Khadka, 2020). This clearly defines the need of charging stations for better adoption of EV in Nepal. Again, a state preference survey conducted in the United Kingdom revealed that higher income group is more likely to consider a EV as a second vehicle (Skippon & Garwood, 2011). So, for any EV to become first choice vehicle, range anxiety is one factor to be considered.

One way to mitigate range anxiety is through the deployment of public charging infrastructure. Expansive installation of EV charging station will definitely reduce range anxiety among EV owners but increases the capital investment for manufacturers or service providers. Also, unplanned deployment of charging infrastructure can leave riders stranded on route, and to situation where stations are underutilized. At last, these factors hamper the adoption as well.

1.3. Research Objective

1.3.1. Main Objective

The main objective of the research is to determine optimal location and number of charging stations for two wheelers electric vehicle.

1.3.2. Specific Objectives

The specific objectives of the project are as follows:

- To develop a generic algorithm that computes the minimum range anxiety to determine optimal location for charging stations along corridor for Yatri P1 model
- To determine optimal location for charging station for Yatri P1on route Kathmandu-Chitwan, Chitwan- Kathmandu, Nepal to complete the trip
- To allocate optimal number of charging station in the location for Yatri P1 on route Kathmandu-Chitwan, Chitwan-Kathmandu, Nepal to serve the load on route

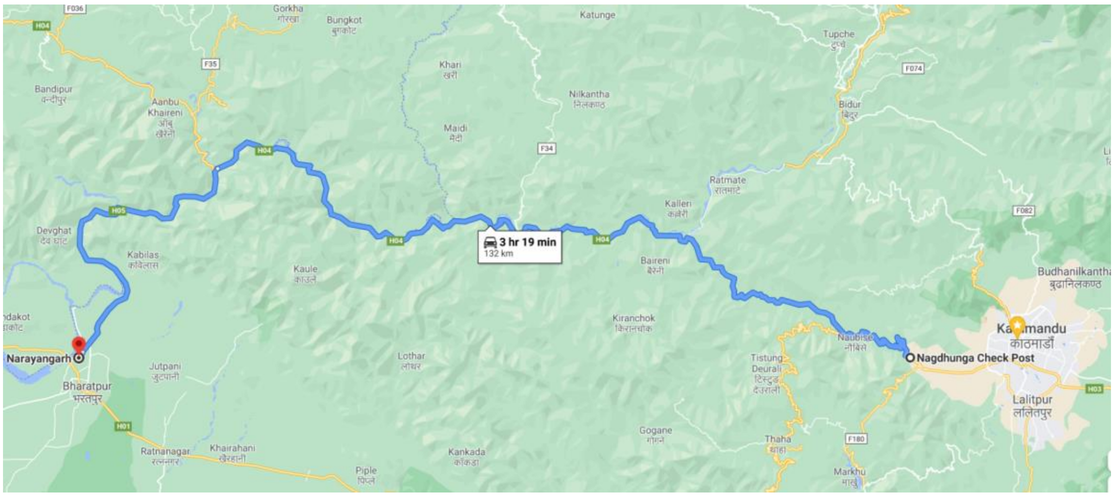

Figure 1.1: Route Map between Naghdhunga-Narayanghat, Nepal

1.4.Assumptions and Limitations

1.4.1. Assumptions

The study is targeted to find the charging locations and numbers of same that can cater only Yatri Motorcycles P1 Model. Other assumptions are made as well which is described in details in Chapter Four: Algorithms and Models.

1.4.2. Limitations

There are some limitations in the study conducted.

- The results obtained from the study is applicable to Yatri Motorcycles P1 model only.
- The number of charging stations to be deployed is calculated assuming no queue.

CHAPTER TWO: LITERATURE REVIEW

2.1.Electric Vehicle Charging Equipment

Electric vehicles, all categories, can be charged via two medium of input current: AC and DC. Almost every vehicle come with an onboard charger that converts the AC supply into DC for the batteries. This way of charging can be performed on normal residential supply of 220V. Depending upon the capacity of the onboard charger of the vehicle, the power output on these types of chargers can go up to 19.2kW. (Lee & Clark, 2018). This type of charging facility is referred to as AC charging.

DC charging is often referred as fast, or quick charging infrastructure where the batteries of the vehicle is directly charged with direct current. An external charger is present that converts the AC source to DC, then the DC is directly supplied to the battery. This charging technology is commonly known as DC Fast Chargers, and found on public spaces like Charging hubs, parking spaces, and other public places.

For four wheelers electric vehicle, there are majorly two type of DC charging ports used worldwide: GS/T and (Combined Charging System) CCS. GS/T charging ports are synonymous to big vehicles like buses whereas CCS are used by other manufacturers like Hyundai Ionic 5, Tata Nexon EV, BYD (Build Your Dream) and MG (Morris Garage) ZS model. Japanese Automaker Nissan's Leaf uses CHAdeMO (Charge de Move) port whereas American EV maker Tesla have their proprietary port. (Juice Blog, 2019)

Similarly, for two wheelers fast charging port no similar port has been used. Yatri Motorcycle's P1 model used a Jnicon Model 23 charging port whereas Indian EV scooter manufacturer Ather have their own proprietary charging port.

2.2.Models used for locating Charging Infrastructure

Location deployment of charging station for EV motorcycles are characterized by EV riders' behavior and decision making process in choosing the route. Taking a definite route with de-tour or on way to final destination what makes the deployment problem complex. To understand the driving behavior in defined network can be characterized by 'Gravity Model'. The model assumes that the trips produced at an origin and attracted to a destination are directly proportional to the total trip productions at the origin and the total attractions at the destination. (Princeton University, 2008). This proportionality is calibrated by friction factor and socioeconomic factors. The earlier implies reluctance to make a trip where if the time travel increases, riders opt out of the trip. For the latter, the factor addresses adjustment by which travelers interchange their individual trips. The constraint for the model is total production must equal total attraction which balances the model.

In study conducted by (Dong , Liu, & Lin, 2014) to reduce range anxiety in electric vehicle users, the team created a model that optimized the location of public chargers while simulating driver travel and charging behavior. In the research, multiday driving data were collected from 445 instrumented gasoline vehicles in the Seattle metropolitan area, the United States of America which was used to simulate regional EV drivers' travel and charging behavior so as to quantify the benefits of building public charging infrastructure in reducing range anxiety and increasing electric mile. The range anxiety was quantified on the basis of number of interrupted trips and missed vehicle miles (based on the original intended trip). The findings of the study showed that very few trips were recorded as missed trips but it was assumed that the gasoline vehicle drivers would have same driving behavior once the drivers switch to EV. The expected detours to nearest charging station phenomenon were excluded.

Ahn and Yeo in 2015 conducted study to estimate the optimal density of Charging stations for electric vehicles in Daejeon city, South Korea that covered an area of 539.97 km^2 with a population greater than 1,550,000. The study formulated a model that charging station density on the basis of number of charging stations per square km area. Delay time to charging and additional access time to nearest charging point were considered to determine the optimal density in reduced cost. The same model was implemented in the city of Daejeon where the city was divided into small 1km X 1km square boxes, and real travel data were collected from EV taxi's plying in the city. The researchers found that 111 charging stations were required in the city. In this case, the EV taxi drivers were assumed not having range anxiety, (Ahn & Yeo, 2015)

Similarly, Shukla and co in 2011 conducted research to site refueling stations for alternative fuel vehicles in Alexandria, Virginia, the United States of America. The research is based on modified form of flow interception facility location. The modified form includes nodes (the starting and end locations), path route taken by individual vehicle, traffic on each path, and cost of each refueling station. The study found that traffic interception increment occurred on first few station and further increase in stations meant rise in investment and diminishing return with each additional station. It concludes to set up very few stations which increased interception, high visibility and lower range anxiety. (Shukla, Pekny, & Venkatasubramanian, 2011)

In another research conducted by Ying-Wei Wang in Taiwan, 2007, the researcher focused in locating optimal number for recharging stations for electric scooters in the historic and tourist attraction island of Magong. As the author has based the research assuming the range of electric scooters depend on battery charge time, riding behavior, roadway environment, time spent at destinations, travel time, and constraints of locating recharging stations at each destination, recharging time, and fleet scale. The model used in the paper is concentrated on locating sufficient number of recharging stations at minimum cost. The constraint used in the model were stay length in any destination point, the status of scooter to recharge in any journey, and minimum time required to recharge to have the scooter back on road. The study has incorporated the most used routes that tourist take to reach the different attraction points and time spent in that destination. The inputs were fed into LINDO's branch and bound method obtain solution. The study conclude that the number of recharging station is strongly linked with the time span tourist spent on certain destination points. Similarly, the arriving fleet of scooters into a destination is another factor that influence the number of recharging station. (Wang, 2007)

Nie and Ghamani in their 2013 study (Nie & Ghamami, 2013) considered long corridor to determine the number of charging stations and charging units in each in objective to reduce social cost. It was noted that 90W charger in the charging station help reduce social cost. The optimization model used focused on travelling through a long corridor that was enough to trigger range anxiety so that total cost of charging stations and batteries are minimized while maintaining the level of service. The level of service in the paper is defined as the time required to regain sufficient battery energy to continue the trip. The model assumed that all trips to have origin and destination as two of the either end points. And, each station thus placed be capable of servicing all trips. The paper assumed that every charging point denoted would be able to service all vehicles considered in the study. If applied on real scenario, the formulation wouldn't be fruitful. Based on the pitfall, the researchers along with Zockaie in 2016 presented a paper that worked on the same corridor model, now addressing the queuing congestion at the charging station. (Ghamami, Zockaie, & Nie, 2016)

In another study by Nicolos and Co in 2004, the researchers used Geographic Information System (GIS) to locate and site hydrogen fuel refilling station in Sacramento County, California, the United States of America. The model first developed a composite map using GIS, existing petrol and diesel fuel station, traffic flow and driving time estimate for individual traffic analysis zones. The composite map was then used a set to create subsets of the potential sites on the basis of the minimization of average driving time. (Nicolas, Handy, & Sperling, 2004)

In a research published in 2017 by Jing and Co, the paper focused on addressing the path choosing behavior of EV riders in a transportation network and addressing the equilibrium flow of these vehicles as well. The objective of research was to maximize the coverage of EV flows in the network via locating optimal numbers of charging stations in different segments of the network. The problem was bound under certain budget and based on mixed integer non-liner program. The study was structured as 'Leader-Follower Stackelberg'game where decision makers are the authority that define the location of charging stations and followers are characterized as EV users who choose path freely. The authors point out that charging decision of EV users depend upon stochastic nature of range anxiety, initial battery level, battery capacity, and battery energy to distance covered ratio. The research concludes that the equilibrium traffic flow are affected by charging speed, range and availability of charging stations and riders are inclined into populating segments with charging stations, and with less charging time. (Jing, An, Ramezani, & Kim, 2017)

In 2020 Kadri and Co, studied on ways to locate EV charging stations to accommodate as much recharge demand as possible using the available investment resource. The paper focused on uncertainty of recharge demand considering number of EV and set of long distance trips to over a multi-period horizon. The paper used multi-stage stochastic integer programming approach based on scenario tree to represent the uncertainties in recharge demands. The location for charging stations were determined using Flow Refueling Location Problem (FRLP) algorithm which focused on maximizing flow coverage area of station constrained by budget. The FRLP was enhanced by forecasting charging demands overs time horizon using multi-stage integer program. In order to reduce computational time of the model, Bender's decomposition model and genetic algorithm were used. (Kadri, Perrouault, Boujelben, & Gicquel, 2020)

Jingzi Tan worked on designing a framework to locate EV charging stations in a urban network with demand uncertainty. The study used a multi-stage stochastic model where the first stage focused on minimizing total cost of opening facilities while second stage focused on capturing the maximum flow with different demand. Further in the third stage, the problem was remodeled to capacitated flow capturing location allocation problem to account the overflow at the facilities. Finally, the last step emphasized on defining user oriented optimal where the paths and demand become certain. (Tan, 2013)

A study published in 2021 by Shabber and Co presents Grey Wolf Optimization algorithm to allocate most optimal locations for charging stations. The study, also, used Markov chain network to estimate demand on charging station on the basis of birth and death model. The researcher assumes the birth to be arrival rate to the station follow Poisson process, and death the charging rate. The resulting queue for a particular station is defined using Little's Law. (Shabbar, Kasabeh, & Ahmed, 2021)

Csonka and Csiszar has defined ways to locate charging stations on intercity route from Budapest to Nyiregyhaza, Hungary. The paper focused on defining strategically important sites for charging stations considering traffic volume, and space availability. A negative factor is considered as well which depends on distance from the appointed charging station location. (Csonka & Csiszar, 2017)

Sathaye and Kelly in 2013 paper provided guidelines to estimate the optimal charging station density rather than exact locations of the stations. The optimization model factored in the traffic flow at peak hours of the day to find the minimum quantity charging infrastructure which ensured that charging ports would be available during the peak traffic period. The model targeted to reduce range anxiety among electric vehicle users driving on the route, as well as delays caused due congestion at charging stations. Demand uncertainty in this case has been neglected due to lack proper documentation and the authors argue the model can adopt to data that can feed later when the driving demand data is more stable and ample. (Sathaye & Kelley, 2013)

2.3.Electric Vehicle Charging Behavior

Electric vehicle charging behavior is broadly divided into three categories in a study (Bi, Xiao, Viswanathan, & Knoll, 2016). The behaviors are named as Zero Estimation Model (ZEM), Semi Estimation Model (SEM), and Full Estimation Model (FEM). All three behavior differ from one another on the basis of information the user has beforehand, mainly SOC threshold, safety margin and number of charging station on the trip. The results show that EV owners tend to charge more if they hold a 20% safety margin which also leads to 80% occupancy of charging stations on average.

Based on a survey conducted (Pareschi, Küng, Georges, & Boulouchos, 2020), the participants plugged in their respective electric vehicle once the battery's SoC dropped below 60% on average. A deviation of 20% was observed as well. Similarly, a 2017 study that focused on prediction of electric vehicles charging demand in the city of Seoul, South Korea assumed vehicle considered on the study charge only when the SoC level fell in between 20% to 30% (Arias, Kim, & Bae, 2017).

In terms of charging behavior, a study in Beijing, China showed that over half of 600 respondents in the survey wanted to charge with 1/3th range left in the vehicle. Also, 70% of the participants were comfortable with waiting time of 5 minutes to 10 minutes in a charging station. And, about 18% responded to waiting till 15 minutes to have their vehicle charged. (Zhuge, Shao, & Li, 2019)

2.4.Vehicle Data Logging Infrastructure

A controller area network (CAN) bus is a high-integrity serial bus system for networking intelligent devices. CAN was developed by Bosch in 1985 for in-vehicle networks. Point-to-point wiring system was used to connect electronics devices by automotive manufacturers in past. Manufacturers began using more and more electronics in vehicles, which resulted in bulky wire harnesses that were heavy and expensive. They then replaced dedicated wiring with in-vehicle networks, which reduced wiring cost, complexity, and weight. CAN, a high-integrity serial bus system for networking intelligent devices, emerged as the standard in-vehicle network. The automotive industry quickly adopted CAN and, in 1993, it became the international standard known as ISO 11898. Since 1994, several higher-level protocols have been standardized on CAN, such as CANopen and DeviceNet. (Engineer Ambitiously, 2022).

CAN devices transmits data across the network in packets called frame. Each frame consists of 0 to 8 bytes of data field where signals get stored. Combination of byte location refer to certain specification of information.

CHAPTER THREE: METHODOLOGY

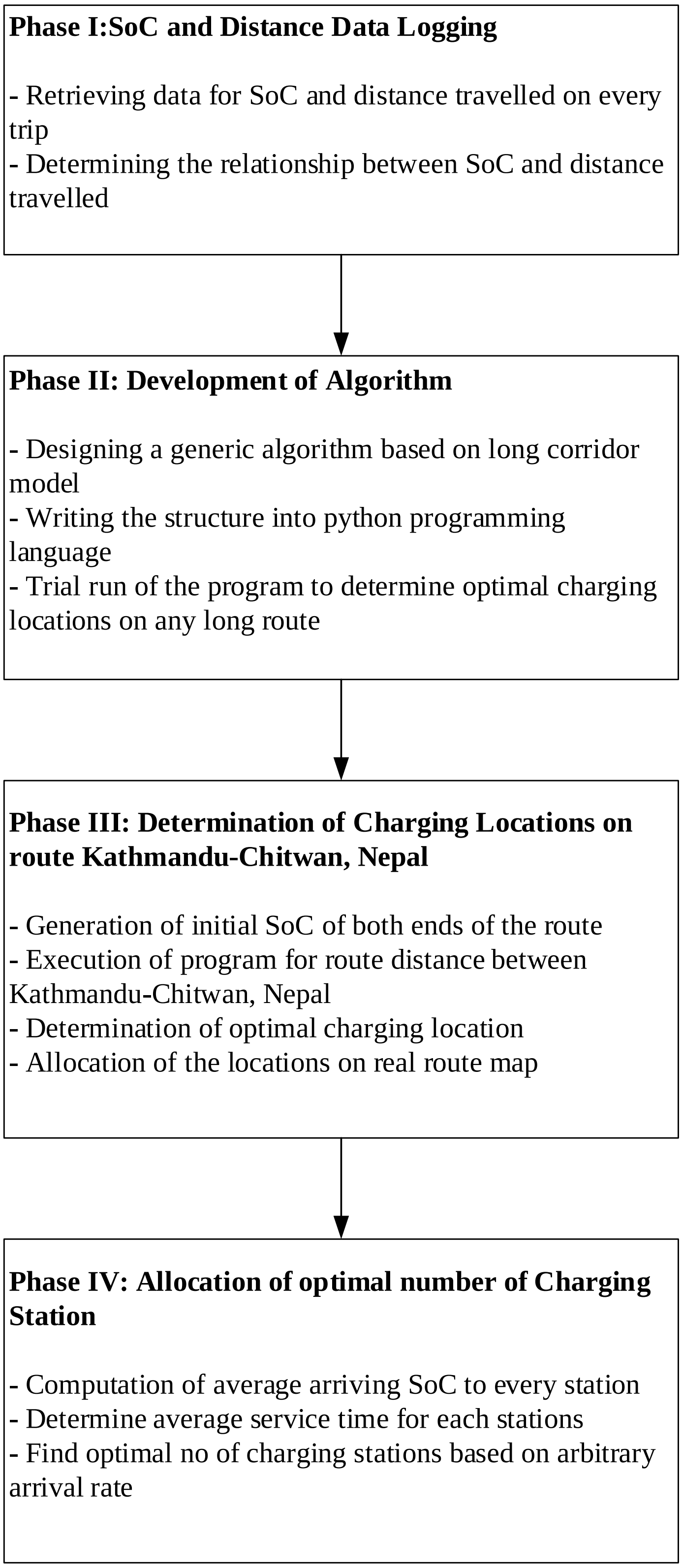

Figure 3.1: Research Methodology

The purpose of the study is clearly defined in the research project. Placement of charging stations for electric vehicle in appropriate places and optimal numbers can benefit both the service providers as well as the riders, and these conclusions can be robustly defended by the literatures presented in the prior chapter. The papers have used several models and formulations to determine the optimal number of charging stations based on the situation and constraints of the study. The methodology used in this study can have roots into different models reviewed, and specially more into model that defines end to end long corridors. Long corridors simplify the scope of study, and builds on the notion of completing the trip. The long corridor, also, eliminates the inclusion of diversion and nodes of traffic which can add complexity into the study. The methodology for the research is based on long corridor where the rider is unable to complete its trip on a single full charge.

The research is divided into major four phases. The four phases are: data logging and calculation, development of algorithm, determination of charging locations on route Kathmandu to Chitwan, Nepal, and allocation of optimal number of charging stations on the locations. The phases are briefly described below.

- Phase I: SoC and Distance Data Logging
- Phase II: Development of Algorithm
- Phase III: Determination of Charging Locations on route Kathmandu-Chitwan, Nepal
- Phase IV: Allocation of Optimal number of Charging Station

3.1.Phase I: SoC and Distance Data Logging

The first phase of the research deals with getting real trip data of Yatri Motorcycles' P1 model. The bike is taken on test ride on different route with same rider and driving characteristics to log the relationship between SoC and Current, Speed, and Distance travelled. The CAN protocol present in the bike stores the information within a 8 bit frame which has unique CAN Id. For example, 0X18CF**** is the unique CAN id for distance where first four bits store odo value and last four trip value against millisecond as time value. Then, the CAN data retrieval program tabulates the data in .txt file which is then converted to .csv. The data in .csv are in hexadecimal, which is converted into integer decimal via a program.

According to the flow presented in Figure 3.2, data for different trips would be collected and converted into useable form. The results would then be used to consider the relationship between SoC level and distance travelled.

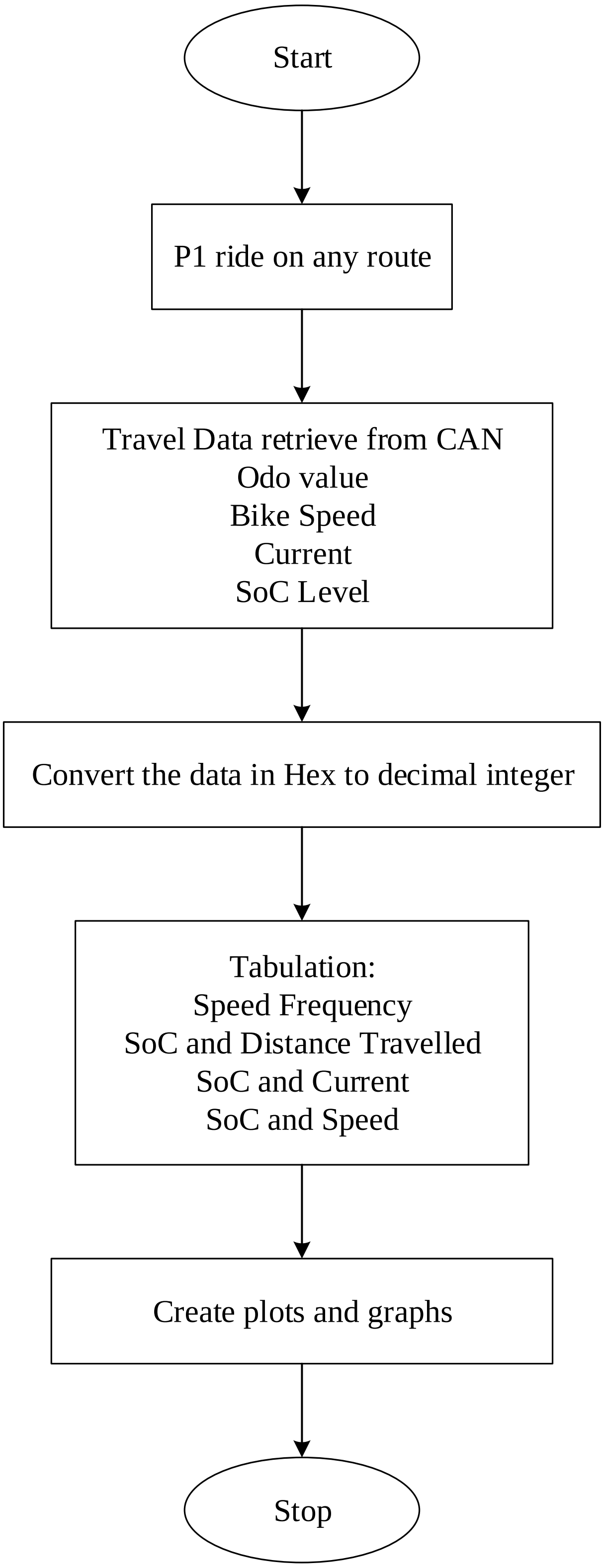

Figure 3.2: Flowchart to log and retrieve test ride data

3.2.Phase II: Development of Algorithm

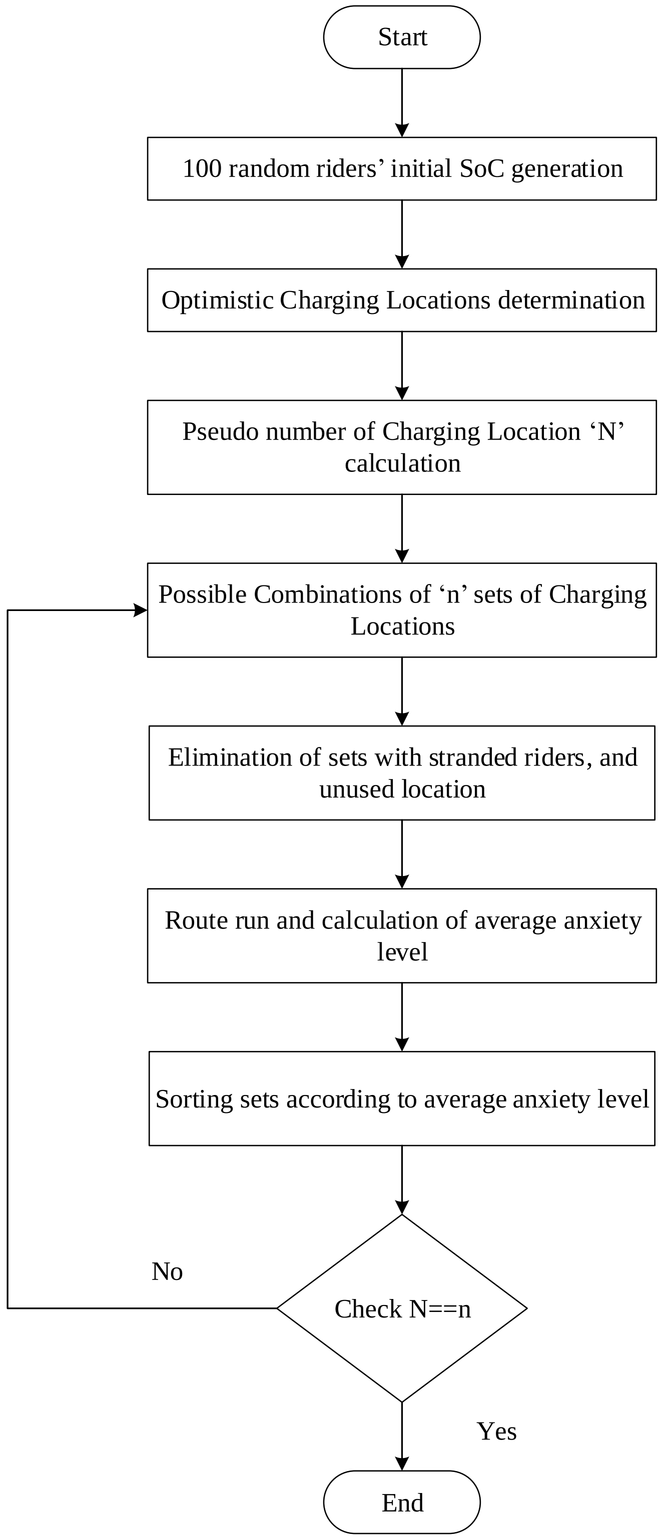

Figure 3.3: Flow of generic algorithm

The second phase majorly focuses on designing an algorithm to determine optimal charging locations for Yatri Motorcycles' P1 model on any long corridor that isn't able to complete its trip on single charge, and in case of P1 it is 100km. The algorithm formed is coded into python language. The output of the program provides optimal charging locations for P1 model on any route that give range anxiety to users.

The flow of operations of the algorithm is as shown in Figure 3.3.:

- Determination of optimistic charging locations
- Determination of maximum number of charging locations along the route
- Determination of sets with combinations of charging locations
- Elimination of sets with stranded riders
- Calculation of Average Range Anxiety level for sets with no-stranded riders
- Sorting the sets according to least range anxiety level measure

The formulations and details of the step are described on Chapter Four. Once, the model is ready, the programmed is test on a trial distance of 200km.

3.3. Phase III: Determination of Charging Locations on route Kathmandu to Chitwan, Nepal

Phase III focuses on applying the program written previously into a specific case: Route Kathmandu to Chitwan, Nepal. The charging locations are pinned out on real maps to check if the locations are suitable for charging or not. The methods used is model developed in Phase I, the only thing that differentiates is initial SoC level generation at starting point. For initial SoC level generation at Nagdhunga, Kathmandu and Nrarayanghat, Chitwan different residential and commercial areas of Kathmandu and Chitwan are pointed out. The distance between these points and starting point is noted, then SoC level depletion is calculated. The range of SoC level obtained is initial SoC level.

3.4.Phase IV: Allocation of Optimal Number of Charging Stations on the Locations

The last stage of the study concentrates on calculating the optimal number of stations to be placed on the locations found in earlier phase. The model used is based on M/G/s queuing model where the arrival rate is exponentially distributed whereas the service rate is generally distributed. A sample rate is considered in the model, and the service rate is determined from average incoming SoC of riders into the station. The optimal number of servers (in this case charging station) is calculated. The model is based on excel, and developed by D. Gross, J.F Shortie, J.M Thompson, and C.M Harris, authors of book, Fundamentals of Queueing Theory.

CHAPTER FOUR: ALGORITHM AND MODEL

4.1.Electric Vehicle Consideration

For the study, Yatri Motorcycles is chosen as vehicles to be used in the study. According to Yatri Motorcycles official website (Yatri Motorcycles, 2020), the company have, currently, two models in the market: Project Zero and Project One.

The specification of the chosen vehicle is listed in Table 4.1. Project 1 is quoted to have range of 110 km per full charge which charges from 20% up to 80% SoC in 40 minutes. These data are crucial for the study as number of charging stations and distribution depend on these.

Table 4.1: Yatri Motorcycles' P1 Specifications

S.No	Description	Value
1	Peak Power	14 kW (19 hp)
2	Range	110 km
3	Top Speed	100 kph
4	Battery Capacity	3.0 kWh
5	Fast Charge	40 minutes (80% SoC)
6	Home Charge	2 hours (100% SoC)

(Source: https://yatrimotorcycles.com/project-one)

4.2.Cost of DC Fast Charger

Yatri Motorcycles' P1 model can be charged with normal 16A AC socket, which is termed as AC charging. According to the company, the motorcycles has an Onboard Charger which charges the motorcycle to 100% from 20% in about 2 hours. The charging infrastructure considered for the study is DC fast charging. The fast charger is capable of charging the bike in 40 minutes from 20% to 80%. The fast charger is rated at 3.3kW capacity. It uses Jnicon Model 23 IP67 rated charging port that is capable of delivering 70A maximum current (Alibaba.com, 2022).

Table 4.2: Cost of DC Fast Charger

S.No	Component	Price
1	Housing and Post Component	25000
2	Charger and Electrical Component	70000
3	Electronics Component	45000
4	Contingency	5000
5	Maintenance and Service	10000
6	Setup Cost	12000
	Total	**167000**

(Source: Yatri Motorcycles)

Yatri's DC Fast Charger is an entire package with mechanical, electrical and electronic component. The mechanical component comprises the external housing and post, the housing hosts the electric 3.3kW charger, and other electronic boards. According to the company, it would cost around NRs 1.7 lakh just to setup a single DC charger.

4.3.Assumptions for Algorithm

The algorithm developed is based on certain assumptions which were considered to simplify the design process without significantly hampering the motive the research. The considerations assumed during designing the algorithm are as follows.

- Yatri Motorcycle's P1 model is chosen for the study
- The study assumes that EV would decide to recharge up to 100% once the current SoC level fall below 50%. (Arias, Kim, & Bae, 2017) (Pareschi, Küng, Georges, & Boulouchos, 2020)
- The relationship between distance covered and SoC level decrement is in 1:1 ratio based on test ride data conducted in Phase I.
- Charging decision is independent of proximity of destination.
- 100 P1 users with variable initial SoC level at both the end points (A and B)
- Variable initial SoC level defined between range of 90% to 70%
- Range anxiety trigger when SoC drops below 50% (Pareschi, Küng, Georges, & Boulouchos, 2020) (Zhuge, Shao, & Li, 2019)
- Assumed range of P1 on full charge =100km
- Minimum distance between consecutive charging locations = 25km
- Maximum distance between consecutive charging locations = 50km

- Minimum distance between Point A and first station location = 25km
- Maximum distance between Point A and first station location = 50km
- Minimum distance between Point B and nth station location = 25km
- Maximum distance between Point B and nth station location = 50km
- Battery Capacity = 3300 Wh
- Energy consumption per km = 3300/100 = 33Wh/km
- Power dissipation and SoC level relationship: 1% = 33Wh/km
- Numerical figures for range anxiety is provided in Table 4.3

4.3.1. Range Anxiety

Range anxiety is the most crucial parameter in the study because the main objective of the study is to create an environment where every user reaches their destination without or getting very minimal range anxiety. In order to quantify this feeling, a finite numerical value is assigned to certain bracket of SoC level as shown in Table 4.3

Table 4.3: Quantitative values for Range Anxiety

S.No	SoC Range at recharge (%)	Anxiety Value
1	50-46	1
2	45-41	2
3	40-36	3
4	35-31	4
5	30-26	5
6	25-21	6
7	20-16	7
8	15-11	8
9	10-6	9
10	5-0	10

4.4.Stages of Algorithm

The algorithm developed to find the optimal locations of charging stations along any long corridor is designed into different segments of programming modules. The output of every module acts as input for the adjacent module in the programming flow. The modules can be listed as below.

- Determination of optimistic charging locations

- Determination of maximum number of charging locations along the route
- Determination of sets with combinations of charging locations
- Elimination of sets with stranded riders
- Calculation of Average Range Anxiety level for sets with no-stranded riders
- Sorting the sets according to least range anxiety level measure

4.4.1. Determination of Optimistic Charging Location

Optimistic charging location is defined as every location where the riders' SoC level drops to 50%, and the SoC level is recharged to 100%. Riders start the route with randomly generated initial SoC level within a range, and run through the route from both ends. Every location where SoC level drops to 50% is listed for Optimistic Charging Location. The flowchart of the algorithm is present in Appendix 2.

4.4.2. Determination of pseudo number of charging locations along the route

The base numbers of charging locations for the model is calculated from Equation 4-1

$$\text{Base Number of Charging Locations} = \text{Round}\left(\frac{Distance\ of\ Route}{Range\ x\ 0.8}\right) \qquad \text{Equation 4-1}$$

The divisor is considered such that base number of charging locations would be spaced at least on range distance. Along with range, a factor of 0.8 is multiplied with the divisor to account the fact that vehicle start the trip with average SoC of 80%.

Similarly, the limiting number for the model to calibrate the suitable number of charging locations is given by Equation 4-2

$$\text{Limiting Number of Charging Locations} = 2\ \text{X Base Number of Charging Location} \qquad \text{Equation 4-2}$$

The limiting number is assumed to be two times the base number of charging locations because having charging locations spaced at half the range distance is the most favorable solution.

4.4.3. Determination of sets with combinations of charging location

The module to determine sets with combinations of charging locations develops sets with members ranging from minimum to maximum number calculated previously. The members of the set are formed following a criterion where distance between consecutive charging locations are between 25km and 50 km. Also, the distance between first station location and starting point ‘A’ must be within 25km to 50km. And, same case for Point ‘B’ and nth station location. The flowchart for the algorithm is given in Appendix 3

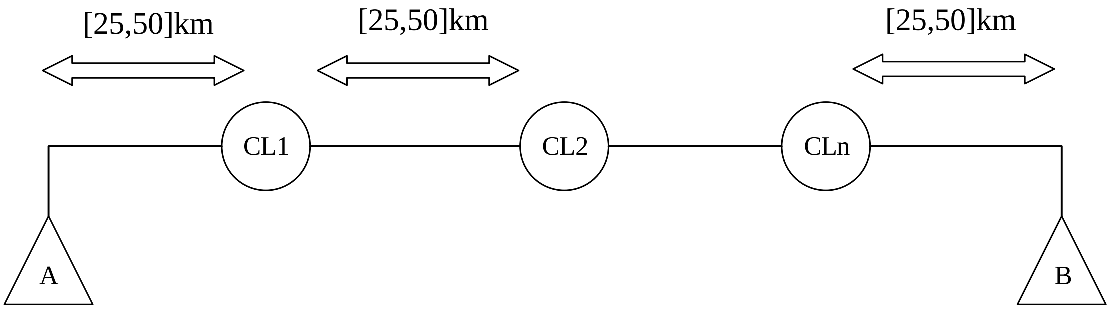

Figure 4.1: Criteria for making sets of charging locations

4.4.4. Elimination of sets with stranded riders, and unused location

In this module, the riders with random initial SoC level run through the route considering the members of set as charging locations. If any one of the riders don’t complete the trip, the set is omitted. A new collection of sets is formed after the elimination process.

The sets are once again filtered on the basis of usability of the location. If any charging location on any set has zero riders using it, the set is eliminated as well. After the module, the quantity of sets is reduced to sets with most feasible locations. The module’s flow is presented in Appendix 4.

4.4.5. Calculation of Average Range Anxiety level for sets with no-stranded riders

The sets with most feasible locations is tested with the same riders riding along the route. Based on SoC level upon reaching the charging location while there is need for recharge, anxiety level is calculated. For each set, average range anxiety level is calculated, along with average ending SoC level at end of route. The modules working is presented in Appendix 5.

4.4.6. Sorting the sets according to least range anxiety level measure

On the basis of average anxiety level, the sets are listed in ascending order. The set with least range anxiety level is the optimal solution. If there are two or more possible locations with same anxiety level measure, these are further sorted on the basis of highest average ending SoC level. The members are the best charging locations for the route.

4.5.Trip Model (Kathmandu-Chitwan Route)

The algorithm is implemented into a specific route: Kathmandu to Chitwan, Nepal. The distance along the route is 132km long. And, the route is capable to give range anxiety to the P1 users as the range of bike is 100km (assumed for study). The route's point A is located at Nagdhunga Check Post, Kathmandu, whereas point B is pinned at Narayanghat Bus Park, Chitwan.

4.5.1. Initial SoC Generation

The generic algorithm is developed with consideration that the initial SoC of every rider at start of trip be within 70% to 90%. Rather than simply assuming the consideration, initial SoC for Kathmandu-Chitwan is calculated on the basis of distances of different places within the Kathmandu valley and Nagdhunge Check Post.

For calculation, eighteen different locations are taken under consideration: Budanilkantha, Sano Thimi, Khokona, Mahalaxmi, Boudha, Kirtipur, New Road, Patan, Kalanki, Sitapaila, Sanepa, Kapan, Dadikot, Bhaktapur, Harisiddhi, Purano Naikap, Jorpati, and Balkhu. Distance and approximate SoC level a motorcycle can attain reaching Naghdhunga Check Post is shown in Table 4.4

Table 4.4: Distance and SoC level attained on reaching Naghdhunga Checkpoint

S.No	Location		Distance(Km)	End SoC (%)
1	Budanilkantha	Naghdhunga Check Post	22	78
2	Sano Thimi	Naghdhunga Check Post	22	78
3	Khokona	Naghdhunga Check Post	16	84
4	Mahalaxmi	Naghdhunga Check Post	20	80
5	Boudha	Naghdhunga Check Post	25	75
6	Kirtipur	Naghdhunga Check Post	16	84
7	New Road	Naghdhunga Check Post	13	87
8	Patan	Naghdhunga Check Post	14	86
9	Kalanki	Naghdhunga Check Post	8	92
10	Sitapaila	Naghdhunga Check Post	12	88
11	Sanepa	Naghdhunga Check Post	13	87

S.No	Location		Distance(Km)	End SoC (%)
12	Kapan	Naghdhunga Check Post	20	80
13	Dadikot	Naghdhunga Check Post	26	74
14	Bhaktapur	Naghdhunga Check Post	27	73
15	Harisidhi	Naghdhunga Check Post	18	82
16	Purano Naikap	Naghdhunga Check Post	7	93
17	Jorpati	Naghdhunga Check Post	23	77
18	Balkhu	Naghdhunga Check Post	10	90

Using the data, the SoC levels of 100 bikes are synthesized using random number generator between 73 and 93. The mean of 83% and standard deviation of 6.1 was obtained.

Table 4.5: Distance and SoC level attained on reaching Narayanghat Buspark

Sno	Location		Distance (km)	SoC (%)
1	Sauraha	Narayanghat Bus Park	18	82
2	Tandi Bazar	Narayanghat Bus Park	14	86
3	Padampur	Narayanghat Bus Park	9	91
4	Rampur	Narayanghat Bus Park	12	88
5	Megauli	Narayanghat Bus Park	27	73

For initial SoC level at point B i.e. Narayanghat Bus Park, Chitwan the same random values generated for point A is used. Table shows the starting points i.e. major residential and commercial sectors of Chitwan fall within 30km to 10km from Narayanghat Bus Park, Chitwan.

4.6.M/G/c Queuing Model

Queuing theory in management science terminology represents the body of knowledge that deals with waiting lines. (Ragsdale, 2008) There are different models of queuing theory, which differ based on characteristics of arrival rate and service rate, and number of servers. The model used for the study is M/G/s, the Kendell-Lee notations mentioned defines M as inter arrival times are random variable having an exponential distribution. Similarly, G as service times that follow some general distribution, and c as number of servers in the system.

Let us assume,

Arrival Rate (λ) = a

Service Rate (μ) = b

Absolute Maximum Number of Servers (c_{max}) = C

Target Overflow Probability (p_c) = P

Optimum number of Servers = C_{opt}

So we have,

Mean Inter-arrival time ($1/\lambda$) = 1/a — Equation 4-3

Effective Arrival Rate (λ_{eff}) = a X (1-P) — Equation 4-4

Server Utilization (ρ_{eff}) = λ_{eff} / (C_{opt} X μ) — Equation 4-5

Using the formulations presented, optimum number of servers are calculated. In the model, arrival rate and service rate for each charging locations remain constant, whereas target overflow probability is variable.

For the study, the arrival rate at peak is considered to be 3 bikes/hour. The service rate for the model is calculated on the basis of average arriving SoC level of every motorcycles when charge is initiated. The arriving SoC level provides the estimated time to recharge the motorcycle at every station.

CHAPTER FIVE: RESULTS AND DISCUSSION

5.1.Test Ride Data

5.1.1. Kathmandu-Chitwan-Kathmandu First Test Ride

Table 5.1: Trip data Kathmandu-Chitwan-Kathmandu

Kathmandu-Chitwan	Odo	SoC	Distance/SoC
Trip 1	389	100	
	463	39	
	74	**61**	**1.21**
Trip 2	463	74	
	512	25	
	49	**49**	**1**
Trip 3	512	71	
	548	35	
	36	**36**	**1**
Return			
Trip 4	0	100	
	55	35	
	55	**65**	**0.85**
Trip 5	77	44	
	88	33	
	11	**11**	**1**
Trip 6	88	91	
	121	49	
	33	**42**	**0.79**
Trip 7	122	78	
	157	27	
	35	**51**	**0.69**
	Average		**0.93**

The 1st trip data is taken from the test ride between Kathmandu-Chitwan-Kathmandu conducted from 8th December, 2021 to 9th December, 2021 with a 70 kg rider. In this case CAN data wasn't logged, but SoC level and Odo were recorded on charging stops. The data recorded are presented on Table 5.1. It can be observed that the relationship between SoC level and distance travelled is almost linear with distance to SoC ratio of 0.93.

5.1.2. Second Test Ride with Data Logging system

The second test trip was conducted with data logging system, and carried out on 18th and 19th May, 2022. The rider from the first test ride carried out this test ride as well. The trip was between Budanilkantha, Kathmandu and Dhulikhel, Kavre.

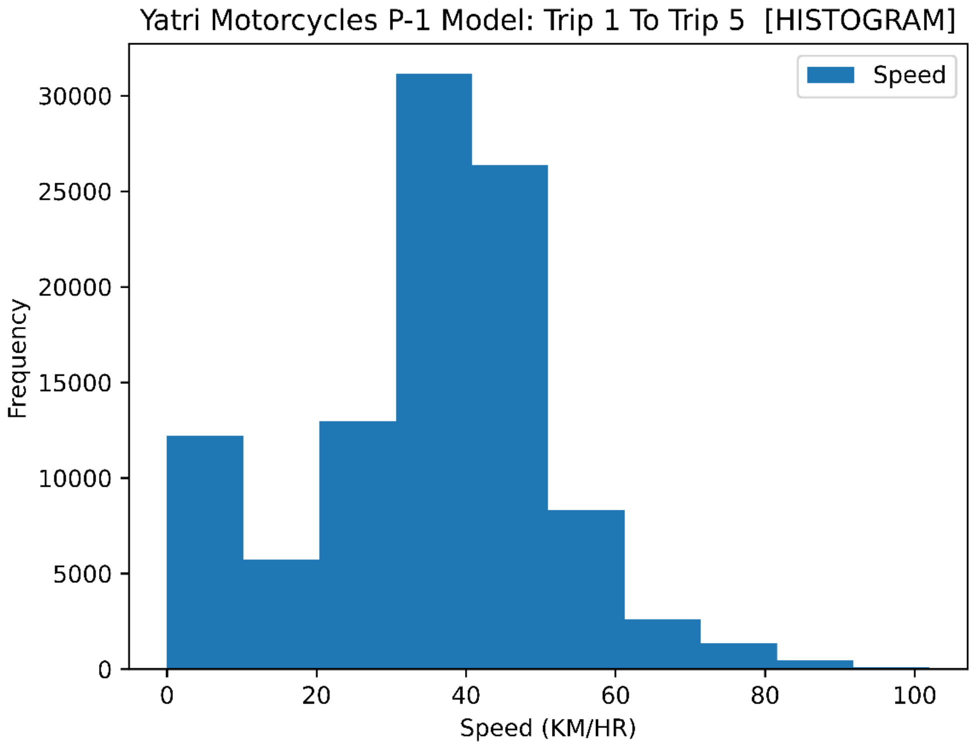

Figure 5.1: Speed histogram for entire second test trip

Figure 5.1 shows the speed histogram for entire second trip. It can be observed that the bike cruised between 30km/hr to 50 km/hr during the entire trip.

The second test ride was completed with 5 trips. The first and second trip were performed on 18th May, 2022, whereas fourth and fifth was done on 19th May, 2022.

Table 5.2: Trip data for second test ride

Trips	**Odo**	**SoC**	**Distance/SoC**
Trip 1	128	46	
	171	9	
	43	**37**	**1.16**

Trips	Odo	SoC	Distance/SoC
Trip 2	171	62	
	209	5	
	38	**57**	**0.67**
Trip 3	209	100	
	285	23	
	76	**77**	**0.99**
Trip 4	285	100	
	325	50	
	40	**50**	**0.80**
Trip 5	325	100	
	376	50	
	51	**50**	**1.02**
		Average	**0.93**

It can be observed from Table 5.2 that the average SoC level to distance ratio is 0.93 for entire test ride. The individual trip's SoC to distance ratio was obtained in range of 1.16 to 0.67.

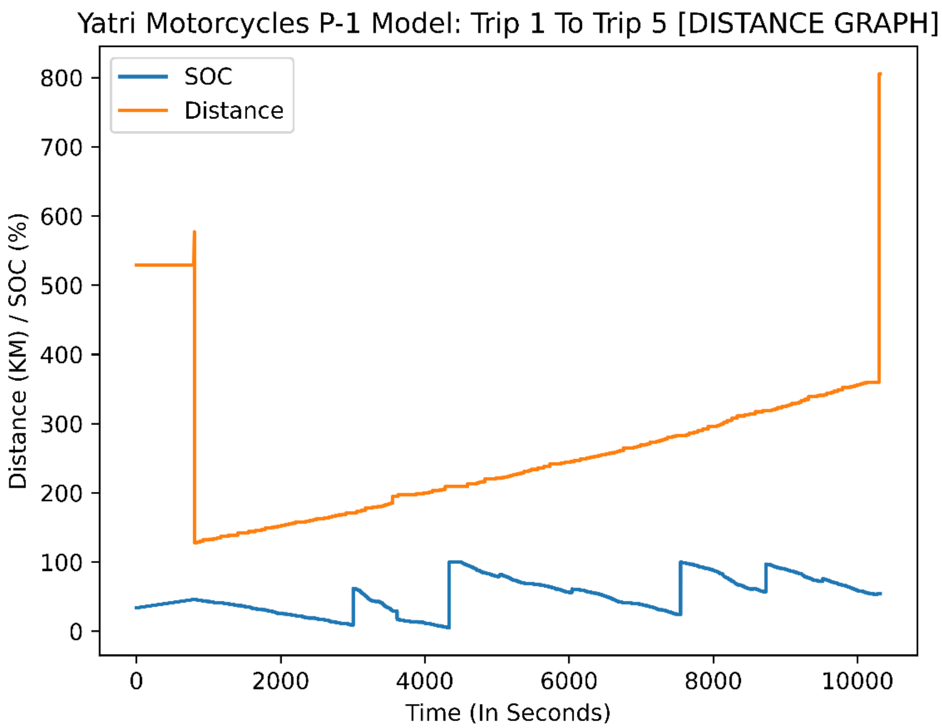

Figure 5.2: SoC and Distance with log time for second test ride

Figure 5.2 shows the graph of SoC level and distance travelled plotted against time. The steep increment along Y axis for SoC level indicates charging, and the same line characteristics is used to differentiate trips as well. For every trip, the relationship between SoC level and distance travelled trends to be linear.

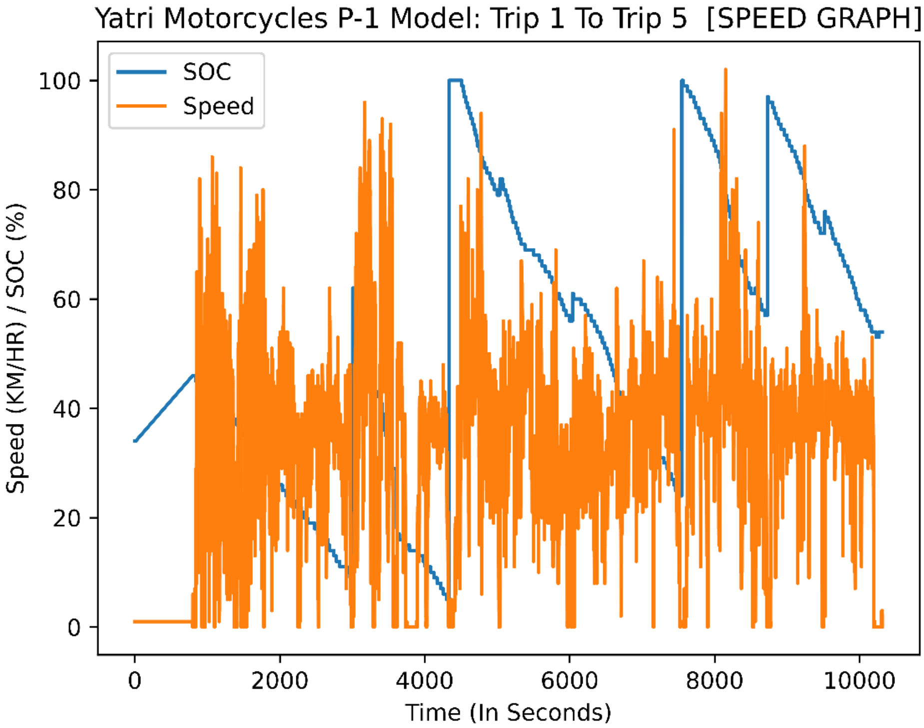

Figure 5.3: Speed and SoC with time log for second trip

The average speed of the vehicle is about 40 km/hr which can be observed from Figure 5.3. The speed line can be seen fluctuating between 0 km/hr, during charging phase, to 100 km/hr, during 4th trip.

5.2.Charging Locations from Generic Algorithm

The model developed is first tested with an arbitrary distance of 200km. The algorithm produces feasible number of charging locations and their distances from the starting point.

5.2.1. Assumed distance 200km

The model developed was tested with arbitrary distance value of 200km,

Table 5.3: 3 Charging Locations on 200km route

S.N.	Number of Locations			Anxiety Level	Ending SoC
	S1	S2	S3		
1	50	100	150	1.97	50

In 200km distance, only a single combination of 3 charging locations is possible due to the distance criteria to locate the locations. The three charging locations are 50km, 100km, and 150km from the initial starting point. The only possible set has anxiety level of 1.97 which means riders arrive at each location with average SoC level of 41%.

Table 5.4: Top 10 list with 4 Charging Locations on 200km route

S.N.	Number of Locations				Anxiety Level	Ending SoC
	S1	S2	S3	S4		
1	28	57	107	157	1.95	50
2	43	93	143	172	1.95	50
3	29	57	107	157	1.96	50
4	43	93	143	171	1.96	50
5	30	57	107	157	1.97	50
6	43	93	143	170	1.97	50
7	31	57	107	157	1.98	50
8	43	93	143	169	1.98	50
9	25	57	107	157	1.99	50
10	26	57	107	157	1.99	50

From Table 5.4 shown above, the program produced charging locations for route distance of 200km. With four charging locations at 28, 57, 107, and 157km from Point A, the riders riding on the route experienced an average range anxiety of 1.95. The figure describes that every rider had around 45% SoC while arriving into the nearest charging location. For the same case, the average ending SoC is 50%.

Table 5.5: Top 10 list with 5 Charging Locations on 200km route

S.N.	**Number of Locations**					**Anxiety Level**	**Ending SoC**
	S1	**S2**	**S3**	**S4**	**S5**		
1	42	67	96	121	150	1.73	53.71
2	50	79	104	133	158	1.73	53.71
3	42	67	96	122	150	1.73	53.72
4	42	67	96	123	150	1.73	53.73
5	42	67	96	124	150	1.73	53.74
6	42	67	96	125	150	1.73	53.75
7	42	68	96	121	150	1.73	53.71
8	42	68	96	122	150	1.73	53.72
9	42	69	96	121	150	1.73	53.71
10	42	69	96	122	150	1.73	53.72

Similarly, for case of five charging location pinned at 42, 67, 96, 121, and 150km from Point A. With the addition of a charging location, the riders experienced an average range anxiety of 1.73. Riders were able to find a charging location with SoC level of around 47%. Also, the average ending SoC level for the trip is found to be 54%.

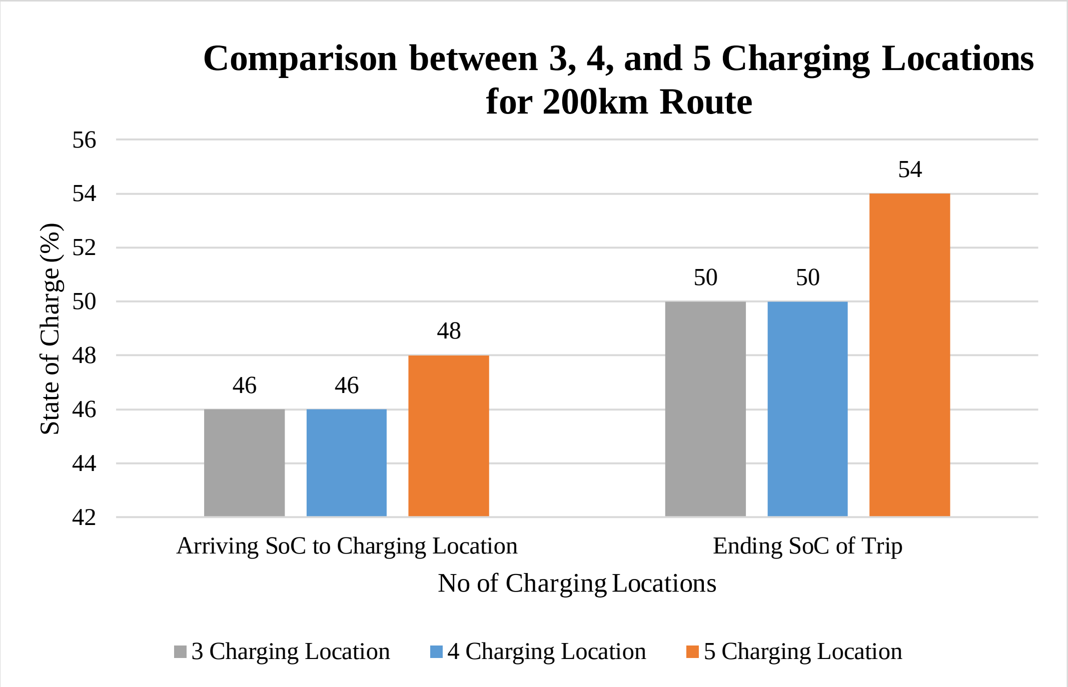

Figure 5.4: Comparison between 3, 4, and 5 Charging Locations

After comparing the results of all three conditions, five charging locations looks feasible because it has the lowest range anxiety level.

5.3.Kathmandu-Chitwan Route

The distance considered for the study is 132km which is distance between Nagdhunga Check Post in Kathmandu to Narayanghat Bus Park in Chitwan. The model predicts to have charging locations within range of two locations to four locations. From Equation 4-1 and Equation 4-2

Base Number of Charging Locations = Roundup (132/100 x 0.8) = 2

Limiting Number of Charging Locations = 2 x Round (132/100 x 0.8) = 4

5.3.1. Two Charging Locations

Table 5.6 shows top 10 prime locations to have two charging locations along the route. The locations are sorted according to least anxiety level.

Table 5.6: Top 10 list with Two Charging Locations on Route: Kathmandu-Chitwan

Sno	Station1 Location	Station 2 Location	Average Anxiety Level	Average Ending SoC
1	43	89	2.6	11.00
2	43	88	2.68	11.50
3	44	89	2.68	11.50
4	42	87	2.71	11.90
5	45	90	2.71	11.90
6	43	87	2.75	12.00
7	45	89	2.75	12.00
8	44	88	2.76	12.00
9	42	86	2.81	12.40
10	46	90	2.81	12.40

The charging locations with least anxiety level is 2.6, so 43km, and 83km assuming Nagdhunga (Point A) as 0 km is the best solution for two charging locations. The average anxiety level among the riders was 2.6, meaning most of the riders reached the nearest charging location with 43% SoC. The ending SoC level for this case is 11%, which is very low.

5.3.2. Three Charging Locations

Table 5.7 shows top 10 prime locations to have two charging locations along the route. The locations are sorted according to least anxiety level

Table 5.7: Top 10 list of Three Charging Locations on Route: Kathmandu-Chitwan

Sno	Station1 Location	Station 2 Location	Station 3 Location	Average Anxiety Level	Average Ending SoC
1	33	58	87	2.16	53.60
2	45	74	99	2.16	53.60
3	32	57	86	2.22	53.02
4	46	75	100	2.22	53.02
5	33	58	86	2.22	53.36
6	46	74	99	2.22	53.36
7	32	58	86	2.27	53.30
8	46	74	100	2.27	53.30
9	32	57	85	2.28	52.80
10	47	75	100	2.28	52.80

The suitable charging locations for three charging locations are 33km, 58km, and 87km assuming Nagdhunga (Point A) as 0 km. The solution is based on least average anxiety level of 2.16 among the riders, which means every rider on average were able to charge their motorcycle when their SoC level were around 45%. SoC level at end of the trip was 53.6% on average.

5.3.3. Four Charging Locations

Table 5.8 shows top 10 prime locations to have two charging locations along the route. The locations are sorted according to least anxiety level

Table 5.8: Top 10 list of Four Charging Locations for Route: Kathmandu-Chitwan

Sno	Station1 Location	Station 2 Location	Station 3 Location	Station 4 Location	Average Anxiety Level	Average Ending SoC
1	27	52	77	102	2.01	63.50
2	27	52	78	103	2.01	64.30
3	29	54	80	105	2.01	64.30
4	30	55	80	105	2.01	63.50
5	27	52	80	105	2.02	66.50
6	28	53	78	103	2.03	63.38
7	27	52	80	105	2.03	66.50

Sno	Station1 Location	Station 2 Location	Station 3 Location	Station 4 Location	Average Anxiety Level	Average Ending SoC
8	28	53	78	103	2.04	63.38
9	28	53	80	105	2.04	65.50
10	27	52	77	103	2.04	64.25

The charging locations with least anxiety level for case of four charging locations are 27km, 52km, 77km, and 102km assuming Nagdhunga (Point A) as 0 km The anxiety level is 2.01 which means riders reach the nearest charging locations with around 45% SoC. The average ending SoC for the case is 63.5% which is good.

5.4.Solution for Charging Location

5.4.1. Anxiety Level and Ending SoC

The route distance between Kathmandu-Chitwan spans over a distance of 132km, where two, three and four locations can serve the charging needs. A comparison between most feasible solution for all the locations numbers is performed. With only two charging locations, the ending SoC at end of the trip is very poor. Riders end their trip with barely 10% SoC, although the anxiety level during the trip is not so high. Riders reach nearest charging location with 43% SoC.

In case of three charging locations, the anxiety level is similar to two charging locations, but the ending SoC measure increased from 11% to 54%. The significant rise in the ending SoC projects three charging location to be more suitable solution. Also, the results for four charging locations along the route is good as well. Although, the anxiety level stays around 2.01, 45% arriving SoC, similar to earlier case, there is visible growth in figures of ending SoC. Ending SoC increased by 9% in comparison to three charging locations.

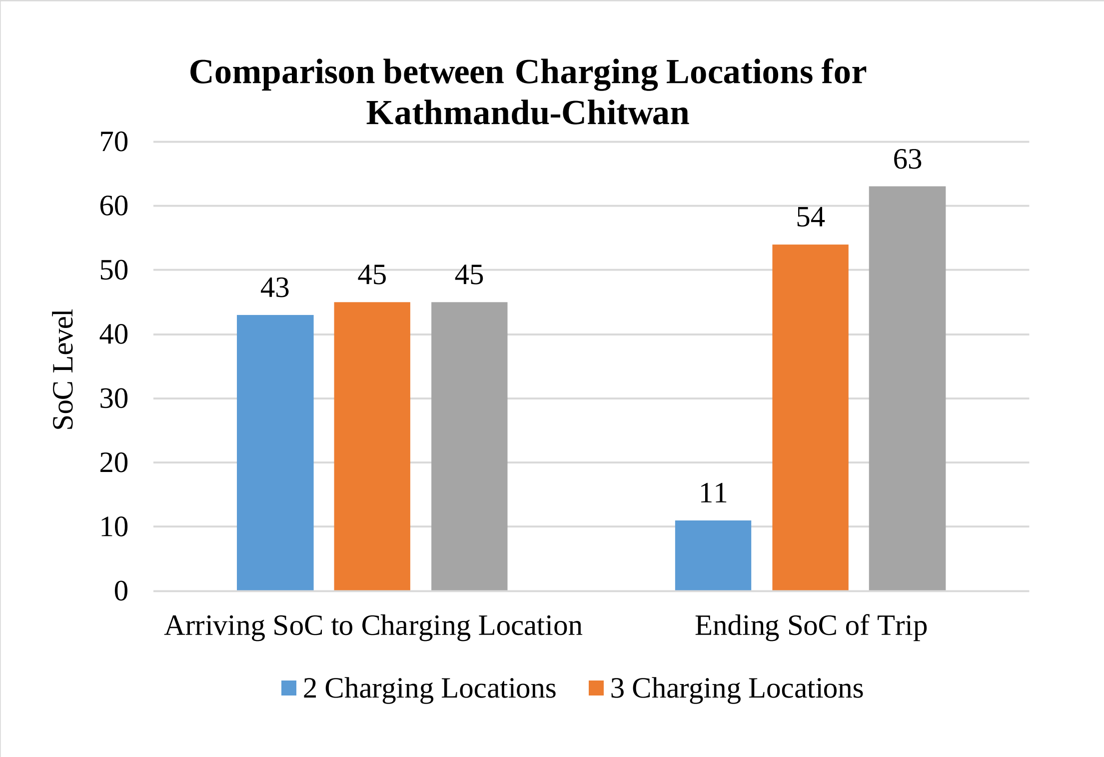

Figure 5.5: Comparison between Charging Locations for Kathmandu–Chitwan

Along with anxiety level, and ending SoC level there are other factors to consider before an optimal solution is found.

5.4.2. Charging Location Usage

Usage parameter of charging location is characterized as charging facilitation count of a particular charging location. The rate of usage is calculated by dividing the charging facilitation count and total number of riders riding on the route. For the case of Kathmandu-Chitwan route, 200 riders were considered. The results of usage and rate of usage aid in analyzing the charging behavior in the route given a certain number of charging locations.

Table 5.9: Usage for Two Charging Locations for Kathmandu-Chitwan

	Station Location	
	S1: 43km	**S2: 89km**
Usage	100	100
Rate of Usage	50%	50%

For two charging locations on route, 100 riders charged in both the locations: 43km and 89km. This implies on route both of the locations have equal rate of usage. A peculiar charging behavior can be observed where a rider charges the motorcycle only once per trip in any of the two stations.

Table 5.10: Usage for Three Charging Locations on Route: Kathmandu-Chitwan

	Station Locations		
	S1: 33km	**S2: 58km**	**S3: 87km**
Usage	151	49	151
Rate of Usage	80%	20%	80%

Three charging locations along the route defines a different charging behavior. Out of 200 riders plying on the route, 49 riders charge only single time throughout the trip, whereas 151 riders charge two times in station location1 and station location3. The rate of usage for each location as shown in Table, are 80% for station location 1 and 3, and 20% for station location 2.

Table 5.11: Usage for Four Charging Locations on Route: Kathmandu-Chitwan

	Station Locations			
	S1: 27km	**S2: 52km**	**S3: 77km**	**S4: 102km**
Usage	93	107	93	107
Rate of Usage	47%	54%	47%	54%

Similarly, usage of station locations for four charging locations along the route are 93, 107, 93, and 107 for charging locations 1, 2, 3, and 4 respectively. A different kind of charging behavior is observed in this case as well where the rider population is split into two distinct categories. One set of users' charge in location1 and 3, and rest of users' charge in location2 and 4.

It is well observed that the charging station locations for every case were underutilized where riders didn't charge in all the available charging locations.

5.4.3. 5% Unit Change in Initial SoC Range

In order to check the robustness of each solution, 5% unit change on both ends of initial SoC range is increased. In previous case, range of 73% and 93% was used. Now, the range is decreased to 68% and increased on other side to 98%. Three sets of 100 random values are synthesized that meets the criteria and loaded as initial SoC level for all three solutions of Kathmandu-Chitwan route.

Table 5.12: Anxiety Level for 4 charging locations with 5% unit change in initial SoC

S.N	Random Data	Average Anxiety Level	Ending SoC (%)
A	5% change A	1.92	60.88
B	5% change B	1.97	63.00
C	5% change C	1.98	61.75
	Mean	**1.96**	**61.88**

The Table 5.12 above present average anxiety level of 1.96 when the riders start with initial SoC level within range of 68% to 98%. The 5% unit change in initial SoC level range decrease the anxiety level, where the riders now can find charging locations when their SoC level has reached 45%. The ending SoC for this case is 62%.

Table 5.13: Anxiety Level for 3 charging locations with 5% unit change in initial SoC

S.N	Random Data	Average Anxiety Level	Ending SoC (%)
A	5% change A	2.37	53.77
B	5% change B	2.46	51.80
C	5% change C	2.34	53.54
	Mean	**2.39**	**53.04**

The Table 5.13 above present average anxiety level of 2.4 when the riders start with initial SoC level within range of 68% to 98%. The 5% unit change in initial SoC level range decrease the anxiety level, where the riders now can find charging locations when their SoC level has reached 44%. The ending SoC for this case is 53%.

Table 5.14: Anxiety Level for 2 charging locations with 5% unit change in initial SoC

S.N	Random Data	Average Anxiety Level	Ending SoC (%)
A	5% change A	3.65	16.52
B	5% change B	3.78	17.44
C	5% change C	3.35	13.76
	Mean	**3.59**	**15.91**

The Table 5.14 above present average anxiety level of 3.6 when the riders start with initial SoC level within range of 68% to 98%. The 5% unit change in initial SoC level range decrease the anxiety level, where the riders can find charging locations when their SoC level has reached 37%. The ending SoC level for this case is 16%.

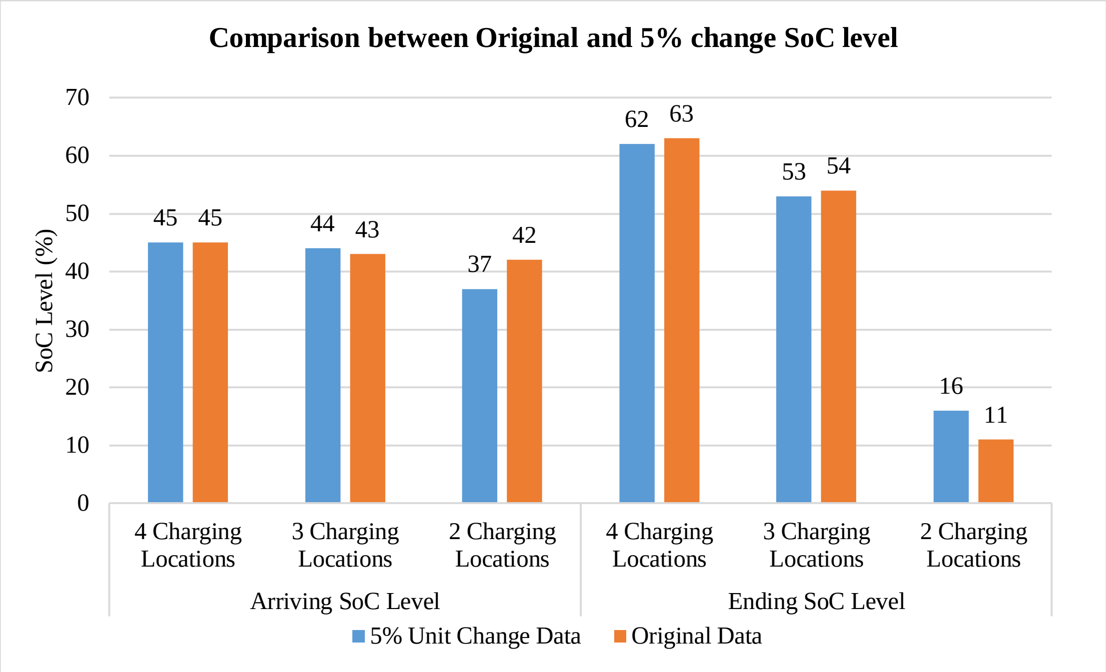

Figure 5.6: Comparison between Original and 5% change in SoC Level Data

The anxiety level for all case show slight changes with not much of difference. For 3 charging locations, arriving SoC level increased by 1% whereas for 4 charging locations, it remained constant. Comparing the ending SoC level for 3 and 4 charging locations, the SoC level remained almost constant.

5.4.4. Recharging up to SoC level 80% behavior

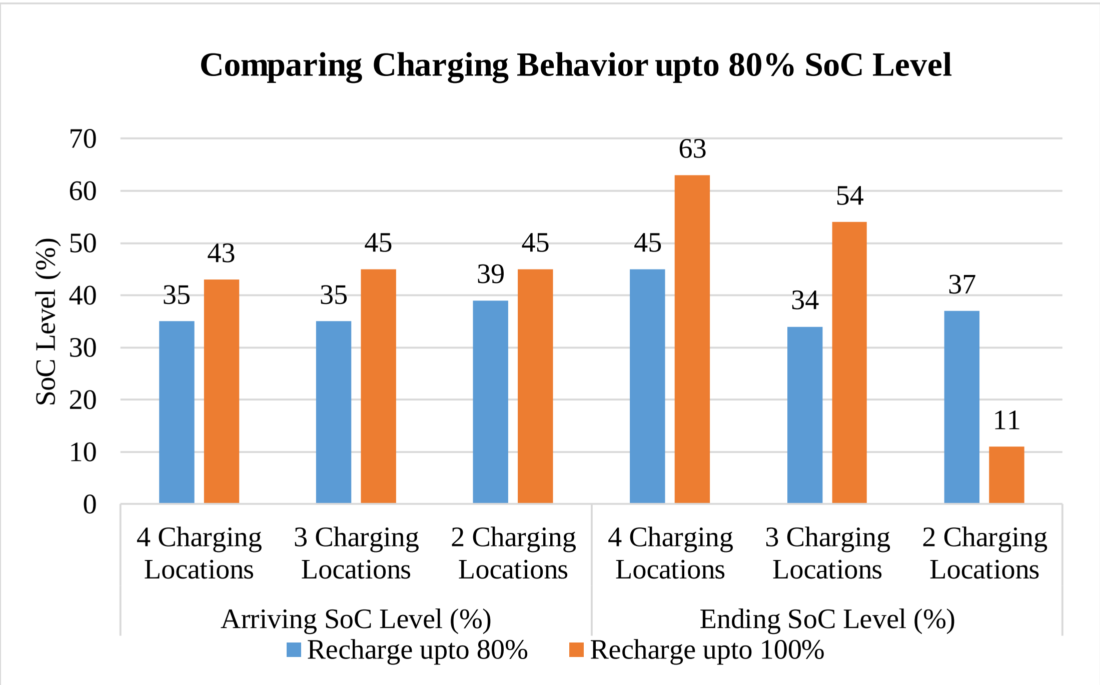

Figure 5.7: Comparing Charging Behavior up to 80% SoC level

The model is fed with new charging behavior where the users would charge their motorcycles up to 80% only. This behavior is considered because the fast charger charge is possible between SoC level of 20% and 80%.

Figure 5.7 shows comparative values of arriving SoC level and ending SoC level for both charging behavior: charging up to 80% SoC level, and charging up to 100% SoC level. It can be observed that in every case there is a drop in arriving SoC level which means anxiety level has increased with charging behavior up to 80%. Similarly, when comparing the ending SoC level, the ending SoC level has dropped as well for cases with 4 and 3 charging locations, but a steep increment for case with 2 charging locations.

5.5.Number of Stations at Locations

Charging at three locations along Kathmandu-Chitwan route can serve the riders leaving no riders stranded on midway, and with very low anxiety level. It is important to determine the actual number of charging stations needed at each location to cater the inflow of motorcycles into the locations. The number of stations is calculated in two steps.

5.5.1. Arriving SoC Level

Determination of arriving SoC level into every charging locations provides the estimated time the motorcycle will spend in the station to recharge the bike. For this case, the motorcycle would recharge to 100%, and the charge time is termed as service time.

Table 5.15:Average Arriving SoC Level into each station location for Kathmandu-Chitwan Route

Parameters	Station Location		
	S1	S2	S3
Average Arriving SoC (%)	45.81	30.12	40.83
Standard Deviation	1.93	2.93	5.98
Estimated Time to Full Charge (min)	36.1	46.6	39.4

Average arriving SoC level for each station locations is presented along with the standard deviation. Station location 1 has the highest arriving SoC level of 46%, so riders spent on average 36 minutes in station 1 to charge the motorcycle. Similarly, motorcycles arrive into Station location 2 and 3 with arriving SoC level of 30% and 40% respectively. The service time at these two stations are 47 minutes and 40 minutes.

5.5.2. Charging Stations at Location1

According to assumptions, and model formulation presented in previous chapter, optimal number of charging stations are calculated. The Table 5.16: Number of Charging Stations at Location 1Table 5.16 shows the input parameters and results thus obtained.

Table 5.16: Number of Charging Stations at Location 1

Input Parameters:						
	Arrival rate (l)	3.00	5.00	8.00	10.00	12.00
	Mean service time (1/m)	0.60	0.60	0.60	0.60	0.60
	Absolute maximum number of servers	8.00	8.00	8.00	8.00	8.00
	Target overflow probability (pc)	0.40	0.40	0.40	0.40	0.40
Results:						
	Mean interarrival time (1/l)	0.33	0.20	0.13	0.10	0.08
	Service rate (m)	1.67	1.67	1.67	1.67	1.67
	Effective arrival rate (leff)	1.80	3.00	4.80	6.00	7.20
	Server utilization (reff)	0.54	0.60	0.72	0.72	0.72
	Optimal number of servers (c)	2.00	3.00	4.00	5.00	6.00

Table above shows the variation of optimal number of charging station with change in arrival rate of motorcycles into the charging location. From average arriving SoC level calculation, the average charging time is 36 minutes. A small range of 3 units to 12 units of P1 entering into location 1 in an hour is presented where the optimal gradually increased from 2 units to 5 units.

5.5.3. Charging Stations at Location 2

As same for the charging location 1, the assumptions and formulations are used to find the number of charging stations at location 2. The charging time location 2 is 46 minutes derived from average arriving SoC level of 30%.

Table 5.17: Number of Charging Stations at Location 2

Input Parameters:						
	Arrival rate (l)	3.00	5.00	8.00	10.00	12.00
	Mean service time (1/m)	0.78	0.78	0.78	0.78	0.78
	Absolute maximum number of servers	8.00	8.00	8.00	8.00	8.00
	Target overflow probability (pc)	0.40	0.40	0.40	0.40	0.40
Results:						
	Mean interarrival time (1/l)	0.33	0.20	0.13	0.10	0.08
	Service rate (m)	1.28	1.28	1.28	1.28	1.28
	Effective arrival rate (leff)	1.80	3.00	4.80	6.00	7.20
	Server utilization (reff)	0.47	0.59	0.75	0.78	0.81
	Optimal number of servers (c)	3.00	4.00	5.00	6.00	7.00

The model is tested with a short range of arrival rates starting with 3 units per hour to 12 units per hour. With every other input parameter constant, the optimal number of servers were found to be 2 units to 6 units according to the arrival rate.

5.5.4. Charging Stations at Location 3

Charging stations at location 3 is determined using the same formulation used in previously. Since the arriving SoC level for location 3 is quite similar to location 2, the results look same as well.

Table 5.18: Number of Charging Stations at Location 3

Input Parameters:						
	Arrival rate (l)	3.00	5.00	8.00	10.00	12.00
	Mean service time (1/m)	0.67	0.67	0.67	0.67	0.67
	Absolute maximum number of servers	8.00	8.00	8.00	8.00	8.00
	Target overflow probability (pc)	0.40	0.40	0.40	0.40	0.40
Results:						
	Mean interarrival time (1/l)	0.33	0.20	0.13	0.10	0.08
	Service rate (m)	1.50	1.50	1.50	1.50	1.50
	Effective arrival rate (leff)	1.80	3.00	4.80	6.00	7.20

Results:						
	Server utilization (reff)	0.40	0.67	0.64	0.67	0.80
	Optimal number of servers (c)	3.00	3.00	5.00	6.00	6.00

The arriving SoC level for location 3 is 41% whose charging time is calculated to be 40 minutes. As shown in Table 5.18, changing the arrival rate of motorcycles into the location, the optimal number of charging stations change.

5.5.5. Number of Charging Stations

According to Yatri Motorcycles, there would be 300 P1 models with customers by end of year 2022. So, it would be wise to assume peak arrival in an hour on the considered route to be 3. With arrival rate of 3 bikes per hour, the number of charging stations to be positioned at each location shown in Table 5.19.

Table 5.19: Number of Charging Stations to catering along Kathmandu-Chitwan route

S.N	Charging Location	Number of Charging Station
1	Location 1	2
2	Location 2	3
3	Location 3	3

5.6.Discussion

5.6.1. SoC Level and Distance travelled Relationship

Two different test rides with same rider and driving styles at two different route were conducted. The average SoC level to distance travelled ratio for both, first and second, were calculated to be 0.93. The outcomes for each trip ranged from 1.16 to 0.67, with higher frequency of values close to 1.00. So, the relationship between SoC level and distance travelled is considered be linear with ratio of 1.00.

The linear characteristics with 1.00 ratio between SoC level and distance travelled would reduce complexity in programming.

5.6.2. Charging Locations

Based on the results presented in Figure 5.5, set with three and four locations have same anxiety level of around 2.00. In the same figure, it can be noted that the ending SoC level for set of 4 locations is 63% compared to 54% for 3 locations. Analyzing other factors like the usage of each location by the users which can be derived from Table 5.10 and Table 5.11 where maximum utilization of charging locations were seen in set of 3 charging locations. For 3 charging locations, location 1 and 3 catered about 80% of the users. For 4 charging locations, the usage of all locations were spread out at average of 50%. At this point it can be inferred that an additional charging location just increased the ending SoC level only.

Another factor under analysis is the condition when users start the journey with wider range of SoC level (68% - 98%) and the results are presented in Figure 5.6. The results don’t vary to the original case where users started with a SoC level between 73% to 93%. In case of set of 3 charging location, the arriving SoC level and ending SoC level remained constant at 45% and 54% respectively whereas for 4 charging locations, the arriving SoC level increased from 43% to 42% while ending SoC level remains constant at 63%.

And, the charging behavior is another avenue presented in the discussion where users charge up to 80% only once they reach a charging locations. From Figure 5.7, it can be inferred that the arriving SoC level for both 3 and 4 charging locations is same at 35%. Although, the ending SoC level is higher for 4 charging locations compared to 3 locations; 45% and 34% respectively, no significant leverage is seen with additional charging location.

So, results obtained by considering every factor directs at the point that it is optimal to have 3 charging locations along 132km long highway stretch connecting Kathmandu and Chitwan, Nepal. The optimal charging locations at Galchi, Dhading District: 33km, Malekhu, Dhading District: 58km, and Kurintar, Chitwan District: 87km from Naghdhunga Checkpoint.

5.6.3. Number of Charging Stations

Number of charging stations at each location is calculated based on arrival rate of motorcycles into each station and average service rate at the station. The average service time calculated for every charging location 1, 2, and 3 are 36 minutes, 47 minutes, and 40 minutes respectively. The number of stations calculated in Table 5.16, Table 5.17, and Table 5.18 have different arrival rates. The arrival rate assumed for the study is 3 bikes/hour, so the optimal number of stations needed at location 1 (Galchi) is 2 charging stations. Similarly, number of stations needed to be deployed at location 2 (Malekhu) and location 3 (Kurintar) is 3 stations. The results obtained are based in situation with no queue, and assuming overflow probability of 0.4.

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1.Conclusion

The assumption needed for the model were based on previous works, and secondary sources cited in papers relating to determining charging locations and numbers. A major consideration for ratio between SoC level and distance travelled is derived from data from two test ride. The ratio assumed is 1.00 with empirical results at 0.93 for SoC to distance ratio.

A generic algorithm was designed and programmed which is capable of finding the optimal locations for placing charging stations along a long highway section based on range of the vehicle. The model was tested with an arbitrary distance of 200km for Yatri Motorcycles P1 model. The program was supposed to iterate solutions with 3,4,5, and 6 locations along the route, but due to limitation of computational hardware results of 3, 4, and 5 were found. Only single combination of locations at 50, 100, and 150km was possible with average range anxiety of 1.97 and ending SoC level of 50%. For 4 charging locations, the average anxiety level was 1.95 with ending SoC level of 50% for the best solution of 28, 57, 107, and 157km. Similarly, best locations for 5 charging locations were found at 42, 67, 96, 121, and 150 km. The trips ended with average SoC level of 54% and average anxiety level of 1.73. The optimal solution based on least anxiety level is 5 charging locations along the 200km route. Although, further analysis can be performed because the anxiety level between all three scenarios are quite similar.

For the specific route between Kathmandu and Chitwan, Nepal, the distance is 132km which is enough to give range anxiety among users. Based on the model, the best result with 2 locations had anxiety level of 2.6 and ending SoC level of 11%. Similarly, the best results with 3 and 4 locations had anxiety level of 2.16 and 2.01 respectively. And, ending SoC level were calculated to be 54% and 63%. The location points found were at 43km and 89km for 2 locations, 33km, 58km and 87km for 3 charging locations, and 27km, 52 km, 77km and 102km for 4 charging locations. All the location points are calculated assuming Nagdhunga Checkpoint as ‘0’ kilo.

Although, placement of 4 charging locations would have least anxiety level, but comparing the situation with other factors like rate of usage of locations, change in initial SoC level range, and charging behavior to 80% showed no significant advantage for 4 charging locations over 3 charging locations. So, having charging locations at

Galchi, Dhading, Malekhu, Dhading, and Kurintar, Chitwan along the Kathmandu-Chitwan highway is the optimal solution.

Similarly, number of stations to be deployed at each location was determined to be 2 stations at Galchi, 3 stations each at Malekhu, and Kurintar. The arrival rate of 3 bikes per hour was assumed while average service time calculated based on average arriving SoC level and time to full charge. The average service time were 36 minutes, 40 minutes, and 47 minutes for location 1, 2, and 3 respectively.

6.2.Recommendation

The formulations used for determining the optimal number of charging stations assumes no queue at the location. This was done to simply the study. Queue length and system capacity is bit difficult to find in case of multi-server models, so having the queue length for each location can help to better visualize the arrival rate and balance the waiting time and number of chargers to deploy.

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APPENDIX

Appendix 1: CAN data logger for second test ride

S. No	Time (Seconds)	SOC (%)	Current (A)	Speed (km/hr)	Odometer (km)
1	2.09	34	0	1	529
2	2.19	34	0	1	529
3	2.2	34	0	1	529
4	2.3	34	0	1	529
5	2.44	34	0	1	529
6	2.57	34	0	1	529
7	2.58	34	0	1	529
8	2.59	34	0	1	529
9	2.69	34	0	1	529
10	2.7	34	0	1	529
11	2.8	34	0	1	529
12	2.89	34	0	1	529
13	3.02	34	0	1	529
14	3.03	34	0	1	529
15	3.13	34	0	1	529
16	3.14	34	0	1	529
17	3.15	34	0	1	529
18	3.16	34	0	1	529
19	3.25	34	0	1	529
20	3.34	34	0	1	529
21	3.43	34	0	1	529
22	3.54	34	0	1	529
23	3.55	34	0	1	529
24	3.56	34	0	1	529
25	3.72	34	0	1	529
26	3.73	34	0	1	529
27	3.74	34	0	1	529
28	3.86	34	0	1	529
29	3.95	34	0	1	529
30	4.04	34	0	1	529
31	4.2	34	0	1	529
32	4.28	34	0	1	529
33	4.29	34	0	1	529
34	4.3	34	0	1	529
35	4.42	34	0	1	529
36	4.43	34	0	1	529
37	4.44	34	0	1	529
38	4.57	34	0	1	529
39	4.67	34	0	1	529
40	4.76	34	0	1	529
41	4.87	34	0	1	529

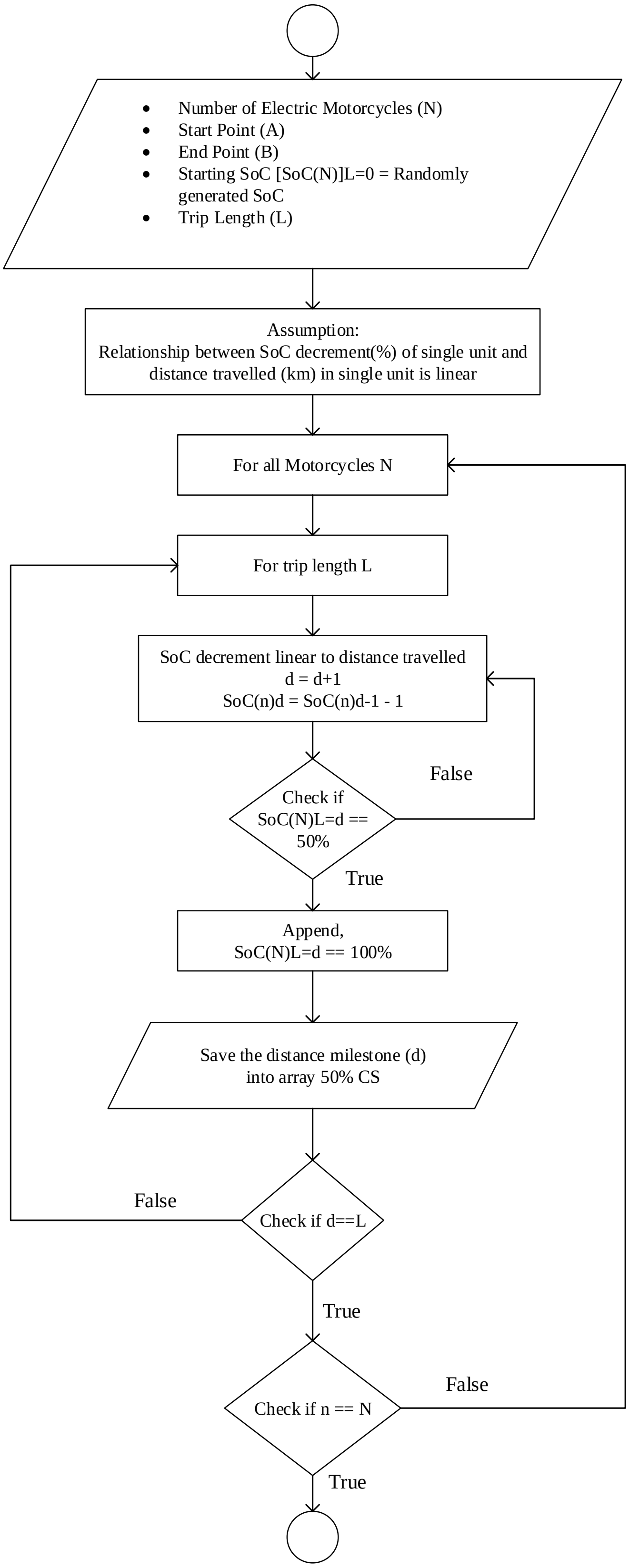
S. No	Time (Seconds)	SOC (%)	Current (A)	Speed (km/hr)	Odometer (km)
42	4.88	34	0	1	529
43	4.9	34	0	1	529
44	4.98	34	0	1	529
45	4.99	34	0	1	529
46	5.18	34	0	1	529
47	5.33	34	0	1	529
48	5.43	34	0	1	529
49	5.52	34	0	1	529
50	5.53	34	0	1	529
51	5.54	34	0	1	529
52	5.64	34	0	1	529
53	5.81	34	0	1	529
54	5.82	34	0	1	529
55	5.95	34	0	1	529
56	6.05	34	0	1	529
57	6.14	34	0	1	529
58	6.39	34	0	1	529
59	6.49	34	0	1	529
60	6.66	34	0	1	529
61	6.67	34	0	1	529
62	6.68	34	0	1	529
63	6.8	34	0	1	529
64	6.91	34	0	1	529
65	7.09	34	0	1	529
66	7.18	34	0	1	529
67	7.27	34	0	1	529
68	7.36	34	0	1	529
69	7.5	34	0	1	529
70	7.64	34	0	1	529
71	7.75	34	0	1	529
72	7.88	34	0	1	529
73	7.89	34	0	1	529
74	7.98	34	0	1	529
75	8.07	34	0	1	529
76	8.17	34	0	1	529
77	8.27	34	0	1	529
78	8.53	34	0	1	529
79	8.67	34	0	1	529
80	8.68	34	0	1	529
81	8.77	34	0	1	529
82	8.86	34	0	1	529
83	8.95	34	0	1	529
84	9.06	34	0	1	529
85	9.16	34	0	1	529
86	9.17	34	0	1	529

S. No	Time (Seconds)	SOC (%)	Current (A)	Speed (km/hr)	Odometer (km)
87	9.33	34	0	1	529
88	9.42	34	0	1	529
89	9.51	34	0	1	529
90	9.6	34	0	1	529
91	9.72	34	0	1	529
92	9.73	34	0	1	529
93	9.82	34	0	1	529
94	9.83	34	0	1	529
95	10.02	34	0	1	529
96	10.13	34	0	1	529
97	10.22	34	0	1	529
98	10.38	34	0	1	529
99	10.66	34	0	1	529
100	10.76	34	0	1	529
101	10.85	34	0	1	529
102	10.94	34	0	1	529
103	11.03	34	0	1	529
104	11.15	34	0	1	529
105	11.16	34	0	1	529
106	11.24	34	0	1	529
107	11.25	34	0	1	529
108	11.26	34	0	1	529
109	11.27	34	0	1	529
110	11.28	34	0	1	529
111	11.29	34	0	1	529
112	11.39	34	0	1	529
113	11.53	34	0	1	529
114	11.63	34	0	1	529
115	11.72	34	0	1	529
116	11.81	34	0	1	529
117	798.14	46	0.1	1	529
118	798.23	46	0.1	0	530
119	798.32	46	0.1	1	531
120	798.41	46	0.1	0	532
121	798.5	46	0.1	1	533
122	798.59	46	0.1	0	534
123	798.68	46	0.1	1	535
124	798.73	46	0.1	0	536
125	798.82	46	0.1	1	537
126	798.91	46	0.1	0	538
127	799.01	46	0.1	1	539
128	799.11	46	0.1	0	540
129	799.2	46	0.1	0	541
130	799.29	46	0.1	1	542
131	799.38	46	0.1	0	543

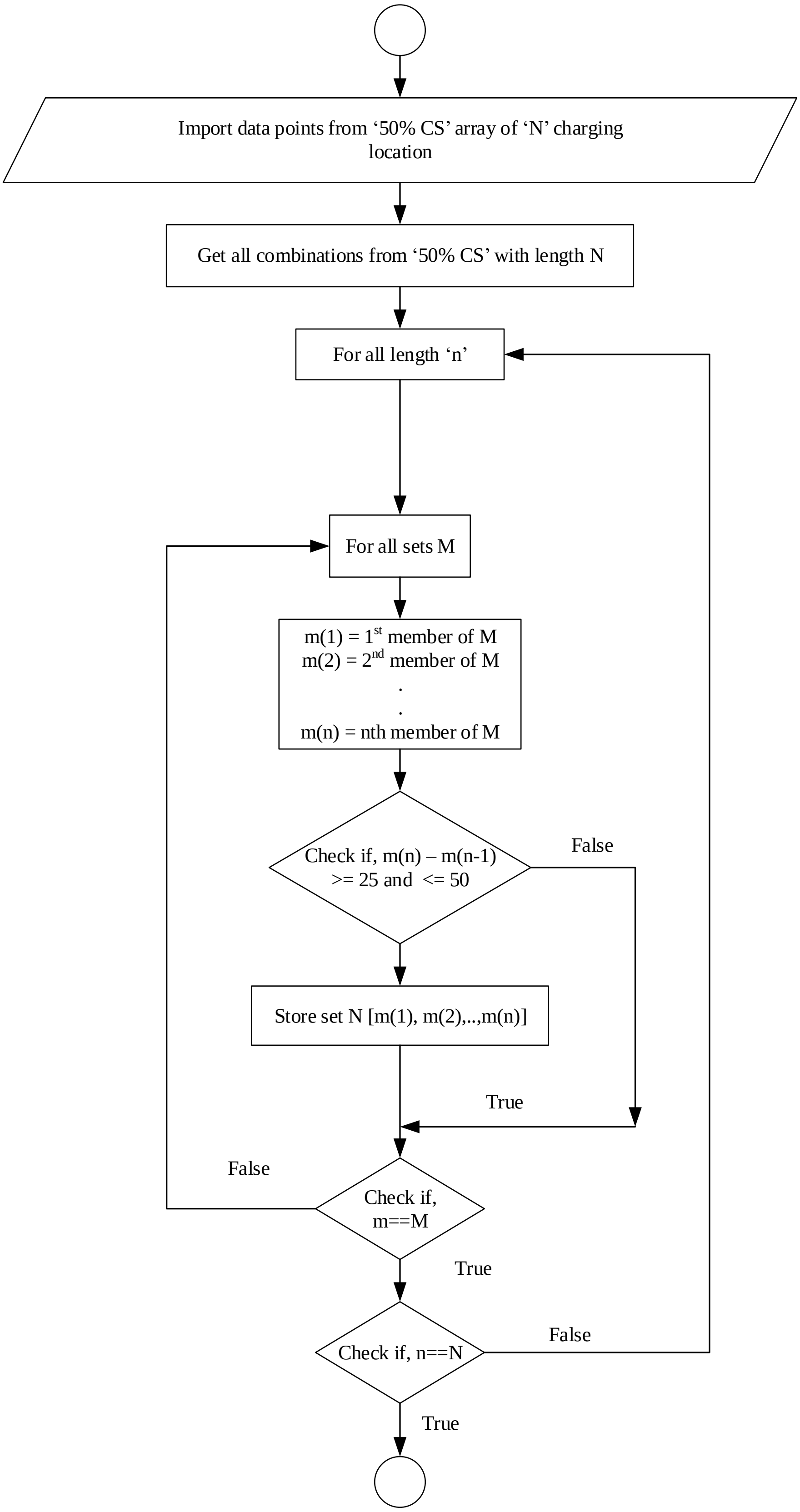
S. No	Time (Seconds)	SOC (%)	Current (A)	Speed (km/hr)	Odometer (km)
132	799.43	46	0.1	1	544
133	799.52	46	0.1	0	545
134	799.61	46	0.1	1	546
135	799.7	46	0.1	0	547
136	799.79	46	0.1	1	548
137	799.88	46	0.1	0	549
138	799.97	46	0.2	1	550
139	800.08	46	0.6	0	551
140	800.12	46	0.6	1	552
141	800.21	46	0.8	0	553
142	800.3	46	0.9	1	554
143	800.39	46	0.9	0	555
144	800.48	46	1.5	2	556
145	800.57	46	0.6	4	557
146	800.68	46	0.6	5	558
147	800.77	46	0.6	4	559
148	800.81	46	0.6	5	560
149	800.9	46	0.6	6	561
150	800.99	46	0.6	6	562
151	801.08	46	0.7	6	563
152	801.17	46	0.7	6	564
153	801.26	46	0.9	5	565
154	801.35	46	0.9	2	566
155	801.44	46	1.1	1	567
156	801.58	46	0.6	1	568
157	801.67	46	0.6	0	569
158	801.76	46	0.7	1	570
159	801.85	46	0.8	0	571
160	801.94	46	0.8	1	572
161	802.03	46	1	0	573
162	802.12	46	1.4	1	574
163	802.26	46	2.4	0	575
164	802.35	46	5.7	1	576
165	802.45	46	1.6	0	577
166	802.54	46	1.6	1	128
167	802.63	46	0.6	0	128
168	802.73	46	0.7	1	128
169	802.82	46	0.7	0	128
170	802.96	46	0.7	1	128
171	803.05	46	0.9	0	128
172	803.16	46	0.9	1	128
173	803.25	46	1.4	0	128
174	803.34	46	2.4	1	128
175	803.44	46	2.7	0	128
176	803.53	46	2.7	1	128

S. No	Time (Seconds)	SOC (%)	Current (A)	Speed (km/hr)	Odometer (km)
177	803.66	46	3.1	0	128
178	803.75	46	3.1	1	128
179	803.84	46	0.7	0	128
180	803.94	46	0.6	1	128
181	804.03	46	0.7	0	128
182	804.13	46	0.7	1	128
183	804.22	46	0.7	0	128
184	804.36	46	1	1	128
185	804.45	46	1	0	128
186	804.54	46	1.6	1	128
187	804.65	46	2.9	0	128
188	804.74	46	2.9	1	128
189	804.83	46	4.2	0	128
190	804.93	46	1.2	1	128
191	805.07	46	1	0	128
192	805.17	46	2.3	1	128
193	805.26	46	4.9	0	128
194	805.35	46	4.9	1	128
195	805.45	46	4.4	0	128
196	805.54	46	4.7	1	128
197	805.64	46	2.5	0	128
198	805.79	46	0.6	1	128
199	805.89	46	0.6	0	128
200	805.98	46	0.6	1	128

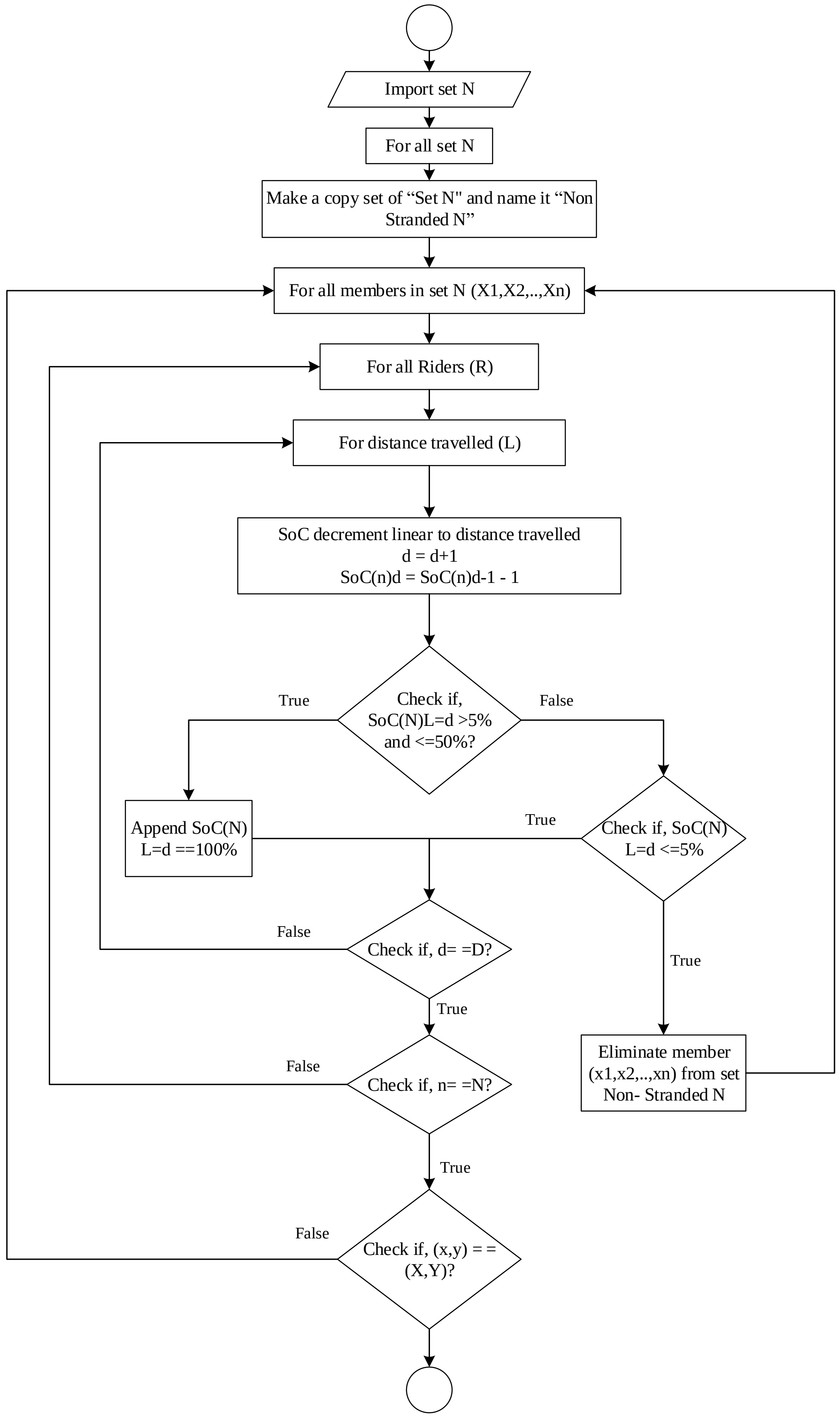
Appendix 2: Flowchart for determination of Optimistic Charging Location



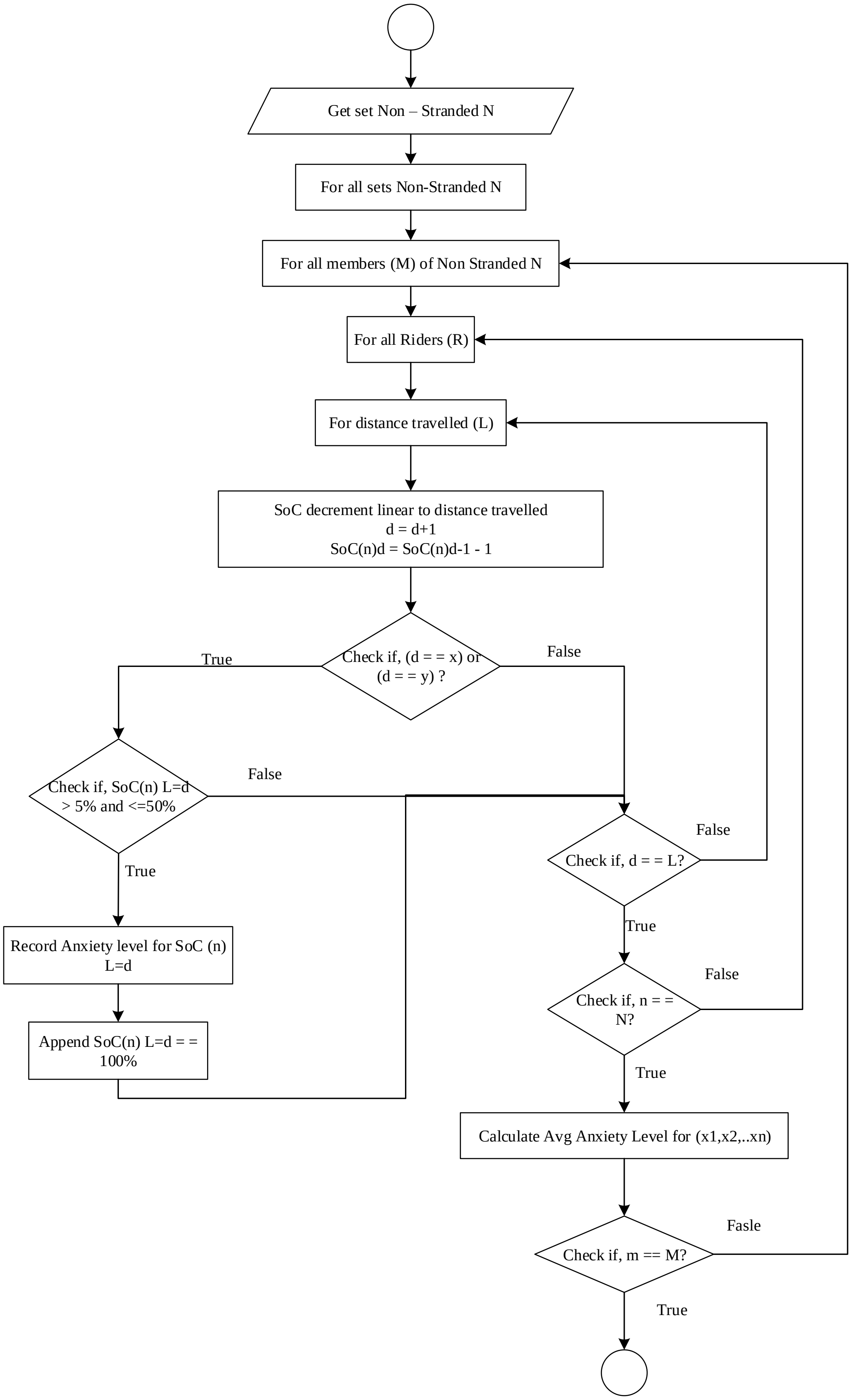
Appendix 3: Determination of Sets with Possible Charging Locations



Appendix 4: Elimination of sets with Stranded Riders



Appendix 5: Average Anxiety Level Calculation



Appendix 6: Random Values used as Initial SoC

S.No	Random data 1	Random Data 2	Random Data 3	Random Data 4	Random Data 5	Random Data 6	Random Data 7	Random Data 8	Random Data 9	Random Data 10
1	92	80	85	89	86	77	74	83	76	82
2	82	85	87	92	90	73	91	76	89	73
3	75	74	77	78	84	85	93	76	82	82
4	92	74	73	74	78	78	86	76	89	83
5	89	73	90	83	86	81	74	81	86	73
6	83	88	82	79	82	75	79	80	91	86
7	90	78	76	75	86	93	79	91	90	77
8	80	91	76	87	92	89	90	85	75	89
9	75	92	80	90	93	91	90	86	90	84
10	91	92	93	92	79	91	89	86	90	83
11	82	84	91	92	79	77	85	77	88	75
12	77	85	89	87	88	91	84	84	74	83
13	88	87	93	93	89	74	79	79	76	82
14	85	86	76	88	83	82	88	92	74	74
15	91	80	77	91	73	76	90	89	89	75
16	88	83	80	87	74	92	91	88	84	78
17	74	80	88	77	81	81	77	92	89	79
18	78	77	78	89	92	85	85	74	75	87
19	85	86	86	84	92	84	76	78	79	79
20	83	80	89	80	83	77	77	73	86	83
21	85	83	81	77	88	77	77	84	87	91
22	91	81	81	80	80	80	90	81	87	84
23	84	88	89	73	88	80	77	86	73	85
24	84	89	80	73	76	84	75	84	83	79
25	73	90	77	74	85	83	73	81	76	87
26	89	88	77	77	93	92	75	78	74	89
27	82	85	73	92	87	89	81	78	89	87
28	87	81	74	73	86	79	81	79	90	80
29	84	78	78	75	88	73	88	76	76	77
30	78	93	89	76	76	93	75	92	82	75
31	77	82	88	90	91	84	89	87	77	77
32	90	91	92	90	87	92	74	78	82	76
33	88	73	88	88	86	87	91	88	86	93
34	76	92	85	86	79	78	81	93	91	74
35	93	88	81	81	75	81	79	84	78	78
36	85	85	90	85	75	73	82	88	88	90
37	84	76	82	80	76	89	87	82	76	82
38	89	86	81	84	78	85	87	82	73	88
39	82	80	81	80	79	77	90	82	90	76
40	86	81	85	83	91	85	74	75	81	78
41	76	81	88	82	86	76	86	77	73	83
42	90	90	93	82	82	73	93	88	78	78

S.No	Random data 1	Random Data 2	Random Data 3	Random Data 4	Random Data 5	Random Data 6	Random Data 7	Random Data 8	Random Data 9	Random Data 10
43	81	84	93	92	75	81	74	88	93	82
44	73	79	73	90	84	76	81	83	83	76
45	83	89	77	77	88	91	81	80	90	91
46	79	89	76	77	91	82	81	81	86	83
47	84	84	76	93	73	90	77	77	79	73
48	76	90	87	93	74	77	78	90	90	77
49	81	81	78	81	79	92	74	86	89	81
50	85	81	81	89	88	86	82	92	82	92
51	89	79	78	89	92	73	89	86	83	93
52	89	79	86	82	85	78	75	78	87	88
53	90	78	73	87	81	84	81	85	83	80
54	91	93	92	78	87	76	89	84	80	85
55	88	76	87	87	88	90	89	78	74	86
56	77	78	82	73	81	75	93	93	85	80
57	79	93	73	90	79	75	88	93	87	89
58	77	88	76	82	89	87	80	84	81	88
59	76	74	76	79	92	85	89	75	85	92
60	85	74	85	87	85	84	86	93	80	77
61	83	91	75	73	93	78	89	82	90	80
62	75	85	92	83	83	90	84	91	84	84
63	77	82	92	78	82	81	85	74	74	73
64	93	77	76	89	84	91	85	77	88	93
65	91	88	92	86	92	81	82	89	80	74
66	74	77	90	90	77	90	79	88	91	80
67	85	85	85	78	74	75	88	76	83	83
68	78	87	77	92	91	92	92	90	79	77
69	87	76	73	88	81	79	84	80	91	93
70	93	75	82	82	77	83	90	83	73	85
71	82	81	75	76	92	75	73	78	74	88
72	87	85	93	78	89	73	92	83	74	73
73	90	85	81	78	85	86	81	83	88	78
74	76	93	74	89	82	92	77	91	74	79
75	91	77	92	89	73	79	84	77	88	84
76	82	91	93	85	90	86	93	73	82	92
77	86	85	90	82	89	93	88	91	85	91
78	91	90	79	82	92	74	76	83	80	90
79	77	88	80	82	78	87	75	74	84	87
80	76	89	92	90	76	76	84	93	88	85
81	75	78	85	88	77	77	93	87	78	92
82	77	84	73	89	82	83	88	73	77	83
83	83	75	84	86	83	73	86	76	84	85
84	81	79	77	89	84	85	76	76	78	85
85	84	84	90	92	77	74	87	77	75	81
86	83	86	78	80	90	89	73	89	81	73

S.No	Random data 1	Random Data 2	Random Data 3	Random Data 4	Random Data 5	Random Data 6	Random Data 7	Random Data 8	Random Data 9	Random Data 10
87	81	74	78	82	93	84	77	78	76	78
88	93	79	81	80	79	87	77	88	83	81
89	74	85	80	74	73	87	81	78	76	75
90	82	80	88	87	92	73	76	83	82	92
91	86	92	92	84	86	78	87	80	86	80
92	89	85	92	91	90	84	76	88	91	79
93	73	86	80	77	88	88	92	85	90	86
94	80	87	90	82	79	74	86	78	80	83
95	82	74	87	76	79	79	74	93	93	73
96	87	80	77	75	82	91	88	73	79	76
97	84	89	81	78	90	91	73	90	80	84
98	73	73	87	90	87	73	77	87	82	76
99	81	87	83	77	93	79	76	84	76	84
100	81	78	78	82	75	87	78	90	88	80

Appendix 7: Random Value for Initial SoC of range (97%-68%)

S.N	5% change A	5% change B	5% change C
1	74	97	81
2	72	70	93
3	87	83	77
4	96	88	91
5	91	73	93
6	73	87	83
7	89	96	86
8	69	70	91
9	74	68	73
10	90	88	72
11	68	72	82
12	77	78	89
13	90	82	95
14	82	76	88
15	72	96	71
16	89	96	76
17	92	86	70
18	83	91	98
19	90	86	81
20	97	85	69
21	78	91	85
22	77	73	91
23	97	70	84
24	88	73	70
25	86	93	71

S.N	5% change A	5% change B	5% change C
26	69	70	80
27	92	84	77
28	81	69	79
29	91	85	92
30	90	83	84
31	71	91	76
32	79	98	69
33	82	70	73
34	72	76	91
35	81	91	83
36	70	82	98
37	71	90	78
38	77	81	69
39	90	70	85
40	76	70	71
41	73	70	72
42	80	72	71
43	85	93	82
44	98	88	69
45	92	89	80
46	68	91	84
47	87	97	92
48	96	96	88
49	91	86	75
50	78	84	86
51	85	68	89
52	93	93	75
53	85	74	70
54	68	84	89
55	68	92	71
56	76	95	90
57	75	84	90
58	94	90	91
59	83	80	70
60	74	73	84
61	72	89	94
62	69	76	84
63	92	98	69
64	78	85	68
65	98	90	86
66	83	97	82
67	83	73	84
68	80	96	88
69	94	86	91
70	68	93	78

S.N	5% change A	5% change B	5% change C
71	78	70	88
72	79	74	89
73	84	80	73
74	68	76	69
75	88	70	81
76	94	83	83
77	85	83	72
78	82	93	69
79	75	74	72
80	71	88	97
81	89	76	77
82	96	73	96
83	90	69	90
84	84	83	89
85	92	87	86
86	68	81	92
87	68	84	80
88	94	89	73
89	96	94	77
90	70	81	90
91	74	96	92
92	76	73	81
93	70	72	74
94	79	94	92
95	90	85	88
96	81	79	92
97	73	93	89
98	72	87	69
99	90	92	71
100	70	85	88

Appendix 8: Occupancy Data for Kathmandu-Chitwan route with 4 Charging Location and 100% recharge

Index	
Route Distance	132 KM
Set of Four used	[27, 52, 77, 102]
Route	A to B to A
Full Charge Upto	100%

S.N.	**Data Collection**	**Occupancy**				**Standard Deviation**				**Avg Arriving SoCs in each station**				**Avg Ending SoCs at destination**
		S1	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**	
1	**Random data 1**	93	107	93	107	1.02	8.24	8.82	2.05	49.58	38.39	36.16	48.89	64.62
2	**Random Data 2**	82	118	82	118	1.09	8.67	8.2	1.91	49.55	38.25	35.79	49.08	64.75
3	**Random Data 3**	86	114	86	114	1.2	8.8	8.92	2.14	49.47	39.59	37.9	48.75	63
4	**Random Data 4**	85	115	85	115	1.12	8.55	8.36	1.99	49.55	38.75	36.59	48.98	64.38
5	**Random Data 5**	87	113	87	113	1.05	8.25	8.04	1.94	49.57	38.53	36.22	49.04	65.12
6	**Random Data 6**	88	112	88	112	1.36	8.78	9.09	2.37	49.28	39.77	38.17	48.5	62.5
7	**Random Data 7**	92	108	92	108	1.16	8.47	9.1	2.25	49.42	39.81	38.05	48.56	62.75
8	**Random Data 8**	84	116	84	116	1.04	8.83	8.64	1.93	49.57	38.71	36.64	48.93	64
9	**Random Data 9**	86	114	86	114	1.2	8.7	8.86	2.21	49.37	38.97	36.98	48.76	63.5
10	**Random Data 10**	82	118	82	118	1.26	9.14	9.17	2.15	49.39	38.96	37.06	48.8	63
A	**5% change A**	91	109	91	109	3.22	8.39	8.69	4.26	47.82	41.86	40.8	47.04	60.88
B	**5% change B**	96	104	96	104	2.77	7.78	8.57	3.95	48.32	41.2	39.42	47.5	63
C	**5% change C**	94	106	94	106	3	8.16	8.89	4.13	48.06	41.21	39.69	47.22	61.75

Appendix 9: Occupancy Data for Kathmandu-Chitwan route with 3 Charging Location and 100% recharge

Index	
Route Distance	**132 KM**
Set of Three used	**[33, 58, 87]**
Route	**A to B to A**
Full Charge Upto	**100%**

S.N.	**Data Collection**	**Occupancy**			**Standard Deviation**			**Avg Arriving SoCs in each station**			**Avg Ending SoCs at destination**
		S1	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	
1	**Random data 1**	111	89	111	2.42	5.05	5.74	41.79	34.33	35.77	48.37
2	**Random Data 2**	111	89	111	2.38	4.91	5.67	41.78	34.43	35.84	48.37
3	**Random Data 3**	111	89	111	2.28	5.78	6.32	41.75	34.08	35.52	48.37
4	**Random Data 4**	111	89	111	2.36	5.23	5.93	41.77	34.62	35.98	48.37
5	**Random Data 5**	111	89	111	2.42	5.22	5.94	41.79	35.15	36.42	48.37
6	**Random Data 6**	118	82	118	2.83	5.4	6.32	42.19	34.3	35.42	49.56
7	**Random Data 7**	116	84	116	2.81	5.41	6.19	42.11	34.36	35.58	49.22
8	**Random Data 8**	109	91	109	2.16	5.38	5.9	41.64	33.96	35.53	48.03
9	**Random Data 9**	115	85	115	2.69	4.95	5.87	42.03	34.18	35.47	49.05
10	**Random Data 10**	114	86	114	2.58	5.05	5.87	41.96	33.59	35.05	48.88
A	**5% change A**	132	68	132	2.4	6.48	8.62	42.19	36.71	35.43	51.94
B	**5% change B**	127	73	127	2.31	6.12	8.38	42.11	37.68	36.46	51.09
C	**5% change C**	130	70	130	2.3	5.71	8.16	42.15	36.51	35.51	51.6

Appendix 10: Occupancy Data for Kathmandu-Chitwan route with 2 Charging Location and 100% recharge

Index	
Route Distance	132 KM
Set of Three used	[43, 89]
Route	A to B to A
Full Charge Upto	100%

S.N.	Data Collection	Occupancy		Standard Deviation		Avg Ending SoCs in each station		Avg Ending SoCs at destination
		S1	S2	S1	S2	S1	S2	
1	**Random data 1**	100	100	5.77	5.77	40.19	40.19	11
2	**Random Data 2**	100	100	5.69	5.69	40.27	40.27	11
3	**Random Data 3**	100	100	6.38	6.38	39.92	39.92	11
4	**Random Data 4**	100	100	5.99	5.99	40.43	40.43	11
5	**Random Data 5**	100	100	6.05	6.05	40.92	40.92	11
6	**Random Data 6**	100	100	6.36	6.36	39.41	39.41	11
7	**Random Data 7**	100	100	6.24	6.24	39.71	39.71	11
8	**Random Data 8**	100	100	5.92	5.92	40.04	40.04	11
9	**Random Data 9**	100	100	5.86	5.86	39.64	39.64	11
10	**Random Data 10**	100	100	5.8	5.8	39.22	39.22	11
A	**5% change A**	100	100	12.35	12.35	33.13	33.13	16.52
B	**5% change B**	100	100	13.1	13.1	33.8	33.8	17.44
C	**5% change C**	100	100	10.71	10.71	36.1	36.1	13.76

Appendix 11: Occupancy Data for Kathmandu-Chitwan route with 3 Charging Location and 80% recharge

Index	
Route Distance	132 KM
Set of Three used	[33, 58, 87]
Route	A to B to A
Full Charge Upto	80%

S.N.	Data Collection	Occupancy			Standard Deviation			Avg Arriving SoCs in each station			Avg Ending SoCs at destination
		S1	S2	S3	S1	S2	S3	S1	S2	S3	
1	**Random data 1**	11	189	200	0.89	6.79	7.98	49	40.5	39.22	31
2	**Random Data 2**	11	189	200	0.7	6.7	7.93	48.91	40.55	39.26	31
3	**Random Data 3**	11	189	200	0.82	7.16	8.27	48.55	40.39	39.08	31
4	**Random Data 4**	11	189	200	0.87	6.73	8	48.82	40.64	39.34	31
5	**Random Data 5**	11	189	200	0.89	6.5	7.9	49	40.89	39.58	31
6	**Random Data 6**	18	182	200	0.88	6.86	8.9	48.78	40.73	37.96	31
7	**Random Data 7**	16	184	200	0.77	6.86	8.66	49.06	40.68	38.35	31
8	**Random Data 8**	9	191	200	0.83	7.08	7.89	48.78	40.26	39.4	31
9	**Random Data 9**	15	185	200	0.7	6.79	8.47	48.93	40.57	38.44	31
10	**Random Data 10**	14	186	200	0.89	7.08	8.47	48.79	40.26	38.36	31
A	**5% change A**	32	168	200	2.36	6.15	10.74	45.91	42.24	35.83	31
B	**5% change B**	27	173	200	1.89	5.71	10.34	46.22	42.49	37.24	31
C	**5% change C**	30	170	200	1.91	5.94	10.42	46	42.09	36.18	31

Appendix 12: Occupancy Data for Kathmandu-Chitwan route with 4 Charging Location and 80% recharge

Index	
Route Distance	132 KM
Set of Four used	[27, 52, 77, 102]
Route	A to B to A
Full Charge Upto	80%

S.N.	Data Collection	Occupancy				Standard Deviation				Avg Arriving SoCs in each station				Avg Ending SoCs at destination
		S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	
1	**Random data 1**	93	107	93	107	8.12	3.9	3.28	7.44	34.74	32.6	31	34.68	44.62
2	**Random Data 2**	82	118	82	118	7.5	4.02	3.22	7.97	33.94	32.15	31.4	35.19	44.75
3	**Random Data 3**	86	114	86	114	8.59	4.4	3.6	8.08	35.74	32.39	31.62	35.95	43
4	**Random Data 4**	85	115	85	115	7.93	4.21	3.33	7.91	34.49	32.49	31.65	35.24	44.38
5	**Random Data 5**	87	113	87	113	7.53	4.34	3.46	7.6	33.94	32.87	31.85	34.7	45.12
6	**Random Data 6**	88	112	88	112	8.58	4.1	3.23	7.9	36.1	32.27	31.35	36	42.5
7	**Random Data 7**	92	108	92	108	8.73	4.02	3.21	7.82	36.16	32.58	31.32	35.79	42.75
8	**Random Data 8**	84	116	84	116	8.16	4.19	3.35	7.98	34.81	32.16	31.4	35.48	44
9	**Random Data 9**	86	114	86	114	8.18	3.77	2.94	7.93	35.19	32.13	31.16	35.61	43.5
10	**Random Data 10**	82	118	82	118	8.38	3.84	3.18	8.2	35.49	31.67	30.96	36.08	43
A	**5% change A**	91	109	91	109	7.58	5.26	4.31	7.01	36.18	33.24	32.45	35.66	40.88
B	**5% change B**	96	104	96	104	7.23	5.37	4.54	6.4	34.99	34.28	32.75	34.42	43
C	**5% change C**	94	106	94	106	7.5	4.74	3.88	6.77	35.72	33.28	32.03	35.14	41.75

Appendix 13: : Occupancy Data for Kathmandu-Chitwan route with 2 Charging Location and 80% recharge

Index	
Route Distance	**132 KM**
Set of Three used	**[43, 89]**
Route	**A to B to A**
Full Charge Upto	**80%**

S.N.	Data Collection	Occupancy		Standard Deviation		Avg Ending SoCs in each station		Avg Ending SoCs at destination
		S1	S2	S1	S2	S1	S2	
1	**Random data 1**	200	200	5.12	5.12	37.1	37.1	37
2	**Random Data 2**	200	200	5.1	5.1	37.14	37.14	37
3	**Random Data 3**	200	200	5.39	5.39	36.96	36.96	37
4	**Random Data 4**	200	200	5.32	5.32	37.22	37.22	37
5	**Random Data 5**	200	200	5.5	5.5	37.46	37.46	37
6	**Random Data 6**	200	200	5.24	5.24	36.7	36.7	37
7	**Random Data 7**	200	200	5.25	5.25	36.85	36.85	37
8	**Random Data 8**	200	200	5.15	5.15	37.02	37.02	37
9	**Random Data 9**	200	200	5.01	5.01	36.82	36.82	37
10	**Random Data 10**	200	200	4.86	4.86	36.61	36.61	37
A	**5% change A**	188	188	9	9	33.54	33.54	37
B	**5% change B**	186	186	9.58	9.58	33.89	33.89	37
C	**5% change C**	194	194	7.74	7.74	35.08	35.08	37

Appendix 14: Rate of Usage with 2 Charging Locations along Kathmandu-Chitwan Route

S.N.	Data Collection	100% Recharge Rate of Usage		80% Recharge Rate of Usage	
		S1	S2	S1	S2
1	**Random data 1**	0.5	0.5	1	1
2	**Random Data 2**	0.5	0.5	1	1
3	**Random Data 3**	0.5	0.5	1	1
4	**Random Data 4**	0.5	0.5	1	1
5	**Random Data 5**	0.5	0.5	1	1
6	**Random Data 6**	0.5	0.5	1	1
7	**Random Data 7**	0.5	0.5	1	1
8	**Random Data 8**	0.5	0.5	1	1
9	**Random Data 9**	0.5	0.5	1	1
10	**Random Data 10**	0.5	0.5	1	1
A	**5% change A**	0.5	0.5	0.94	0.94
B	**5% change B**	0.5	0.5	0.93	0.93
C	**5% change C**	0.5	0.5	0.97	0.97

Appendix 15: Rate of Usage with 3 Charging Locations along Kathmandu-Chitwan Route

S.N.	Data Collection	100% Recharge Rate of Usage			80% Recharge Rate of Usage		
		S1	S2	S3	S1	S2	S3
1	**Random data 1**	0.8	0.2	0.8	0.8	0.2	0.8
2	**Random Data 2**	0.7	0.3	0.7	0.7	0.3	0.7
3	**Random Data 3**	0.8	0.2	0.8	0.8	0.2	0.8
4	**Random Data 4**	0.8	0.2	0.8	0.8	0.2	0.8
5	**Random Data 5**	0.7	0.3	0.7	0.7	0.3	0.7
6	**Random Data 6**	0.8	0.2	0.8	0.8	0.2	0.8
7	**Random Data 7**	0.8	0.2	0.8	0.8	0.2	0.8
8	**Random Data 8**	0.8	0.2	0.8	0.8	0.2	0.8
9	**Random Data 9**	0.8	0.2	0.8	0.8	0.2	0.8
10	**Random Data 10**	0.8	0.2	0.8	0.8	0.2	0.8
A	**5% change A**	0.7	0.3	0.7	0.7	0.3	0.7
B	**5% change B**	0.7	0.3	0.7	0.7	0.3	0.7
C	**5% change C**	0.7	0.3	0.7	0.7	0.3	0.7

Appendix 16: Rate of Usage with 2 Charging Locations along Kathmandu-Chitwan Route

S.N.	Data Collection	100% Recharge				80% Recharge			
		Rate of Usage				Rate of Usage			
		S1	S2	S3	S4	S1	S2	S3	S4
1	**Random data 1**	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
2	**Random Data 2**	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6
3	**Random Data 3**	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6
4	**Random Data 4**	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6
5	**Random Data 5**	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6
6	**Random Data 6**	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6
7	**Random Data 7**	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
8	**Random Data 8**	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6
9	**Random Data 9**	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6
10	**Random Data 10**	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6
A	**5% change A**	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
B	**5% change B**	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
C	**5% change C**	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Appendix 17: Top 100 list with Two Charging Locations for Kathmandu-Chitwan Route

SNo	Location 1	Location 2	Average Range Anxiety	Ending SoC level (%)
1	43	89	2.60	11.00
2	43	88	2.68	11.50
3	44	89	2.68	11.50
4	42	87	2.71	11.95
5	45	90	2.71	11.95
6	43	87	2.75	12.00
7	45	89	2.75	12.00
8	44	88	2.76	12.00
9	42	86	2.81	12.44
10	46	90	2.81	12.44
11	44	87	2.83	12.50
12	45	88	2.83	12.50
13	43	86	2.85	12.50
14	46	89	2.85	12.50

SNo	Location 1	Location 2	Average Range Anxiety	Ending SoC level (%)
15	45	87	2.91	13.00
16	42	85	2.93	12.93
17	47	90	2.93	12.93
18	44	86	2.94	13.00
19	46	88	2.94	13.00
20	43	85	2.97	13.00
21	47	89	2.97	13.00
22	45	86	3.01	13.50
23	46	87	3.01	13.50
24	41	86	3.02	13.53
25	46	91	3.02	13.53
26	44	85	3.05	13.50
27	47	88	3.05	13.50
28	42	84	3.06	13.42
29	48	90	3.06	13.42
30	43	84	3.10	13.50
31	48	89	3.10	13.50
32	46	86	3.11	14.00
33	45	85	3.12	14.00
34	47	87	3.12	14.00
35	41	85	3.13	13.98
36	47	91	3.13	13.98
37	42	83	3.14	13.91
38	49	90	3.14	13.91
39	43	83	3.18	14.00
40	44	84	3.18	14.00
41	48	88	3.18	14.00
42	49	89	3.18	14.00
43	42	82	3.21	14.40
44	50	90	3.21	14.40
45	46	85	3.23	14.50
46	47	86	3.23	14.50
47	43	82	3.25	14.50
48	45	84	3.25	14.50
49	48	87	3.25	14.50
50	50	89	3.25	14.50
51	41	84	3.26	14.44
52	44	83	3.26	14.50
53	48	91	3.26	14.44
54	49	88	3.26	14.50
55	44	82	3.33	15.00

SNo	Location 1	Location 2	Average Range Anxiety	Ending SoC level (%)
56	45	83	3.33	15.00
57	49	87	3.33	15.00
58	50	88	3.33	15.00
59	41	83	3.34	14.89
60	47	85	3.34	15.00
61	49	91	3.34	14.89
62	46	84	3.35	15.00
63	48	86	3.35	15.00
64	41	82	3.40	15.35
65	50	91	3.40	15.35
66	45	82	3.41	15.50
67	50	87	3.41	15.50
68	40	85	3.44	15.55
69	46	83	3.44	15.50
70	47	92	3.44	15.55
71	49	86	3.44	15.50
72	47	84	3.47	15.50
73	48	85	3.47	15.50
74	46	82	3.51	16.00
75	50	86	3.51	16.00
76	47	83	3.55	16.00
77	49	85	3.55	16.00
78	40	84	3.56	15.96
79	48	92	3.56	15.96
80	48	84	3.60	16.00
81	47	82	3.62	16.50
82	50	85	3.62	16.50
83	40	83	3.65	16.37
84	49	92	3.65	16.37
85	39	84	3.67	16.45
86	48	93	3.67	16.45
87	48	83	3.68	16.50
88	49	84	3.68	16.50
89	40	82	3.71	16.78
90	50	92	3.71	16.78
91	38	83	3.71	16.68
92	49	94	3.71	16.68
93	39	83	3.75	16.84
94	49	93	3.75	16.84
95	48	82	3.75	17.00
96	50	84	3.75	17.00

SNo	Location 1	Location 2	Average Range Anxiety	Ending SoC level (%)
97	49	83	3.76	17.00
98	38	82	3.78	17.06
99	50	94	3.78	17.06
100	39	82	3.81	17.23

Appendix 18: Top 100 list with Three Charging Locations for Kathmandu-Chitwan Route

SNo	Location 1	Location 2	Location 3	Average Anxiety Level	Ending SoC Level
1	33	58	87	2.16	53.60
2	45	74	99	2.16	53.60
3	32	57	86	2.22	53.02
4	46	75	100	2.22	53.02
5	33	58	86	2.22	53.36
6	46	74	99	2.22	53.36
7	32	58	86	2.27	53.30
8	46	74	100	2.27	53.30
9	32	57	85	2.28	52.80
10	47	75	100	2.28	52.80
11	33	58	85	2.29	53.12
12	47	74	99	2.29	53.12
13	31	56	85	2.31	52.30
14	47	76	101	2.31	52.30
15	32	58	85	2.34	53.08
16	47	74	100	2.34	53.08
17	31	57	85	2.35	52.60
18	47	75	101	2.35	52.60
19	32	57	84	2.36	52.58
20	48	75	100	2.36	52.58
21	33	58	84	2.36	52.87
22	48	74	99	2.36	52.87
23	30	55	84	2.36	52.01
24	48	77	102	2.36	52.01
25	31	56	84	2.39	52.10
26	48	76	101	2.39	52.10
27	32	57	83	2.41	52.35
28	49	75	100	2.41	52.35
29	31	58	85	2.41	52.90
30	47	74	101	2.41	52.90
31	33	58	83	2.41	52.62

SNo	Location 1	Location 2	Location 3	Average Anxiety Level	Ending SoC Level
32	49	74	99	2.41	52.62
33	30	55	83	2.41	51.82
34	30	56	84	2.41	52.32
35	48	76	102	2.41	52.32
36	49	77	102	2.41	51.82
37	32	58	84	2.41	52.85
38	48	74	100	2.41	52.85
39	29	54	83	2.42	51.58
40	49	78	103	2.42	51.58
41	31	57	84	2.43	52.40
42	48	75	101	2.43	52.40
43	31	56	83	2.43	51.90
44	49	76	101	2.43	51.90
45	32	57	82	2.45	52.12
46	50	75	100	2.45	52.12
47	29	55	83	2.45	51.90
48	49	77	103	2.45	51.90
49	30	55	82	2.46	51.63
50	30	57	84	2.46	52.63
51	48	75	102	2.46	52.63
52	50	77	102	2.46	51.63
53	32	57	90	2.46	53.67
54	42	75	100	2.46	53.67
55	32	58	83	2.46	52.62
56	49	74	100	2.46	52.62
57	30	56	83	2.46	52.13
58	49	76	102	2.46	52.13
59	29	54	82	2.47	51.40
60	50	78	103	2.47	51.40
61	33	58	90	2.47	54.09
62	42	74	99	2.47	54.09
63	31	56	90	2.47	53.05
64	42	76	101	2.47	53.05
65	30	55	89	2.48	52.96
66	43	77	102	2.48	52.96
67	31	56	82	2.48	51.70
68	31	57	83	2.48	52.20
69	49	75	101	2.48	52.20
70	50	76	101	2.48	51.70
71	31	58	84	2.48	52.70
72	48	74	101	2.48	52.70

SNo	Location 1	Location 2	Location 3	Average Anxiety Level	Ending SoC Level
73	32	57	89	2.49	53.70
74	43	75	100	2.49	53.70
75	29	55	82	2.50	51.73
76	50	77	103	2.50	51.73
77	33	58	89	2.50	54.09
78	43	74	99	2.50	54.09
79	29	56	83	2.50	52.23
80	49	76	103	2.50	52.23
81	31	56	89	2.50	53.10
82	43	76	101	2.50	53.10
83	30	56	82	2.50	51.94
84	30	57	83	2.50	52.44
85	49	75	102	2.50	52.44
86	50	76	102	2.50	51.94
87	30	58	84	2.51	52.94
88	48	74	102	2.51	52.94
89	32	58	90	2.51	53.94
90	42	74	100	2.51	53.94
91	31	57	90	2.51	53.34
92	42	75	101	2.51	53.34
93	28	53	82	2.52	50.85
94	50	79	104	2.52	50.85
95	31	57	82	2.52	52.00
96	50	75	101	2.52	52.00
97	30	55	88	2.52	52.77
98	30	56	89	2.52	53.27
99	43	76	102	2.52	53.27
100	44	77	102	2.52	52.77

Appendix 19: Top 100 list with Four Charging Locations for Kathmandu-Chitwan Route

SNo	Location 1	Location 2	Location 3	Location 4	Average Anxiety Level	Ending SoC Level (%)
1	27	52	77	102	2.01	63.50
2	27	52	78	103	2.01	64.38
3	29	54	80	105	2.01	64.38
4	30	55	80	105	2.01	63.50
5	27	52	80	105	2.02	66.50
6	28	53	78	103	2.03	63.38

SNo	Location 1	Location 2	Location 3	Location 4	Average Anxiety Level	Ending SoC Level (%)
7	29	54	79	104	2.03	63.38
8	27	52	79	104	2.04	65.50
9	28	53	80	105	2.04	65.50
10	27	52	77	103	2.04	64.25
11	29	55	80	105	2.04	64.25
12	28	53	79	104	2.05	64.50
13	25	50	77	102	2.06	66.00
14	25	50	78	103	2.06	66.88
15	26	51	77	102	2.06	65.00
16	26	51	78	103	2.06	65.88
17	29	54	81	106	2.06	65.88
18	29	54	82	107	2.06	66.88
19	30	55	81	106	2.06	65.00
20	30	55	82	107	2.06	66.00
21	26	51	80	105	2.06	68.00
22	27	52	78	104	2.06	65.37
23	27	52	81	106	2.06	68.00
24	28	54	80	105	2.06	65.37
25	27	53	78	103	2.07	64.20
26	29	54	79	105	2.07	64.20
27	25	50	75	100	2.08	64.12
28	27	52	79	105	2.08	66.37
29	27	53	80	105	2.08	66.37
30	32	57	82	107	2.08	64.12
31	25	50	79	104	2.08	68.00
32	26	51	79	104	2.08	67.00
33	28	53	78	104	2.08	64.35
34	28	53	81	106	2.08	67.00
35	28	53	82	107	2.08	68.00
36	28	54	79	104	2.08	64.35
37	25	50	76	101	2.08	65.25
38	25	50	77	103	2.08	66.81
39	26	51	76	101	2.08	64.25
40	26	51	77	103	2.08	65.78
41	29	55	81	106	2.08	65.78
42	29	55	82	107	2.08	66.81
43	31	56	81	106	2.08	64.25
44	31	56	82	107	2.08	65.25
45	27	52	77	104	2.09	65.24
46	28	55	80	105	2.09	65.24

SNo	Location 1	Location 2	Location 3	Location 4	Average Anxiety Level	Ending SoC Level (%)
47	27	53	79	104	2.09	65.35
48	28	53	79	105	2.09	65.35
49	25	50	76	102	2.10	65.93
50	26	51	76	102	2.10	64.91
51	30	56	81	106	2.10	64.91
52	30	56	82	107	2.10	65.93
53	27	52	78	105	2.10	66.24
54	27	54	80	105	2.10	66.24
55	25	50	78	104	2.10	67.93
56	25	51	77	102	2.10	65.81
57	25	51	78	103	2.10	66.70
58	26	51	78	104	2.10	66.91
59	28	54	81	106	2.10	66.91
60	28	54	82	107	2.10	67.93
61	29	54	81	107	2.10	66.70
62	30	55	81	107	2.10	65.81
63	26	52	77	102	2.11	64.81
64	26	52	78	103	2.11	65.70
65	29	54	80	106	2.11	65.70
66	30	55	80	106	2.11	64.81
67	25	50	75	101	2.12	65.18
68	26	51	79	105	2.12	67.91
69	27	53	78	104	2.12	65.22
70	27	53	81	106	2.12	67.91
71	27	54	79	104	2.12	65.20
72	28	53	78	105	2.12	65.20
73	28	54	79	105	2.12	65.22
74	31	57	82	107	2.12	65.18
75	25	50	76	103	2.12	66.73
76	26	51	76	103	2.12	65.69
77	26	52	80	105	2.12	67.87
78	27	52	80	106	2.12	67.87
79	29	56	81	106	2.12	65.69
80	29	56	82	107	2.12	66.73
81	25	51	79	104	2.13	67.85
82	27	52	77	105	2.13	66.11
83	27	55	80	105	2.13	66.11
84	28	53	81	107	2.13	67.85
85	25	50	77	104	2.13	67.86
86	25	51	76	101	2.13	65.05

SNo	Location 1	Location 2	Location 3	Location 4	Average Anxiety Level	Ending SoC Level (%)
87	25	51	77	103	2.13	66.63
88	26	51	77	104	2.13	66.82
89	27	53	79	105	2.13	66.24
90	28	55	81	106	2.13	66.82
91	28	55	82	107	2.13	67.86
92	29	55	81	107	2.13	66.63
93	31	56	81	107	2.13	65.05
94	25	50	75	102	2.13	65.86
95	30	57	82	107	2.13	65.86
96	26	52	79	104	2.13	66.85
97	28	53	80	106	2.13	66.85
98	26	52	77	103	2.14	65.61
99	29	55	80	106	2.14	65.61
100	25	51	76	102	2.15	65.74

Appendix 20: Jnicon Model 23 Charging Port

Jnicon
www.jnicon03.en.alibaba.com

(Source: https://www.alibaba.com/product-detail/Jnicon-Charging-Port-Discharging-Port-Waterproof_1600077042649.html)

Appendix 21: Yatri Motorcycles' DC Fast Charger placed at Evoke Café, Jhamsikhel, Lalitpur